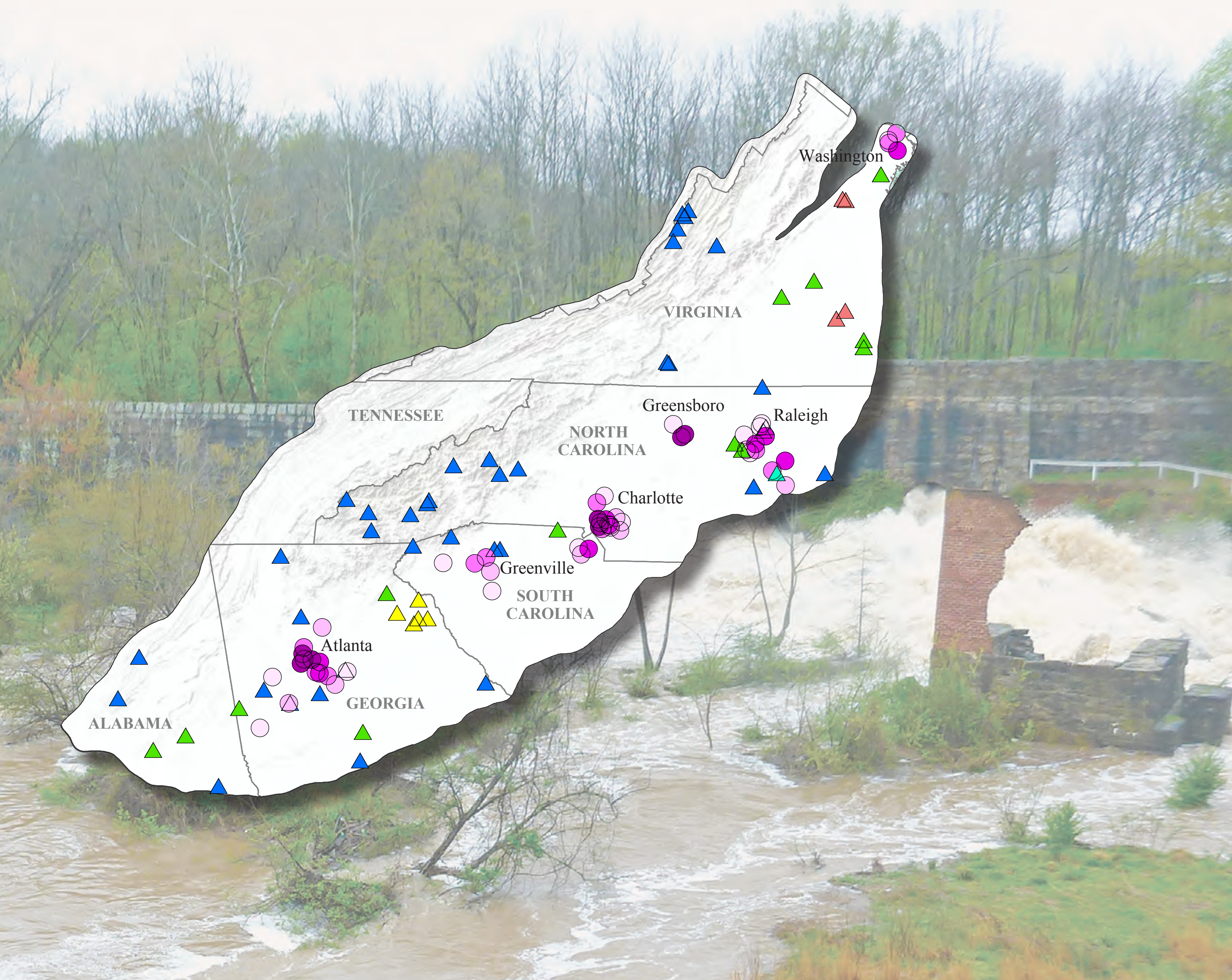
National Water-Quality Assessment Program

Design and Methods of the Southeast Stream Quality Assessment (SESQA), 2014



Open-File Report 2015–1095

U.S. Department of the Interior
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Cover. Front foreground map, see figure 4 in this report for detail; front background, Enoree River in flood (photograph by Celeste A. Journey, USGS); back top left, USGS personnel sampling periphyton at Twelvemile Creek near Liberty, South Carolina, June 2014 (photograph by Celeste A. Journey, USGS); back bottom right, yellowfin shiners, *Notropis lutipinnis* (photograph by Peter VanMetre, USGS); back background, Shoal Creek, downstream of Highway 54, Coweta County, Georgia (photograph by Alan M. Cressler, USGS).

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By Celeste A. Journey, Peter C. Van Metre, Amanda H. Bell, Jessica D. Garrett, Daniel T. Button, Naomi Nakagaki, Sharon L. Qi, and Paul M. Bradley

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Acting Director

U.S. Geological Survey, Reston, Virginia: 2015

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Figures

Tables

Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
micron (µm)	3.937×10^{-5}	inch (in.)
nanometer (nm)	3.937×10^{-8}	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
meter (m)	1.094	yard (yd)
	Area	
square meter (m^2)	0.0002471	acre
square meter (m^2)	10.76	square foot (ft^2)
square centimeter (cm^2)	0.1550	square inch (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
microliter (µL)	2.462×10^{-7}	gallon (gal)
milliliter (mL)	0.0002642	gallon (gal)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
microliter (µL)	6.102×10^{-5}	cubic inch (in^3)
	Flow rate	
meter per second (m/s)	3.281	foot per second (ft/s)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

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

$$°F = (1.8 \times °C) + 32$$

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

$$°C = (°F - 32) / 1.8$$

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83)

Supplemental Information

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), micrograms per liter (µg/L), or nanograms per liter (ng/L).

Abbreviations

ag-CAFO	agriculture-concentrated animal feedlot operations
ASR	Analytical Service Request
BQS	Branch of Quality Systems
CAFO	concentrated animal feedlot operations
CEC	contaminant of emerging concern
CC GC–MAS	capillary column gas chromatography/mass spectrometry
CERC	Columbia Environmental Research Center
DAI	direct aqueous injection
DBA	Database Administrator
DIA	direct-injection aqueous (phase)
DCM	dichloromethane
DQI	data quality indicator
EPA	Environmental Protection Agency
EWI	equal-width increment
ESI	electrospray ionization
FDOM	fluorescent dissolved organic matter
GC	gas chromatographic column
GC/MS	gas chromatography mass spectrometry
GIS	geographic information system
HDI	Hydrologic Disturbance Index

ICP/AES	inductively coupled plasma/atomic emission spectroscopy
ICP–MS	inductively coupled plasma–mass spectrometry
LC–MS/MS	liquid chromatography tandem mass spectrometry
LIMS	Laboratory Information Management System
MDL	method detection limit
MS	mass spectrometer
NAWQA	National Water-Quality Assessment
NHDPlus	National Hydrography Version 2 Dataset
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination Sites
NWQL	National Water Quality Laboratory
NWIS	National Water Information System
MRM	multiple reaction monitoring
OPP	Office of Pesticide Programs
PAH	polycyclic aromatic hydrocarbon
PBDE	polybrominated diphenyl ether
PCFF	Personal Computer Field Form
PCB	polychlorinated biphenyl
POCIS	Polar Organic Compound Integrated Samplers
PVC	polyvinyl chloride
QA/QC	Quality assurance and quality control
QC	quality control
QWDX	Water Quality Data Exchange
RTH	Richest-Targeted Habitat
RP	reference point
RSQA	Regional Stream Quality Assessment
SESQA	Southeastern Stream Quality Assessment
SIM	selected ion monitoring
TP	total phosphorus
USGS	U.S. Geological Survey
WMRL	Wisconsin Mercury Research Laboratory
WSC	Water Science Center
VOC	volatile organic compound

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By Celeste A. Journey, Peter C. Van Metre, Amanda H. Bell, Jessica D. Garrett, Daniel T. Button, Naomi Nakagaki, Sharon L. Qi, and Paul M. Bradley

Abstract

During 2014, the U.S. Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA) assessed stream quality across the Piedmont and southern Appalachian Mountain regions of the southeastern United States. This Southeast Stream Quality Assessment (SESQA) simultaneously characterized watershed and stream-reach water-quality stressors along with instream biological conditions, in order to better understand regional stressor-effects relations. The goal of SESQA is to provide communities and policymakers with information about those human and environmental factors that have the greatest impact on stream quality across the region. The SESQA design focused on hydrologic alteration and urbanization because of their importance as ecological stressors of particular concern to Southeast region resource managers.

Streamflow and land-use data were used to identify and select sites representing gradients in urbanization and streamflow alteration across the region. One hundred fifteen sites were selected and sampled for as many as 10 weeks during April, May, and June 2014 for contaminants, nutrients, and sediment. This water-quality "index" period culminated with an ecological survey of habitat, periphyton, benthic macroinvertebrates, and fish at all sites. Sediment was collected during the ecological survey for analysis of sediment chemistry and toxicity testing. Of the 115 sites, 59 were on streams in watersheds with varying degrees of urban land use, 5 were on streams with multiple confined animal feeding operations, and 13 were reference sites with little or no development in their watersheds. The remaining 38 "hydro" sites were on streams in watersheds with relatively little agricultural or urban development but with hydrologic alteration, such as a dam or reservoir.

This report provides a detailed description of the SESQA study components, including surveys of ecological conditions, routine water sampling, deployment of passive polar organic compound integrative samplers for pesticides and contaminants of emerging concern, and synoptic sediment sampling and toxicity testing at all urban, confined animal feeding operation, and reference sites. Continuous water-quality monitoring and daily pesticide sampling efforts conducted at a subset of urban sites are also described.

Introduction

The U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program's third decade of implementation (Cycle 3; 2013–2022) includes a national assessment of water quality in streams using a regional approach. The Regional Stream Quality Assessment (RSQA) simultaneously characterizes watershed and stream-reach water-quality stressors along with instream biological conditions, in order to better understand regional stressor-effects relations. Each RSQA is a one season or 1 year multi-stressor assessment of stream systems within a targeted, multi-State region.

Multiple natural and anthropogenic stressors can affect stream ecosystems. Variations in streamflow and in sediment and nutrient loads are essential characteristics of natural stream ecosystems, but deviation from their natural ranges can substantially degrade biological condition and ecological function (Lenat and Crawford, 1994; Gregory and Calhoun, 2006; Glover and others, 2008; Nagy and others, 2011). Contaminants differ from other stressors in that most are derived from human activities and, through a variety of toxic effects and other modes of action, have the potential to adversely impact aquatic life. In order to efficiently manage water resources, it is important to understand the conditions under which individual stressors or combinations of stressors adversely affect stream biological condition as well as human water-supply needs.

Multi-stressor effects are commonly assessed in the laboratory under controlled conditions or in the field at small-catchment scales. At these scales, biogeochemical processes and complex environmental interactions are more easily manipulated and monitored; however, results of such studies are not readily extended to larger scales or to unsampled streams. Toward the other end of the spatial continuum, biological condition and individual stressors can be evaluated on a national scale (U.S. Environmental Protection Agency, 2006; Herlihy and others, 2008) and empirical models have been developed to predict metrics of biological condition and environmental stressors across national-scale gradients (Waite and others, 2000; Klemm and others, 2003; Herlihy and others, 2006; Coles and others, 2012). In contrast, RSQA are intended to support communities and policymakers by providing information about human and environmental factors that have the greatest impact on stream quality at the intermediate, regional scale.

In 2014, the NAWQA Program and USGS Columbia Environmental Research Center (CERC) collaborated with the U.S. Environmental Protection Agency (EPA) Office of Pesticide Programs (OPP) to assess stream quality across the southeastern United States. The Southeastern Stream Quality Assessment (SESQA) was the second of the NAWQA Cycle 3 regional studies. The SESQA study area encompassed watersheds in the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions (Omernik, 1987, 1995; McMahon and others, 2001) within the States of Alabama, Georgia, South Carolina, North Carolina, Tennessee, and Virginia (fig. 1). The SESQA targeted hydrologic alteration (for example, quantity and timing of streamflow) and urbanization because of their importance as ecological stressors of particular concern to resource managers in the Southeast.

Purpose and Scope

The purpose of this report is to describe the design and methods used in the SESQA. A network of stream sites was selected throughout the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the southeastern United States for assessment of water and sediment quality, ecological community status, and habitat condition during early spring and summer of 2014 (fig. 1, table 1). Landscape-scale and instream multi-stressor effects associated with urbanization and hydrologic alteration were assessed as ecological stressors.

The major objectives of the SESQA included the following:

1. Monitor and assess the status of ecological conditions; the spring-early summer seasonal concentrations of contaminants of emerging concern, volatile organic compounds (VOCs), trace elements, pesticides, nutrients, sediment, and streamflow; and associated toxicity of sediment in wadeable streams in the region.

2. Assess relations among concentrations of contaminants, nutrients, sediment, and streamflow conditions, associated toxicity of sediment, and ecological conditions in monitored streams.

3. Identify and evaluate natural and anthropogenic landscape characteristics affecting streamflow quantity and timing, and ecological conditions in sampled streams.

4. Develop statistical models to predict concentrations of contaminants, nutrients, sediment, and, if possible, ecological conditions in comparable, unmonitored streams throughout the region.

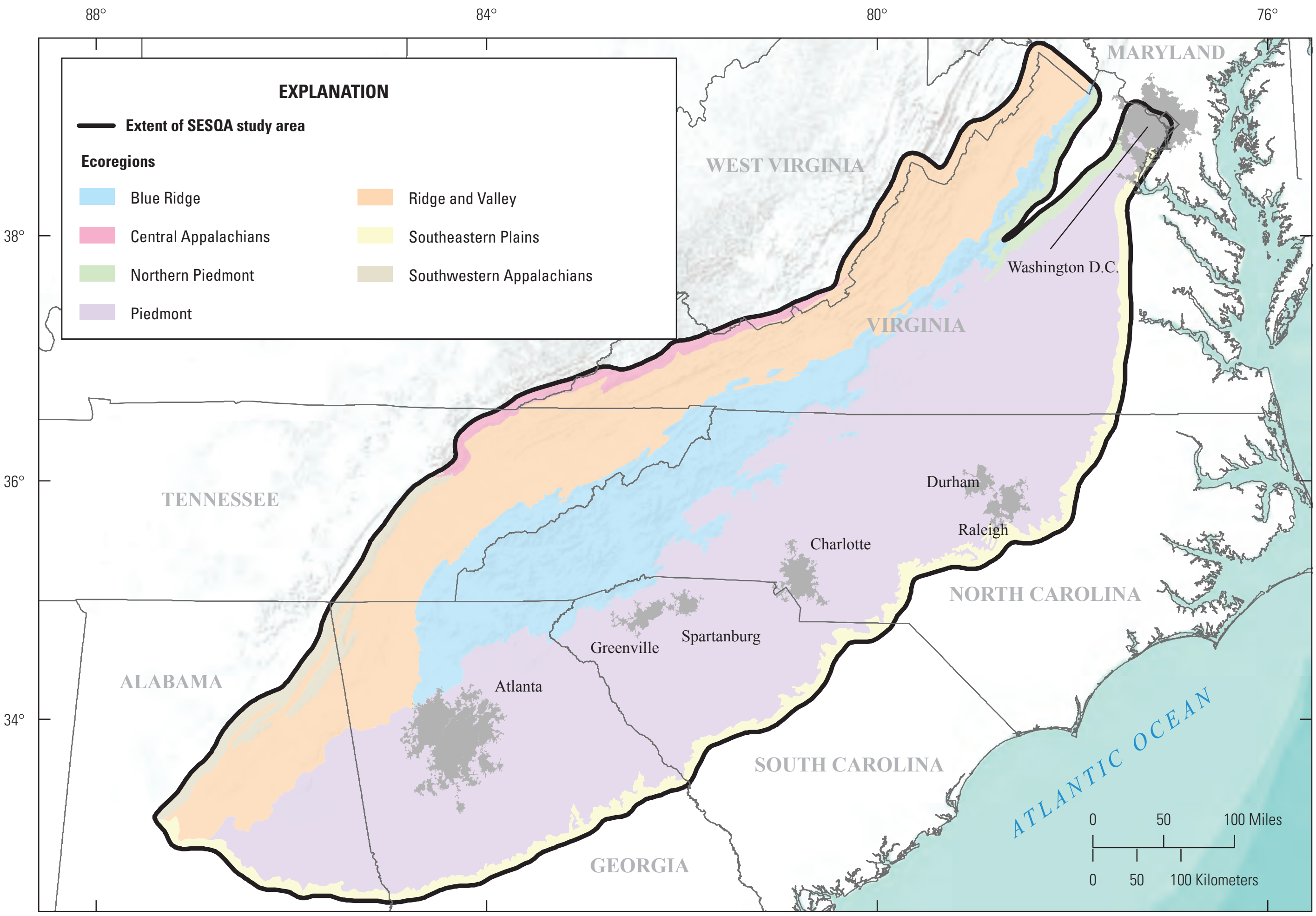
Study Area Description

The SESQA region lies within the Valley and Ridge, Piedmont and Blue Ridge physiographic provinces and has a subtropical to temperate climate (Fenneman, 1938, 1946). The southern Piedmont ecoregion of the United States, where the more intensive monitoring by the SESQA was focused, has a comparatively mild climate, producing generally mild winters with light snowfall (Gregory and Calhoun, 2006). Average annual temperatures for the period of 1981 to 2010 ranged from minimums of 6 to 10 degrees Celsius (°C) to maximums of 20 to 23 °C (table 2; National Climatic Data Center, 2010). Average annual precipitation in the Piedmont ecoregion ranged from 105.7 (41.6 inches [in.]) to 135 centimeters (cm) (53.2 in.) during the same period (table 2). The Piedmont is characterized by gently rolling to steep terrain and clayey surface and subsurface soils. Historically, the abundant precipitation and perennial streams serve as reliable sources of water for agricultural, industrial, and municipal use.

