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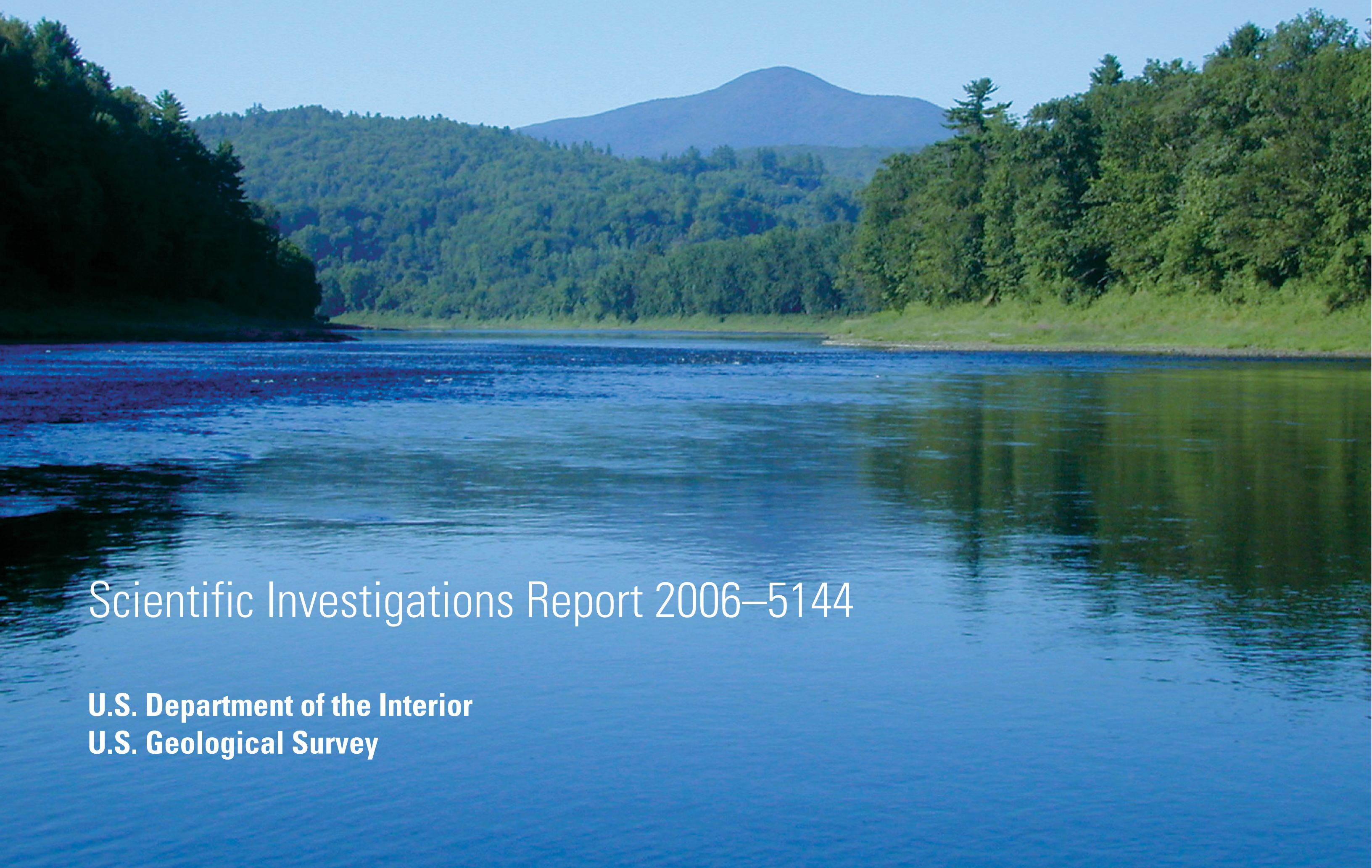
Assessment of Total Nitrogen in the Upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts, December 2002–September 2005



Scientific Investigations Report 2006–5144

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

Cover. Photograph shows the Connecticut River and Mt. Ascutney, Vermont, in the background.

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The authors acknowledge and appreciate the efforts of their U.S. Geological Survey colleagues provided by Ann Chalmers, Kimberly Campo, Domenic Murino, Joseph Martin, Jason Pollender, Tim Sargent, and Guy Holzer for their assistance in the collection of water-quality samples, and Sarah Flanagan, U.S. Geological Survey, for the formation of computer files for load estimation. Appreciation also is extended to the Connecticut Water Science Center for the collection and use of data from the Connecticut River at Thompsonville, CT. Thanks are extended to Norman Spahr and John Mullaney, U.S. Geological Survey, for their critical review of this report. Appreciation is extended to Kay E. Hedrick for the editorial report review, Ann Marie Squillacci for manuscript and layout, and Tina Cotton for graphics.

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Conversion Factors, Datums, and Abbreviated Water-Quality Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Weight	
pound per year (lb/yr)	0.4536	kilogram per year (kg/yr)
pound per square mile (lb/mi^2)	0.2819	kilogram per square kilometer (kg/km^2)

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).

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

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

Abbreviated water-quality units used in this report: Chemical concentrations in water are reported in milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents as weight (milligrams) of chemical per unit volume (liter) of water.

Assessment of Total Nitrogen in the Upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts, December 2002–September 2005

By Jeffrey R. Deacon[1], Thor E. Smith[1], Craig M. Johnston[1], Richard B. Moore[1], Rebecca M. Weidman[2], and Laura J. Blake[2]

Abstract

A study of total nitrogen concentrations and loads was conducted from December 2002 to September 2005 at 13 river sites in the upper Connecticut River Basin. Ten sites were selected to represent contributions of nitrogen from forested, agricultural, and urban land. Three sites were distributed spatially on the main stem of the Connecticut River to assess the cumulative total nitrogen loads. To further improve the understanding of the sources and concentrations and loads of total nitrogen in the upper Connecticut River Basin, ambient surface water-quality sampling was supplemented with sampling of effluent from 19 municipal and paper mill wastewater-treatment facilities.

Mean concentrations of total nitrogen ranged from 0.19 to 2.8 milligrams per liter (mg/L) at river sampling sites. Instantaneous mean loads of total nitrogen ranged from 162 to 58,300 pounds per day (lb/d). Estimated mean annual loads of total nitrogen ranged from 49,100 to 21.6 million pounds per year (lb/yr) with about 30 to 55 percent of the loads being transported during the spring. The estimated mean annual yields of total nitrogen ranged from 1,190 to 7,300 pounds per square mile per year (lb/mi^2)/yr.

Mean concentrations of total nitrogen ranged from 4.4 to 30 mg/L at wastewater-treatment sampling sites. Instantaneous mean loads of total nitrogen from municipal wastewater-treatment facilities ranged from 36 to 1,780 lb/d. Instantaneous mean loads of total nitrogen from paper mill wastewater-treatment facilities ranged from 96 to 160 lb/d.

