National Water-Quality Assessment Program

Environmental and Biological Data for Assessment of the Nutrient Enrichment Effects on Agricultural Stream Ecosystems, 2006-08: A Project of the National Water-Quality Assessment Program

Data Series 517

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

Cover: Freeman Creek in Greeley County, Nebraska. Photograph taken by Mark Munn, U.S. Geological Survey, October 2002.

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By Robin A. Brightbill and Jill D. Frankforter

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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 groundwater, 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).

Multiple national and regional assessments are ongoing in the second decade (2001–2012) of the NAWQA Program as 42 of the 51 Study Units are reassessed. These assessments extend the findings in the Study Units by determining status and trends at sites that have been consistently monitored for more than a decade, and filling critical gaps in characterizing the quality of surface water and groundwater. For example, increased emphasis has been placed on assessing the quality of source water and finished water associated with many of the Nation's largest community water systems. During the second decade, NAWQA is addressing five national priority topics that build an understanding of how natural features and human activities affect water quality, and establish links between *sources* of contaminants, the *transport* of those contaminants through the hydrologic system, and the potential *effects* of contaminants on humans and aquatic ecosystems. Included are topics on the fate of agricultural chemicals, effects of urbanization on stream ecosystems, bioaccumulation of mercury in stream ecosystems, effects of nutrient enrichment on aquatic ecosystems, and transport of contaminants to public-supply wells. These topical studies are conducted in those Study Units most affected by these issues; they comprise a set of multi-Study-Unit designs for systematic national assessment. In addition, national syntheses of information on pesticides, volatile organic compounds (VOCs), nutrients, selected trace elements, and aquatic ecology are continuing.

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
Associate Director for Water

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Conversion Factors

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
micrometer (µm)	0.00003937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)
square meter (m^2)	10.76	square foot (ft^2)
milliliter (mL)	0.001	liter (L)
liter (L)	33.82	ounce, fluid (fl. oz)

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

$$°F=(1.8×°C)+32.$$

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

$$°C=(°F-32)/1.8.$$

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), milligrams per square meter (mg/m^2), or grams per square meter (g/m^2).

Abbreviations and Acronyms

Abbreviation and Acronym	Meanng
Bio-TDB	Biological Transactional Database
DEM	Digital Elevation Model
DOQ	digital orthophotographic quadrangles
DTH	Depositional habitat
GIS	Geographic Information System
HDAS	Habitat Data Analysis System
NEET	Nutrient Enrichment Effects Team
NHD	National Hydrologic Dataset
LULC	land use and land cover
NAWQA	National Water Quality Assessment
NLCD	National Land Cover Database
NWQL	National Water Quality Laboratory
OZRK	Ozark Plateau
RTH	richest targeted habitat
STATSGO	State Soil Geographic
UMIS	Upper Mississippi River basin
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USNK	Upper Snake River basin

Environmental and Biological Data for Assessment of the Nutrient Enrichment Effects on Agricultural Stream Ecosystems, 2006–08: A Project of the National Water-Quality Assessment Program

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Abstract

In 2000, the U.S. Environmental Protection Agency began the process of developing regional nutrient criteria for streams and rivers. In response to concerns about nutrients in streams and rivers by the U.S. Environmental Protection Agency and others, the U.S. Geological Survey National Water-Quality Assessment Program (NAWQA) began studying the effects of nutrient enrichment on agricultural stream ecosystems to aid in the understanding of how nutrients affect the biota in agricultural streams. Streams in three study areas were sampled from 2006 through 2008. These three study areas were in three NAWQA study units: Ozark Plateau (OZRK), Upper Mississippi River Basin (UMIS), and Upper Snake River Basin (USNK). Data collected included nutrients (nitrogen and phosphorous) and other chemical constituents in the water column, biological samples [chlorophyll, algal assemblages, invertebrate assemblages, and fish assemblages (at a limited number of sites)], stream habitat, riparian land cover, and basin characteristics. This report describes and presents the data collected from these study areas.

Introduction

As part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program, a study assessing the effects of nutrient enrichment on agricultural stream ecosystems was implemented in 2001. The ongoing effort by the U.S. Environmental Protection Agency (USEPA) to develop regional nutrient criteria and nutrient total maximum daily loads has created a need for a better understanding of how nutrient conditions are affected by natural processes and human-related factors, and how nutrients affect aquatic biological communities (algae and invertebrates). The NAWQA program is designed to use standardized sampling methods leading to nationally comparable data and analysis. These consistent data collection and analysis methods were incorporated into the Nutrient Enrichment Effects Team (NEET) study of small, perennial streams in different agricultural regions of the United States. More information about the NAWQA program can be accessed online at http://water.usgs.gov/nawqa and at http://wa.water.usgs.gov/neet/ for the NEET study.

This report includes biological, chemical, and physical data, as well as data generated using a Geographic Information System (GIS). These data are presented here for ease of reference for other NEET reports and for their use by other scientific investigators. Brief descriptions of methods and references are provided except when a protocol was altered. For an altered protocol, the description of a method is provided to aid in understanding how the data were collected and the possible limitations of the data.

Site Selection

This study was done in three study areas in three NAWQA study units (table 1). The studies were in the Ozark Plateau (OZRK), Upper Mississippi River Basin (UMIS), and Upper Snake River Basin (USNK) study units. A single USEPA Level III Ecoregion (Omernik, 1987) in each area was selected for the study area in order to restrict the sample of streams to those sharing, soils, climate, land use, and biota in a single map classification. To be selected, a single ecoregion had to contain major agricultural activities, a range in nutrient conditions as determined by geospatial datasets of candidate drainage basins in study units overlayed with predicted nutrients loads and concentrations, a summarization of known nutrient data at sites, and a sufficient number of suitably sized streams for study (fig. 1). These three areas are in addition to the five areas studied in 2003 and 2004 (Brightbill and Munn, 2008).