The Blue Ridge ecoregion extends from southern Pennsylvania to northern Georgia and comprises the southern Appalachian mountains (fig. 1). Climate differs across the Blue Ridge ecoregion because of large variations in altitude, physiography, and latitude, as indicated by narrow ridges and hilly plateaus that transition to more mountainous areas with high peaks. Consequently, the Blue Ridge ecoregion has a colder, wetter temperate climate with greater spatial variation in average annual precipitation and temperature than the Piedmont ecoregion. Average annual temperatures for the period of 1981 to 2010 ranged from minimums of 4 to 8 °C to maximums of 12 to 21 °C in the Blue Ridge ecoregion (table 2; National Climatic Data Center, 2010). During the same period, average annual precipitation ranged from 94.0 cm (37.0 in.) to 214.6 cm (84.5 in.) (table 2).

A small portion of the SESQA region lies within the Ridge and Valley ecoregion in Alabama that has a warmer and much wetter climate than the Piedmont and Blue Ridge ecoregions. Average annual temperatures for the period of 1981 to 2010 ranged from minimums of 10 to 12 °C to maximums of 23 to 25 °C in the Blue Ridge ecoregion (table 2; National Climatic Data Center, 2010). During the same period, average annual precipitation ranged from 136.4 cm (53.7 in.) to 139.6 cm (55.0 in.) (table 2).

The Piedmont Ecoregion Level III is a northeast-southwest trending ecoregion that comprises a transitional area between the mostly mountainous ecoregions of the Appalachians to the northwest and the relatively flat coastal plain to the southeast (Omernik, 1987, 1995; McMahon and others, 2001). Within the ecoregion, Precambrian and Paleozoic metamorphic rocks underlie hills and moderately dissected plains. The underlying geology is Precambrian and Paleozoic metamorphic and igneous rocks with moderately dissected irregular plains and some hills. The historic oak-hickory-pine forest was dominated by white oak



State basemap from the National Map, 1:1,000,000 scale digital data
Level III Ecoregions from U.S. Environmental Protection Agency, 2010, 1:250,000 scale
WGS 1984 Web Mercator projection
Basemap city boundary data and terrain image is the intellectual property of Esri and is used herein under license.

Figure 1. Location of selected stream watersheds within the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the southeastern United States that were assessed as part of the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Southeastern Stream Quality Assessment (SESQA) in 2014.

(*Quercus alba*), southern red oak (*Quercus falcata*), post oak (*Quercus stellata*), and hickory (*Carya spp.*), with shortleaf pine (*Pinus echinata*), loblolly pine (*Pinus taeda*), and to the north and west, Virginia pine (*Pinus virginiana*). Presently, much of this region consists of planted pine or has reverted to successional pine and hardwood woodlands.

The soils tend to be finer-textured in the Piedmont ecoregion than in coastal plain regions. Potential for soil erosion is high throughout the Piedmont and is greatest near the Blue Ridge because of the steeper terrain (Trimble, 2008). The Blue Ridge is characterized by a wide range in altitude (225–900 meters [m]) and steeply sloping terrain. Soil parent rock includes sandstone, shale, and metamorphic/igneous rocks; therefore, soil particle size varies widely (Martin and Boyce, 1993). The predominant soil order in the southeast region is Ultisols, which are strongly leached and nutrient poor with a subsurface accumulation of clay (Bailey, 1980; Natural Resources Conservation Service, 2009).

The environmental setting of the Piedmont, Blue Ridge, and Ridge and Valley Level III Ecoregions generates highly diverse endemic aquatic biota, when compared to other temperate freshwater systems (Conroy and others, 2003). Stream habitat in the southern Piedmont supports about 200 native species of freshwater fish (Warren and others, 2000) and diverse mollusk populations (Neves and others, 1997). Over the past decade, 51 species of endemic fish and about 25 percent of mollusk populations in parts of these ecoregions were classified as threatened, endangered, or vulnerable to extirpation (local extinction) (Warren and others, 2000; Neves and others, 1997). Declines in endemic fish were

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[NWIS, USGS National Water Information System database; POCIS, Polar Organic Compound Integrated Samplers; latitude and longitude from NWIS based on NAD 83 datum and shown in decimal degrees. Latitude and longitude values in bold indicate sampling was conducted at a different location than the gaging station; hydro, hydrologic alteration site; tier 1–5, urban gradient site with tier 1 with least urbanization and tier 5 with the greatest urbanization; ag, agriculture; CAFO, confined animal feeding operations; hydrid, mixture of urban tier and another land use; Ala., Alabama; Ga., Georgia; N.C., North Carolina; S.C., South Carolina; Va., Virginia; temp., temperature; SC, specific conductance; DO, dissolved oxygen; turb., turbidity; —, no data]

Map identifier (fig. 4)	NWIS station number	NWIS station name	Field ID	Urban center	Site type	State
1	02418760	Chewacla Creek at Chewacla State Park near Auburn	AL_Chewacla	—	Hydro	Ala.
2	02423414	Little Cahaba River at Cah Bea Road near Cahaba Heights, Ala.	AL_L.Cahaba	—	Hydro	Ala.
3	02455185	Blackburn Fork Little Warrior River near Holly Springs	AL_Blackburn	—	Hydro	Ala.
4	02408540	Hatchet Creek below Rockford Ala.	AL_Hatchet	Atlanta	Reference	Ala.
5	02415000	Hillabee Creek near Hackneyville Ala.	AL_Hillabee	Atlanta	Reference	Ala.
6	02183650	Shoal Creek at Shoal Creek Road, near Lavonia, Ga.	GA_ShoalCAFO	—	Ag-CAFO	Ga.
7	02187660	Coldwater Creek (Cr 60) near Nuberg, Ga.	GA_Coldwater	—	Ag-CAFO	Ga.
8	02188350	Beaverdam Creek at Vanna Road, near Royston, Ga.	GA_Beaverdam	—	Ag-CAFO	Ga.
9	021912435	Carlan Creek at Ga.326 near Carnesville, Ga.	GA_Carlan	—	Ag-CAFO	Ga.
10	02191284	Mill Shoal Creek at Parham-Dudley Road, near Harrison, Ga.	GA_Mill	—	Ag-CAFO	Ga.
11	02176930	Chattooga River at Burrells Ford, near Pine Mountain, Ga.	GA_Chattoga	—	Hydro	Ga.
12	02195320	Kiokee Creek at Ga.104, near Evans, Ga.	GA_Kiokee	—	Hydro	Ga.
13	02204285	Pates Creek near Flippen, Ga.	GA_Pates	—	Hydro	Ga.
14	02207418	Big Haynes Creek at Jack Turner Dam, near Milstead, Ga.	Ga_BigHaynes	—	Hydro	Ga.
15	02213500	Tobesofkee Creek near Macon, Ga.	GA_Tobesofkee	—	Hydro	Ga.
16	02337500	Snake Creek near Whitesburg, Ga.	GA_Snake. Whitesburg	—	Hydro	Ga.
17	02344605	Line Creek below Ga. 54, near Peachtree City, Ga.	GA_Line	—	Hydro	Ga.
18	02384540	Mill Creek near Crandall, Ga.	GA_MillCreek	—	Hydro	Ga.
19	02391840	Hickory Log Creek near Canton, Ga.	GA_Hickory	—	Hydro	Ga.
20	021890105	Middle Fork Broad River at Red Root Road, near Toccoa, Ga.	GA_M.Broad	Atlanta	Reference	Ga.
21	02212600	Falling Creek near Juliette, Ga.	GA_Falling	Atlanta	Reference	Ga.
22	02338523	Hillabahatchee Creek at Thaxton Road, near Franklin, Ga.	GA_Hillabahatchee	Atlanta	Reference	Ga.
23	02207435	Little Haynes Creek at Dial Mill Road near Milstead, Ga.	GA_L.Haynes	Atlanta	Tier 1	Ga.
24	02337410	Dog River at Ga. 5, near Fairplay, Ga.	GA_Dog	Atlanta	Tier 1	Ga.
25	02338840	Yellowjacket Creek-Hammett Road, below Hogansville, Ga.	GA_YelJack	Atlanta	Tier 1	Ga.

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[NWIS, USGS National Water Information System database; POCIS, Polar Organic Compound Integrated Samplers; latitude and longitude from NWIS based on NAD 83 datum and shown in decimal degrees. Latitude and longitude values in bold indicate sampling was conducted at a different location than the gaging station; hydro, hydrologic alteration site; tier 1–5, urban gradient site with tier 1 with least urbanization and tier 5 with the greatest urbanization; ag, agriculture; CAFO, confined animal feeding operations; hydrid, mixture of urban tier and another land use; Ala., Alabama; Ga., Georgia; N.C., North Carolina; S.C., South Carolina; Va., Virginia; temp., temperature; SC, specific conductance; DO, dissolved oxygen; turb., turbidity; —, no data]

Latitude	Longitude	Drainage area (square miles)	Continuous streamflow	Continuous water quality	Pankow sampler	NAWQA fixed site	Water-quality sampling events	Ecological sampling events	POCIS deployments
32.54819	–85.48050	45.8	Yes	—	—	—	1	1	0
33.43983	–86.69888	47	Yes	—	—	—	1	1	0
33.86065	–86.44582	36.1	Yes	—	—	—	1	1	0
32.91679	–86.27025	263	Yes	—	—	—	4	1	1
33.06540	–85.87802	190	Yes	—	—	—	4	1	1
34.43694	–83.04361	13.8	No	—	—	—	10	1	2
34.24705	–82.93653	12.6	No	—	—	—	10	1	2
34.24806	–83.04861	26	No	—	—	—	10	1	2
34.30306	–83.30694	17.5	No	—	—	—	10	1	2
34.19611	–83.10167	11.3	No	—	—	—	10	1	2
34.97453	–83.11617	46.7	Yes	Temp.	—	—	1	1	0
33.60097	–82.23262	106	Yes	—	—	—	1	1	0
33.4925	–84.245	11.9	Yes	—	—	—	1	1	0
33.72917	–83.93722	46.3	Yes	—	—	—	1	1	0
32.80889	–83.75833	182	Yes	—	—	—	1	1	0
33.52956	–84.92827	35.5	Yes	—	—	—	1	1	0
33.39556	–84.60694	38.1	Yes	—	—	—	1	1	0
34.87202	–84.72133	8.24	Yes	—	—	—	1	1	0
34.26500	–84.47389	8.33	Yes	—	—	—	1	1	0
34.50067	–83.43200	17.1	No	—	—	—	4	1	1
33.09985	–83.72351	72.2	Yes	—	—	—	4	1	1
33.34067	–85.22689	16.8	Yes	—	—	—	4	1	1
33.71111	–83.91444	25.8	Yes	—	—	—	10	1	2
33.65381	–84.82103	66.5	Yes	Nutrient flux	—	—	10	1	2
33.13957	–84.97522	91	Yes	—	—	—	10	1	2

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Map identifier (fig. 4)	NWIS station number	NWIS station name	Field ID	Urban center	Site type	State
26	02204130	Honey Creek at Ga. 212, near Conyers, Ga.	GA_Honey	Atlanta	Tier 2	Ga.
27	02335580	Big Creek at Ga. 9, near Cumming, Ga.	GA_Big	Atlanta	Tier 2	Ga.
28	02344620	Shoal Creek near Sharpsburg, Ga.	GA_Shoal.Sharpsburg	Atlanta	Tier 2	Ga.
29	02203831	Doolittle Creek at Flat Shoals Road, near Decatur, Ga.	GA_Doolittle	Atlanta	Tier 3	Ga.
30	02204037	Pole Bridge Creek at Evans Mill Road near Lithonia, Ga.	GA_Pole	Atlanta	Tier 3	Ga.
31	02335870	Sope Creek near Marietta, Ga.	GA_Sope	Atlanta	Tier 3	Ga.
32	02203863	Shoal Creek at Columbia Drive near Atlanta, Ga.	GA_Shoal.Atlanta	Atlanta	Tier 4	Ga.
33	02336152	South Fork Peachtree at Casa Road near Clarkston, Ga.	GA_S.F.Peach	Atlanta	Tier 4	Ga.
34	02336410	Nancy Creek at West Wesley Road, at Atlanta, Ga.	GA_Nancy	Atlanta	Tier 4	Ga.
35	02336120	North Fork Peachtree Creek, Buford Hwy near Atlanta, Ga.	GA_N.F.Peach	Atlanta	Tier 5	Ga.
36	02336526	Proctor Creek at Jackson Parkway, at Atlanta, Ga.	GA_Proctor	Atlanta	Tier 5	Ga.
37	02335910	Rottenwood Creek at Interstate North Parkway, near Smyrna, Ga.	GA_Rottenwood	Atlanta	Tier 5	Ga.
38	0208758850	Swift Creek near Mccullars Crossroads, N.C.	NC_Swift.McCul	Raleigh	Hybrid-hydro	N.C.
39	02077670	Mayo Creek near Bethel Hill, N.C.	NC_Mayo	—	Hydro	N.C.
40	0208524975	Little River below Little River tributary at Fairntosh, N.C.	NC_L.River.Fairntosh	—	Hydro	N.C.
41	02086500	Flat River at Dam near Bahama, N.C.	NC_Flat.AtDam	—	Hydro	N.C.
42	02090380	Contentnea Creek near Lucama, N.C.	NC_Contentnea	—	Hydro	N.C.
43	02102192	Buckhorn Creek near Corinth, N.C.	NC_Buckhorn	—	Hydro	N.C.
44	02137727	Catawba River near Pleasant Gardens, N.C.	NC_Catawba.Pleasant	—	Hydro	N.C.
45	02138520	Catawba River at SR1223 below Lake James near Bridgewater, N.C.	NC_Catawba.Bridge-water	—	Hydro	N.C.
46	03453000	Ivy Creek near Marshall, N C	NC_Ivy	—	Hydro	N.C.
47	03455500	West Fork Pigeon River above Lake Logan near Hazelwood, N.C.	NC_W.F.Pigeon.Hazel-wood	—	Hydro	N.C.
48	0345577330	West Fork Pigeon River near Retreat, N.C.	NC_W.F.Pigeon.Retreat	—	Hydro	N.C.

Table 1. Description of selected stream watersheds within the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the southeastern United States that were assessed as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Southeastern Stream Quality Assessment (SESQA) in 2014.—Continued

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Latitude	Longitude	Drainage area (square miles)	Continuous streamflow	Continuous water quality	Pankow sampler	NAWQA fixed site	Water-quality sampling events	Ecological sampling events	POCIS deployments
33.57983	–84.06408	26	Yes	Temp., SC, turb.	—	—	10	1	2
34.15593	–84.21853	37.4	Yes	—	—	—	10	1	2
33.38928	–84.62326	24.1	Yes	—	—	—	10	1	2
33.70566	–84.29242	4.25	Yes	Temp., DO, SC, pH, turb.	—	—	10	1	2
33.66844	–84.15103	16.1	Yes	Temp., DO, SC, pH, turb.	—	—	10	1	2
33.95389	–84.44333	30.7	Yes	Nutrient flux	Yes	Yes	10	1	2
33.69319	–84.25389	8.63	Yes	Temp., DO, SC, pH, turb.	—	—	10	1	2
33.80833	–84.24794	5.67	Yes	—	—	—	10	1	2
33.83844	–84.43937	37.7	Yes	—	—	—	10	1	2
33.83149	–84.34270	34.8	Yes	—	—	—	10	1	2
33.79427	–84.47437	13.4	Yes	Nutrient flux	Yes	—	10	1	2
33.89371	–84.45771	18.6	Yes	—	—	—	10	1	2
35.69361	–78.69222	35.8	Yes	—	—	—	4	1	1
36.54083	–78.87194	53.5	Yes	—	—	—	1	1	0
36.11333	–78.85972	98.9	Yes	—	—	—	1	1	0
36.14861	–78.82889	168	Yes	—	—	—	1	1	0
35.69111	–78.10972	161	Yes	—	—	—	1	1	0
35.55972	–78.97361	76.3	Yes	—	—	—	1	1	0
35.68583	–82.06028	126	Yes	—	—	—	1	1	0
35.74036	–81.83467	386	Yes	—	—	—	1	1	0
35.76972	–82.62083	158	Yes	—	—	—	1	1	0
35.39611	–82.9375	27.6	Yes	—	—	—	1	1	0
35.42667	–82.91972	33.5	Yes	—	—	—	1	1	0

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Map identifier (fig. 4)	NWIS station number	NWIS station name	Field ID	Urban center	Site type	State
49	03463300	South Toe River near Celo, N.C.	NC_S.Toe	—	Hydro	N.C.
50	03504000	Nantahala River near Rainbow Springs, N.C.	NC_Nantahala.Rainbow	—	Hydro	N.C.
51	03505550	Nantahala River near Hewitt, N.C.	NC_Nantahala.Hewitt	—	Hydro	N.C.
52	03508050	Tuckasegee River at SR 1172 near Cullowhee, N.C.	NC_Tuckasegee	—	Hydro	N.C.
53	0351706800	Cheoah River near Bearpen Gap near Tapoco, N.C.	NC_Cheoah	—	Hydro	N.C.
54	02096846	Cane Creek near Orange Grove, N.C.	NC_Cane	Raleigh	Reference	N.C.
55	02097464	Morgan Creek near White Cross, N.C.	NC_Morgan.Cross	Raleigh	Reference	N.C.
56	02085000	Eno River at Hillsborough, N.C.	NC_Eno	Raleigh	Tier 1	N.C.
57	0208524090	Mountain Creek at SR 1617 near Bahama, N.C.	NC_Mountain	Raleigh	Tier 1	N.C.
58	02085500	Flat River at Bahama, N.C.	NC_Flat	Raleigh	Tier 1	N.C.
59	02093800	Reedy Fork near Oak Ridge, N.C.	NC_ReedyFk	Raleigh	Tier 1	N.C.
60	02097517	Morgan Creek near Chapel Hill, N.C.	NC_Morgan.Chapel	Raleigh	Tier 1	N.C.
61	0212393300	West Branch Rocky River below mouth of South Prong River near Cornelius, N.C.	NC_Rocky	Charlotte	Tier 1	N.C.
62	0212466000	Clear Creek at SR 3181 near Mint Hill, N.C.	NC_Clear	Charlotte	Tier 1	N.C.
63	02088000	Middle Creek near Clayton, N.C.	NC_Middle	Raleigh	Tier 2	N.C.
64	0209734440	Bolin Creek at Village Drive at Chapel Hill, N.C.	NC_Bolin	Raleigh	Tier 2	N.C.
65	0212430653	Mckee Creek at SR 2804 near Wilgrove, N.C.	NC_McKee	Charlotte	Tier 2	N.C.
66	0212467595	Goose Creek at SR 1525 near Indian Trail, N.C.	NC_Goose	Charlotte	Tier 2	N.C.
67	0214657975	Irvins Creek at SR 3168 near Charlotte, N.C.	NC_Irvins	Charlotte	Tier 2	N.C.
68	02087580	Swift Creek near Apex, N.C.	NC_SwiftApex	Raleigh	Tier 3	N.C.
69	02097280	Third Fork Creek at Woodcroft Parkway near Blands, N.C.	NC_ThirdFk	Raleigh	Tier 3	N.C.
70	0214265808	Torrence Creek at Bradford Hill Lane near Huntersvlle, N.C.	NC_Torrence	Charlotte	Tier 3	N.C.
71	0214655255	McAlpine Creek at SR 3150 near Idlewild, N.C.	NC_McAlpine	Charlotte	Tier 3	N.C.
72	02146700	McMullen Creek at Sharon View Road near Charlotte, N.C.	NC_McMullen	Charlotte	Tier 3	N.C.
73	0208732885	Marsh Creek near New Hope, N.C.	NC_Marsh	Raleigh	Tier 4	N.C.
74	0209722970	Sandy Creek at Cornwallis Road near Durham, N.C.	NC_Sandy	Raleigh	Tier 4	N.C.