The median concentration of total nitrogen was 0.24 mg/L at forested sites, 0.48 mg/L at agricultural sites, 0.54 mg/L at urban sites, 0.48 mg/L at main-stem sites, and 14 mg/L at wastewater-treatment sites. Concentrations of total nitrogen at forested sites were significantly less than at all other site types ($p<0.05$). Concentrations of total nitrogen at agricultural, urban, and main stem sites were not significantly different among each other ($p>0.05$) but were significantly greater ($p<0.05$) than at forested sites and significantly less than concentrations at wastewater-treatment sites ($p<0.05$). Total nitrogen concentrations at wastewater-treatment sites were significantly different from all other site types ($p<0.05$).

Annual yields of total nitrogen ranged from 732 to 1,920 (lb/mi^2)/yr at forested sites; 1,550 to 2,980 (lb/mi^2)/yr at agricultural sites; 1,280 to 1,860 (lb/mi^2)/yr at urban sites that were not directly affected by wastewater effluent; 7,090 to 7,770 (lb/mi^2)/yr at an urban site directly affected by wastewater effluent; and 1,300 to 2,390 (lb/mi^2)/yr at main-stem sites.

In this study, the mean annual load and yield of total nitrogen at the Connecticut River at Wells River, VT, was estimated at 4.47 million lb/yr and 1,690 (lb/mi^2)/yr, respectively. The mean annual load and yield of total nitrogen at the Connecticut River at North Walpole, NH, was estimated at 9.60 million lb/yr and 1,750 (lb/mi^2)/yr, respectively. The mean annual load and yield of total nitrogen leaving the upper Connecticut River Basin, as estimated at the Connecticut River at Thompsonville, CT, was 21.6 million lb/yr and 2,230 (lb/mi^2)/yr, respectively.

Introduction

A long-term study was initiated in 1985 to protect and restore the health of Long Island Sound (LIS) (U.S. Environmental Protection Agency, State of Connecticut, State of New York, Interstate Sanitation Commission, National Oceanic and Atmospheric Administration, 1985; New York Department of Environmental Conservation/Connecticut Department of Environmental Protection, 2000). Low concentrations (less than 3.5 mg/L) of dissolved oxygen (hypoxia) as a result of nitrogen enrichment often occur during the summer in the western part of LIS. Excess nitrogen levels can lead to the enhanced growth of algae, which eventually die and decay, consuming oxygen in the process. The ensuing hypoxic conditions have

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resulted in the exceedance of water-quality standards in LIS during the summer, with oxygen levels often falling below 1 or 2 mg/L. Nitrogen sources include nonpoint-source runoff from agricultural and urban areas, atmospheric deposition of nitrogen, and direct and indirect discharges from wastewater (Mullaney and others, 2002).

In response to this problem, Connecticut and New York developed a Total Maximum Daily Load (TMDL) that specifies the maximum amount of nitrogen that can be discharged to LIS. According to the TMDL analysis, an annual baseline load of about 53,300 tons of nitrogen is delivered to LIS from all sources in Connecticut and New York combined. An additional estimated 13,600 tons of nitrogen reach LIS annually from the part of the Connecticut River Basin originating north of the State of Connecticut. Of this total load, an estimated 12,500 tons of nitrogen is delivered to LIS by way of the Connecticut River. Total nitrogen loads account for terrestrial, atmospheric, and effluent from wastewater-treatment facilities. The TMDL specifies a 58.5-percent reduction in human-generated nitrogen from point and nonpoint sources. The TMDL requires Connecticut to remove about 6,300 tons of nitrogen delivered to LIS each year from wastewater dischargers located throughout the State, as well as another 400 tons of nitrogen resulting from nonpoint sources. The required nitrogen load reduction from wastewater discharge and other sources in New York is about 17,200 tons per year.

The LIS TMDL also specifies the need for additional actions beyond the nitrogen load reductions in Connecticut and New York. In particular, nitrogen reduction actions are needed for other sources, including sources of nitrogen that originate in States north of Connecticut (New Hampshire, Vermont, and Massachusetts) that drain to LIS.

The New England Interstate Water Pollution Control Commission (NEIWPCC) is assisting the U.S. Environmental Protection Agency (USEPA) and the States of Connecticut, Massachusetts, New Hampshire, and Vermont to better define nitrogen sources and loads in the upper Connecticut River Basin (drainage basin upstream from the Connecticut-Massachusetts state line). In order to define these sources, current data on nitrogen concentrations and loads are needed. To assess the current nitrogen loads, the U.S. Geological Survey (USGS), in cooperation with the NEIWPCC, designed and operated a surface water-quality monitoring network from December 2002 to September 2005 to collect water-quality and streamflow data to determine the current concentrations and loads of nitrogen from selected sites representing different land uses and from sites representing effluent from wastewater treatment in the upper Connecticut River Basin.

Purpose and Scope

This report summarizes concentrations of total nitrogen and other water-quality constituent data collected at 13 river sites and 19 wastewater-treatment sites in the upper Connecticut River Basin. Estimates of mean annual load and yield of total nitrogen from river sites and total nitrogen data relative to land use and land-cover classification also are included.

Twelve river sites and 19 wastewater-treatment sites were sampled in New Hampshire, Vermont, and Massachusetts, and one river site was sampled in Connecticut on the Connecticut River at Thompsonville, CT. All river water-quality sampling sites were co-located with a USGS streamflow-gaging station (referred to as a “station” in this report). References made to land use in the remaining sections of this report include land use and land cover. Field measurements of streamflow, specific conductance, pH, water temperature, and concentrations of dissolved oxygen, and nitrogen, phosphorus, and suspended-sediment data are presented in the report. The primary focus of this report is the assessment of concentrations, loads, and yields of total nitrogen at selected sites; however, concentrations, loads, and yields of total phosphorus and concentrations of other water-quality constituents also are presented.

Previous Studies

Several previous studies have provided estimates of nitrogen and phosphorus loads in the Connecticut River Basin and in the northeastern United States. Trench (1999) provides a summary of total nitrogen and total phosphorus loads for 25 monitoring stations in the Connecticut River Basin through 1995. The estimated load of total nitrogen ranged from 15 million pounds in 1995 to about 41 million pounds in 1984 at the USGS Connecticut River at Thompsonville, CT, water-quality monitoring station. That study also estimates yields of total nitrogen and total phosphorus for basins representing urban, agricultural, and forested land use. The estimated yields of total nitrogen at the USGS Connecticut River at Thompsonville, CT, water-quality monitoring station ranged from 1,550 pounds per square mile in 1995 to 4,210 pounds per square mile in 1984. Mullaney and others (2002) estimated annual loads of nonpoint nitrogen for 1988–98 at 28 monitoring stations and 26 unmonitored basins that drain to LIS. A multiple-linear regression equation was developed, on the basis of total nitrogen yields and associated basin characteristics from monitored sites and applied to unmonitored and other monitored sites, for estimating nonpoint nitrogen yields. The estimated nonpoint nitrogen load to LIS ranged from 21 million pounds in 1995 to 50 million pounds in 1990 (Mullaney and others, 2002). Mullaney (2004) provides a summary of water-quality trends in the Connecticut River, including trends in concentrations of total nitrogen. Since 1988, downward trends in total nitrogen were observed at the long-term USGS water-quality monitoring station at Connecticut River at Thompsonville, CT. The downward trend likely is a result of improved nitrogen removal from wastewater-treatment facilities but may relate to changes in land use, such as agricultural land changing to residential or forested land (Mullaney, 2004).

