National Water-Quality Assessment Program

# Data to Support Statistical Modeling of Instream Nutrient Load Based on Watershed Attributes, Southeastern United States, 2002

Open-File Report 2008–1163

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

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**U.S. Geological Survey**
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Suggested citation:
Hoos, A.B., Terziotti, Silvia, McMahon, Gerard, Savvas, Katerina, Tighe, K.C., and Alkons-Wolinsky, Ruth, 2008, Data to support statistical modeling of instream nutrient load based on watershed attributes, southeastern United States, 2002: U.S. Geological Survey Open-File Report 2008–1163, 50 p.

# Foreword

The U.S. Geological Survey (USGS) is committed to providing the Nation with credible scientific information that helps to enhance and protect the overall quality of life and that facilitates effective management of water, biological, energy, and mineral resources (*http://www.usgs.gov/*). Information on the Nation's water resources is critical to ensuring long-term availability of water that is safe for drinking and recreation and is suitable for industry, irrigation, and fish and wildlife. Population growth and increasing demands for water make the availability of that water, now measured in terms of quantity and quality, even more essential to the long-term sustainability of our communities and ecosystems.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to support national, regional, State, and local information needs and decisions related to water-quality management and policy (*http://water.usgs.gov/nawqa*). The NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. From 1991–2001, the NAWQA Program completed interdisciplinary assessments and established a baseline understanding of water-quality conditions in 51 of the Nation's river basins and aquifers, referred to as Study Units (*http://water.usgs.gov/nawqa/studyu.html*).

In the second decade of the Program (2001–2012), a major focus is on regional assessments of water-quality conditions and trends. These regional assessments are based on major river basins and principal aquifers, which encompass larger regions of the country than the Study Units. Regional assessments extend the findings in the Study Units by filling critical gaps in characterizing the quality of surface water and ground water, and by determining status and trends at sites that have been consistently monitored for more than a decade. In addition, the regional assessments continue to build an understanding of how natural features and human activities affect water quality. Many of the regional assessments employ modeling and other scientific tools, developed on the basis of data collected at individual sites, to help extend knowledge of water quality to unmonitored, yet comparable areas within the regions. The models thereby enhance the value of our existing data and our understanding of the hydrologic system. In addition, the models are useful in evaluating various resource-management scenarios and in predicting how our actions, such as reducing or managing nonpoint and point sources of contamination, land conversion, and altering flow and (or) pumping regimes, are likely to affect water conditions within a region.

Other activities planned during the second decade include continuing national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected trace elements, and aquatic ecology; and continuing national topical studies on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on stream ecosystems, and transport of contaminants to public-supply wells.

The USGS aims to disseminate credible, timely, and relevant science information to address practical and effective water-resource management and strategies that protect and restore water quality. We hope this NAWQA publication will provide you with insights and information to meet your needs, and will foster increased citizen awareness and involvement in the protection and restoration of our Nation's waters.

The USGS recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for cost-effective management, regulation, and conservation of our Nation's water resources. The NAWQA Program, therefore, depends on advice and information from other agencies—Federal, State, regional, interstate, Tribal, and local—as well as nongovernmental organizations, industry, academia, and other stakeholder groups. Your assistance and suggestions are greatly appreciated.

Matthew C. Larsen
Acting Associate Director for Water

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# Conversion Factors

Inch/Pound to SI

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in.) | 2.54 | centimeter (cm) |
| inch (in.) | 25.4 | millimeter (mm) |

SI to Inch/Pound

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| millimeter (mm) | 0.03937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| | Area | |
| hectare (ha) | 2.471 | acre |
| square kilometer ($km^2$) | 247.1 | acre |
| hectare (ha) | 0.003861 | square mile ($mi^2$) |
| | Flow rate | |
| millimeter per year (mm/yr) | 0.03937 | inch per year (in/yr) |
| | Mass | |
| kilogram (kg) | 2.205 | pound avoirdupois (lb) |
| | Application rate | |
| kilograms per hectare per year [(kg/ha)/yr] | 0.8921 | pounds per acre per year [(lb/acre)/yr] |

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

$$°F=(1.8\times°C)+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Elevation, as used in this report, refers to distance above the vertical datum.