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Latitude	Longitude	Drainage area (square miles)	Continuous streamflow	Continuous water quality	Pankow sampler	NAWQA fixed site	Water-quality sampling events	Ecological sampling events	POCIS deployments
35.83139	–82.18417	43.3	Yes	—	—	—	1	1	0
35.12750	–83.61861	51.9	Yes	—	—	—	1	1	0
35.30500	–83.65222	145	Yes	—	—	—	1	1	0
35.28778	–83.14389	147	Yes	—	—	—	1	1	0
35.43833	–83.91889	206	Yes	—	—	—	1	1	0
35.98722	–79.20611	7.54	Yes	—	—	—	4	1	1
35.92361	–79.11500	8.35	Yes	Nutrient flux	—	—	4	1	1
36.07111	–79.09556	66	Yes	—	—	—	10	1	2
36.14972	–78.89667	7.97	Yes	—	—	—	10	1	2
36.20021	**–78.88615**	149	Yes	—	—	—	10	1	2
36.1725	–79.95278	20.6	Yes	—	—	—	10	1	2
35.89333	–79.01972	41	Yes	Nutrient flux	—	—	10	1	2
35.46778	–80.79028	20.8	Yes	—	—	—	4	1	1
35.20833	–80.58000	12.6	Yes	—	—	—	10	1	2
35.57083	–78.59056	83.5	Yes	—	—	—	10	1	2
35.92231	–79.06600	7.9	Yes	Nutrient flux	—	—	10	1	2
35.25389	–80.64806	5.76	Yes	—	—	—	10	1	2
35.12500	–80.60278	11	Yes	—	—	—	10	1	2
35.15861	–80.71333	8.37	Yes	—	—	—	10	1	2
35.71889	–78.75222	21	Yes	—	Yes	Yes	10	1	2
35.92264	–78.95242	14.79	Yes	—	—	—	10	1	2
35.40361	–80.88278	7.29	Yes	—	—	—	10	1	2
35.17583	–80.71917	7.33	Yes	—	—	—	10	1	2
35.14083	–80.82000	6.95	Yes	—	—	—	10	1	2
35.81694	–78.59306	6.84	Yes	—	Yes	—	10	1	2
35.98322	–78.95681	4.67	Yes	—	—	—	10	1	2

Table 1. Description of selected stream watersheds within the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the southeastern United States that were assessed as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Southeastern Stream Quality Assessment (SESQA) in 2014.—Continued

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Map identifier (fig. 4)	NWIS station number	NWIS station name	Field ID	Urban center	Site type	State
75	0214642825	Briar Creek near Charlotte, N.C.	NC_Briar	Charlotte	Tier 4	N.C.
76	02146562	Campbell Creek near Charlotte, N.C.	NC_Campbell	Charlotte	Tier 4	N.C.
77	02086849	Ellerbe Creek near Gorman, N.C.	NC_Ellerbe	Raleigh	Tier 4	N.C.
78	02094659	South Buffalo Creek near Pomona, N.C.	NC_S.Buffalo	Raleigh	Tier 5	N.C.
79	02095181	North Buffalo Creek at Westover Terrace at Greensboro, N.C.	NC_N.Buffalo	Raleigh	Tier 5	N.C.
80	0214627970	Stewart Creek at State Street at Charlotte, N.C.	NC_Stewart	Charlotte	Tier 5	N.C.
81	02146409	Little Sugar Creek at Medical Center Drive at Charlotte, N.C.	NC_L.Sugar	Charlotte	Tier 5	N.C.
82	02146470	Little Hope Creek at Seneca Place at Charlotte, N.C.	NC_L.Hope	Charlotte	Tier 5	N.C.
83	02156999	North Tyger River below Wellford, S.C.	SC_N.Tyger	—	Hydro	S.C.
84	02157510	Middle Tyger River near Lyman, S.C.	SC_M.Tyger	Greenville	Hydro	S.C.
85	02162290	South Saluda River near Cleveland, S.C.	SC_S.Saluda	—	Hydro	S.C.
86	02153778	Long Branch (Road 705) at Kings Mountain State Park, S.C.	SC_Long	Charlotte	Reference	S.C.
87	021473426	Tools Fork Creek near Rock Hill, S.C.	SC_Tools	Charlotte	Tier 1	S.C.
88	02165200	South Rabon Creek near Gray Court, S.C.	SC_S.Rabon	Greenville	Tier 1	S.C.
89	02186000	Twelvemile Creek near Liberty, S.C.	SC_Twelvemile	Greenville	Tier 1	S.C.
90	021473428	Wildcat Creek below Rock Hill, S.C.	SC_Wildcat	Charlotte	Tier 2	S.C.
91	02160381	Durbin Creek above Fountain Inn, S.C.	SC_Durbin	Greenville	Tier 2	S.C.
92	02160326	Enoree River at Pelham, S.C.	SC_Enoree	Greenville	Tier 3	S.C.
93	02164000	Reedy River near Greenville, S.C.	SC_Reedy	Greenville	Tier 3	S.C.
94	02146110	Manchester Creek at Rock Hill, S.C.	SC_Manchester	Charlotte	Tier 4	S.C.
95	01667850	Mine Run at Route 611 at Burr Hill, Va.	VA_Mine	—	Hybrid-rural	Va.
96	01667870	Mountain Run at Route 611 near Burr Hill, Va.	VA_Mountain	—	Hybrid-rural	Va.
97	02040919	Cellar Creek at Route 610 near Spainville, Va.	VA_Cellar	—	Hybrid-rural	Va.
98	02041038	Sweathouse Creek at Route 708 near Scotts Fork, Va.	VA_Sweathouse	—	Hybrid-rural	Va.
99	02011460	Back Creek near Sunrise, Va.	VA_Back.NearSunrise	—	Hydro	Va.
100	02011470	Back Creek at Sunrise, Va.	VA_Back.AtSunrise	—	Hydro	Va.
101	02011490	Little Back Creek near Sunrise, Va.	VA_L.Back	—	Hydro	Va.
102	02011500	Back Creek near Mountain Grove, Va.	VA_Back.MtnGrove	—	Hydro	Va.
103	02011800	Jackson River below Gathright Dam near Hot Springs, Va.	VA_Jackson	—	Hydro	Va.

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Latitude	Longitude	Drainage area (square miles)	Continuous streamflow	Continuous water quality	Pankow sampler	NAWQA fixed site	Water-quality sampling events	Ecological sampling events	POCIS deployments
35.23611	–80.77111	5.2	Yes	—	—	—	10	1	2
35.18667	–80.73667	5.71	Yes	—	—	—	10	1	2
36.05931	–78.83251	21.9	Yes	—	—	—	10	1	2
36.04944	–79.85528	7.33	Yes	—	—	—	10	1	2
36.07917	–79.81278	9.55	Yes	—	—	—	10	1	2
35.24028	–80.86833	9.07	Yes	—	—	—	10	1	2
35.20361	–80.83694	11.8	Yes	—	—	—	10	1	2
35.16444	–80.85306	2.63	Yes	—	—	—	10	1	2
34.94000	–82.05333	34.1	Yes	—	—	—	1	1	0
34.94012	–82.12344	69	Yes	—	—	—	1	1	0
35.06345	–82.65013	17.8	Yes	—	—	—	1	1	0
35.13500	–81.35583	1.97	No	—	—	—	4	1	1
34.95653	–81.10619	9.6	Yes	—	—	—	10	1	2
34.52012	–82.15705	29.5	Yes	—	—	—	10	1	2
34.80150	–82.74847	106	Yes	—	—	—	10	1	2
34.88959	–81.06925	29.7	Yes	—	—	—	10	1	2
34.71679	–82.17372	14	Yes	—	—	—	10	1	2
34.85651	–82.22622	84.2	Yes	—	—	—	10	1	2
34.80012	–82.36512	48.6	Yes	—	Yes	—	10	1	2
34.94444	–80.97972	5.8	Yes	—	Yes	—	10	1	2
38.34346	–77.85888	32.7	No	—	—	—	4	1	1
38.35374	–77.89361	28.8	No	—	—	—	4	1	1
37.20275	–77.97083	20.1	No	—	—	—	4	1	1
37.27914	–77.86111	18.2	No	—	—	—	4	1	1
38.24540	–79.76866	60.9	Yes	—	—	—	1	1	0
38.19040	–79.81172	75.6	Yes	—	—	—	1	1	0
38.21457	–79.83755	4.9	Yes	—	—	—	1	1	0
38.06957	–79.89700	134	Yes	—	—	—	1	1	0
37.94846	–79.94922	345	Yes	—	—	—	1	1	0

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Map identifier (fig. 4)	NWIS station number	NWIS station name	Field ID	Urban center	Site type	State
104	02021500	Maury River at Rockbridge Baths, Va.	VA_Maury	—	Hydro	Va.
105	02072000	Smith River near Philpott, Va.	VA_Smith.Philpott	—	Hydro	Va.
106	02072500	Smith River at Bassett, Va.	VA_Smith.Bassett	—	Hydro	Va.
107	01658500	South Fork Quantico Creek near Independent Hill, Va.	VA_S.F.Quantico	Washington, D.C.	Reference	Va.
108	02038850	Holiday Creek near Andersonville, Va.	VA_Holiday	Washington, D.C.	Reference	Va.
109	02034414	Bonbrook Creek near Whiteville, Va.	VA_Bonbrook	Washington, D.C.	Reference	Va.
110	02045370	Buckskin Creek at Route 609 near Mckenny, Va.	VA_Buckskin	Washington, D.C.	Reference	Va.
111	02046160	Sappony Creek at Route 646 near Dewitt, Va.	VA_Sapony	Washington, D.C.	Reference	Va.
112	01645762	South Fork Little Difficult Run above mouth near Vienna, Va.	VA_S.F.Difficult	Washington, D.C.	Tier 1	Va.
113	01645704	Difficult Run above Fox Lake near Fairfax, Va.	VA_Difficult.Fox	Washington, D.C.	Tier 3	Va.
114	01646000	Difficult Run near Great Falls, Va.	VA_Difficult.Falls	Washington, D.C.	Tier 3	Va.
115	01654000	Accotink Creek near Annandale, Va.	VA_Accotink	Washington, D.C.	Tier 4	Va.

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Latitude	Longitude	Drainage area (square miles)	Continuous streamflow	Continuous water quality	Pankow sampler	NAWQA fixed site	Water-quality sampling events	Ecological sampling events	POCIS deployments
37.90735	–79.42198	329	Yes	—	—	—	1	1	0
36.78069	–80.02476	215	Yes	—	—	—	1	1	0
36.77014	–80.00088	259	Yes	—	—	—	1	1	0
38.58734	–77.42860	7.62	Yes	—	—	—	4	1	1
37.41542	–78.63584	8.54	Yes	—	—	—	4	1	1
37.57008	–78.24094	7.34	Yes	—	—	—	4	1	1
36.92583	–77.63811	13.6	Yes	—	—	—	4	1	1
36.99347	–77.64064	15.3	Yes	—	—	—	4	1	1
38.90889	–77.33826	2.71	Yes	—	—	—	10	1	2
38.88470	–77.33243	5.49	Yes	—	—	—	10	1	2
38.97594	–77.24581	57.8	Yes	—	—	—	10	1	2
38.81289	–77.22832	23.9	Yes	—	Yes	Yes	10	1	2

Table 2. Average annual precipitation and air temperature for the period of 1981 to 2010 at selected stations in the Southeastern Stream Quality Assessment (SESQA) region based on National Oceanographic and Atmospheric Administration National Climatic Data Center data.

[Data compiled from National Climatic Data Center (2010). °F, degrees Fahrenheit; °C, degrees Celsius; Ga., Georgia; N.C., North Carolina; S.C., South Carolina; Va., Virginia; Ala., Alabama; —, missing data]

Location of weather station	State	Area	Precipitation			Temperature			
			Inches	Centimeters	Days	High (°F)	Low (°F)	High (°C)	Low (°C)
Charlottesville	Va.	Blue Ridge	47.7	121.1	124	68	47	20	8
Danville	Va.	Blue Ridge	44.9	114.1	115	70	47	21	8
Lynchburg	Va.	Blue Ridge	41.6	105.6	116	67	44	20	7
Philpott Lake Dam	Va.	Blue Ridge	47.4	120.3	—	68	45	20	7
Galax	Va.	Blue Ridge	43.6	110.7	112	63	41	17	5
Roanoke	Va.	Blue Ridge	41.3	104.8	116	67	47	20	8
Asheville	N.C.	Blue Ridge	37.0	94.0	126	67	46	19	8
Banner Elk	N.C.	Blue Ridge	49.5	125.7	131	60	38	15	4
Blowing Rock	N.C.	Blue Ridge	63.7	161.9	151	58	40	15	5
Boone	N.C.	Blue Ridge	52.7	133.8	140	61	39	16	4
Grandfather Mountain	N.C.	Blue Ridge	61.2	155.5	169	54	40	12	4
Highlands	N.C.	Blue Ridge	84.5	214.6	160	63	41	17	5
Kerr Scott Reservoir	N.C.	Blue Ridge	50.7	128.7	129	69	45	21	7
Morganton	N.C.	Blue Ridge	48.3	122.8	117	69	46	21	8
Oconaluftee	N.C.	Blue Ridge	53.8	136.6	127	68	41	20	5
Pisgah Forest	N.C.	Blue Ridge	61.7	156.8	136	68	42	20	6
Caesars Head State Park	S.C.	Blue Ridge	70.0	177.9	127	63	44	17	7
Blairsville	Ga.	Blue Ridge	56.0	142.2	129	—	—	—	—
Clayton	Ga.	Blue Ridge	69.0	175.2	135	—	—	—	—
Helen	Ga.	Blue Ridge	68.6	174.2	111	—	—	—	—
Toccoa	Ga.	Blue Ridge	57.4	145.7	114	—	—	—	—
Median	**All states**	**Blue Ridge**	**52.7**	**134**	**127**	**67**	**44**	**20**	**7**
Minimum	**All states**	**Blue Ridge**	**37.0**	**94.0**	**111**	**54**	**38**	**12**	**4**
Maximum	**All states**	**Blue Ridge**	**84.5**	**214.6**	**169**	**70**	**47**	**21**	**8**
John H Kerr Dam	Va.	Piedmont	42.8	108.7	110	71	48	22	9
Richmond	Va.	Piedmont	43.6	110.7	114	70	48	21	9
Cary	N.C.	Piedmont	46.3	117.6	—	70	48	21	9
Chapel Hill	N.C.	Piedmont	47.3	120.2	121	71	48	21	9
Charlotte	N.C.	Piedmont	41.6	105.7	110	71	49	22	9
Durham	N.C.	Piedmont	47.8	121.4	105	69	47	21	8
Gastonia	N.C.	Piedmont	43.0	109.1	100	72	49	22	10
Greensboro	N.C.	Piedmont	42.2	107.3	111	69	49	21	10
Henderson	N.C.	Piedmont	44.6	113.2	95	70	44	21	7
Mount Airy	N.C.	Piedmont	46.8	118.8	131	68	42	20	6
Raleigh	N.C.	Piedmont	46.0	116.9	100	72	50	22	10
Winston-Salem	N.C.	Piedmont	46.9	119.1	—	70	50	21	10
Anderson	S.C.	Piedmont	48.4	122.8	93	73	51	23	10
Calhoun Falls	S.C.	Piedmont	44.4	112.9	102	74	50	23	10
Greer	S.C.	Piedmont	47.2	119.9	114	72	51	22	10

Table 2. Average annual precipitation and air temperature for the period of 1981 to 2010 at selected stations in the Southeastern Stream Quality Assessment (SESQA) region based on National Oceanographic and Atmospheric Administration National Climatic Data Center data.—Continued

[Data compiled from National Climatic Data Center (2010). °F, degrees Fahrenheit; °C, degrees Celsius; Ga., Georgia; N.C., North Carolina; S.C., South Carolina; Va., Virginia; Ala., Alabama; —, missing data]

Location of weather station	State	Area	Precipitation			Temperature			
			Inches	Centimeters	Days	High (°F)	Low (°F)	High (°C)	Low (°C)
Ninety Nine Islands Reservoir	S.C.	Piedmont	46.0	116.9	104	71	46	22	8
Spartanburg	S.C.	Piedmont	48.4	123.0	99	74	48	23	9
Athens	Ga.	Piedmont	46.3	117.7	110	—	—	—	—
Atlanta	Ga.	Piedmont	49.7	126.3	113	—	—	—	—
Gainesville	Ga.	Piedmont	53.2	135.0	107	—	—	—	—
Median	**All states**	**Piedmont**	**46.3**	**117.7**	**110**	**71**	**48**	**22**	**9**
Minimum	**All states**	**Piedmont**	**41.6**	**105.7**	**100**	**68**	**42**	**20**	**6**
Maximum	**All states**	**Piedmont**	**53.2**	**135.0**	**131**	**74**	**51**	**23**	**10**
Birmingham	Ala.	Ridge and Valley	53.7	136.4	117	74	53	23	12
Gadsden	Ala.	Ridge and Valley	54.6	138.7	105	73	51	23	10
Tuscaloosa	Ala.	Ridge and Valley	55.0	139.6	99	76	54	25	12
Median	**All states**	**Ridge and Valley**	**54.6**	**138.7**	**111**	**74**	**53**	**23**	**12**
Minimum	**All states**	**Ridge and Valley**	**53.7**	**136.4**	**105**	**73**	**51**	**23**	**10**
Maximum	**All states**	**Ridge and Valley**	**55.0**	**139.6**	**117**	**76**	**54**	**25**	**12**

linked to habitat alteration and degradation resulting from forest conversion to intensive agriculture, urbanization, and hydrologic alteration.