Table 1. Summary of dominant features for the three study areas of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

[**Study areas:** OZRK, Ozark Plateau, UMIS, Upper Mississippi River Basin, and USNK, Upper Snake River Basin; values in parentheses ( ) are the ranges (minimum and maximum); EPA, Environmental Protection Agency; km^2, square kilometer]

Dominant features	Study areas		
	OZRK	UMIS	USNK
Number of sites	30	29	31
Climate and physiography	Humid plateaus and mountains	Subhumid to humid plains	Arid plains, arid to humid plateaus
Agricultural region	Pasture land associated with poultry and cattle	Corn and soybean	Potatoes, wheat, sugar beets, hay, barley, and pasture
EPA Level III Ecoregion	Ozark Highlands	Western Corn Belt Plains	Idaho Batholith, Snake River Basin, Northern Basin and Range
Mean basin size (km^2) (range)	170.9 (49.9–483.6)	230.9 (31.2–634.1)	814.9 (0.22–5,225.1)
Mean percentage of agricultural land (range)	35.9 (1.4–80.6)	55.5 (2.1–88.8)	18.8 (0–91.6)

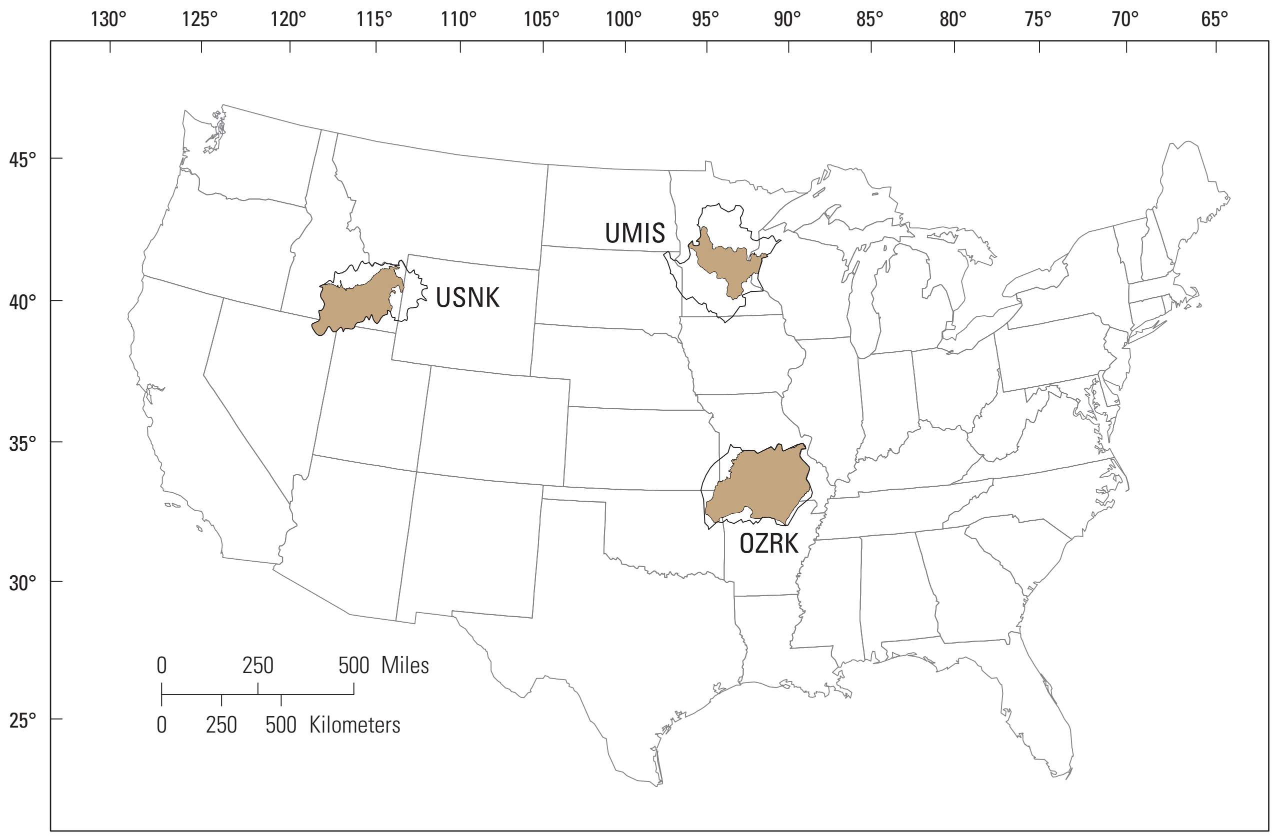

Figure 1. Agricultural nutrient gradient study areas of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08. Shaded parts of the study areas indicate the ecoregion where samples were collected.

In each of the three study areas, basin and reach boundary datasets were constructed from the USGS Elevation Derivatives for National Applications project using 30-m Digital Elevation Model data (U.S. Geological Survey, 2003). Independent basins draining between 50 and 2,500 km^2 were selected and the National Hydrologic Dataset (NHD) was used to verify the locations of streams (U.S. Geological Survey and U.S. Environmental Protection Agency, 2003). A number of independent basins were selected to represent a range in the estimated loadings of nitrogen and phosphorus to each basin. Estimates of nutrient loads were based on atmospheric deposition, county-level data for animal populations, and fertilizer sales (Ruddy and others, 2006).

Based on the review of the reconnaissance results, 29–31 sites were selected in each study area for a total of 90 sites—OZRK, 30 sites; UMIS, 29 sites; and USNK, 31 sites. Each site (or reach) had to be at least 150 m in length and was defined by a repetition of a geomorphic sequence (for example, 2 riffles and 2 pools) or 20 channel widths in length if repetitive geomorphic units were not available (Fitzpatrick and others, 1998). All sites selected and sampled are shown in appendix 1.