Regional nitrogen modeling studies include application of the USGS New England Spatially Referenced Regression on Watershed Attributes (SPARROW) model, which uses regression equations to relate total nitrogen stream loads to nutrient sources and watershed characteristics. Significant predictor variables of total nitrogen included (1) nitrogen loadings from permitted municipal wastewater discharge, (2) atmospheric deposition, (3) the area of agricultural land, and (4) the area of urban land (Moore and others, 2004). The estimated total nitrogen load at the mouth of the Connecticut River for 1992–93 was 17,800 tons. The estimated total nitrogen load at the Connecticut River at Thompsonville, CT, was 14,100 tons for 1992–93. Results of simulations made with the SPARROW model also indicated that total nitrogen stream-loss rates were significant only in streams with average annual flows less than or equal to 100 cubic feet per second (ft^3/s). Seitzinger and others (2002) developed a regression model that predicts the amount of nitrogen removed from rivers and its application to drainages in the northeastern United States. Results from this study indicated that as much as 37 to 76 percent of nitrogen inputs to rivers is removed during transport and about half of that is removed in first- to fourth-order streams, accounting for 90 percent of the total stream length in the basins.

Mueller and others (1995) compiled historical data on nutrient concentrations (nitrogen and phosphorus) from 20 study units of the USGS National Water-Quality Assessment Program. More than 220,000 surface-water samples were analyzed on regional and national scales. Results of the study indicated that nutrient concentrations in surface water generally were related to land use. Nitrate concentrations were highest in samples from sites downstream from agricultural or urban areas. Results also indicated the elevated concentrations of nitrate in surface water in the northeastern United States may be related to large amounts of atmospheric deposition.

Description of the Study Area

The Connecticut River Basin, the largest in New England, encompasses 11,250 square miles (mi^2) (fig. 1). The Connecticut River traverses 410 miles (mi) from its headwaters near the New Hampshire-Canada border to its mouth in Old Saybrook, CT, where it drains into Long Island Sound. The river drops 2,400 feet (ft) in elevation from its source to its outlet, and has an estimated average discharge of about 19,200 ft^3/s at the outlet (Garabedian and others, 1998). The Connecticut River makes up 70 percent of the freshwater flow into LIS .

Elevations in the Connecticut River Basin range from sea level in coastal Connecticut to 6,288 ft above sea level at the peak of Mount Washington in the White Mountains of New Hampshire. Topography is characterized by rolling hills and low, rounded mountains with numerous, generally narrow valleys. The relief is greatest in the northern part of the basin where the Green Mountains of Vermont and the White Mountains of New Hampshire generally reach elevations between 2,000 and 4,000 ft above sea level. The Connecticut River valley forms a broad lowland just south of the New Hampshire-Vermont-Massachusetts state lines to within about 20 mi of LIS (Grady and Garabedian, 1991).

Average annual temperatures range from less than 5 degrees Celsius (^{o}C) in the northern mountainous regions to about $10^{o}C$ in the southern regions. Average annual precipitation ranges from about 34 inches (in.) in the northern areas of the Connecticut River Basin to more than 65 in. in some of the mountainous regions (Garabedian and others, 1998).

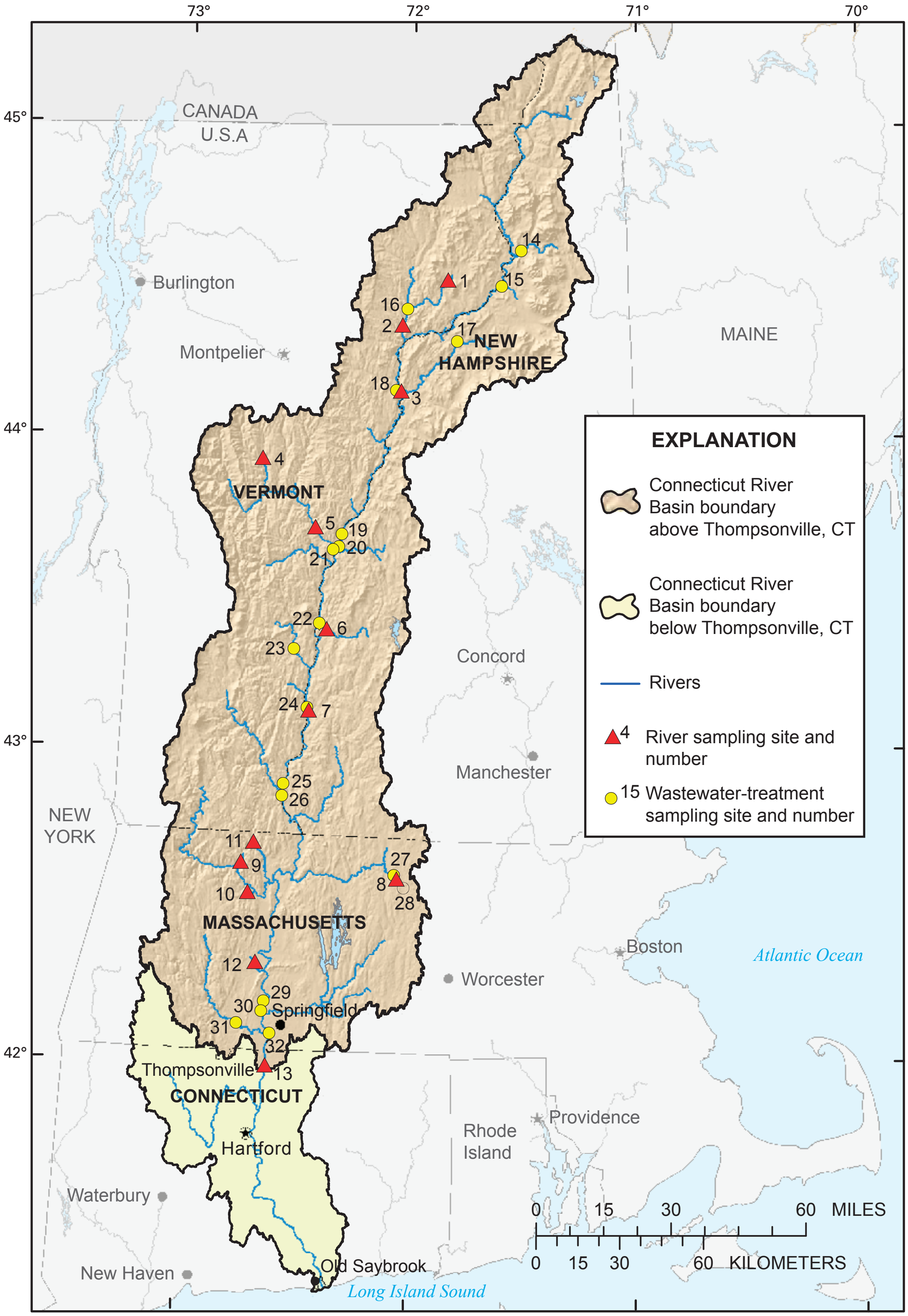
For purposes of this report, the upper Connecticut River Basin is defined as the drainage basin above the USGS streamgaging station at Connecticut River at Thompsonville, CT (site 13, fig. 1). The station is near the Connecticut-Massachusetts State line and serves as the outlet site to the upper basin. Streamflow at the station averages about 12,700 ft^3/s. The upper Connecticut River Basin encompasses approximately 9,660 mi^2 in New Hampshire, Vermont, and Massachusetts (fig. 1). The population is approximately 1 million people and is distributed amongst densely populated, urban areas in the southernmost section of the basin in Massachusetts to sparsely populated, rural and agricultural regions in the northern areas of the basin in New Hampshire and Vermont. The agricultural land use in New Hampshire and Vermont is predominantly related to dairy farm operations. The agricultural land use in Massachusetts is predominantly related to orchards, row crops, and some dairy operations. The land use and land cover in the upper basin consists of about 80 percent forest, 9 percent agriculture, 5 percent urban, and 6 percent wetlands and barren.