The southeastern United States, including the Piedmont region, has experienced extreme changes in land use from the 1800s to present day (Wear, 2002; Gregory and Calhoun, 2006; Trimble, 2008; Nagy and others, 2011; Harper and others, 2012). Deforestation from agricultural expansion began in the 19th Century, resulting in erosion of an average of 10 to 30 cm of topsoil across the entire Piedmont physiographic province by the 1930s (Trimble, 2008; Nagy and others, 2011). From the 1930s to 1980s, much of the land formerly used for agriculture was converted to managed coniferous forest by the forest industry (Wear, 2002; Drummond and Loveland, 2010). Nonetheless, the impacts of the historical agricultural practices that produced extensive sedimentation in Piedmont streams continue today (Gregory and Calhoun, 2006; Nagy and others, 2011; Harper and others, 2012).

More recently, agricultural and forested lands in the Piedmont have been converted to urban land uses. In 2002, urbanization was identified as the leading cause of forest loss within the region (Nagy and others, 2011; Harper and others, 2012). The expanding metropolitan areas of Atlanta, Georgia; Greenville-Spartanburg, South Carolina; Charlotte and Raleigh, North Carolina; and Washington, D.C. are located in the SESQA region. Associated increases in streamflow regulation and surface-water utilization were identified as major threats to aquatic biota in the southeastern United States (Richter and others, 1997). Therefore, the SESQA design focused on hydrologic alteration and on other stressors (for example, biochemical contamination) associated with urbanization. Although agricultural land use (largely associated with livestock production in the Piedmont) represented a comparatively small percentage of the study area, a few watersheds containing multiple concentrated animal feeding operations (CAFOs) also were included in the SESQA design because of their potential importance as local stream-quality drivers.

Study Design

Within the Piedmont, multiple biochemical stressors associated with population increase and urban development have the potential to adversely affect instream ecological health. A wide range of potential water and sediment contaminants were sampled at selected Piedmont stream sites, including contaminants of emerging concern (CECs; for example, pharmaceuticals, hormones, and personal care products), VOCs, pesticides, and trace elements. Because urban development also modifies channel structure and the quantity and timing of streamflow, multiple stressors associated with hydrologic alteration are also intrinsic components of urbanization in the Piedmont region.

Development and operation of surface-water reservoirs to meet southeastern region energy and water-supply needs has resulted in substantial hydrologic alteration of numerous Piedmont, Blue Ridge, and Ridge and Valley stream systems, even in non-urbanized locations. Streamflow alteration is a common cause of degraded stream quality across the United States and is increasingly subject to management and regulation in the Southeast (Carlisle and others, 2010; Carlisle and others, 2012; Eng and others, 2013). Thus, multiple stressors associated with hydrologic alteration were targeted in selected Blue Ridge and Ridge and Valley streams in rural areas in order to help distinguish the relative effects of biochemical alterations (contamination) and physical alterations on the ecological quality of southeastern region streams.

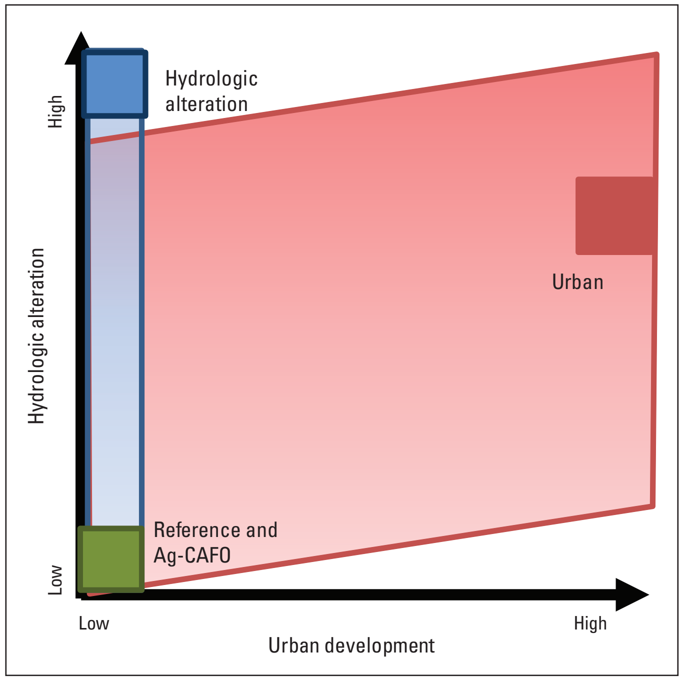

Figure 2. Conceptualization of the gradient approach for increasing urban development and hydrologic alteration and group comparison approach for high hydrologic alteration (blue box), high urban development (red box), agricultural concentrated animal feeding operations (ag-CAFO) and reference (green box) endmembers for the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey National Water-Quality Assessment Program in 2014. [Light red shaded area represents the targeted range of urbanization and streamflow alteration for site selection of multi-stressor sites and light blue shaded area represents targeted range for hydrologic alteration only sites.]

Approach

The SESQA study design incorporated two distinct experimental approaches, namely gradient and group comparison. Comparison using the gradient approach was applied to the selection of stream sites that represented a range of urban development and hydrologic alteration. However, in relation to agricultural land use in the SESQA study area, which exhibited a very limited range in the level of land use, a group comparison approach was applied to asses the effects of high agricultural confined animal feedlot operations (CAFO) on stream quality. These two approaches guided the site selection and network design process.

For the gradient comparison approach, streams within the SESQA study area exhibit considerable variability in the extent of within-watershed urban development. Watersheds that lie predominantly or entirely within protected areas like National Parks, State Parks, and wildlife refuges or are predominately forested exhibit limited or no impact from urban development and, for this study, were considered reference conditions. At the other end of the continuum are watersheds located within major urban centers of the Piedmont region that are subject to high-intensity urban development. For this reason, the impacts of multiple stressors associated with urbanization within the Piedmont region of the SESQA study area were assessed by targeting streams that captured the regional gradient from low- to high-intensity urban development (fig. 2).

As with urban development, streams within the SESQA study area exhibit a considerable range in the extent of within-watershed hydrologic alteration. Watersheds that lie predominantly or entirely within protected areas like National Parks, State Parks, and wildlife refuges or that are predominantly forested exhibit limited or no alteration in historical streamflow quantity and timing, aside from those changes associated with climate variation. At the other end of the spectrum are watersheds in which instream flows are highly regulated by impoundments or influenced by extensive impervious surfaces, producing flow conditions that bear little resemblance to historical flow patterns. For this reason, the impacts of multiple stressors associated with hydrologic alteration within the SESQA study area were assessed by targeting non-urban streams that represented the regional gradient from low- to high-intensity hydrologic alteration (fig. 2).

For the group comparison approach, agricultural land use (largely associated with livestock production in the Piedmont) represented a comparatively small percentage of the study area and, consequently, a gradient approach was not considered suitable for assessing the relative importance of animal agriculture as a driver of local stream quality. Because of the potential importance of such facilities as stream quality drivers, however, five watersheds containing multiple CAFO were included in the SESQA design as CAFO-affected endmembers in order to allow direct comparison with five sites selected from the above gradient studies to represent low-impacted protected watershed (reference), high hydrologic-alteration-impacted (low urban) watershed, and high urban-contaminant-impacted watershed endmembers (fig. 2).

Site Selection

Perennial, wadeable stream sites were selected to represent urban multi-stressor (urban-related contamination and hydrologic alteration) or predominantly hydrologic-alteration-stressor gradients for the SESQA study. Hereafter, the phrase “urban tier sites” refers to multi-stressor sites selected to assess biochemical contamination and hydrologic alteration impacts associated with different levels, or tiers, of urban development. In addition, the phase “hydro sites” hereafter refers to sites primarily affected by hydrologic alteration, with minimal or no urban development. Land use and land cover within candidate watersheds were considered to capture urban gradients ranging from reference conditions to highest urban intensity for the four primary Piedmont-region urban centers (Atlanta, Greenville-Spartanburg, Charlotte, and Raleigh) and hydrologic-alteration gradients ranging from reference conditions to highest hydrologic-alteration intensity (fig. 3; tables 1, 3). Representative spatial coverage of monitored stream sites with streamflow gaging stations was prioritized to ensure that regional inferences could be made about stream quality and the relative importance of contaminants and hydrologic alterations as drivers of the aquatic ecosystem condition and to develop spatially explicit models of water- and sediment-quality stressors and ecological conditions in unmonitored streams throughout the study region.

Initial steps in the site selection process focused on the development of a geospatial database to evaluate the distributions of urban and hydrologic-alteration gradients in the region. The database consisted of watershed-scale land-cover characteristics aggregated at USGS streamflow gaging stations, using a combination of medium-resolution (1:100,000-scale) hydrography from the National Hydrography Version 2 Dataset (NHDPlus; U.S. Environmental Protection Agency and the

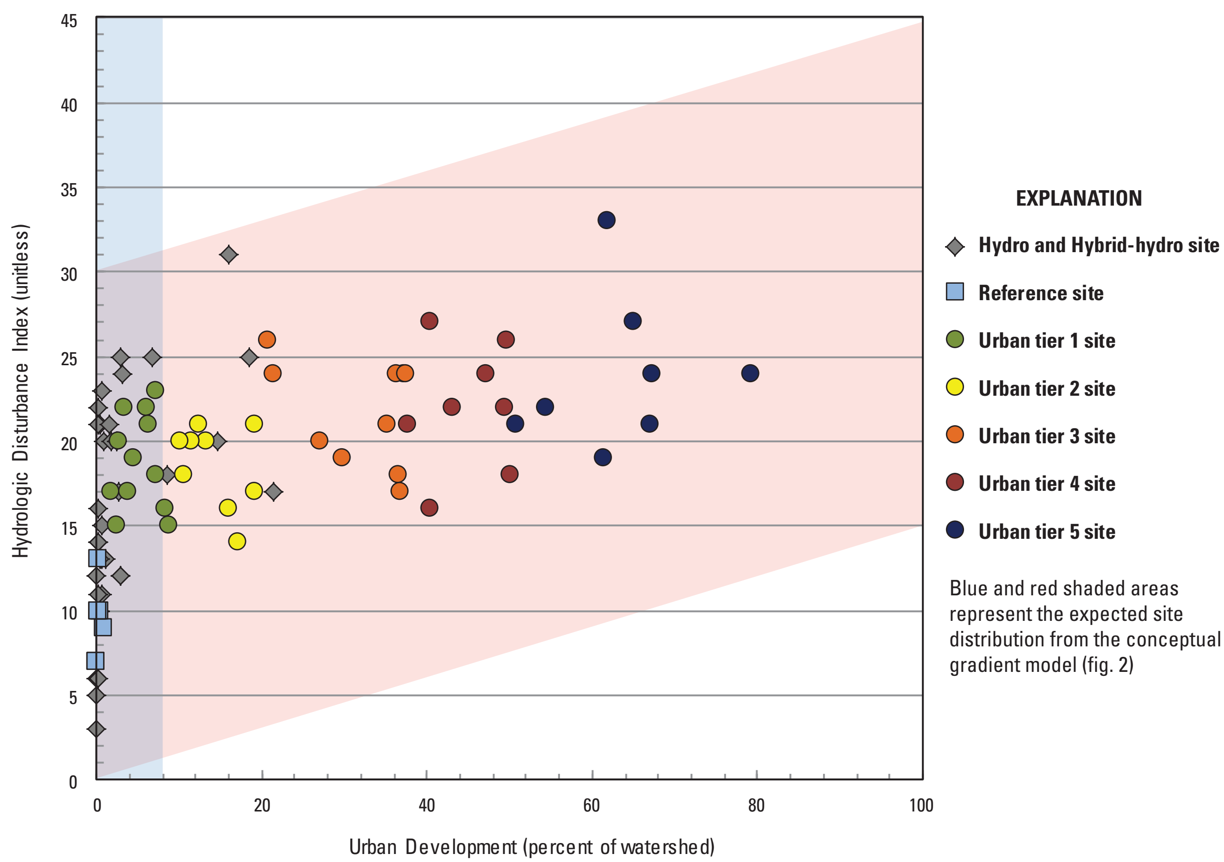

Figure 3. Range of hydrologic disturbance and urban development at selected sites in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey National Water-Quality Assessment Program in the Piedmont, Ridge and Valley, and Blue Ridge Level III ecoregions in 2014. [Nine ungaged sites—five that represent agricultural confined animal feeding operations and four that represent hybrid rural sites—are not shown because a lack of streamflow data prevented computation of hydrologic disturbance indices for these sites. Also not shown are 15 other sites for which no hydrologic disturbance indices were computed (table 3).]

Table 3. Hydrologic disturbance index and urban density index for stream watersheds within the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program in 2014.

[NWIS, USGS National Water Information System database; hydro, hydrologic alteration site; ag, agriculture; CAFO, confined animal feeding operations; tier 1–5, urban gradient site with tier 1 with least urbanization and tier 5 with the greatest urbanization; hybrid, mixture of urban tier and other land use; ag-CAFO, agricultural confined animal feeding operations; Ala.; Alabama; Ga., Georgia; N.C., North Carolina; S.C., South Carolina; Va., Virginia; —, not applicable]

Map identifier (fig. 4)	NWIS station number	Field ID	State	Urban center	Site type	Hydrologic Disturbance Index[1] (unitless)	Urban land use (percent)[2]
1	02418760	AL_Chewacla	Ala.	—	Hydro	18	8.56
2	02423414	AL_L.Cahaba	Ala.	—	Hydro	31	16.01
3	02455185	AL_Blackburn	Ala.	—	Hydro	13	1.10
4	02408540	AL_Hatchet	Ala.	Atlanta, Ga.	Reference	10	0.30
5	02415000	AL_Hillabee	Ala.	Atlanta, Ga.	Reference	10	0.12
6	02183650	GA_ShoalCAFO	Ga.	—	Ag-CAFO	—	3.87
7	02187660	GA_Coldwater	Ga.	—	Ag-CAFO	—	2.56
8	02188350	GA_Beaverdam	Ga.	—	Ag-CAFO	—	4.95
9	021912435	GA_Carlan	Ga.	—	Ag-CAFO	—	1.88
10	02191284	GA_Mill	Ga.	—	Ag-CAFO	—	3.72
11	02176930	GA_Chattoga	Ga.	—	Hydro	—	0.49
12	02195320	GA_Kiokee	Ga.	—	Hydro	11	0.72
13	02204285	GA_Pates	Ga.	—	Hydro	25	6.65
14	02207418	Ga_BigHaynes	Ga.	Atlanta, Ga.	Hydro	17	21.40
15	02213500	GA_Tobesofkee	Ga.	—	Hydro	21	1.43
16	02337500	GA_Snake.Whitesburg	Ga.	—	Hydro	12	2.87
17	02344605	GA_Line	Ga.	—	Hydro	20	14.65
18	02384540	GA_MillCreek	Ga.	—	Hydro	5	0.00
19	02391840	GA_Hickory	Ga.	—	Hydro	—	—
20	021890105	GA_M.Broad	Ga.	—	Reference	—	1.06
21	02212600	GA_Falling	Ga.	Atlanta, Ga.	Reference	7	0.03
22	02338523	GA_Hillabahatchee	Ga.	Atlanta, Ga.	Reference	10	0.52
23	02207435	GA_L.Haynes	Ga.	Atlanta, Ga.	Tier 1	15	8.87
24	02337410	GA_Dog	Ga.	Atlanta, Ga.	Tier 1	21	6.19
25	02338840	GA_YelJack	Ga.	Atlanta, Ga.	Tier 1	—	2.23
26	02204130	GA_Honey	Ga.	Atlanta, Ga.	Tier 2	16	15.90
27	02335580	GA_Big	Ga.	Atlanta, Ga.	Tier 2	21	19.23
28	02344620	GA_Shoal.Sharpsburg	Ga.	Atlanta, Ga.	Tier 2	20	11.38
29	02203831	GA_Doolittle	Ga.	Atlanta, Ga.	Tier 3	—	35.13
30	02204037	GA_Pole	Ga.	Atlanta, Ga.	Tier 3	—	37.03
31	02335870	GA_Sope	Ga.	Atlanta, Ga.	Tier 3	24	37.40
32	02203863	GA_Shoal.Atlanta	Ga.	Atlanta, Ga.	Tier 4	—	38.38
33	02336152	GA_S.F.Peach	Ga.	Atlanta, Ga.	Tier 4	—	46.01
34	02336410	GA_Nancy	Ga.	Atlanta, Ga.	Tier 4	27	40.38
35	02336120	GA_N.F.Peach	Ga.	Atlanta, Ga.	Tier 5	21	50.84