Sample Collection and Laboratory Analysis

Samples were collected in the OZRK in 2006 and 2007, and in the UMIS and USNK in 2007 and 2008. Field parameters of water quality, water chemistry, chlorophyll *a* and biomass for benthic and seston algae, benthic algal community taxonomy, macroinvertebrate community taxonomy, habitat characteristics, riparian-buffer land-cover data, and basin characteristics generally were collected or measured at all 90 sites. Fish community data were collected only in the OZRK study area.

A subset of sites was selected for seasonal sampling for 1 year after the collection of synoptic samples. Appendix 1 shows all sites sampled and indicates which sites had a seasonal component. Seasonal constituents included nutrients and carbon, water quality, algal chlorophyll and biomass, algal taxonomy, macroinvertebrate taxonomy, microhabitat information where algae and macroinvertebrates were sampled, and reach-level physical habitat characteristics.

Field Parameters

Field parameters were collected at a cross section within a reach. Water temperature and dissolved oxygen were measured directly from the stream at several verticals along the cross section and used to compute a cross-section mean value. Discharge was measured at the same cross section where the other field parameters were collected. Specific conductance, pH, and turbidity were measured instream. Alkalinity was determined by titration using a subsample from the churn splitter (U.S. Geological Survey, variously dated).

Water Chemistry Samples

Water chemistry samples were collected in an integrated width/depth composite, which was placed in a churn splitter. Subsamples were withdrawn from the churn splitter, filtered through a 0.45–µm glass fiber filter, chilled and maintained at 4 °C, and shipped to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colo., and analyzed for ammonia, nitrite, nitrate plus nitrite, and orthophosphate according to methods in Fishman (1993). Unfiltered water subsampled from the churn splitter was acidified with 1 mL of 4.5 normality sulfuric acid, chilled and maintained at 4 °C, and immediately shipped to NWQL to be analyzed for total nitrogen (ammonia + nitrite + nitrate + organic nitrogen) according to method of Patton and Kryskalla (2003) and total phosphorus according to the methods described by the U.S. Environmental Protection Agency (1993). Nutrient samples (nitrogen and phosphorus) were collected about 30 days prior to and again at the time of biological sampling.

The dissolved organic carbon samples were filtered using SUPOR® filters. The filtered water sample was placed into a 125-mL amber glass bottle. The sample was acidified to a pH of less than 2 with sulfuric acid, chilled and maintained to 4 °C, and immediately shipped to NWQL for analysis (Brenton and Arnett, 1993).

Water was filtered through 25-mm glass fiber filters for analyses of inorganic carbon, organic carbon, inorganic plus organic carbon, and total nitrogen in suspended sediment. The filters were folded in half, wrapped in aluminum foil, placed in sealable plastic bags, chilled and maintained at 4°C, and immediately shipped to NWQL. Laboratory analyses were completed according to USGS guidelines as stated in the Office of Water Quality Technical Memorandum, 2000.08 (U.S. Geological Survey, 2000).

Unfiltered water subsamples also were collected from the churn splitter for suspended-sediment analyses. Concentrations of suspended sediments were determined at USGS sediment laboratories according to methods described by Guy (1969) and the American Society for Testing and Materials (2007).

Seston Algae

Subsamples for seston (water column) algae also were drawn from the churn splitter. The sample water was filtered through a 47-mm glass fiber filter. The filter was folded into quarters, wrapped in aluminum foil, placed in a labeled Petri dish, placed in a plastic bag, and frozen on dry ice for shipment to NWQL (Moulton and others, 2002). Seston samples were analyzed for chlorophyll *a* and pheophytin *a* by NWQL using protocols outlined in Arar and Collins (1997).

Benthic Algae

Benthic algae were sampled within the richest targeted habitat (RTH) areas consisting of coarse cobble-sized rocks or woody debris using methods as described in Moulton and others (2002). Two subsamples of the RTH were sampled. One was filtered (0.3-µm pore size) for chlorophyll *a* concentration, and one for ash free dry weight (Moulton and others, 2002), frozen on dry ice, and sent to NWQL for analysis (Britton and Greeson, 1987). The portion that was not filtered was retained and preserved for community composition (Moulton and others, 2002) and sent to the Academy of Natural Sciences of Philadelphia, Penn., for identification and enumeration processing (Charles and others, 2002). Cell counts and biovolume data were included in the taxonomic datasets. Cell counts are number of cells/cm^2. The biovolume, or how much space the cell takes up, is the estimated size of the taxon algal cell in the sampled area.

Benthic algae also were sampled in the depositional habitat (DTH) areas of organically rich or sandy sediment along stream margins using methods as described in Moulton and others (2002). NAWQA does not have a standardized method for the field processing of DTH chlorophyll concentrations; therefore, methods were modified from Stevenson and Stoermer (1981). Details of the adapted method are in Brightbill and Munn (2008).

Benthic Invertebrates

All benthic invertebrate sampling, processing, and preservation methods were adopted based on protocols described by Moulton and others (2002). Benthic invertebrates were collected from RTH habitats—areas of coarse-grained riffles or woody snags—for identification and enumeration. RTH samples were collected using a 500-µm mesh Nitex® Slack-sampler with an attached 500-µm mesh dolphin bucket. Samples were collected at five discrete locations and composited, rinsed, and elutriated by pouring the sample through a 500-µm mesh sieve to retain the sample but not the water. The retained sample was placed in a jar and preserved with 10-percent buffered formalin. Samples were sent to NWQL for identification and enumeration (Moulton and others, 2000).

Fish

The OZRK staff sampled fish communities as part of this assessment. Fish were collected by electrofishing (Moulton and others, 2002). These fish were identified to species, which was recorded along with the number of fish of each species. The fish were then released back into the stream.