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

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## Abstract

This report presents and describes the digital datasets that characterize nutrient source inputs, environmental characteristics, and instream nutrient loads for the purpose of calibrating and applying a nutrient water-quality model for the southeastern United States for 2002. The model area includes all of the river basins draining to the south Atlantic and the eastern Gulf of Mexico, as well as the Tennessee River basin (referred to collectively as the SAGT area). The water-quality model SPARROW (SPAtially-Referenced Regression On Watershed attributes), developed by the U.S. Geological Survey, uses a regression equation to describe the relation between watershed attributes (predictors) and measured instream loads (response). Watershed attributes that are considered to describe nutrient input conditions and are tested in the SPARROW model for the SAGT area as source variables include atmospheric deposition, fertilizer application to farmland, manure from livestock production, permitted wastewater discharge, and land cover. Watershed and channel attributes that are considered to affect rates of nutrient transport from land to water and are tested in the SAGT SPARROW model as nutrient-transport variables include characteristics of soil, landform, climate, reach time of travel, and reservoir hydraulic loading. Datasets with estimates of each of these attributes for each individual reach or catchment in the reach-catchment network are presented in this report, along with descriptions of methods used to produce them.

Measurements of nutrient water quality at stream monitoring sites from a combination of monitoring programs were used to develop observations of the response variable—mean annual nitrogen or phosphorus load—in the SPARROW regression equation. Instream load of nitrogen and phosphorus was estimated using bias-corrected log-linear regression models using the program Fluxmaster, which provides temporally detrended estimates of long-term mean load well-suited for spatial comparisons. The detrended, or normalized, estimates of load are useful for regional-scale assessments but should be used with caution for local-scale interpretations, for which use of loads estimated for actual time periods and employing more detailed regression analysis is suggested. The mean value of the nitrogen yield estimates, normalized to 2002, for 637 stations in the SAGT area is 4.7 kilograms per hectare; the mean value of nitrogen flow-weighted mean concentration is 1.2 milligrams per liter. The mean value of the phosphorus yield estimates, normalized to 2002, for the 747 stations in the SAGT area is 0.66 kilogram per hectare; the mean value of phosphorus flow-weighted mean concentration is 0.17 milligram per liter.

Nutrient conditions measured in streams affected by substantial influx or outflux of water and nutrient mass across surface-water basin divides do not reflect nutrient source and transport conditions in the topographic watershed; therefore, inclusion of such streams in the SPARROW modeling approach is considered inappropriate. River basins identified with this concern include south Florida (where surface-water flow paths have been extensively altered) and the Oklawaha, Crystal, Lower Sante Fe, Lower Suwanee, St. Marks, and Chipola River basins in central and northern Florida (where flow exchange with the underlying regional aquifer may represent substantial nitrogen influx to and outflux from the surface-water basins).

## Introduction

Riverine and coastal eutrophication from nutrient loading is a serious water-quality problem throughout the United States. Excessive nitrogen and phosphorus loading has been cited as causing impairment in more than 50,000 miles of the Nation's rivers and streams, which represents about 20 percent of the approximately 270,000 impaired river and stream miles (U.S. Environmental Protection Agency, 2002). Eutrophic conditions have been documented in 44 of the Nation's estuaries, or about 35 percent of the estuarine surface area of the conterminous United States, with freshwater inflows of nitrogen identified as an influencing factor in over half of these (Bricker and others, 1999). Improved understanding of the sources, transport, and fate of nutrients in the watersheds contributing to impaired water bodies is needed in order to design effective load-reduction programs.

Nutrient loading to rivers and coastal areas is determined by source inputs, such as wastewater discharge and runoff from agricultural and urban land areas, and by environmental factors, such as geology, topography, climate, and stream channel hydraulics, which influence transport rates along the pathway from source to target water body. The water-quality model SPARROW (SPAtially-Referenced Regression On Watershed attributes), developed by the U.S. Geological Survey, statistically relates source inputs and environmental factors to instream loads. Specifically, SPARROW quantifies the relation between each measured source input and the nutrient mass delivered to water bodies, and quantifies the effect of various environmental factors on the transport of mass along the pathway from source to target water body. The model can be used to evaluate alternative hypotheses about the important sources and environmental factors that control transport (Smith and others, 1997; Schwarz and others, 2006).