Data Collection and Analysis

Data were collected for this study to improve the understanding of current total nitrogen concentrations and loads at selected sites and to estimate the contributions originating from different land uses and the effluent from wastewater-treatment facilities in the basin. Field measurements of streamflow, specific conductance, pH, water temperature, and concentrations of dissolved oxygen, were made, and nitrogen, phosphorus, and suspended-sediment concentration data were collected. Total nitrogen was calculated as the sum of nitrite plus nitrate and total ammonia plus organic nitrogen.

Site Selection

Approximately 80 stream sites initially were considered as potential sampling sites. The sites were categorized by stream size, percentage of land-use types, and estimated total nitrogen loads from the New England SPARROW model (Moore and others, 2004). The final selection of the sites was based on topographic map inspections and field reconnaissance, the existing USGS streamgaging network in the upper Connecticut River Basin, and whether water-quality data had previously been collected at the site. The process also



Shaded relief from U.S. Geological Survey 30-meter National Eleva ion Dataset, 1999

Figure 1. Sampling sites and site-identification numbers in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts. (Site identification numbers are shown in table 1.)

included an analysis of the New England SPARROW model results that estimated the percentage of land-use classifications contributing nitrogen to the stream site. Thirteen river sites were selected for the study (table 1, fig. 1). Ten sites were selected to represent contributions of nitrogen from forested, agricultural, and urban land. Forest was the predominant land use at all sites in the basin. Sites that were selected to represent agricultural and urban land use in this study generally had agriculture and urban land use as the second predominant land use in the basin. Three sites were distributed spatially on the main stem of the Connecticut River. The Connecticut River at Thompsonville, CT, was sampled as part of the USGS Connecticut Water Science Center programs.

Ambient water-quality sampling at river sites was supplemented with the collection of effluent samples from 19 wastewater-treatment facilities in New Hampshire, Vermont, and Massachusetts (table 1, fig. 1). Sixteen sampling sites were located at municipal wastewater-treatment facilities and three sites were located at paper mill wastewater-treatment facilities. The facilities were selected on the basis of size, type, and location in the basin. The samples of effluent from wastewater-treatment facilities, referred to as wastewater-treatment sampling sites in this report, will provide an estimate of the contribution of total nitrogen from the effluent from these facilities.

Sample Collection

Samples were collected monthly from December 2002 through September 2005 at each of the 13 river sites by using field procedures outlined in Wilde and Radtke (1998a,b). Forty to 45 water samples were collected at each river sampling site. Samples were collected in baseflow, periodic rainstorm, and snowmelt conditions. About three additional samples were collected during the snowmelt runoff period each year to characterize the period when constituent concentrations might be more variable. Ten to 15 samples were collected at the wastewater-treatment sampling sites, generally from April through September, to assist in providing current total nitrogen data from the effluent from these facilities. During each site visit, onsite measurements were made for specific conductance, pH, water temperature, and concentrations of dissolved oxygen, and water samples were collected for subsequent laboratory analysis of the concentrations of dissolved nitrite plus nitrate, dissolved ammonia, total ammonia plus organic nitrogen, dissolved orthophosphate, total phosphorus, and suspended-sediment. Instantaneous streamflow was determined at the time of sample collection using established USGS stage—discharge relations at streamgaging stations for river sites and from the facilities gage at wastewater-treatment sites. Water samples were analyzed at the USGS water-quality laboratory in Lakewood, CO. Suspended-sediment concentration analysis was conducted at the USGS Kentucky sediment laboratory in Louisville, KY. All data are available from the USGS National Water Information System (NWIS) database and are published in USGS annual Water-Data Reports (Keirstead and others, 2003, 2004; Kiah and others, 2005; Socolow and others, 2003, 2004, 2005).

Data Analysis

Selected results of the data collection and water-quality analyses for each of the 13 river sampling sites are presented in the following sections. For each river site, water-quality conditions are described, and a map and three pages of graphs of selected data are presented. Ranges of constituent values not plotted in the graphs are statistically summarized in the text. For nitrite, ammonia, and orthophosphate summary statistics, data were re-censored from the laboratory reporting level (LRL) to the long-term method detection level (LT-MDL). Re-censoring provides useful information for constituents that are censored at the laboratory reporting level but have qualified values between the LT-MDL and the LRL (Helsel, 2005). For nitrite, the LRL was 0.008 mg/L and the LT-MDL was 0.004 mg/L; therefore, nitrite data were re-censored at 0.004 mg/L. For ammonia, the LRL was 0.010 mg/L and the LT-MDL was 0.005 mg/L; therefore, ammonia was re-censored at 0.005 mg/L. For orthophosphate in the years 2003 and 2004, the LRL was 0.02 mg/L and the LT-MDL was 0.01 mg/L; therefore, orthophosphate was re-censored at 0.01 mg/L for data collected in 2003 and 2004. Orthophosphate was analyzed at a lower level during 2005 when the LRL was 0.006 mg/L and the LT-MDL was 0.003 mg/L; therefore, orthophosphate was re-censored at 0.003 mg/L for data collected in 2005. Long-term method detection and laboratory reporting levels for samples analyzed at the USGS National Water Quality Laboratory are described by Childress and others (1999).