Algal and Invertebrate Microhabitat

Microhabitat data were collected at the areas where invertebrates and algae were collected. Water depth, instantaneous point velocity, substrate type, and shade characteristics were recorded to describe the precise habitat where the invertebrates and algae were collected (Moulton and others, 2002).

Habitat

Habitat was characterized along the sample reach. A total of 11 equidistant transects oriented perpendicular to streamflow were established throughout the reach, with channel width measured at each transect. Water depth, current velocity, and substrate type (bedrock, boulder, cobble, gravel, sand, and silt) were measured at three points across each transect. Pebble counts also were done at each transect. Additional details on methods used to collect habitat data are available in Fitzpatrick and others (1998).

Channel shading was determined using a Solar Pathfinder™ (2003). This device was used to estimate solar energy along the study reach at the time biological samples were collected. Data were collected midchannel on 5 of the 11 habitat transects.

The method used for determining the percentage of either submerged macrophytes or macroalgae cover or both was modified from Biggs and Kilroy (2000). Five equidistant points along each of the 11 transects were sampled. A 0.09-m^2 quadrat (a measured and marked rectangle used to isolate a sample area for the purpose of enumerating the population of different species in that area) was placed at each sampling point. The cover from filamentous algae and (or) submerged macrophytes greater than 3 cm in length was estimated to the nearest 10 percent. These 55 values were then averaged to obtain an estimate of the mean percentage of cover of the reach provided by macroalgae and macrophytes.

Basin Geographic Information System Ancillary Data

Digital datasets were aggregated by the NAWQA GIS team (Nakagaki, U.S. Geological Survey, written commun., 2008). Basin characteristics and riparian land-cover data were calculated for each site using a nationally consistent approach, various national datasets, and standardized spatial analysis methods. Basin characteristics included drainage area, land cover, ecoregions, physiography, geology, hydrologic landscape regions, and various climatic, soil, and surface hydrology related to rainfall and runoff. The computer software used for processing the ancillary data was the Environmental Systems Research Institute's ArcInfo Workstation (Environmental Systems Research Institute, Redlands, Calif.) and all geospatial coordinate data referenced the Albers Conical Equal-Area projection.

The drainage basin area for each site was determined as the area of the polygon that represented the drainage basin boundary, as delineated using digital topographic and hydrologic maps ranging from 1:24,000 to 1:250,000 scale, depending on the size of the drainage basin. The digital maps of each drainage basin also were converted from vector to raster format at 30-m resolution to facilitate overlay analyses.

Land cover, ecoregions, physiography, geology, and hydrologic landscape regions were characterized by component percentage of the drainage basin. The sources for land-cover data were versions of the USGS 2001 National Land Cover Database (NLCD) (Vogelmann and others, 2001; Nakagaki and Wolock, 2005), a 30-m resolution product based on multispectral satellite imagery. Land-cover percentages were compiled for the total drainage basin, by land classification, as well as for the basin-level network of riparian areas, that is, streamside buffers that extended 90 m, nominally, from the stream centerline. Additional national datasets of (1) land cover (U.S. Geological Survey, 1999), (2) level III ecoregions (Omernik, 1987) aggregated for national nutrient assessment (Omernik, 2000), (3) physiography (Fenneman and Johnson, 1946), (4) bedrock geology (King and Beikman, 1974a, 1974b; Schruben and others, 1998), and (5) surficial geology (Hunt, 1979; Clawges and Price, 1999) were gridded at 30-m resolution, then using an overlay analysis with the 30-m resolution drainage basin boundaries, the area of each classification in the drainage basin was determined. The hydrologic landscape regions (Wolock, 2003a) were gridded at 100-m resolution prior to the overlay process with the drainage basin boundary. The basin area of each category was divided by the drainage area to compute the percentage of the basin by category.

Stream density was computed for a drainage basin by intersecting the national streams data with the polygon defining the basin boundary summing the length of all streams in the basin and dividing that sum by the area of the drainage basin. The source for nationwide streams data was the 1:100,000-scale National Hydrography Dataset (U.S. Geological Survey and U.S. Environmental Protection Agency, 2003).

The basin estimates for hydroclimatic characteristics—mean annual precipitation, air temperature, potential evapotranspiration, and runoff; the *R* factor of the Universal Soil Loss Equation, mean land-surface altitude, the baseflow index [total volume of base flow divided by total volume of runoff for a period (Wahl and Wahl, 1995)]—were determined by overlaying the 30-m resolution polygon defining the basin boundary with the respective national thematic data layer to compute the basin mean of the grid-cell data values in the drainage basin. The source for mean annual and monthly precipitation and temperature from 1980 to 1997 was the 1-km resolution grid data from the Daymet conterminous United States database (Thorton and Running, 1999). Potential evapotranspiration was estimated using 1-km resolution national temperature data (David W. Wolock, U.S. Geological Survey, written commun., 2005) derived from the Parameter-Elevation Regressions on Independent Slopes Model (Daly, 2006) and an equation for estimating potential evapotranspiration (Hamon, 1961). The source for estimating mean annual runoff from 1990 through 2002 was a time series of runoff (streamflow per unit area), computed for the hydrologic cataloging units in the conterminous United States (Steeves and Nebert, 1994) following the approach of Krug and others (1987). The mean annual (1971–2000) *R* factor (rainfall erosivity) of the Universal Soil Loss Equation was based on a national 2.5-minute (about 4-km) resolution gridded dataset developed by Daly and Taylor (2002). The mean land-surface altitude in the drainage basin was based on the USGS National Elevation Dataset (U.S. Geological Survey, 2003) gridded at the 100-m resolution. Baseflow, the component of streamflow that can be attributed to groundwater discharge into streams, was estimated for drainage basins from the national baseflow gridded data at 1-km resolution dataset developed by Wolock (2003b).