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Map identifier (fig. 4)	NWIS station number	Field ID	State	Urban center	Site type	Hydrologic Disturbance Index[1] (unitless)	Urban land use (percent)[2]
36	02336526	GA_Proctor	Ga.	Atlanta, Ga.	Tier 5	19	61.30
37	02335910	GA_Rottenwood	Ga.	Atlanta, Ga.	Tier 5	27	65.01
38	0208758850	NC_Swift.McCul	N.C.	Raleigh, N.C.	Hybrid-hydro	25	18.46
39	02077670	NC_Mayo	N.C.	—	Hydro	23	0.62
40	0208524975	NC_L.River.Fairntosh	N.C.	—	Hydro	20	0.91
41	02086500	NC_Flat.AtDam	N.C.	—	Hydro	20	1.71
42	02090380	NC_Contentnea	N.C.	—	Hydro	17	2.57
43	02102192	NC_Buckhorn	N.C.	—	Hydro	25	3.00
44	02137727	NC_Catawba.Pleasant	N.C.	—	Hydro	13	0.65
45	02138520	NC_Catawba.Bridgewater	N.C.	—	Hydro	—	0.00
46	03453000	NC_Ivy	N.C.	—	Hydro	15	0.55
47	03455500	NC_W.F.Pigeon.Hazelwood	N.C.	—	Hydro	6	0.14
48	0345577330	NC_W.F.Pigeon.Retreat	N.C.	—	Hydro	11	0.13
49	03463300	NC_S.Toe	N.C.	—	Hydro	6	0.18
50	03504000	NC_Nantahala.Rainbow	N.C.	—	Hydro	3	0.06
51	03505550	NC_Nantahala.Hewitt	N.C.	—	Hydro	12	0.03
52	03508050	NC_Tuckasegee	N.C.	—	Hydro	—	—
53	0351706800	NC_Cheoah	N.C.	—	Hydro	13	0.40
54	02096846	NC_Cane	N.C.	Raleigh, N.C.	Reference	10	0.10
55	02097464	NC_Morgan.Cross	N.C.	Raleigh, N.C.	Reference	13	0.23
56	02085000	NC_Eno	N.C.	Raleigh, N.C.	Tier 1	22	3.36
57	0208524090	NC_Mountain	N.C.	Raleigh, N.C.	Tier 1	15	2.52
58	02085500	NC_Flat	N.C.	Raleigh, N.C.	Tier 1	17	1.85
59	02093800	NC_ReedyFk	N.C.	Raleigh, N.C.	Tier 1	16	8.37
60	02097517	NC_Morgan.Chapel	N.C.	Raleigh, N.C.	Tier 1	23	7.14
61	0212393300	NC_Rocky	N.C.	Charlotte, N.C.	Tier 1	18	7.23
62	0212466000	NC_Clear	N.C.	Charlotte, N.C.	Tier 1	19	4.54
63	02088000	NC_Middle	N.C.	Raleigh, N.C.	Tier 2	18	10.49
64	0209734440	NC_Bolin	N.C.	Raleigh, N.C.	Tier 2	—	16.94
65	0212430653	NC_McKee	N.C.	Charlotte, N.C.	Tier 2	20	13.18
66	0212467595	NC_Goose	N.C.	Charlotte, N.C.	Tier 2	20	10.06
67	0214657975	NC_Irvins	N.C.	Charlotte, N.C.	Tier 2	21	12.35
68	02087580	NC_SwiftApex	N.C.	Raleigh, N.C.	Tier 3	20	27.17
69	02097280	NC_ThirdFk	N.C.	Raleigh, N.C.	Tier 3	21	35.24
70	0214265808	NC_Torrence	N.C.	Charlotte, N.C.	Tier 3	19	29.76

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Map identifier (fig. 4)	NWIS station number	Field ID	State	Urban center	Site type	Hydrologic Disturbance Index[1] (unitless)	Urban land use (percent)[2]
71	0214655255	NC_McAlpine	N.C.	Charlotte, N.C.	Tier 3	24	37.23
72	02146700	NC_McMullen	N.C.	Charlotte, N.C.	Tier 3	24	36.21
73	0208732885	NC_Marsh	N.C.	Raleigh, N.C.	Tier 4	22	49.53
74	0209722970	NC_Sandy	N.C.	Raleigh, N.C.	Tier 4	16	40.28
75	0214642825	NC_Briar	N.C.	Charlotte, N.C.	Tier 4	24	47.08
76	02146562	NC_Campbell	N.C.	Charlotte, N.C.	Tier 4	26	49.56
77	02086849	NC_Ellerbe	N.C.	Raleigh, N.C.	Tier 4	21	37.62
78	02094659	NC_S.Buffalo	N.C.	Raleigh, N.C.	Tier 5	21	67.10
79	02095181	NC_N.Buffalo	N.C.	Raleigh, N.C.	Tier 5	22	54.44
80	0214627970	NC_Stewart	N.C.	Charlotte, N.C.	Tier 5	33	61.89
81	02146409	NC_L.Sugar	N.C.	Charlotte, N.C.	Tier 5	24	79.13
82	02146470	NC_L.Hope	N.C.	Charlotte, N.C.	Tier 5	24	67.22
83	02156999	SC_N.Tyger	S.C.	—	Hydro	24	3.04
84	02157510	SC_M.Tyger	S.C.	Greenville, S.C.	Hydro	20	2.47
85	02162290	SC_S.Saluda	S.C.	—	Hydro	—	0.00
86	02153778	SC_Long	S.C.	Charlotte, N.C.	Reference	—	0.00
87	021473426	SC_Tools	S.C.	Charlotte, N.C.	Tier 1	17	3.72
88	02165200	SC_S.Rabon	S.C.	Greenville, S.C.	Tier 1	22	5.96
89	02186000	SC_Twelvemile	S.C.	Greenville, S.C.	Tier 1	20	2.74
90	021473428	SC_Wildcat	S.C.	Charlotte, N.C.	Tier 2	17	19.23
91	02160381	SC_Durbin	S.C.	Greenville, S.C.	Tier 2	14	17.21
92	02160326	SC_Enoree	S.C.	Greenville, S.C.	Tier 3	24	21.43
93	02164000	SC_Reedy	S.C.	Greenville, S.C.	Tier 3	18	36.53
94	02146110	SC_Manchester	S.C.	Charlotte, N.C.	Tier 4	18	50.07
95	01667850	VA_Mine	Va.	—	Hybrid-rural	—	0.25
96	01667870	VA_Mountain	Va.	—	Hybrid-rural	—	0.20
97	02040919	VA_Cellar	Va.	—	Hybrid-rural	—	1.71
98	02041038	VA_Sweathouse	Va.	—	Hybrid-rural	—	0.14
99	02011460	VA_Back.NearSunrise	Va.	—	Hydro	6	0.01
100	02011470	VA_Back.AtSunrise	Va.	—	Hydro	14	0.16
101	02011490	VA_L.Back	Va.	—	Hydro	21	0.51
102	02011500	VA_Back.MtnGrove	Va.	—	Hydro	14	0.13
103	02011800	VA_Jackson	Va.	—	Hydro	16	0.13
104	02021500	VA_Maury	Va.	—	Hydro	10	0.38
105	02072000	VA_Smith.Philpott	Va.	—	Hydro	22	0.11

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Map identifier (fig. 4)	NWIS station number	Field ID	State	Urban center	Site type	Hydrologic Disturbance Index[1] (unitless)	Urban land use (percent)[2]
106	02072500	VA_Smith.Bassett	Va.	—	Hydro	21	0.13
107	01658500	VA_S.F.Quantico	Va.	Washington, D.C.	Reference	9	0.87
108	02038850	VA_Holiday	Va.	Washington, D.C.	Reference	7	0.04
109	02034414	VA_Bonbrook	Va.	Washington, D.C.	Reference	—	0.31
110	02045370	VA_Buckskin	Va.	Washington, D.C.	Reference	—	0.64
111	02046160	VA_Sapony	Va.	Washington, D.C.	Reference	—	0.20
112	01645762	VA_S.F.Difficult	Va.	Washington, D.C.	Tier 1	—	6.77
113	01645704	VA_Difficult.Fox	Va.	Washington, D.C.	Tier 3	17	36.66
114	01646000	VA_Difficult.Falls	Va.	Washington, D.C.	Tier 3	26	20.63
115	01654000	VA_Accotink	Va.	Washington, D.C.	Tier 4	22	43.01

[1]Hydrologic Disturbance Index defined in Falcone and others (2010).

[2]Urban tier categories defined as ranges of percent urban land use in a watershed computed as the cumulative percentage of low, median, and high intensity developed land from the 2006 National Landcover Datasets (NLCD; classes 22, 23,24) (Fry and others, 2011): tier 1, 1 to 10 percent; tier 2, 10 to 20 percent; tier 3, 20 to 37.5 percent; tier 4, 37.5 to 50 percent; and tier 5, greater than 50 percent.

U.S. Geological Survey, 2012; McKay and others, 2012), and selected geographic information system (GIS) parameters summarized for gaged watersheds in the United States (Falcone and others, 2010; Falcone, 2011). The watersheds for USGS gaging station sites in the NHDPlus dataset were characterized by identifying the stream segment intersecting the gaged site, then accumulating the land-cover characteristics for that stream segment and all of its upstream reaches and catchments (Wieczorek and LaMotte, 2013). The median length of stream segments in NHDPlus was 1.5 kilometers (km). Candidate urban-gradient stream sites were categorized into five tiers on the basis of an urbanized metric of cumulative percentage of low-, medium-, and high-intensity developed land in the stream watershed (fig. 3; tables 3, 4) calculated by using 2006 land-cover data from the National Land Cover Database (NLCD) (Fry and others, 2011; Wickham and others, 2012; U.S. Geological Survey, 2011).

Candidate hydro sites were selected on the basis of a multi-parameter Hydrologic Disturbance Index (HDI) (Falcone and others, 2010, Falcone, 2011; fig. 3, table 3). The HDI represents the overall disturbance of anthropogenic stressors summarized within the gaged stream watershed. The HDI stressors include the density of major dams, change in reservoir storage, percentage of canals and artificial paths along the mainstem of each gage, distance to National Pollutant Discharge Elimination Sites (NPDES), freshwater withdrawal estimates, and landscape fragmentation (Falcone and others, 2010). Visual assessments of topographic maps of dams, intense urbanization, and poor watershed practices also were used to provide information that may be unaccounted for in HDI calculations. Minimal hydrologic disturbance sites were defined as streams with no major upstream impoundments on the mainstem, low total reservoir storage from tributaries, little to no diurnal fluctuation, and low amounts of urbanization (less than 15 percent of area) and channelization in the watershed (Falcone and others, 2010).

Candidate reference stream segments were selected on the basis of watersheds having a low degree of agricultural and urban development and, wherever possible, an extent predominantly or entirely within protected lands. Visible satellite imagery was reviewed to identify the location of CAFO to select candidate agriculture-CAFO (ag-CAFO) sites for group comparison purposes.

Additional site distribution guidelines included the following:

1. Reference sites were distributed across all States and, to the extent possible, located near each major urban center in the Piedmont ecoregion.
2. Urban tier sites were targeted to capture the complete urban gradient at each of four urban centers (Atlanta, Charlotte, Greenville-Spartanburg, and Raleigh-Durham-Greensboro); four more intensively urban sites were included in suburban Washington D.C. (tables 3, 4). All of the major urban centers are in the Piedmont ecoregion.
3. Ag-CAFO sites were targeted in five northeastern Georgia Piedmont watersheds characterized by multiple poultry CAFO facilities but minimal urbanization (less than 5 percent) or hydrologic alteration (for example, low normalized reservoir storage).
4. Hydro sites were targeted in the Ridge and Valley, Blue Ridge, and, where possible, Piedmont ecoregion watersheds characterized by varying degrees of hydrologic alteration and minimal urban or agricultural land use.

On the basis of the above selection criteria and on desktop reconnaissance of satellite imagery, approximately 150 candidate stream sites representing urban tier, hydro, reference, or ag-CAFO conditions were selected for instream reconnaissance conducted by the USGS during the fall and winter of 2013. Instream reconnaissance included logistical and site-type

Table 4. Description of low, medium, and high intensity developed land from datasets in the 2006 National Land Cover Database (NLCD) used in the determination of urban land use in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey National Water-Quality Assessment Program in 2014.

[More information available at http://www.mrlc.gov; %, percent]

NLCD classification code	NLCD classification	NLCD classification description
22	Developed, low intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.
23	Developed, medium intensity	Areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
24	Developed, high intensity	Highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

representativeness considerations for a 300-m stream reach. Information recorded by field notes and photography included (but was not limited to) the location and description of the nearest bridge for water-chemistry sampling, stream-reach wadeability, the presence of discharge pipes in the stream, stream accessibility, streambed substrate, richest target habitat, and potential landowner contacts. Field notes and photography were recorded onsite using a tablet-based, electronic field reconnaissance form. Electronic forms from all reconned sites were compiled into spreadsheet form for review and site selection.

Network Design

On the basis of field reconnaissance results, a total of 115 stream sites were selected for inclusion in the 2014 spring/summer regional assessment. Of these, 77 sites were multi-stressor (urban, ag-CAFO, reference, and hybrid-rural) sites and the remaining 38 were hydro sites (tables 1, 3; fig. 4). Multi-stressor sites were located on perennial, wadeable streams throughout the Piedmont Level III Ecoregion in the southeastern United States (figs. 1, 4). Hydro sites were located throughout the Ridge and Valley, Blue Ridge, and Piedmont Level III Ecoregions in the southeastern United States along perennial wadeable streams with minimal urban and agricultural land use in their watersheds (figs. 1, 4).

Multi-Stressor Site Network

The SESQA multi-stressor sites were selected to assess watershed-scale and instream water-quality stressors and instream ecological integrity. Watershed-scale stressors included a number of landscape and land-use changes in the Piedmont ecoregion. In addition to potential direct impacts on aquatic communities, landscape changes can, in turn, trigger instream physical, chemical, and biological alterations that directly affect aquatic community health (fig. 5). An increase in the intensity of agricultural and urban land use can increase the concentrations of contaminants in a stream, including metals, nutrients, wastewater compounds, pharmaceuticals, polycyclic aromatic hydrocarbons (PAHs), and pesticides, and may degrade ecosystem health (Lenat and Crawford, 1994; Cuffney and others, 2011; Bryant and Carlisle, 2012).

Fifty-four of the multi-stressor sites were USGS continuous streamflow gaging stations and were classified as urban tier sites ranging from 1 (least urbanized) to 5 (most urbanized) (tables 1, 3). The five multi-stressor sites selected to assess watershed ag-CAFO impacts did not have existing USGS continuous streamflow monitoring and, consequently, required streamflow and water-level monitoring during the SESQA sampling period. Similarly, the majority of the 13 reference stream sites did not have existing continuous streamflow monitoring and required additional streamflow and water-level monitoring during the SESQA data collection effort (table 1). Four multi-stressor sites were considered a hybrid of urban tier 1 and low-intensity, pasture-hay agriculture; these sites were classified as hybrid-rural. One multi-stressor site was an urban tier 3 site located immediately downstream from a reservoir and paired with an urban tier 3 site located upstream from the reservoir. This reservoir-influenced site was classified as a hybrid-hydro site.

Sampling frequency varied by site type (table 5; appendix 1, table 1–1, fig. 1–1). Weekly water sampling at urban tier and ag-CAFO sites spanned 10 weeks during April, May, and early June 2014. Sampling at reference, hybrid-rural, and hybrid-hydro sites spanned the final 4 weeks of the 10-week sampling period (mid-May to early June 2014). Contaminants sampled at the multi-stressor sites included contaminants of emerging concern (CECs; for example, pharmaceuticals, hormones, and personal care products), VOCs, pesticides, and trace elements (including mercury), in addition to nutrients and suspended sediment (appendix 1, fig. 1–1). A one-time ecological survey of habitat, algae, benthic macroinvertebrates, and fish was conducted at all Piedmont multi-stressor sites during the final 2 weeks of the 10-week water-quality “index” period. Streambed sediment also was collected during the ecological survey for analysis of sediment chemistry and toxicity.

Hydro Site Network

Hydrologic alteration of the natural flow regime of rivers and streams by channelization or impoundment is associated with ecosystem degradation (Konrad and others, 2008; Carlisle and others, 2010). Previous studies have established generalized correlations between certain human activities and specific types of hydrologic alteration (Carlisle and others, 2012; Eng and others, 2013). For example, flood control operations at a dam reduce peak flow during a flood but extend the duration of high flows when the reservoir is drained. Storing water in a reservoir for water supply reduces the rate and variability of downstream flow, whereas reservoir releases for power generation or downstream navigational purposes increase the downstream flow rate. Land cover conversions (removing native vegetation and soils; grading the land surface; and constructing drainage networks, roads, and buildings) typically increase the frequency and magnitude of storm runoff while reducing the shallow groundwater discharge, which normally contributes to streamflow for days or weeks following storm events. Surface-water diversion and shallow groundwater withdrawals further reduce base flow in streams.

The 38 hydro sites sampled were along streams in watersheds having little evidence of agricultural or urban land use but clear evidence of hydrologic alteration, such as a dam and reservoir (tables 1, 3; fig. 4). These sites were targeted to assess the effects of hydrologic alteration on aquatic organisms, such as fish and invertebrates, without the confounding influences of multiple other stressors associated with urban development. Hydro sites were sampled once for water and sediment chemistry, concurrent with the one-time ecological survey (table 5; appendix 1, table 1–1, fig. 1–1).