For each river site, the illustrations begin with a map of the site showing the major stream network and the land-use classifications (U.S. Geological Survey, 2000). Information about land use assists in the understanding of natural and anthropogenic factors that affect water quality. Two graphs are presented on the second page of illustrations to describe the streamflow and the distribution of water-quality samples in relation to streamflow. In the first graph, annual streamflow is described by use of a bar chart. Streamflow for each water year of the study period is represented by one bar in the graph. A water year is the period from October through September and is defined by the year in which it ends. Historical data also are provided for the period prior to data collection for this study. A comparison of historical data to data collected for this study indicates in general terms whether runoff during the data-collection period was above average, below average, or normal. In the second graph, daily mean streamflow for the data-collection period as well as dates and instantaneous streamflow for the water-quality samples are presented. Because the water-quality samples are displayed with the corresponding instantaneous streamflow, these points do not

Table 1. Selected characteristics for the study sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[USGS, U.S. Geological Survey; mi², square miles; WY, water year; na, not applicable; WWTF, wastewater-treatment facility; --, no data]

Site number (fig. 1)	USGS station number	Station name	Site type in this study	Latitude	Longitude	Drainage area (mi²)	Mean annual streamflow (WY 1980–2002)	Mean annual streamflow (WY 2003–05)
		River sampling sites					(in thousands of acre-feet)	
1	01134500	Moose River at Victory, VT	Forest	44°30'42"	71°50'13"	75.2	111	107
2	01135500	Passumpsic River at Passumpsic, VT	Agriculture	44°21'56"	72°02'23"	436	572	554
3	01138500	Connecticut River at Wells River, VT	Main stem	44°09'13"	72°02'34"	2,644	3,750	3,560
4	01142500	Ayers Brook at Randolph, VT	Agriculture	43°56'04"	72°39'30"	30.5	37.3	38.2
5	01144000	White River at West Hartford, VT	Agriculture	43°42'51"	72°25'07"	690	885	959
6	01152500	Sugar River at West Claremont, NH	Urban	43°23'15"	72°21'45"	269	304	341
7	01154500	Connecticut River at North Walpole, NH	Main stem	43°07'34"	72°26'14"	5,493	7,160	7,070
8	01163200	Otter River at Otter River, MA	Urban	42°35'18"	72°02'29"	34.1	45.3	53.4
9	01169000	North River at Shattuckville, MA	Agriculture	42°38'18"	72°43'32"	89.0	138	167
10	01169900	South River near Conway, MA	Agriculture	42°32'31"	72°41'39"	24.1	37.1	48.1
11	01170100	Green River near Colrain, MA	Forest	42°42'12"	72°40'16"	41.4	61.4	74.4
12	01171500	Mill River at Northhampton, MA	Urban	42°19'08"	72°39'56"	54.0	73.0	88.4
13[a]	01184000	Connecticut River at Thompsonville, CT	Main stem	41°59'14"	72°36'21"	9,660	12,700	13,000
		Point-source sampling sites					(in millions of gallons)	
14	443558071303001	Wasau Paper WWTF, NH	Point source	44°35'58"	71°30'30"	na	na	1,670
15	442906071354401	Lancaster WWTF, NH	Point source	44°29'06"	71°35'44"	na	na	--
16	442436072010001	St. Johnsbury WWTF, VT	Point source	44°24'36"	72°01'00"	na	na	407
17	441827071473701	Littleton WWTF, NH	Point source	44°18'27"	71°47'37"	na	na	303
18	440835072022501	Woodsville WWTF, NH	Point source	44°08'35"	72°02'25"	na	na	63
19	434145072175601	Hanover WWTF, NH	Point source	43°41'45"	72°17'56"	na	na	531
20	433844072185501	Hartford/White River Junction WWTF, VT	Point source	43°38'44"	72°18'55"	na	na	365
21	433813072192001	Lebanon WWTF, NH	Point source	43°38'13"	72°19'20"	na	na	659
22	432359072234001	Claremont WWTF, NH	Point source	43°23'59"	72°23'40"	na	na	578
23	431648072280801	Springfield WWTF, VT	Point source	43°16'48"	72°28'08"	na	na	--
24	430745072263701	Bellows Falls WWTF, VT	Point source	43°07'45"	72°26'37"	na	na	206
25	425322072323701	Fibermark Products WWTF, VT	Point source	42°53'22"	72°32'37"	na	na	518
26	425029072325901	Brattleboro WWTF, VT	Point source	42°50'29"	72°32'59"	na	na	575
27	423542072031001	Seaman Paper WWTF, MA	Point source	42°35'42"	72°03'10"	na	na	329
28	423413072011201	Gardner WWTF, MA	Point source	42°34'13"	72°01'12"	na	na	1,300
29	421132072365001	Holyoke WWTF, MA	Point source	42°11'32"	72°36'50"	na	na	3,270
30	420908072373301	Chicopee WWTF, MA	Point source	42°09'08"	72°37'33"	na	na	3,590
31	420702072435601	Westfield WWTF, MA	Point source	42°07'02"	72°43'56"	na	na	1,400
32	420508072351401	Springfield WWTF, MA	Point source	42°05'08"	72°35'14"	na	na	15,900

[a] Sampled by the USGS Connecticut Water Science Center.

always fall on the line representing the daily mean discharge. The distribution of water-quality samples with respect to time also is represented.

The third page of illustrations presents the distribution of selected water-quality constituents at the various sites. Concentrations of selected constituents are shown in relation to streamflow and instantaneous loads of total nitrogen are shown in relation to time. Box plots in the right margins of the graphs summarize the distribution of concentrations or loads for each constituent.

Two bar graphs are presented on the fourth page of illustrations to describe the total nitrogen loads and mean annual yields. The first graph is the estimated total nitrogen load by water year for the river site, and the second graph presents the mean annual nitrogen yield (2003–05) compared to all other river sampling sites.

Selected results of the analysis of total nitrogen in samples collected at the wastewater-treatment sampling sites are presented as summary statistics in the text and as bar graphs in the illustrations. The concentrations of total nitrogen among and in relation to site types are summarized in box plots. The Kruskal-Wallis test, a nonparametric analysis of variance test (ANOVA), was used to determine significant statistical differences among groups of data (Helsel and Hirsch, 1992). The level of significance for ANOVA was set at alpha equals 0.05. When the nonparametric ANOVA indicated significant statistical differences, ranked transformed data were used for the Tukey's multiple comparison test to determine which groups were significantly different (Helsel and Hirsch, 1992). All statistical analyses were performed using Statview and SAS statistical software (SAS Institute, Inc., 1998, 2000).

The LOAD ESTimator (LOADEST) computer program (Runkel and others, 2004) was used to estimate total nitrogen and total phosphorus loads at the study sites. LOADEST is based on a regression equation in which time series of streamflow and constituent concentrations are used as calibration data for the estimation of constituent loads. Explanatory variables within the regression model include various functions of streamflow and time (seasonality). For total nitrogen or total phosphorus at each site, models were fit using all possible combinations of these variables and the best model was selected based on the Akaike Information Criteria (Akaike, 1981). The specific method used for model calibration and load estimation is described by Runkel and others (2004). Data on annual loads, yields, confidence intervals, seasonal load estimates, and the regression equations used in LOADEST for total nitrogen and total phosphorus estimates are in appendix tables A-1 through A-4.