Soil characteristics included but were not limited to soil hydrologic groups, available water capacity, permeability, and the *K* factor (soil erodibility) of the Universal Soil Loss Equation, which were based on State Soil Geographic (STATSGO) database (Natural Resources Conservation Service, 1994). The STATSGO database is organized geographically by soil associations map units, which are based on the proportionate extent of the component soils and their properties (Natural Resources Conservation Service, 2006). Each map unit is associated with many tabular files of soil characteristics. Soil map units were gridded at 100-m resolution and overlaid with 30-m resolution basin boundaries to first determine the areal weights of solid characteristics by using soil map units for each drainage basin, followed by the computation of the weighted average value for each soil characteristic. Soil hydrologic groups were extracted from an enhanced version of STATSGO (Barbara C. Ruddy and William A. Battaglin, U.S. Geological Survey, written commun., 1998), in which missing soil hydrologic group values for some map units were populated based on soil characteristics described by Foth and Schafer (1980). Many of the remaining STATSGO soil characteristics used in this study were compiled by Wolock (1997); soil characteristics not included in Wolock (1997) were assembled using the same methods (David M. Wolock, U.S. Geological Survey, written commun., 2004). The mean *K* factor was estimated using data for the uppermost soil horizon.

Reach and Segment-Scale Riparian GIS Data

Riparian land-cover characteristics were determined at the reach and segment (a length of stream that is relatively homogeneous with respect to physical, chemical, and biological properties) scales based on the site locations and streamside buffer areas determined using GIS. Buffer analysis and overlay analysis were completed using GIS. Protocols used for this work are described in Johnson and Zelt (2005). The riparian area was characterized using several different fixed-width buffer zones along the stream segment. At the segment scale, four specific buffer zones were delimited on the basis of respective buffer distances from the stream centerline—50, 100, 150, and 250 m. The relative extent of various categories of land use and land cover (LULC) in each buffer zone was estimated by delimiting and classifying polygons of contrasting LULC on aerial digital orthophotographic quadrangles (DOQ) on the basis of standard methods for photograph interpretation (U.S. Fish and Wildlife Service, 1995). Data were obtained from Naomi Nakagaki (U.S. Geological Survey, written commun., 2008).

Environmental and Biological Data

The electronic datasets included in this report are shown in table 2 and presented as appendixes 1–13. Much of the data presented in this report are stored in established USGS national databases, but some data are unique to the NEET study and, therefore, are being released with this report. All water chemistry and chlorophyll data were obtained through the NAWQA Data-Warehouse (http://water.usgs.gov/nawqa/data.html). Habitat and biological data were retrieved from the Biological Transactional Database (Bio-TDB) (Soriyffsje and Ratnayaka, 2002). The remaining datasets, including riparian land-cover and land-use data, were entered into spreadsheets for long-term storage and are archived in this report.

Review and Revision of Environmental and Biological Sample Data

Because this report includes a wide array of data types, different approaches were used for the quality-assurance review and revision of sample data. Most data were entered into various USGS national databases and reviewed by study unit personnel. Data were retrieved and compiled after review and verification against the original field and laboratory sheets. These datasets were reviewed again by NEET members in order to check for consistency between study units. This standardized process was established for the following datasets: nutrients, field parameters, chlorophyll, and habitat. The algal and invertebrate taxonomic data were standardized by a laboratory review and revision processes prior to release (Moulton and others, 2000). All GIS ancillary data were generated using standardized GIS procedures with the most up-to-date drainage basin delineations generated by the study unit personnel. For verification of the site location, the basin delineations were checked against their respective station locations. Study unit personnel were responsible for verifying the accuracy of the resulting datasets.

Quality-control samples designed to measure bias and variability in the field included blank and replicate samples (Mueller and others, 1997). Field blanks are used to monitor for possible contamination or bias during sample collection and consist of subjecting analyte-free water to all aspects of normal sample collection, processing, and handling. Split replicate samples are subsamples of a single, larger sample and are used to characterize the reproducibility of sample processing and the analytical process. Quality-control samples in the laboratory are routinely analyzed as part of the quality-assurance plan described by Maloney (2005). These samples include standard reference materials, laboratory reagent blanks, spikes, and surrogates. The laboratory procedures used to process all algal samples, including all quality-control procedures, are presented in Charles and others (2002). Invertebrate samples were processed using standard quality-control procedures outlined in Moulton and others (2000).

Table 2. Brief description of the datasets collected and analyzed, as part of the National Water-Quality Assessment Nutrient Enrichment Effects Team Study of the National Water-Quality Assessment Program, 2006–08.

[GIS, Geographic Information System]

Dataset	Brief description
Sites	List of sites by study area and overview of collected data types (appendix 1).
Nutrients	Nitrogen and phosphorus data from the water column (appendix 2).
Carbon and nitrogen	Carbon concentrations in the water column and carbon and nitrogen concentrations of the particulates suspended in the water column (appendix 3).
Field parameters and water chemistry	Discrete measurements of water temperature, instantaneous stream discharge, pH, specific conductance, dissolved oxygen, alkalinity, turbidity, suspended-sediment concentration (appendix 4).
Chlorophyll	Includes seston (phytoplankton) chlorophyll *a*, along with chlorophyll *a* and ash-free dry weight for periphyton samples from both Richest Targeted Habitat (rock or wood) and Depositional Targeted Habitat (sand or silt) (appendix 5).
Richest Targeted Habitat algae	Benthic algal assemblage data from Richest Targeted Habitat substrate including cell count and biovolume (appendix 6).
Depositional Targeted Habitat algae	Benthic algal assemblage data from Depositional Targeted Habitat substrate including cell count and biovolume (appendix 7).
Richest Targeted Habitat (wood or rock) invertebrates	Benthic invertebrate assemblage data from Richest Targeted Habitat substrate (appendix 8).
Fish	Fish assemblage data from Ozark River Basin study unit only (appendix 9).
Algal and macroinvertebrate microhabitat	Summary of habitat characteristics in the immediate area where algae and macroinvertebrate samples were collected (appendix 10).
Reach-level habitat	Summary of reach-scale in-stream habitat data (appendix 11).
GIS riparian land-cover data	GIS-derived riparian-buffer data at various scales (appendix 12).
GIS basin features	GIS-derived data on basin features including land use, soils, nutrient loadings, precipitation, runoff, geology, and ecoregions (appendix 13).