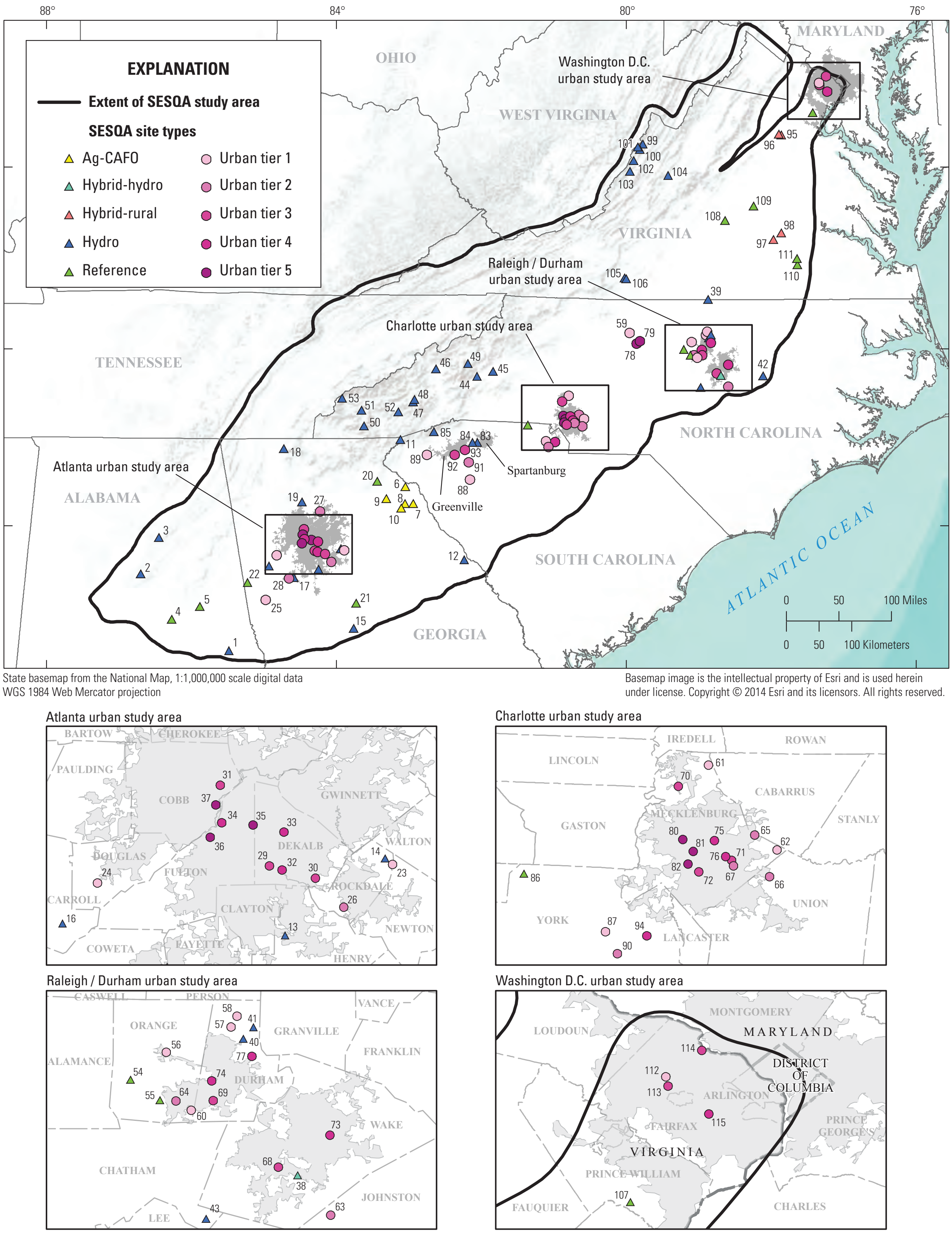

Figure 4. Spatial distribution of the selected stream sites by site type for the Southeastern Stream Quality Assessment in the U.S. Geological Survey National Water-Quality Assessment Program in 2014. [ag-CAFO, land use dominated by poultry confined animal feeding operations; Hydro, dominated by hydrologic alteration; urban tiers range from 1 to 5 and 1 is least urbanized and 5 is most urbanized; reference, minimal disturbance by human activities; hybrid-hydro, mixed urban and hydrologic alteration; hybrid-rural, mix of urban tier 1, agriculture (pasture-hay type), and reference]

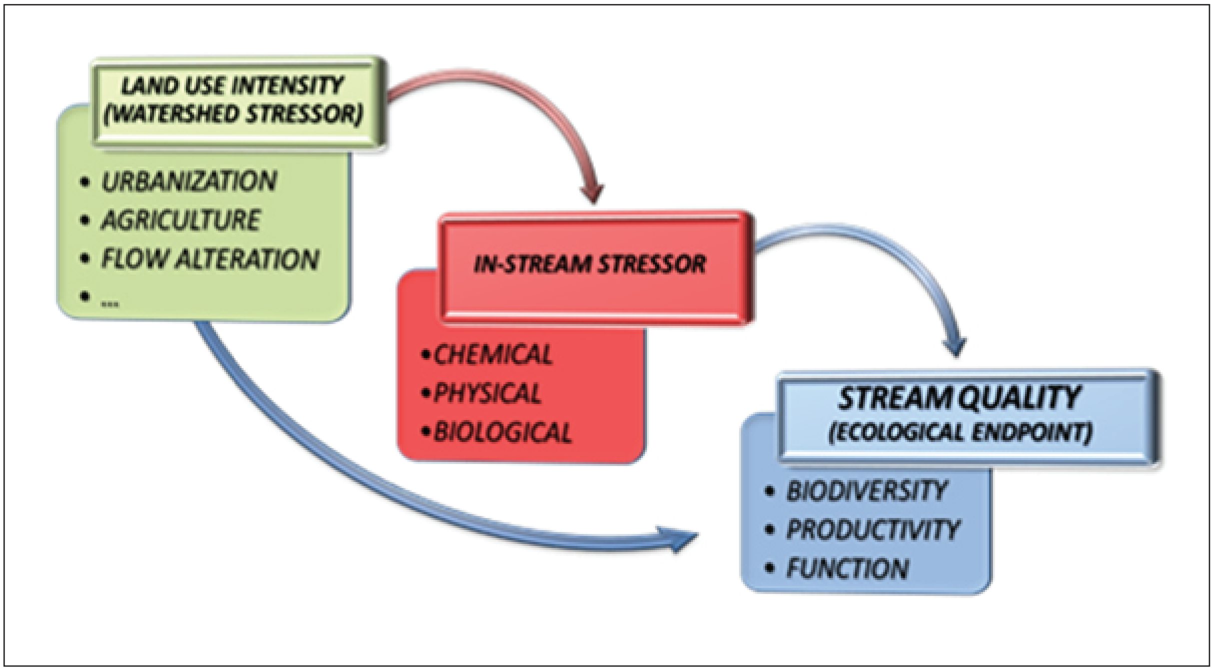

Figure 5. Conceptualization of the general study approach in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey National Water-Quality Assessment Program assessing relations between watershed (land use intensity) stressors, instream stressors, and instream aquatic health indices (ecological endpoints) in 2014.

Table 5. Field and laboratory analyses at stream sites monitored as part of the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program in 2014, by focus area and site type.

[POCIS, Polar Organic Compound Integrated Samplers; DOC, dissolved organic carbon; Hydro, hydrologically altered conditions; Ag-CAFO, agricultural confined animal feeding operations; —, no data]

Focus area	Targeted ecoregion	Site type	Water column		
			Continuous monitoring April to September, 2014	Time-integrated water chemistry March to June 2014	Discrete field measurement during sampling
Multi-stressor (n=77)	Piedmont	Reference (n=13)	Water level Water temperature	Pesticides using POCIS	Dissolved oxygen pH Specific conductance Water temperature Streamflow
		Urban tier (n=54)	Streamflow Water level Water temperature Chlorophyll Dissolved oxygen pH Specific conductance Nitrate & nitrite	Pesticides using POCIS Pesticides using Pankow	Dissolved oxygen pH Specific conductance Water temperature
		Hybrid sites (n=5)	Streamflow Water level Water temperature	Pesticides using POCIS	Dissolved oxygen pH Specific conductance Water temperature
		Ag-CAFO (n=5)	Water level Water temperature	Pesticides using POCIS	Dissolved oxygen pH Specific conductance Water temperature Streamflow
Hydrologic alteration (n=38)	Piedmont, Blue Ridge, and Ridge and Valley (Highlands)	Hydro	Streamflow Water level Water temperature	—	Dissolved oxygen pH Specific conductance Water temperature

Table 5. Field and laboratory analyses at stream sites monitored as part of the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program in 2014, by focus area and site type.—Continued

[POCIS, Polar Organic Compound Integrated Samplers; DOC, dissolved organic carbon; Hydro, sites with hydrologically altered conditions; Ag-CAFO, sites with agricultural influenced related to concentrated animal feeding operations; —, no data]

Water column—Continued		Streambed sediment		Ecology			
Discrete water chemistry		Chemistry	Toxicity testing	Peri-phyton	Benthic macro-inver-tebrate	Fish	Habitat
Frequency	Constituents	One-time sampling					
Weekly from May 19 to June 16, 2014	Major ions Suspended sediment Nutrients Pesticides Total mercury Methylmercury DOC Stable isotopes	Major elements Trace elements Radionuclides Polycyclic aromatic hydrocarbons Semi-volatile organic compounds Halogenated compounds	Yes	Yes	Yes	Yes	Yes
Weekly from April 7 to June 16, 2014	Major ions Suspended sediment Nutrients Pesticides Pharmaceuticals Organic wastewater indicators Volatile organic compounds Total mercury Methylmercury DOC Stable isotopes	Major elements Trace elements Radionuclides Polycyclic aromatic hydrocarbons Semi-volatile organic compounds Halogenated compounds Current use pesticides Organic wastewater indicators Hormones	Yes	Yes	Yes	Yes	Yes
Weekly from April 7 to June 16, 2014	Major ions Suspended sediment Nutrients Pesticides Total mercury Methylmercury DOC Stable isotopes	Major elements Trace elements Radionuclides Polycyclic aromatic hydrocarbons Semi-volatile organic compounds Halogenated compounds	Yes	Yes	Yes	Yes	Yes
Weekly from April 7 to June 16, 2014	Major ions Suspended sediment Nutrients Pesticides Pharmaceuticals Organic wastewater indicators Hormones Total mercury Methylmercury DOC Stable isotopes	Major elements Trace elements Radionuclides Polycyclic aromatic hydrocarbons Semi-volatile organic compounds Halogenated compounds Hormones	Yes	Yes	Yes	Yes	Yes
Once from June 19 to August 20, 2014	Major ions Suspended sediment Nutrients Total mercury Methylmercury DOC Stable isotopes	Major elements Trace elements Radionuclides Polycyclic aromatic hydrocarbons Semi-volatile organic compounds Halogenated compounds Hormones	Yes	Yes	Yes	Yes	Yes

Data Collection and Processing

The number and type of water samples collected during SESQA varied by site type and required the use of parts-per-billion protocols (U.S. Geological Survey, 2006). Sample collection and analysis timelines are presented in table 5 and appendix 1 (tables 1–1 to 1–3, fig. 1–1). More than twelve 2-person teams from five States in the southeastern United States were required to complete the water-quality data collection effort. To ensure consistency among the water-quality teams, training for the collection and processing of water-quality samples was provided by the USGS in the spring of 2014 for all personnel involved with sample collection. To ensure benthic invertebrate, fish, algal community, and physical habitat surveys were completed within the shortest timeframe, seven 6-person teams were trained on USGS ecological sampling and bottom sediment collection protocols during the spring of 2014, prior to the water-quality sampling period.

Water Temperature and Water Level Monitoring

Water temperature is an important component of stream-water quality, especially in relation to the health of a stream ecosystem. Because urbanization, agricultural activities, and hydrologic alteration can affect water temperatures (Poole and Berman, 2001; Webb and Zhang, 1997), digital temperature-data loggers were used to continuously monitor water temperature at all stream sites in the SESQA study. Internally logging digital devices were deployed prior to April 7, 2014, the beginning of the data collection period, and remained deployed until December 2014. When possible, loggers were deployed approximately 15 cm above the streambed and out of direct sunlight on stable parts of the streamgage infrastructure or bridge piers.

Specifications for the HOBO Water Temp Pro v2 U22 loggers used in the SESQA study are provided in table 6. Guidance from the manufacturer and U.S. Forest Service concerning the deployment, calibration, and maintenance was adopted, in large part, for the SESQA study (Onset Computer Corporation, 2012; Dunham and others, 2005).

At the 11 sites where continuous streamflow gaging stations did not exist (table 1), digital water level loggers were deployed that recorded both water temperature and water level. The internally logging digital devices were deployed prior to April 7, 2014, the beginning of the data collection period, and remained deployed until December 2014. Specifications for the HOBO U20–001–04 digital water level loggers used for the SESQA study are provided in table 6. Guidance from the manufacturer and the USGS concerning the deployment, calibration, and maintenance was adopted, in large part, for the SESQA study (Onset Computer Corporation, 2014; Sauer and Turnipseed, 2010). Guidelines for deployment included the installation of two loggers per site—one to measure water level (water column) and one to measure barometric pressure (air). Location and infrastructure design required each logger to be deployed in a permanently fixed protective casing that allowed the logger to be returned to the exact location in the water column or the air following data download. The water-level logger was mounted at a depth where it could remain submerged yet be accessed at all stages. To avoid the risk of it getting wet, the barometric logger typically was not installed with the transducer in the casing but instead was fixed to a nearby tree or bridge infrastructure.

Table 6. Onset Computer Corporation specifications for the HOBO Water Temp Pro v2 U22 and U20 Water Level Loggers used to monitor continuous water temperature and water level, respectively, at selected stream sites as part of the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey National Water-Quality Assessment Program in 2014.

[°C, degrees Celsius; °F, degrees Fahrenheit, m/s, meter per second; kPa, kilopascal; psi, pound per square inch; ft, foot; cm, centimeter; m, meter; m/s, meter per second; FS, full scale pressure; <, less than]

Specifications	Range
	HOBO Water Temp Pro v2 U22 Logger
Operation range	–40 to 70 °C (–40 to 158 °F) in air; maximum sustained temperature of 50 °C (122 °F) in water
Accuracy	±0.21 °C from 0 to 50 °C (±0.38 °F from 32 to 122 °F)
Resolution	0.02 °C at 25 °C (0.04 °F at 77 °F)
Response time (90 percent)	5 minutes in water; 12 minutes in air moving 2 m/s (typical)
Stability (drift)	0.1 °C (0.18 °F) per year
	HOBO U20-001-04 Water Level Logger
Operation range	0 to 145 kPa (0 to 21 psi); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level
Accuracy	±0.75 percent FS, 0.3 cm (0.01 ft) water
Resolution	<0.014 kPa (0.063 psi); 0.14 cm (0.005 ft) water
Pressure response time (90 percent)	<1 second

After installation, a reference point (RP) was established on a permanently fixed structure, such as a fencepost or mark on a bridge, to measure the distance to water surface to verify that the deployed water-level logger had not moved. Guidelines for establishing the reference marks or RP are as follows:

1. An arbitrary datum number that covers all low stages (to ensure no negative numbers) was chosen. For example, if the maximum depth of a cross section is 5 feet (ft), and the lowest RP is 0.5 ft out of the water, a datum number of 6.0 ft would be selected for a lower RP.
2. A second, higher RP is chosen and referenced to the same datum as the first RP.
3. The water-level logger and RPs are located in the same stream pool with the same control conditions.

Figure 6. Deployed Polar Organic Compound Integrated Sampler (POCIS) on cinder-block-and-cable infrastructure in Manchester Creek near Rock Hill, South Carolina, 2014 (photograph by Celeste Journey, USGS).

Water-Quality Data Collection

During the SESQA study, water-quality data were collected using time-integrated and discrete methods. Event-level streamflow concentration hysteresis, short-term “spikes” in contaminant concentrations, and seasonal land-application periods can result in fluvial fluxes of pesticides and other organic compounds that cannot be directly related to streamflow. Weekly discrete samples of water chemistry may not accurately reflect the exposure of biota to these instream stressors and their potential acute toxic and cumulative sublethal effects. Therefore, to complement weekly collection of discrete stream samples, high-frequency, discrete micro-autosamplers (Pankow samplers) and passive-integrated sampling devices were employed in the SESQA study (tables 1, 5).

Integrated Water-Quality Sampling

Passive samplers were used to collect time-weighted average concentrations of polar organic compounds at multi-stressor sites during the SESQA study. Additionally, at a much smaller subset of urban tier sites, micro-autosamplers were deployed to evaluate daily and weekly changes in pesticide concentrations as part of the SESQA study.

Polar Organic Compound Integrated Samplers

Polar Organic Compound Integrated Samplers (POCIS) used for the passive collection of polar organic compounds were deployed at all 77 multi-stressor sites during the SESQA data collection period. The POCIS devices allow estimation of time-weighted average concentrations of chemical stressors, including pharmaceuticals, personal care products, and current-use pesticides, for ecological risk assessment.

At the 54 urban tier and 5 ag-CAFO sites, POCIS were deployed twice (fig. 6, table 3; appendix 1, table 1–1, fig. 1–1). The first deployment lasted 7 weeks, from the week of March 3 until the week of April 21, 2014. Coincident with retrieval of the first POCIS during the week of April 21, the second POCIS was deployed for 7 weeks and retrieved the week of June 9, 2014. At the remaining 18 reference and hybrid sites, POCIS were deployed only once for 7 weeks from the week of April 21 until the week of June 9, 2014.

Field deployment was in accordance with guidelines provided in Alvarez (2010). Field considerations for the deployment site required a stream location that was deep enough to remain submerged during all streamflow conditions and was protected from excessive sediment accumulation, flood debris, and vandalism. Effective anchoring systems were adopted on the basis of site-specific characteristics (for example, sandy versus rocky substrate, streamflow variability, and so forth). Field logs were maintained that included the site name, date and time of deployment and retrieval, and observations of streambed substrate, streamflow conditions, and water clarity.

About 10 percent (six blanks during the first deployment and seven during the second) of the POCIS samples were field blanks used to assess any accumulation of target and non-target compounds from the air during shipment and transport. The POCIS field-blank collection protocols required the blank canisters to be open to the air at the same time and place as the field POCIS were exposed to air during deployment and retrieval. Between deployment and retrieval of the field POCIS, POCIS blank canisters were kept sealed and stored between –20 to 0 °C. All field POCIS and blank canisters were stored on ice during transport to the field location.

After the 7-week deployment period, deployment canisters containing the POCIS samplers, field blanks, and log sheets were shipped to CERC immediately upon retrieval or stored at –20 to 0 °C until shipment. The CERC eluted the concentrated extract from the field and blank POCIS samplers using a mixture of dichloromethane (DCM): methyl-*tert*-butyl ether

(80:20, v:v; Coes and others, 2013). Concentrated extracts were sealed in 1-milliliter (mL) amber glass ampules, kept below 20 °C, and shipped to the USGS National Water Quality Laboratory (NWQL) in Denver, Colorado for analysis. At the NWQL, the extracts were transferred to receiver tubes and evaporated to final volume. Lab blank and lab-fortified spike samples were prepared using comparable volumes of DCM and processed with the POCIS extracts (Coes and others, 2013).