Quality-control procedures included analyses of field blank and replicate samples. Field blanks provide information on bias or the potential for contamination of analytical results by sample collection, processing, and analysis (Spahr and Boulger, 1997). Analyses of the field blank samples indicated that concentrations of constituents discussed in this report were less than the LRL. Replicate samples provide information on the variability of analytical results caused by sample collection, processing, and analysis (Spahr and Boulger, 1997). Differences in concentrations of the constituents of interest in environmental and replicate samples at river sampling sites were within 0.01 mg/L and 0.05 mg/L for nitrite plus nitrate and total ammonia plus organic nitrogen, respectively. This resulted in concentration differences in environmental and replicate samples for total nitrogen being within 0.1 mg/L. Differences in concentrations in environmental and replicate samples at wastewater-sampling sites, where concentrations generally were greater, were within 10 percent for nitrite plus nitrate and total ammonia plus organic nitrogen. This resulted in differences in environmental and replicate samples for total nitrogen also being within 10 percent. Differences in concentrations in environmental and replicate samples for other constituents discussed in this report were low. It was concluded that sample processing and analysis did not introduce enough variation in the environmental data to affect interpretation of results.

Characterization of Total Nitrogen at River Sampling Sites

Mean concentrations of total nitrogen at river sampling sites ranged from 0.19 to 2.8 mg/L and mean instantaneous loads of total nitrogen ranged from 162 to 58,300 pounds per day (lb/d). Estimated mean annual loads of total nitrogen ranged from 49,100 to 21.6 million pounds per year (lb/yr) with about 30 to 55 percent of the load being transported during the spring. The estimated mean annual yields of total nitrogen ranged from 1,190 to 7,300 (lb/mi^2)/yr.

In the following sections, selected constituent concentrations and loads of total nitrogen are summarized in the text and are plotted in graphs to examine relations to streamflow and time at each site. Ranges of field measurement values and other water-quality constituent values are presented in the text. Estimated loads and yields of total nitrogen and total phosphorus at river sampling sites are presented in table 2. The 95-percent confidence intervals of the mean load, the standard error of prediction, and the ratio of the standard error of prediction to the mean load also are presented in table 2. The ratio of the standard error of prediction to the mean load standardizes the model error and provides a comparison among sites having large differences in load estimates. The prediction error ranged from 2.2 to 10 percent of the mean loads for total nitrogen estimates and from 9.7 to 54 percent of the mean loads for total phosphorus estimates. This indicates that the models had low error in the estimates of total nitrogen and more error in the estimates of total phosphorus.

Table 2. Mean annual loads, yields, confidence intervals, standard error of prediction, and the ratio of the standard error of prediction to the mean annual load for total nitrogen and total phosphorus at river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/yr, pounds per year; (lb/mi^2)/yr, pounds per square mile per year]

Site number (table 1; fig. 1)	USGS station number	Station name	Mean load (lb/d)	Mean load (lb/yr)	Yield (lb/mi^2)/yr	95-percent confidence interval		Standard error of prediction (lb/yr)	Ratio of standard error of prediction to mean load (percent)
						Lower (lb/yr)	Upper (lb/yr)		
			Total nitrogen						
1	01134500	Moose River at Victory, VT	331	121,000	1,610	106,000	138,000	6,470	5.3
2	01135500	Passumpsic River at Passumpsic, VT	2,250	822,000	1,890	749,000	901,000	35,000	4.2
3	01138500	Connecticut River at Wells River, VT	12,200	4,470,000	1,690	4,250,000	4,690,000	97,500	2.2
4	01142500	Ayers Brook at Randolph, VT	205	74,900	2,450	67,900	82,300	2,660	3.5
5	01144000	White River at West Hartford, VT	3,460	1,260,000	1,830	1,170,000	1,360,000	34,300	2.7
6	01152500	Sugar River at West Claremont, NH	1,020	372,000	1,380	335,000	413,000	14,600	3.9
7	01154500	Connecticut River at North Walpole, NH	26,300	9,600,000	1,750	8,820,000	10,500,000	400,000	4.1
8	01163200	Otter River at Otter River, MA	682	249,000	7,300	230,000	270,000	9,790	3.9
9	01169000	North River at Shattuckville, MA	531	194,000	2,180	163,000	229,000	13,600	7.0
10	01169900	South River near Conway, MA	147	53,700	2,230	48,000	59,800	2,350	4.4
11	01170100	Green River near Colrain, MA	134	49,100	1,190	38,500	61,800	5,070	10
12	01171500	Mill River at Northhampton, MA	262	95,400	1,770	88,800	103,000	2,860	3.0
13	01184000	Connecticut River at Thompsonville, CT	59,000	21,600,000	2,230	20,300,000	22,900,000	650,000	3.0
			Total phosphorus						
1	01134500	Moose River at Victory, VT	23	8,300	110	5,530	12,000	1,650	20
2	01135500	Passumpsic River at Passumpsic, VT	205	74,800	172	54,600	100,000	11,600	16
3	01138500	Connecticut River at Wells River, VT	642	234,000	89	191,000	285,000	24,200	10
4	01142500	Ayers Brook at Randolph, VT	111	40,300	1,320	16,300	83,900	17,600	44
5	01144000	White River at West Hartford, VT	959	350,000	507	177,000	626,000	116,000	33
6	01152500	Sugar River at West Claremont, NH	72	26,200	97	21,100	32,100	2,790	11
7	01154500	Connecticut River at North Walpole, NH	1,720	626,000	114	512,000	765,000	64,200	10
8	01163200	Otter River at Otter River, MA	41	15,000	438	12,200	18,100	1,520	10
9	01169000	North River at Shattuckville, MA	57	20,900	235	10,300	38,000	7,180	34
10	01169900	South River near Conway, MA	13	4,810	200	1,580	11,400	2,580	54
11	01170100	Green River near Colrain, MA	7	2,420	58	1,360	3,990	679	28
12	01171500	Mill River at Northhampton, MA	9	3,340	62	2,740	4,020	325	9.7
13	01184000	Connecticut River at Thompsonville, CT	4,900	1,790,000	185	1,450,000	2,190,000	189,000	11

Moose River at Victory, VT, Station 01134500

Moose River at Victory, VT, represents a forested site in the study area with minimal effects on water quality from land use. The contributing drainage basin upstream from the site encompasses 75 mi^2 and is about 90 percent forested, 7 percent wetlands, and 3 percent barren (fig. 2). Annual streamflow for 1980–2002 averaged 111,000 acre-feet, with considerable year-to-year variation (fig. 3A). Annual streamflow for the data-collection period for water years 2003–05 averaged 107,000 acre-feet (table 1). Streamflow during the period was less than the long-term mean for the first year of the study period, greater than the long-term mean for the second year, and about equal to the long-term mean for the third year (fig. 3A).

Daily mean streamflow and time distribution for 42 water-quality samples are shown in figure 3B. The minimum streamflow at which the water samples were collected was 16 ft^3/s, and the maximum streamflow at which samples were collected was 721 ft^3/s.