A total of 14 blank samples were analyzed for nutrients, 7 for carbon, and 4 for seston chlorophyll *a* and pheophyton *a*. Reported values for all blank samples were near or less than detection limits. The mean percentage of differences between nutrient replicate samples (subsamples of a single, larger sample and used to characterize the reproducibiity of sample processing and the analytical process) ranged from 3.4 to 13 for all nutrient species (table 3). The mean percentages of difference were highest for ammonia and phosphorus. The variation in sample results due to variability in handling or laboratory analysis was relatively small. The mean percentage of difference between particulate carbon-nitrogen replicate samples ranged from 3.9 to 99 percent. A poor recovery of particulate carbon probably was due to variability in handling or laboratory analysis was larger than the variation for nutrient samples. The mean percentage of difference for 11 replicate samples of seston chlorophyll *a* ranged from 0 to 50 percent, and the mean percentage of difference for 11 replicate samples of seston pheophyton *a* ranged from 0 to 15 percent. The mean percentage of difference for 10 replicate samples of RTH algae chlorophyll *a*, pheophytin *a*, and ash free dry weight were 12, 9.1, and 8.7 percent, respectively. No blanks or replicate samples were run for DTH algal samples. Suspended-sediment concentration quality-control samples also exhibited poor precision. The reason for the high mean percentage of difference of 106 percent between suspended-sediment samples is unknown.

Table 3. Quality-control results from nutrient and carbon analyses, and benthic and seston chlorophyll *a* and ash-free dry weight, as part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

[–, no replicates; µm, micrometer; <, less than]

Constituent	Number of samples	Percentage of difference between replicate samples		
		Minimum	Maximum	Mean
Nutrients				
Nitrogen, ammonia, filtered	18	0	104	13
Nitrogen, nitrite, filtered	18	0	77	7.2
Nitrogen, nitrite plus nitrate, filtered	18	0	19	3.4
Total nitrogen, nitrate plus nitrite plus ammonia plus organic-nitrogen, unfiltered	18	.26	41	7.0
Phosphorus, orthophosphate, filtered	18	0	82	13
Total phosphorus, unfiltered	18	0	27	11
Carbon, nitrogen, and suspended sediments				
Organic carbon in filtered water	15	0.043	26	3.9
Inorganic carbon in suspended sediment	15	0	198	99
Organic carbon in suspended sediment	15	0	272	28
Inorganic plus organic carbon in suspended sediment	15	0	275	28
Particulate nitrogen in suspended sediment	15	0	100	19
Suspended sediment <63 µm	1	79	79	79
Suspended-sediment concentration	9	7.7	450	106
Benthic and seston algae				
Richest targeted habitat (rock or wood) periphyton chlorophyll *a*	10	0.06	41	12
Richest targeted habitat periphyton biomass as ash-free dry weight	10	.09	30	8.7
Richest targeted habitat pheophyton *a*	10	.54	23	9.1
Depositional targeted habitat periphyton chlorophyll *a*	0	–	–	–
Depositional targeted habitat (sand/silt) periphyton biomass as ash-free dry weight	0	–	–	–
Depositional targeted habitat pheophyton *a*	0	–	–	–
Seston (phytoplankton) chlorophyll *a*	11	0	50	12
Seston (phytoplankton) pheophyton *a*	11	0	15	5.3

Summary

As part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, three study areas across the United States were sampled from 2006 through 2008. Data were collected to enhance the understanding of how nutrient conditions affect stream biological communities across different geographic regions in agricultural settings using consistent sampling methods. Data collected included water quality (nutrients, carbon), biology (chlorophyll, benthic algal and invertebrate assemblages, and fish assemblages at a limited number of sites), habitat characteristics, and ancillary data. Basic methods and references for more detailed sampling procedures also were presented to enhance the use of the data by the reader.

References Cited

American Society for Testing and Materials, 2007, Standard test methods for determining sediment concentration in water samples: American Society for Testing and Materials D3977-97(2007), doi:10.1520/D3977-97R07, accessed September 20, 2007, at http://www.astm.org/Standards/D3977.htm.

Arar, E.J., and Collins, G.B., 1997, U.S. Environmental Protection Agency Methods 445.0, in vitro determination of chlorophyll *a* and pheophytin *a* in marine and freshwater algae by fluorescence, Revision 1.2: Cincinnati, Ohio, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Office of Research and Development, 22 p. (Also available at http://www.epa.gov/microbes/m445_0.pdf.)

Biggs, B.J.F., and Kilroy, C., 2000, Stream periphyton monitoring manual: Christchurch, New Zealand, New Zealand Ministry for the Environment, National Institute of Water & Atmospheric Research, 246 p. (Also available at http://www.niwa.co.nz/our-science/freshwater/tools/periphyton.)

Brenton, R.W., and Arnett, T.L., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of dissolved organic carbon by UV-promoted persulfate oxidation and infrared spectrometry: U.S. Geological Survey Open-File Report 92-480, 12 p. (Also available at http://pubs.er.usgs.gov/usgspubs/ofr/ofr92480.)

Brightbill, R.A., and Munn, M.D., 2008, Environmental and biological data of the nutrient enrichment effects on stream ecosystems project of the National Water Quality Assessment Program, 2003–04: U.S. Geological Survey Data Series 345, 12 p. (Also available at http://pubs.usgs.gov/ds/345.)