Pankow Pesticide Micro-Autosamplers

High frequency, micro-autosamplers (Pankow samplers) that collected daily and weekly composite (4-hour aliquot interval for daily; 8-hour aliquot interval for weekly) pesticide water samples were deployed at seven SESQA multi-stressor stream sites for the entire 10-week water-quality index period. These autosamplers were developed and assembled at Portland State University to collect fixed-point, low-volume samples for analysis of pesticides in water using newly developed direct-injection aqueous phase (DIA) methods (fig. 7). The Pankow micro-autosamplers were developed to determine if increased sampling frequency more accurately described the instream stressor conditions experienced by indigenous biota, including short-lived but acutely toxic events.

Pankow pesticide micro-autosamplers were deployed at tier 3–5 urban gradient sites in four States in the SESQA study area (table 1). Two sites (Sope Creek near Marietta, GA, and Proctor Creek at Jackson Parkway, at Atlanta, GA) were located in Atlanta, Ga. One site (Manchester Creek near Rock Hill, SC) was located near Charlotte, N.C., and another (Reedy Creek near Greenville) was located in Greenville, S.C. Two more sites (Marsh Creek near New Hope, NC, and Swift Creek near Apex, NC) were located in Raleigh, N.C. The final site (Accotink Creek near Annandale, VA) was located near Washington, D.C.

The Pankow micro-autosamplers were programmed for unattended collection of streamwater aliquots over a 1-week period. An aliquot of streamwater was collected every 4 hours into daily composite vials (one vial per day) and every 8 hours into one weekly composite vial. A 6-mL aliquot of buffer solution was added to all nine vials at the beginning of each week as a preservative. A ninth vial containing a known pesticide spike in organic-free blank water also was included to assess the potential for compound degradation during the weekly collection period. Samplers were swapped weekly in order to collect sample vials, charge batteries, clean tubing, and replace consumable components such as filters.

Prior to deployment, each vial was labeled with the station identification number, vial number, date, and initial weight. Daily-composite samples (vials 1 through 7) were analyzed for pesticide concentrations by the EPA Office of Pesticide Program. The weekly composite sample (vial 9) and the spike (vial 8) control were analyzed for pesticide concentration by the NWQL. Analytical Service Request (ASR) forms (USGS) and cooler inventory forms (USGS and EPA) were included with sample shipments. Barcodes were affixed to each vial as an auxiliary data match.

Discrete Water-Quality Sampling

At the urban tier, reference, hybrid, and ag-CAFO sites, discrete water samples were collected over a range of flow conditions during the 10-week “water-quality index” period (urban tier and ag-CAFO sites) or during the final 4 weeks (reference and hybrid sites). For the majority of the constituents, discrete water-sample collection was conducted using an isokinetic, equal-width increment (EWI) approach (U.S. Geological Survey, 2006), whereby subsamples were collected at 10 increments across the stream using either a DH–81 or

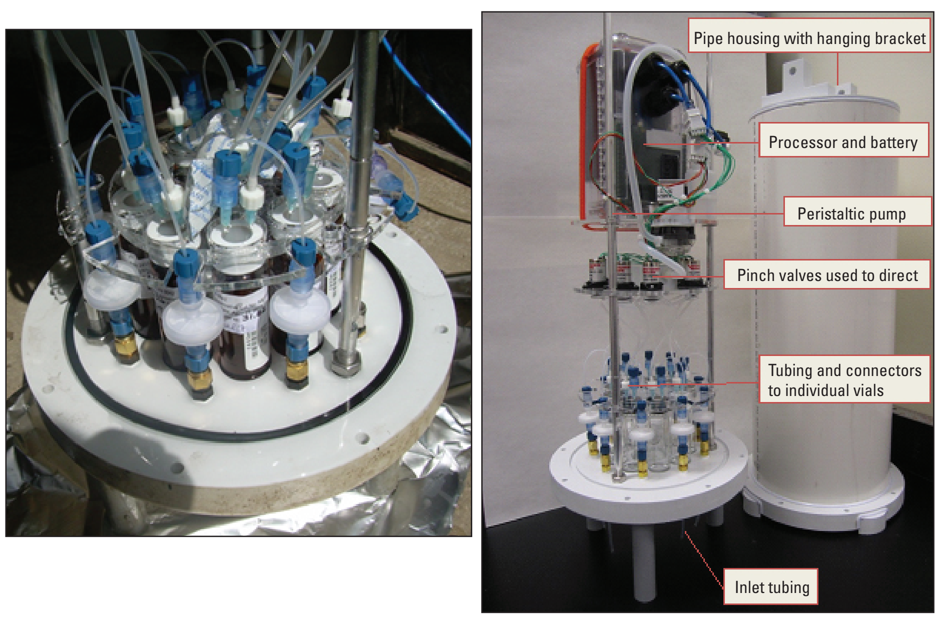

Figure 7. Micro-autosamplers used to collect filtered water at sub-daily intervals for pesticide analysis as part of the Southeastern Stream Quality Assessment (SESQA) study by the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program in 2014. The micro-autosamplers were designed and built at Portland State University.

DH–95 sampler (Davis, 2005) (appendix 1, table 1–4). The sampler had a precleaned Teflon cap and nozzle assembly that fitted a 1-liter (L) Teflon bottle (U.S. Geological Survey, 2006). Each incremental sample was placed immediately into a precleaned, acid- and methanol-rinsed Teflon churn for compositing prior to processing. All field equipment was precleaned prior to sampling according to USGS protocols (Wilde, 2004) and rinsed with native water immediately prior to sample collection.

Ultra-trace-level clean-sampling procedures and equipment were used to collect surface-water samples at selected sites for low-level total mercury and methylmercury analysis (U.S. Environmental Protection Agency, 1996; Lewis and Brigham, 2004). Water samples were collected as a grab sample from the centroid of flow at about 0.3 m below the water surface in a Teflon bottle. The collected sample was acidified immediately with ultra-pure hydrochloric acid (Lewis and Brigham, 2004).

Samples were collected and processed using protocols documented in the USGS National Field Manual (Wilde and others, 2004). Field properties of specific conductance, pH, dissolved oxygen, and water temperature were measured at the time of sampling with a field-calibrated multiparameter sonde (Wilde, variously dated).

Field property and analytical data were reviewed according to established quality-assurance and quality-control protocols. After review, all data were stored in the USGS National Water Information System (NWIS) database.

Sediment Data Collection

Streambed sediment samples for all SESQA sites were collected once during the ecological survey immediately before ecological sampling using established USGS protocols (Radtke, 2005). Four-inch (about 10 cm) polyvinyl chloride (PVC) cylinders were used to collect the streambed material. Shallow depositional areas of the ecological assessment reach were targeted for sediment collection. The plastic cylinder was pushed into the streambed to a depth of 2 cm, then a 12×12-cm plastic sheet was slid under the cylinder to support the enclosed streambed core. Each streambed core was lifted gently out of the water to minimize the loss of fine material and composited in a large plastic bucket. Approximately 6 to 10 L of streambed material was collected along the ecological assessment reach. The bulk sediment sample was immediately placed on ice and shipped to CERC.

Ecological Data Collection

Algae, invertebrate, and fish samples were collected from the ecological assessment reach (150 to 300 m in length) according to the methods documented in Moulton and others (2002). The physical stream habitat in the reach also was assessed and field measurements were taken. Ecological assessments were conducted in early June or mid-August 2014 for Piedmont, Blue Ridge, and Ridge and Valley streams, respectively. All field data were recorded in-reach on electronic forms using hand-held tablets. All data were summarized electronically and loaded into the USGS BioData biological database.

Algal and invertebrate communities were sampled using protocols for quantitative richest-targeted habitat (RTH) samples. The RTH sample was intended to represent the habitat (usually a riffle) having the greatest diversity of organisms within a given stream reach. In some cases, such as sand-bottomed streams with no riffles, woody snags were sampled as the richest target habitat. Collection of algal and invertebrate samples was coordinated in space and time. Algal samples were collected using standard USGS methods (Porter and others, 1993; Moulton and others, 2002; Hambrook and Canova, 2007). The periphyton biofilm was scraped from natural substrates, either hard riffle substrate or woody snags, to obtain a targeted area of 150 cm^2. The substrates were scraped into a 500-mL bottle and combined into a single composited algal sample to represent the site. Two subsamples were removed and filtered for analysis of chlorophyll *a* and ash-free dry mass by the NWQL. Two addition subsamples were processed as backups in the event of sample loss or damage. The remainder of the sample was preserved with buffered formalin to a concentration of approximately 5 percent and sent to the University of Colorado for algal community identification and enumeration.

Invertebrate samples also were collected using standard USGS methods (Moulton and others, 2002). Invertebrate samples were collected from the RTH (rock riffle, when present, or woody snags), using a modified Surber sampler with 500-micron (µm) mesh net. The invertebrate sample area was targeted at 12,500 cm^2 for both riffle and woody snag substrates. The samples were sieved through a 500-µm sieve and large organic and inorganic debris was removed. The sample was then transferred to a 1-L bottle and preserved with 10-percent buffered formalin. Large or rare invertebrates, such as crayfish and larger mollusks, were photographed and released in accordance with collection permit procedures. Identification and enumeration of invertebrate taxa (generally either genus or species) were completed by the NWQL.

A representative fish-community sample was collected at each site using backpack-mounted electrofishing units. In streams wider than approximately 10 m, two backpack units were used in tandem to cover a larger area of the stream and to increase efficiency. Two electrofishing passes of the sampling reach were conducted using the same number of backpacks in each pass. Fish were identified to taxa (generally species), counted in the field, and then released downstream from the collection reach. In the few cases where a fish could not be positively identified in the field, an individual sample was preserved for later identification.

The physical habitat reach was characterized following USGS protocols (Fitzpatrick and others, 1998). Reach lengths for this study were standardized to either 150 or 300 m, determined by mean wetted width as less than or greater than 10 m, respectively, at the sampling site. Qualitative and quantitative measurements were collected at 11 primary and 10 secondary transects. Depending on the transect type, these measurements included, but were not limited to, depth, wetted width, substrate particle size, canopy cover, macrophyte coverage, bank height, presence of bars and islands, and instream habitat.

Nutrient Flux and Biological Response

A focused investigation of nutrients and associated biological response was conducted at six of the urban tier sites in the SESQA region to provide high resolution information on seasonal nutrient dynamics (table 1). The six sites had existing streamgages and were nested within two urban watersheds, one in Raleigh, N.C., and one in Atlanta, Ga. The sites were instrumented with YSI EXO and SUNA (nitrate) continuous water-quality monitors for 6 months from March to September 2014. The following parameters were measured continuously during the study: temperature, dissolved oxygen, pH, specific conductance, turbidity, chlorophyll *a*, fluorescent dissolved organic matter (FDOM—a proxy for carbon concentrations), and nitrate. Reach-scale benthic chlorophyll samples were collected monthly during the 6-month monitoring period. Aquatic macrophyte cover was determined during the monthly sampling using established transect methods.

Source and Quality of Suspended Sediment

Suspended-sediment samples were collected in 14 streams using a time-integrating passive sampler referred to as a Walling tube (Phillips and others, 2000). The tubes were deployed for two purposes: (1) to identify sources of suspended sediments using metals and radionuclides, and (2) to evaluate relations between coal-tar pavement sealcoat and other urban PAHs sources and concentrations of PAHs actively being transported by the streams. The sediment sampler was made from commercially available PVC pipe (dimensions of 98-millimeter [mm] inner-diameter width by 1-m length) (fig. 8). The pipe was cut to a length of approximately 1.0 m, and the cylinder ends were sealed by threaded end caps. A hole was drilled into the center of the end caps to allow a 4-mm plastic tube to be inserted. The passive samplers were placed on posts that were pounded into the riverbed with the funnel-shaped tube end facing into the flow. Typically, four samplers were installed in the channel. To ensure collection of suspended sediment and avoid sampling bed load, the samplers were not placed close to the channel bed but were either submerged or placed above base flow.

Suspended sediment collection by Walling tube was conducted during the water-quality sampling index period. The tubes were inspected at either a set time interval (approximately 1 week) or after an event to determine if the collected sediment was adequate for sampling. To collect samples, the samplers were removed from their posts, the end caps were

Figure 8. Installation of Walling tubes by U.S. Geological Survey personnel in North Fork Peachtree Creek in Atlanta, Georgia, in 2014 (photograph by Celeste Journey, USGS).

opened, and the water and sediment were released into a 5-gallon (gal) plastic bucket. A spray bottle filled with deionized water was used to rinse sediment from the tubes. After sampling, the tubes were cleaned with a brush and deionized water, then rinsed with native water. The water-sediment mixture in the 5-gal plastic bucket was stored immediately on ice or in a cooler prior to final laboratory preparation.

Laboratory Analyses

The majority of the laboratory analyses for water, sediment, and algal samples were conducted by the NWQL (appendix 2, tables 2–1 to 2–12). Analytical results from the NWQL were uploaded to the NWIS QWDATA database of the USGS for storage and archival purposes. Results of each sample in QWDATA were uniquely identified by station identification number, date, time, and medium code. Additionally, each SESQA sample was labeled with a unique barcode as a backup sample tracking identifier.

Integrated Water Samples

The NWQL analyzed the POCIS extracts for concentrations of current-use pesticides (appendix 2, table 2–3), organic wastewater indicators (appendix 2, table 2–8), and pharmaceuticals (appendix 2, table 2–6). Weekly composite and spike Pankow samples were analyzed for current-use pesticides (appendix 2, table 2–3) only.

The current-use pesticide analytical method quantified 265 pesticides and pesticide degradates in filtered water samples, using a direct-aqueous-injection liquid chromatography–tandem mass spectrometry (LC–MS/MS) (appendix 2, table 2–3; Sandstrom and others, 2015; Sandstrom and Wilde, 2014; Furlong and others, 2014). The targeted pesticides represent a broad range of chemical classes and were selected on the basis of criteria such as current use intensity, probability of occurrence in streams and groundwater, and toxicity to humans or aquatic organisms. The method involves direct injection of a 100-microliter (μL) sample onto the LC–MS/MS without any sample preparation other than filtration. Samples were analyzed with two injections—one in electrospray ionization (ESI) positive mode and one in ESI negative mode—using dynamic multiple reaction monitoring (MRM) conditions, with two MRM transitions for each analyte. Recoveries for most analytes ranged from 80 to 120 percent in the water types tested, with relative standard deviations of less than 30 percent. The method detection limits (MDLs) for most analytes ranged from 1 to 103 nanograms per liter (ng/L) for 183 analytes analyzed in the ESI positive mode, and from 2 to 106 ng/L for 42 analytes analyzed in the ESI negative mode. Nearly all of the pesticide compounds (227 of 229) were stable after 14 days of storage at 4 °C. The NWQL employed direct aqueous injection (DAI) LC–MS/MS for the determination of 112 human-use pharmaceuticals in filtered water samples (Furlong and others, 2014) and capillary column gas chromatography/mass spectrometry (CC GC–MS) for the determination of organic wastewater indicator compounds (Zaugg and others, 2006b).

Discrete Water Samples

All weekly samples were analyzed for pesticides, nutrients, and major ions by the NWQL. Current-use pesticides were analyzed in filtered water samples by the NWQL using a DAI LC–MS/MS (appendix 2, table 2–3; Sandstrom and others, in press). Samples for nutrients and major ions were analyzed by the NWQL as specified in appendix 2 (tables 2–1, 2–2) and described in Fishman and Friedman (1989), Fishman (1993), Patton and Kryskalla, (2003), and Patton and Kryskalla (2011). Total phosphorus (TP) concentrations were determined by colorimetry according to EPA method 365.1 (O'Dell, 1993). Dissolved ammonia, nitrite, and orthophosphate colorimetric analyses are described by Fishman (1993). Dissolved nitrate-plus-nitrite concentrations were determined by low-level enzyme reduction colorimetry using an automated discrete analyzer, as described by Patton and Kryskalla (2011). Concentrations of dissolved cations were determined by inductively coupled plasma–atomic emission spectroscopy (ICP/AES) (Fishman, 1993), and concentrations of dissolved anions were determined by ion chromatography, as described by Fishman and Friedman (1989).

Composited, whole-water samples for urban tier and ag-CAFO sites were analyzed biweekly (five times) for organic wastewater indicator compounds by CC GC/MS (appendix 2, table 2–8; Zaugg and others, 2006b; Zaugg and others, 2007) and for pharmaceuticals by DAI LC–MS/MS (appendix 2, table 2–6; Furlong and others, 2008, 2014). At ag-CAFO sites only, composited whole-water samples were analyzed by the NWQL for hormones using solid-phase extraction followed by derivatization and gas chromatography with tandem mass spectrometry (GC-MS/MS) (appendix 2, table 2–7; Foreman and others, 2012).

Grab samples for VOCs were collected three times over the 10-week period and analyzed by two custom methods by the NWQL. Ambient-temperature purge-and-trap gas chromatography/mass spectrometry (GC/MS) was used for the determination of 43 VOCs and heated purge-and-trap GC/MS was used for the determination of 38 additional VOCs (Connor and others, 1998; Rose and others, 2015). In both the heated and the ambient purgeable methods, VOCs were purged from the sample matrix by simultaneously bubbling helium through a 25-mL aqueous sample at either 60 °C or ambient temperature. The compounds were trapped in a tube containing suitable sorbent materials and then thermally desorbed into a capillary gas chromatographic column (GC) interfaced to a mass spectrometer (MS). For the heat purgeable method, the compounds were determined using electron impact in the simultaneous full scan/selected ion monitoring (SIM) mode. The heat purgeable method reported data from the SIM data file using the full-scan data file for confirmation if interferences were present from non-target compounds. For the ambient purgeable method, the compounds were determined using electron impact in the full scan mode. Both methods utilized similar instrumentation, with different GC columns, traps, and operating conditions.