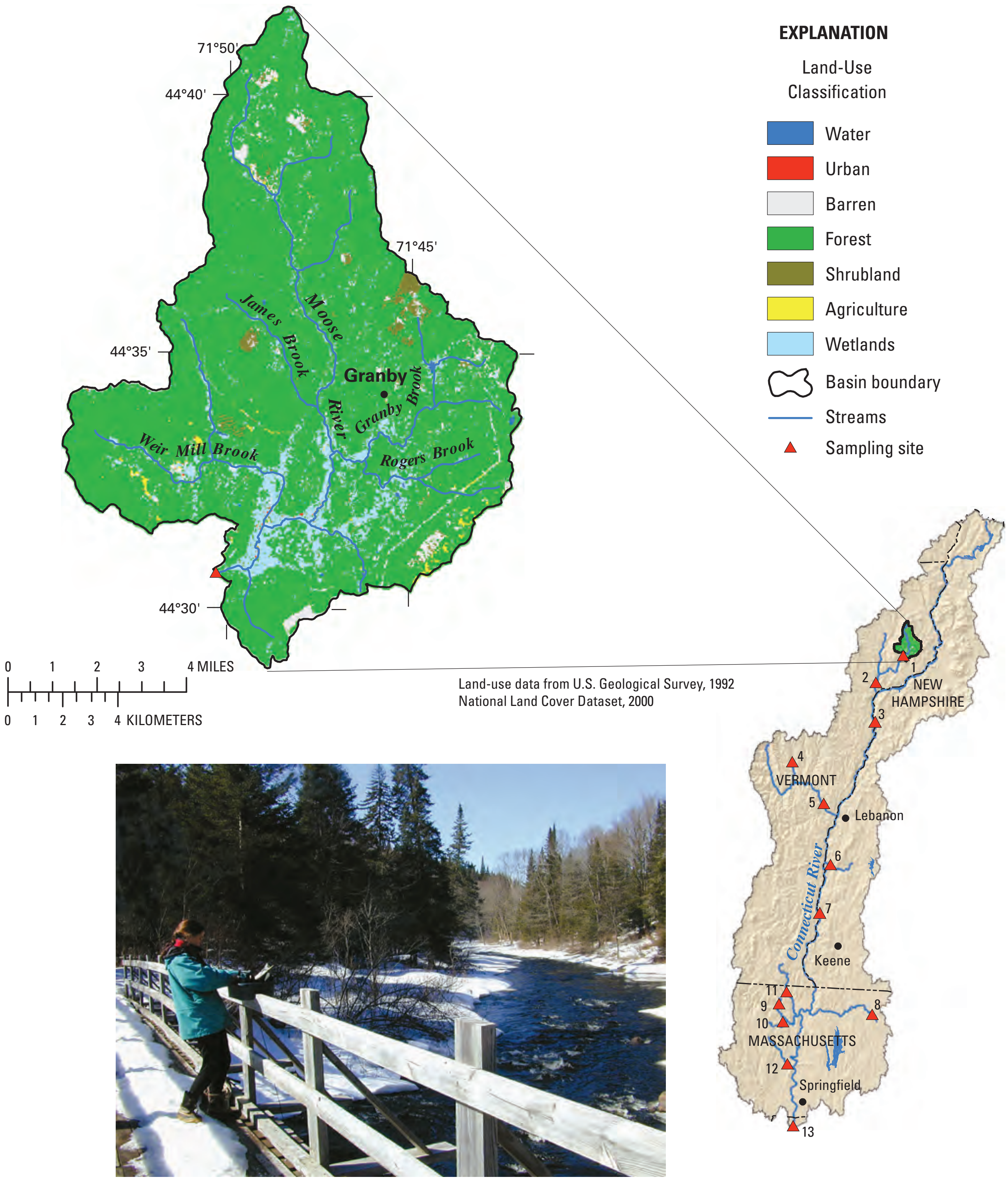
The minimum concentration of dissolved oxygen at this site (7.0 mg/L) equaled the State of Vermont water-quality criterion for Class B waters for dissolved oxygen of 7.0 mg/L for cold water fish habitat (Vermont Water Resources Board, 2000). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 4). Concentrations of dissolved nitrite plus nitrate ranged from an estimated 0.016 to 0.373 mg/L, and showed no apparent relation to streamflow (fig. 4A). Total ammonia plus organic nitrogen ranged from 0.13 to 0.81 mg/L and also showed no apparent relation to streamflow (fig. 4B). The maximum concentration of total ammonia plus organic nitrogen (0.81 mg/L) was in a sample collected at a streamflow of 570 ft^3/s, just prior to the maximum daily mean streamflow, which occurred during snowmelt in water year 2004 (fig. 4B). Concentrations of total nitrogen (dissolved nitrite plus nitrate plus total ammonia plus organic nitrogen) ranged from 0.20 to 0.90 mg/L (fig. 4C), with the maximum concentration observed during spring snowmelt in water year 2004. Concentrations of total phosphorus generally were low and ranged from 0.005 to 0.124 mg/L and showed a slight increase with an increase in streamflow (fig. 4D). The maximum concentration of total phosphorus (0.124 mg/L) also was collected at a streamflow of 570 ft^3/s, just prior to the maximum daily mean streamflow during snowmelt in water year 2004 (fig. 4D). Instantaneous loads of total nitrogen generally were representative of the instantaneous streamflow at the time of sample collection and ranged from 22 to 2,700 lb/d (fig. 4E). In other words, instantaneous loads of total nitrogen were greater in samples collected during high streamflows and less in samples collected during base-flow or low-flow conditions. Ranges of concentrations or values for water-quality constituents not shown in figure 4 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	18	32	31	49
pH	5.7	6.5	6.4	7.4
Water temperature	.0	6.8	3.0	21.8
Dissolved oxygen	7.0	10.8	11.2	14.1
Dissolved nitrite	< .004	—	<.004	.005
Dissolved ammonia	.005	.017	.013	.074
Dissolved orthophosphate (WY 2003–04)	< .01	—	<.01	< .01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.003
Suspended sediment	1	13	3	165

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year. < less than; —, not calculated.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 5A). The mean annual load of total nitrogen was 121,000 lb/yr with a ratio of the standard error of prediction to the mean load of 5.3 percent (table 2, fig. 5A). An estimated 47 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean total nitrogen yield (1,610 (lb/mi^2)/yr) generally was less than at sites representing other land uses (fig. 5B). Trench (1999) reported similar results in that forested basins generally had lower yields of total nitrogen than agricultural and urban basins of similar size. In general, water quality at this site typifies background conditions for this area of the basin. Concentrations of total nitrogen and other water-quality constituents generally were low.

Moose River at Victory, VT, Station 01134500



Photograph by Thor Smith, U.S. Geological Survey

Figure 2. Location, land-use classification, and photograph of sampling site for Moose River at Victory, VT, station 01134500. (Refer to table 1 and figure 1 for additional site information.)