The SPARROW model uses a nonlinear regression equation to describe the relation between spatially referenced watershed and channel attributes (predictors) and instream load (response). A spatially distributed model structure allows separate estimation of mass transport from sources to streams and transport within the stream network (Schwarz and others, 2006, p. 2). SPARROW's hybrid process-based and statistical approach to watershed modeling incorporates the modeling strategies recommended by the National Research Council (2001) for water-quality assessments, including assessments needed for the Total Maximum Daily Load (TMDL) program for impaired water bodies. The recommended strategy and the SPARROW model approach relate water body nutrient conditions to watershed characteristics using a physically based description of processes, while also providing for estimates of the errors associated with predictions of stream nutrient load.

The SPARROW model has been applied to assess stream nutrient loading and to evaluate nutrient reduction strategies at the national scale (Smith and others, 1997; Alexander and others, 2000; Smith and Alexander, 2000) and for individual regions and river basins, such as the Chesapeake Bay watershed, New England river basins (Moore and others, 2004), eastern North Carolina river basins (McMahon and others, 2003), and Tennessee, Kentucky, and Alabama river basins (Hoos, 2005). Beginning in 2005, the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey identified eight large geographical regions across the Nation (referred to as "major river basins") as the basis for assessments of status and trends; in 2007 the NAWQA Program began to integrate the SPARROW modeling approach in the interpretation of nutrient water quality in six of these major river basins.

The area included in the major river basin model assessment for the southeastern United States includes the South Atlantic–Gulf Region, comprising all of the river basins draining to the south Atlantic and the eastern Gulf of Mexico, as well as the Tennessee River basin. This collection of river basins is referred to in this report as the SAGT river basins (fig. 1). The river basins in south Florida are excluded from the model area because surface-water flow paths in this area have been altered, instream nutrient conditions therefore may not reflect conditions in the topographic watershed, and consequently application of the regional SPARROW modeling approach is inappropriate.

SPARROW model development begins with compilation of the extensive datasets used for model input. A broad array of spatial datasets describing watershed and channel features are gathered from U.S. Geological Survey (USGS) programs and other Federal and State organizations; for example, data describing wastewater discharges of nutrients to streams are gathered from the U.S. Environmental Protection Agency (USEPA) as well as individual State databases. Comparable data on nutrient concentrations in streams are compiled from monitoring programs operated by the USGS and other Federal, regional, State, and local organizations. The procedures used to compile the datasets that support the SPARROW model assessment for the SAGT river basins are documented in this report.

## Purpose and Scope

This report presents and documents the digital datasets that characterize nutrient source inputs, environmental characteristics, and instream nutrient loads for the purpose of calibrating and applying SPARROW nutrient models for the southeastern United States for 2002. The spatial datasets defining the reach and catchment network, the digital datasets of attributes, and the corresponding metadata are presented in downloadable files. The metadata include detailed descriptions of the sources and methods used to create the datasets and descriptions of each data attribute. The area described by these datasets includes all of the SAGT river basins, equivalent to hydrologic regions 03 and 06 (Seaber and others, 1987), with the exception of the southern Florida drainage basins (hydrologic subregion 0309).

## Acknowledgments

This work was supported by the National Water-Quality Assessment Program of the USGS. The authors thank Richard Alexander, Richard Smith, Greg Schwarz, John Brakebill, and Stephen Preston, USGS, for guidance in planning and data compilation. The authors also acknowledge the time and extra effort of individuals who provided stream monitoring data—Lynn Sisk, Alabama Department of Environmental Management; Jeff Thomas, Mississippi Department of Environmental Quality; and Tyler Baker, Tennessee Valley Authority. This work further benefitted from review comments and suggestions from Mike Wieczorek and Jonathan Musser, USGS.