Compounds were identified using strict identification criteria, which included analyzing standard reference materials and comparing retention times and relative ratios of the mass spectrum. Compounds were quantitated using internal standard procedures. Concentrations determined below the lowest calibration standard were qualified to signify the lower confidence in the extrapolated concentration. Compounds were not quantitated and were reported as not detected if they did not strictly adhere to MS identification criteria. Compounds identified with concentrations within the calibration range were reported without qualification unless quality control or holding times were compromised. Compounds with concentrations above the highest calibration standard were diluted to within the calibration range and reanalyzed.

Weekly composited whole-water samples were analyzed for suspended-sediment concentrations at the USGS Kentucky Sediment Laboratory, in Louisville, Kentucky. Methods for processing suspended-sediment concentrations are described in Knott and others (1993) and Shreve and Downs (2005).

Biweekly samples were analyzed for methylmercury by gas chromatographic separation with cold vapor atomic fluorescence spectrometry (De Wild and others, 2002) and for total mercury by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry (Method 1631, revision E; U.S. Environmental Protection Agency, 2002) at the USGS Wisconsin Mercury Research Laboratory (WMRL) in Middleton, Wisconsin. The WMRL also analyzed weekly samples for dissolved organic carbon and ultraviolet absorbance at 254 nanometers.

Sediment Samples

An aliquot of each streambed sediment sample was analyzed for organic wastewater indicator compounds by solid-phase extraction CC GC/MS (appendix 2, table 2–9; Burkhardt and others, 2006) and for polycyclic aromatic hydrocarbons and other semi-volatile compounds by solid-phase extraction GC/MS (appendix 2, table 2–10; Zaugg and others, 2006a). A custom method that extracted the sample by pressurized liquid extraction and solid-phase extraction and analyzed by electron-capture negative ionization mode (GC/ECNIMS) with ammonia reagent gas was used for the determination of organo-chlorine insecticides, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ethers (PBDEs) in sediment (appendix 2, table 2–11; William Foreman, USGS NWQL, written commun., April 1, 2015). Trace metals in sediment were determined by the USGS Geologic Division laboratory using ICP/AES and inductively coupled plasma–mass spectrometry (ICP–MS) following dissolution in a mixture of hydrochloric, nitric, perchloric, and hydrofluoric acids (Smith and others, 2013).

Ecological Samples

Samples for chlorophyll *a*, pheophytin *a*, and periphyton ash-free dry mass that were collected during the ecological survey were processed onto 0.47-µm glass-fiber filters. The filters were analyzed using Standard Methods and EPA method 445.0, respectively, by the NWQL (appendix 2, table 2–12; American Public Health Association, 1998; Arar and Collins, 1997).

Whole sediment toxicity tests were conducted with the amphipod *Hyalella azteca* (28-day exposures), with the midge *Chironomus dilutus* (10-day exposures), and with the mussel *Lampsilis siliquoidea* (28-dau exposures) (Christopher Ingersoll, Columbia Environmental Research Center, U.S. Geological Survey, written commun., April 3, 2015). Endpoints measured included survival, weight, and biomass of test organisms. Exposures were conducted at 23 °C in 300-ml beakers containing 10 test organisms fed daily and 100 ml of sediment with two volume additions per day of overlying water. The toxicity tests were conducted following methods outline in U.S. Environmental Protection Agency (2000) and in American Society for Testing and Materials International (2014a) for sediment testing and in American Society for Testing and Materials International (2014b) for mussel testing.

Suspended Sediment

An aliquot of each suspended sediment sample from the Walling tubes was analyzed for PAHs and other semi-volatile organic compounds by solid-phase extraction GC/MS (appendix 2, table 2–10; Zaugg and others, 2006a).

Quality Assurance and Quality Control

Quality assurance and quality control (QA/QC) procedures maintain the integrity, accuracy, and legal defensibility of results from data collection and assessment. Documented QA/QC policies and procedures were implemented in the SESQA study to ensure that the data can be interpreted properly and be scientifically defensible (Mueller and others, 1997; U.S. Geological Survey, 2006). To achieve that goal, QC samples were collected to identify, quantify, and document bias and variability in data that result from the sampling procedure, including collection, processing, shipping, and handling of samples. Additionally, training was held for all field personnel prior to the sampling period to ensure appropriate and consistent methods were utilized.

The QC samples included field blanks, matrix spikes, and replicates (table 7; appendix 3). Field blanks were used to demonstrate that cleaning procedures were adequate to remove any sampling equipment contamination introduced by samples obtained at previous sites and ensure that sample collection, processing, handling, and shipping did not result in contamination (Mueller and others, 1997; U.S. Geological Survey, 2006). Field split replicates were prepared by dividing a single volume of water into two samples. These replicates provided a measure of the variability introduced during sample processing and analysis (Mueller and others, 1997; U.S. Geological Survey, 2006). Field and laboratory matrix spikes were used to assess the potential bias for analytes in a particular sample matrix. Bias is estimated from spiked samples by calculating the percentage of the added analyte (spike material) measured (recovered) in the sample (Mueller and others, 1997; U.S. Geological Survey, 2006). Recovery can be either greater than or less than 100 percent, so the bias can be either positive or negative; however, matrix interference and analyte degradation generally result in a negative bias.

Field blanks were collected once at 24 to 28 sites for the basic laboratory schedules (nutrients, major ion, dissolved organic carbon, pesticides, and glyphosate by immunoassay) collected weekly (appendix 3; table 7). For QA/QC samples collected as part of NAWQA, Mueller and others (1997) recommends one field blank or replicate per every 30 (3.3 percent) or 20 (5 percent) environmental samples for the previously mentioned constituents when sampling at long-term sites; however, if a large number of environmental samples are collected in a short period of time, as was the case in the SESQA study, it is recommended to lower the QC sample frequency to one per month. Therefore, for the SESQA study, the recommended percentage was computed as one monthly QC sample at 59 sites or 1.6 percent. Actual field blanks represented 3.4 to 4.0 percent of the environmental samples and split replicates for the same analyses represented 4.0 to 4.2 percent of the environmental samples, which met the recommended frequency (table 7; Mueller and others, 1997). No recommendation was provided for the organic compounds of emerging concern (pharmaceuticals, organic wastewater indicators, hormones) in Mueller and others (1997). Field blanks and split replicates for pharmaceutical and organic wastewater indicator analyses represented 4.7 percent of the environmental samples and increased to 5 and 25 percent, respectively, for hormone analysis (table 7). Matrix spikes were performed on all analyses for organic compounds, with the exception of glyphosate analysis by immunoassay. The frequency of these spikes was about 1 spike per every 20 environmental samples (table 7).

Quality assurance included maintaining standardized sample collection and handling protocols among all field personnel as described in the National Field Manual (U.S. Geological Survey, variously dated) for water and sediment sampling and by Moulton and others (2002) for ecological sampling. All sampling and handling protocols were reviewed by field personnel involved in the SESQA study during training courses prior to field work. Additionally, several programs exist within the USGS Branch of Quality Systems (BQS) to help document the quality of project results. For laboratory analyses conducted by the NWQL, documented QC included double-blind analyses of blanks for organic and inorganic constituents and provision of graphical and tabular control data for the analytical lines. Field personnel involved in the SESQA study were tested annually to verify their proficiency in collecting field data, including temperature, pH, dissolved oxygen, alkalinity, and specific conductivity.

Water-quality data from each sampled event were reviewed for completeness, precision, bias, and transcription errors when received from the laboratory as part of the QA/QC procedures. Water-quality and sediment-quality data were stored in the NWIS database. Quality-assured water-quality and sediment-quality data are available for retrieval on the internet at http://waterdata.usgs.gov/sc/nwis/sw. The NWQL provides all QA/QC documentation for their analytical services on the internet at http://nwql.usgs.gov/Public/quality.shtml.

The final goal of the data management process for the RSQA, including SESQA, is to have all appropriate data reviewed, approved, and stored with the appropriate data quality indicator (DQI) code in the NWIS database. The sampling locations and teams for the SESQA study were located in multiple States that each have their own USGS Water Science Center (WSC) NWIS database host for data entry and retrieval. Additionally, a central team of national RSQA and regional SESQA members play a role in the data management process. Therefore, the centralization of the data management process was essential to ensure consistency among the WSCs and among RSQA study areas. The nine main steps implemented for the data management process were as follows:

1. Sampling matrix and sample coding design
2. Electronic field form utilization
3. Sample status checks at all laboratories
4. NWIS sample record checks
5. Data transfer from laboratory to NWIS
6. Establishment of project networks
7. Sample coding and field parameter checks
8. Data quality checks (water, sediment)
9. Approval of data in NWIS

Prior to the start of sampling, the SESQA central team prepared the sample matrix design and sample coding plan for all aspects of the field process. The sampling matrix distributed QC samples equally across sites, sample teams, and time periods for optimum coverage. The matrix also served as a summary diagram for the type, frequency, and location of environmental and QC samples to be collected. The field data and field supply managers of the central team employed a consistent sample coding scheme among the SESQA sampling teams to ensure a well-structured and manageable dataset. Additionally, training and written guidelines for sampling coding were made available to sampling teams prior to the start of sampling.

The SESQA sampling teams from all of the WSCs utilized the Personal Computer Field Form (PCFF) version 7.1 software created by the USGS, which provides electronic field forms for data collection at sampling sites. The PCFF software streamlines the process of uploading (logging in) field data and sample codes to NWIS by automatically generating the batch load files required by NWIS (qwsample and qwresult), thereby resulting in a more efficient process of data flow from field and laboratory to database. The information uploaded to NWIS for each sample is stored under a unique number associated with that sample, as are later results received from the laboratory. In addition, the automation of data upload to NWIS limits the incidence of transcription errors that may occur during the manual entry of data into NWIS. Although PCFF can be used to generate the NWQL ASR documents for samples being submitted to the NWQL, field data and field supply managers of the central team preprinted and provided ASRs each week, along with the corresponding bottle sets.

Sample shipment schedules were established prior to the start of sampling for SESQA, which ranged from once per day to once per week depending on the sample type (appendix 1, table 1–2). Sampling teams and other WSC personnel were responsible for the shipment process. The field data manager of the central team continuously tracked the shipments to verify that the shipped samples were received at all laboratories (1) within the correct holding times, (2) in the proper condition (for example, chilled samples received at the appropriate temperature of 4 °C, and (3) with proper documentation. The field data manager worked with the laboratories to correct problems with mislabeled samples or ASRs in a timely manner and to communicate problem-resolution approaches to WSC personnel. During this process, the field data manager also established the connection between the USGS laboratory's

Table 7. Summary counts of environmental, field blank, replicate, and spike samples of streamwater from the 115 stream sites sampled in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA) in 2014.

[Recommended percentage from Mueller and others (1997); QA quality assurance; KS OGRL, Kansas organic geochemistry research laboratory; QC, quality control; —, no data]

Laboratory schedule	Type of sample	Sample counts	Ratio of QA to environmental samples (percent)	
Major ions	Environmental	700	Actual	Recommended
	Blank	25	3.6	[1]1.6
	Replicate	28	4.0	[1]1.6
	Spike	0	0	0
Nutrients	Environmental	700	Actual	Recommended
	Blank	24	3.4	[1]1.6
	Replicate	28	4.0	[1]1.6
	Spike	0	0	0
Dissolved organic carbon	Environmental	700	Actual	Recommended
	Blank	28	4.0	[1]1.6
	Replicate	28	4.0	[1]1.6
	Spike	0	0	0
Pesticides	Environmental	662	Actual	Recommended
	Blank	25	3.8	[1]1.6
	Replicate	28	4.2	10
	Spike	77	11.6	[2]11.6
Glyphosate (immunoassay)	Environmental	662	Actual	Recommended
	Blank	28	4.2	—
	Replicate	28	4.2	—
	Spike	0	0	—
Pharmaceuticals	Environmental	295	Actual	Recommended
	Blank	14	4.7	—
	Replicate	14	4.7	—
	Spike	14	5	—
Organic wastewater indicators	Environmental	295	Actual	Recommended
	Blank	14	4.7	—
	Replicate	14	4.7	—
	Spike	14	4.7	—
Glyphosate (KS OGRL)	Environmental	177	Actual	Recommended
	Blank	0	0.0	—
	Replicate	9	5.1	—
	Spike	9	5.1	—
Volatile organic compounds	Environmental	162	Actual	Recommended
	Blank	10	6.2	5.0
	Replicate	10	6.2	5.0
	Spike	7	4.3	[2]33

Table 7. Summary counts of environmental, field blank, replicate, and spike samples of streamwater from the 115 stream sites sampled in the Southeastern Stream Quality Assessment (SESQA) of the U.S. Geological Survey (USGS) National Water-Quality Assessment Program (NAWQA) in 2014.—Continued

[Recommended percentage from Mueller and others (1997); QA quality assurance; KS OGRL, Kansas organic geochemistry research laboratory; QC, quality control; —, no data]

Laboratory schedule	Type of sample	Sample counts	Ratio of QA to environmental samples (percent)	
Mercury	Environmental	405	Actual	Recommended
	Blank	22	5.4	[1]1.6
	Replicate	19	4.7	[1]1.6
	Spike	0	0	0
Hormones	Environmental	20	Actual	Recommended
	Blank	1	5.0	—
	Replicate	5	25.0	—
	Spike	1	5.0	—
Isotopes	Environmental	136	Actual	Recommended
	Blank	0	0.0	—
	Replicate	27	19.9	—
	Spike	0	0	—

[1]Mueller and others (1997) recommends substituting one per month if a large number of environmental samples are collected in a short period of time rather than a set 1 per 30 (3.3 percent) or 20 (5 percent). Therefore, for the SESQA study, weekly samples were collected at 59 sites for 10 weeks, so the recommended percentage was computed as one monthly QC sample at 59 sites, or 1.6 percent.

[2]Recommended amount is one per site.

Laboratory Information Management System (LIMS) used to transfer sample results and NWIS database used to receive and store sample results.

During sampling and the corresponding establishment of sample records in NWIS, the field data manager of the central team inspected sample coding and procedures of sample records in NWIS to make sure samples were established properly and in a consistent manner. Sample coding or procedures were modified if found to be inaccurate or inconsistent. These modifications involved changes or corrections to sample time offsets, sample type coding, or other documentation at the laboratory or in NWIS. Modifications in sample coding or procedures related to data management or sample submittal were communicated immediately to sampling teams to ensure appropriate adjustments were made before the next sampling.

The majority of the laboratories used for sample analysis by SESQA transmitted sample results through the Water Quality Data Exchange (QWDX) for automatic upload into the NWIS database (appendix 1, table 1–2). For those laboratories without the ability to use QWDX, sample results were loaded into NWIS using manually created batch files. Batch files were created by the field data manager upon receipt of electronic data from the laboratory. Batch files were loaded into the respective WSC NWIS host by either the field data manager (if granted access), WSC personnel, or the local Database Administrator (DBA). The field data manager verified that the manually loaded data were properly loaded into NWIS. Data files provided through email by labs and data not applicable to NWIS (for example CERC toxicity data), were stored electronically in a centrally located database rather than NWIS.

Once sampling sites were selected for SESQA, the field data manager, with input from the central team, identified the appropriate network designations in NWIS ProjectNetworks to allow integration of similar sites across many regions and to designate the site type in the NAWQA Data Warehouse. These network designations were obtained from the Project planning documents and, where possible, kept consistent with other network designations from previous regional studies. ProjectNetworks documentation was provided to local WSC personnel so they could establish their sites in NWIS ProjectNetworks.

After sampling was completed, the field data manager inspected the NWIS sample records for completeness regarding field data collection, including stream measurements (streamflow, stage, sampling points, stream width, and so forth), field parameters (pH, air and water temperature, specific conductance, dissolved oxygen), and proper sample coding (sample purpose, purpose of site visit, sampling method, sampler type, and multiple QC-related sample codes). Manual checks were made for each sample and any corrections were communicated to WSC personnel. The field data manager, WSC personnel, or DBA made any needed changes in NWIS.

National RSQA members of the central team reviewed the water-quality and sediment-quality results received from the laboratory. The water-quality data reviews included identification of extremes in the data (outliers), inconsistencies or unexpected results in the data, and major differences between environmental samples and replicates, detected values in blanks, and low analyte recoveries in spike samples. These team members communicated request reruns, reloads, and verification of results from the laboratory. The National RSQA team members involved in the review process worked closely with the field data manager to verify the completeness of sample results, and a final dataset was established in NWIS and the RSQA Team Database.

Upon completion of the data review process by the National RSQA team members, the field data manager provided the appropriate WSC personnel with a table of the data review results from the RSQA Team Database for their own internal review. Subsequently, WSC personnel changed the DQI codes for each individual water-quality parameter, based on the results of the review, to reviewed and accepted (R) or reviewed and rejected (Q). Data that were considered reviewed and rejected were neither used in the data analysis nor interpretation process of the study.

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Appendixes 1–3

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Appendix 1. Description of the Sampling Timelines, Matrix, Collection, and Processing for Water, Sediment, and Ecological Samples

Appendix 2. Description of the U.S. Geological Survey National Water Quality Laboratory Schedules Used for Water, Sediment, and Periphyton

Table 2–1. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2590 for major ions in water.

Table 2–2. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2711 for nutrients in water.

Table 2–3. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2437 for current use pesticides in water.

Table 2–4. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 4437 for volatile organic compounds in water.

Table 2–5. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 4436 for volatile organic compounds in water.

Table 2–6. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 2440 for pharmaceutical compounds in water.

Table 2–7. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 4434 for hormone compounds in water.

Table 2–8. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 4433 for organic wastewater indicator compounds in water.

Table 2–9. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 5433 for organic wastewater indicator compounds in bed sediment.

Table 2–10. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 5433 for semi-volatile organic compounds in bed sediment.

Table 2–11. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 8093 for halogenated organic compounds in bed sediment.

Table 2–12. U.S. Geological Survey (USGS) National Water Quality Laboratory (NWQL) Schedule 1632 for chlorophyll *a*, pheophytin *a*, and ash-free dry mass in periphyton.

Appendix 3. Counts of Environmental (Environ), Field Blank, Replicate (Rep), and Spike Samples of Streamwater by Site and Laboratory Analysis From the 115 Stream Sites Sampled in the U.S. Geological Survey (USGS) Southeastern Stream Quality Assessment (SESQA) Study in 2014

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