Britton, L.J., and Greeson, P.E., eds., 1987, Methods for collection and analysis of aquatic biological and microbiological samples: U.S. Geological Survey Techniques of Water-Resources Investigation, book 5, chapter A4, 363 p. (Also available at http://pubs.usgs.gov/twri/twri5a4/html/pdf.html.)

Charles, D.F., Knowles, Candia, and Davis, R.S., eds., 2002, Protocols for the analysis of algal samples collected as part of the U.S. Geological Survey National Water-Quality Assessment Program: Philadelphia, Pa., The Academy of Natural Sciences, Report no. 02-06, 124 p. (Also available at http://water.usgs.gov/nawqa/protocols/algprotocol/algprotocol.pdf.)

Clawges, R.M., and Price, C.P., 1999, Digital dataset describing principal aquifers, surficial geology, and ground-water regions of the conterminous United States: U.S. Geological Survey Open-File Report 99–77 [digital map], accessed April 2003 at http://pubs.usgs.gov/of/1999/ofr99-77/.

Daly, Christopher, 2006, Guidelines for assessing the suitability of spatial climate data sets: International Journal of Climatology, v. 26, p. 707–721.

Daly, Christopher, and Taylor, G.H., 2002, United States mean annual R-factor, 1971–2000, [digital map]: accessed May 2003, at http://www.ocs.orst.edu/pub/maps/Precipitation/rfactor/U.S./us_rfactor_meta.html.

Fenneman, N.M., and Johnson, D.W., 1946, Physical divisions of the United States: U.S. Geological Survey digital data, scale 1:7,000,000, [digital data], accessed January 2005 at http://water.usgs.gov/GIS/metadata/usgswrd/XML/physio.xml.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p. (Also available at http://pubs.er.usgs.gov/usgspubs/ofr/ofr93125.)

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R., Maupin, M.A., and Gurtz, M.E., 1998, Revised methods for characterizing stream habitat in the National Water-Quality Assessment Program: U.S. Geological Survey Water-Resources Investigations Report 98–4052, 67 p. (Also available at http://pubs.usgs.gov/wri/wri984052/.)

Foth, H.D., and Schafer, J.W., 1980, Soil geography and land use: New York, John Wiley and Sons, Inc., 484 p.

Guy, H.P., 1969, Laboratory theory and methods for sediment analysis: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. C1, 58 p. (Also available at http://pubs.usgs.gov/twri/twri5c1/.)

Hamon, W.R., 1961, Estimating potential evapotranspiration: Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers, v. 87, p. 107–120.

Hunt, C.D., 1979, National Atlas of the United States of America–Surficial Geology: U.S. Geological Survey, NAC-P-0204-75M-O [map].

Johnson, M.R., and Zelt, R.B., 2005, Protocols for mapping and characterizing land use/land cover in riparian zones: U.S. Geological Survey Open-File Report 2005–1302, accessed December 4, 2006, at http://pubs.usgs.gov/of/2005/1302.

King, P.B., and Beikman, H.M., 1974a, Explanatory text to accompany the geologic map of the United States: U.S. Geological Survey Professional Paper 901, 40 p. (Also available at http://pubs.er.usgs.gov/pp/pp901.)

King, P.B., and Beikman, H.M., 1974b, Geologic map of the United States (exclusive of Alaska and Hawaii) on a scale of 1:2,500,000: U.S. Geological Survey map, 3 plates.

Krug, W.R., Gebert, W.A., and Graczyk, D.J., 1987, Preparation of average annual runoff map of the United States, 1951–80: U.S. Geological Survey Open-File Report 87–535, 414 p. (Also available at http://pubs.er.usgs.gov/usgspubs/ofr/ofr87535)

Maloney, T.J., (ed.), 2005, Quality management system, U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 2005–1263, version 1.3, 93 p. (Also available at http://pubs.usgs.gov/of/205/1263/.)

Moulton, S.R., II, Carter, J.L., Grotheer, S.A., Cuffney, R.F., and Short, T.M., 2000, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory–Processing, taxonomy, and quality control of benthic macroinvertebrate samples: U.S. Geological Survey Open-File Report 00–212, 49 p. (Also available at http://nwql.usgs.gov/public/pubs/ofr00-212.html.)

Moulton, S.R., II, Kennen, J.G., Goldstein, R.M., and Hambrook, J.A., 2002, Revised protocols for sampling algal, invertebrate, and fish communities as part of the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 02–150, 74 p. (Also available at http://pubs.usgs.gov/of/2002/ofr-02-150/.)

Mueller, D.K., Martin, J.D., and Lopex, T.J., 1997, Quality-control design for surface-water sampling in the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 97–223, 17 p. (Also available at http://pubs.usgs.gov/of/1997/223.)

Natural Resources Conservation Service, 1994, State soil geographic (STATSGO) database—Data use information: U.S. Department of Agriculture, National Soil Survey Center, Miscellaneous Publication no. 1492, 110 p.

Natural Resources Conservation Service, 2006, Soil Survey Geographic (SSURGO) Database: Fort Worth, Tex., Natural Resources Conservation Service, accessed March 22, 2010, at http://www.soils.usda.gov/survey/geography/ssurgo/.

Omernik, J.M., 1987, Ecoregions of the conterminous United States: Annals of the Association of American Geographers, v. 77, no. 1, p. 118–125, 1 pl., scale 1:7,500,000.

Omernik, J.M., 2000, Draft aggregations of level III ecoregions for the National Nutrient Strategy: accessed March 28, 2008 at http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/.

Ruddy, B.C., Lorenz, D.L., and Mueller, D.K., 2006, County-level estimates of nutrient inputs to the land surface of the conterminous United States, 1982–2001: U.S. Geological Survey Scientific Investigations Report 2006-5012, 17 p., accessed March 28, 2008 at http://pubs.usgs.gov/sir/2006/5012.