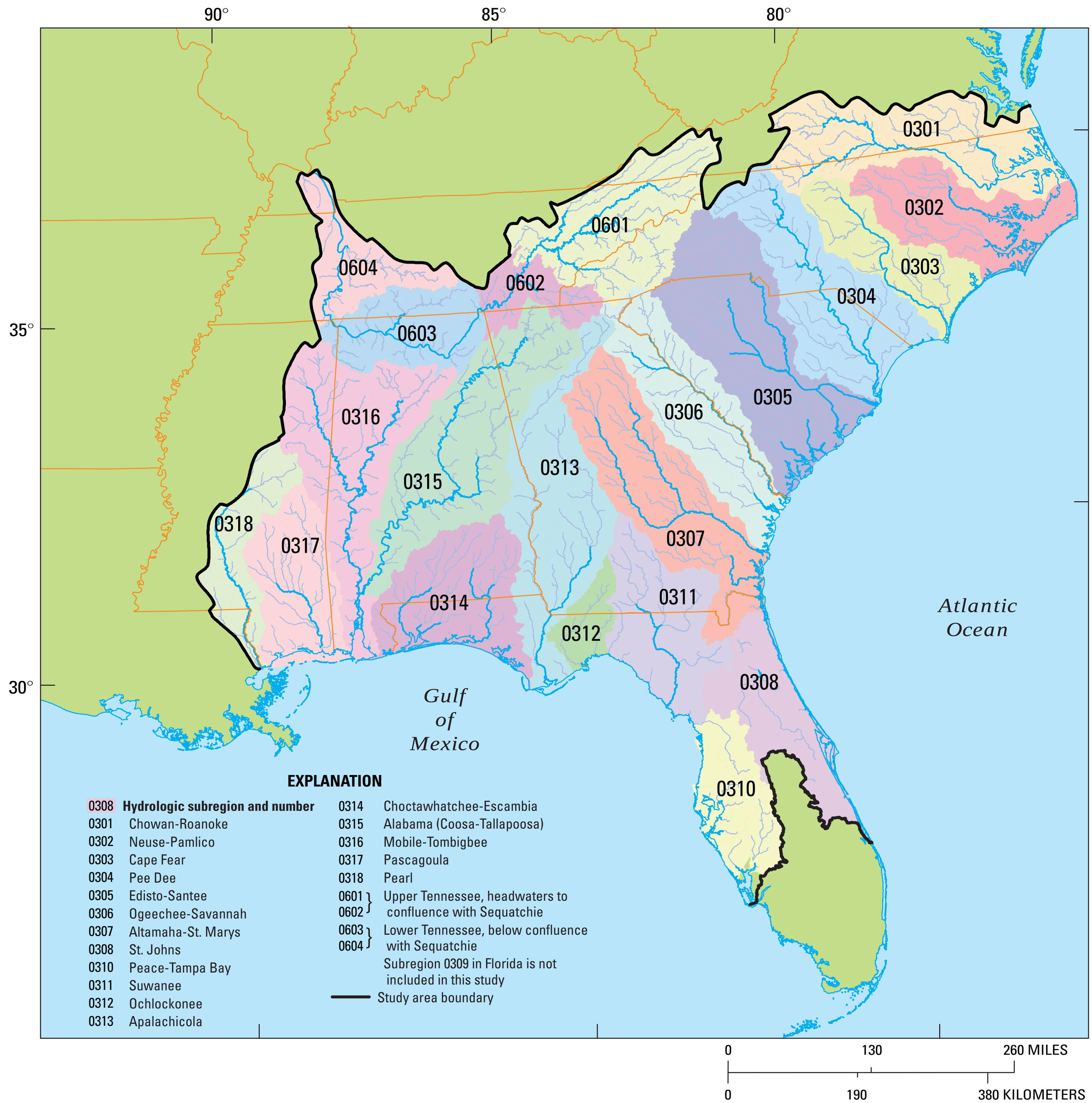


**Figure 1.** Location of the South Atlantic-Gulf Region and the Tennessee River basin in the southeastern United States, and hydrologic subregion boundaries.