Schruben, P.G., Arndt, R.E., and Bawiec, W.J., 1998, Geology of the conterminous United States at 1:2,500,000 scale—A digital representation of the 1974 P.B. King and H.M. Beikman map: U.S. Geological Survey Digital Data Series 11 (Release 2), accessed June 1999 at http://pubs.usgs.gov/dds/dds11/.

Solar Pathfinder, 2003, Instruction manual for the solar pathfinder: Linden, Tenn., Solar Pathfinder 27 p.

Sprouffske, K. and Ratnayaka, C., 2002, BioTDB Export User’s Guide, Patrick Center for Environmental Research, Academy Natural Sciences of P, Philadelphia, PA., 8 p.

Steeves, P.A., and Nebert, D.D., 1994, 1:250,000-scale Hydro¬logic units of the United States: U.S. Geological Survey Open-File Report 94–0236, variously paginated.

Stevenson, R.J., and Stoermer, E.F., 1981, Quantitative differences between benthic algal communities along a depth gradient in Lake Michigan: Journal of Phycology, v. 17, p. 29–36.

Thorton, P.E., and Running, S.W., 1999, An improved algorithm for estimating incident daily solar radiation from measurements of temperature, humidity, and precipitation: Agricultural and Forest Meteorology, v. 93, p. 211–228.

U.S. Environmental Protection Agency, 1993, Methods for the determination of inorganic substances in environmental samples: Environmental Monitoring Systems Laboratory, EPA/600/R-93/100, variously paginated.

U.S. Fish and Wildlife Service, 1995, Photointerpretation conventions for the National Wetlands Inventory: NWI Group, St. Petersburg, FL.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, accessed November 7, 2006, at http://pubs.water.usgs.gov/twri9A.

U.S. Geological Survey, 1999, National land cover data 1992 (NLCD 1992), [digital map]: accessed August 2003 at http://landcover.usgs.gov/landcoverdata.php.

U.S. Geological Survey, 2000, New method for particulate carbon and particulate nitrogen: U.S. Geological Survey Office of Water Quality Technical Memorandum 2000.08 accessed November 13, 2006, at http://water.usgs.gov/admin/memo/QW/qw00.08.html.

U.S. Geological Survey and U.S. Environmental Protection Agency, 2003, National Hydrography Dataset (NHD): U.S. Geological Survey [digital data], accessed June 2003 at http://nhd.usgs.gov/.

U.S. Geological Survey, 2008, National Land Cover Database 2001 (NLCD 2001): U.S. Geological Survey, accessed October 2008 at http://www.mrlc.gov/nlcd.php.

U.S. Geological Survey and U.S. Environmental Protection Agency, 2003, National Hydrography Dataset (NHD): U.S. Geological Survey [digital data], accessed June 2003 at http://nhd.usgs.gov/.

Wahl, K.L. and Wahl, T.L., 1995, Determining the flow of Comal Springs at New Braunsfel, Texas: Proceedings of Texas Water ‘95, A Component Conference of the First International Conference of Water Resources Engineering, American Society of Civil Engineers, August 16–17, 1995, San Antonio, Texas, p. 77–86.

Wolock, D.M., 1997, STATSGO soil characteristics for the conterminous United States: U.S. Geological Survey Open-File Report 97–656 [digital data], accessed December 2004 at http://water.usgs.gov/lookup/getspacial?muid.

Wolock, D.M., 2003a, Hydrologic landscape regions of the United States: U.S. Geological Survey Open-File Report 03–145, [digital data], accessed December 2004 at http://water.usgs.gov/lookup/getspatial?hlrus.

Wolock, D.M., 2003b, Base-flow index grid for the United States: U.S. Geological Survey Open-File Report 03–263, [digital data], accessed September 2005 at http://water.usgs.gov/lookup/getspatial?bfi48grd.

Appendixes

The electronic datasets available in this report are listed in appendixes 1–13 and can be accessed and downloaded at URL http://pubs.usgs.gov/ds/517/.

Appendix 1. Sites by Study Area, Collection Year, and What Was Sampled at Each Site, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 2. Nitrogen and Phosphorus Data from the Water Column by Study Area and Stream, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 3. Carbon Concentrations in Water Column and Carbon and Nitrogen Concentrations in Suspended-Sediment Samples by Study Area, Stream Name, Sample Date and Time Collected, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 4. Field Parameters Including Water Temperature, Instantaneous Discharge, Specific Conductance, and Other Parameters, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water- Quality Assessment Program, 2006–08.

Appendix 5. Periphyton and Seston Chlorophyll *a*, Pheophytin *a*, and Biomass from both the Richest and Depositional Targeted Habitat and from the Water Column by study area, stream, sample date, and time collected as part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water Quality Assessment Program, 2006–08.

Appendix 6. Algal taxonomic data collected from richest targeted (rock or wood) habitat by study area, stream, sample date and time as part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water Quality Assessment Program, 2006–08.

Appendix 7. Algal taxonomic data collected from sand and silt habitat by study area, stream, sample date and time as part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water Quality Assessment Program, 2006–08.

Appendix 8. Macroinvertebrate taxonomic and density data from the richest targeted habitat by study area as part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water Quality Assessment Program, 2006–08.

Appendix 9. Fish Taxonomic Data Collected for Ozark Plateau Stream Sampling Sites, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006.

Appendix 10. In-stream Microhabitat Data by Study Area and Stream, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 11. Reach-Scale In-Stream Habitat and Solar Pathfinder® Data by Study Area and Stream, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 12. GIS-derived riparian Land-Cover Data Collected at Segment and Reach Scales, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

Appendix 13. GIS-Derived Basin Features Data by Study Area and Stream, as Part of the Nutrient Enrichment Effects on Stream Ecosystems Study of the National Water-Quality Assessment Program, 2006–08.

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215 Limekiln Road
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