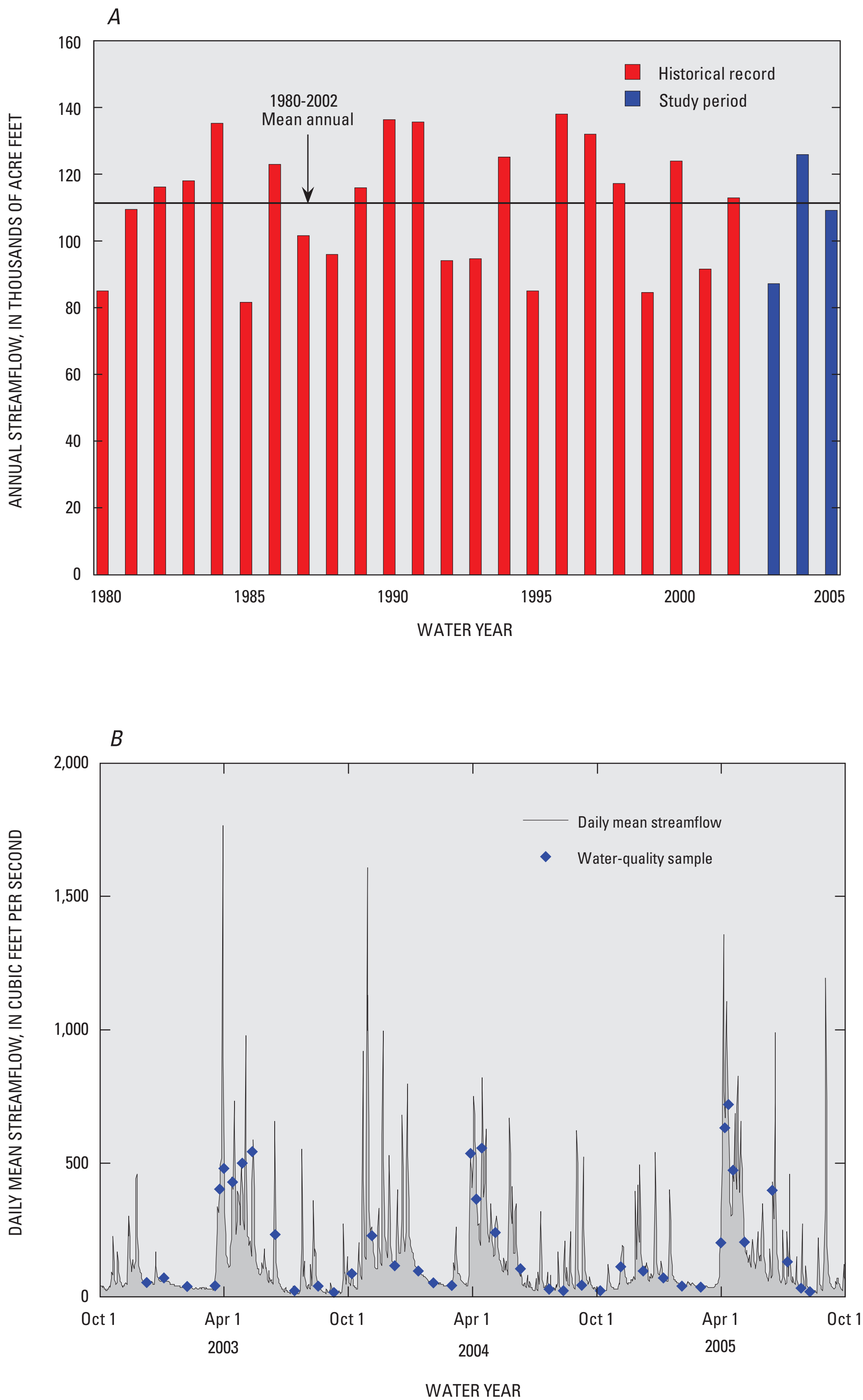


Figure 3. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Moose River at Victory, VT, station 01134500.

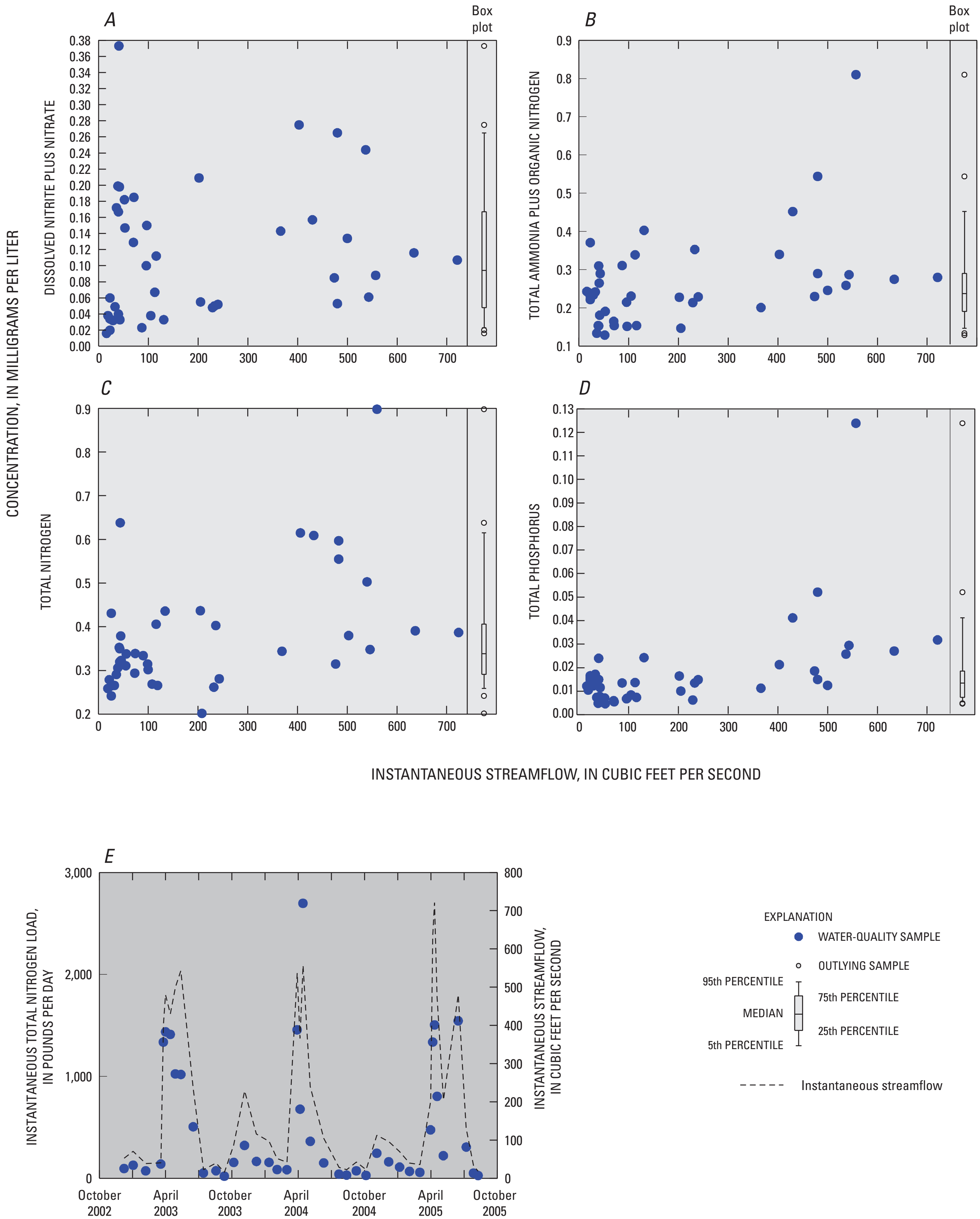


Figure 4. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Moose River at Victory, VT, station 01134500. (Refer to table 1 and figure 1 for station location.)

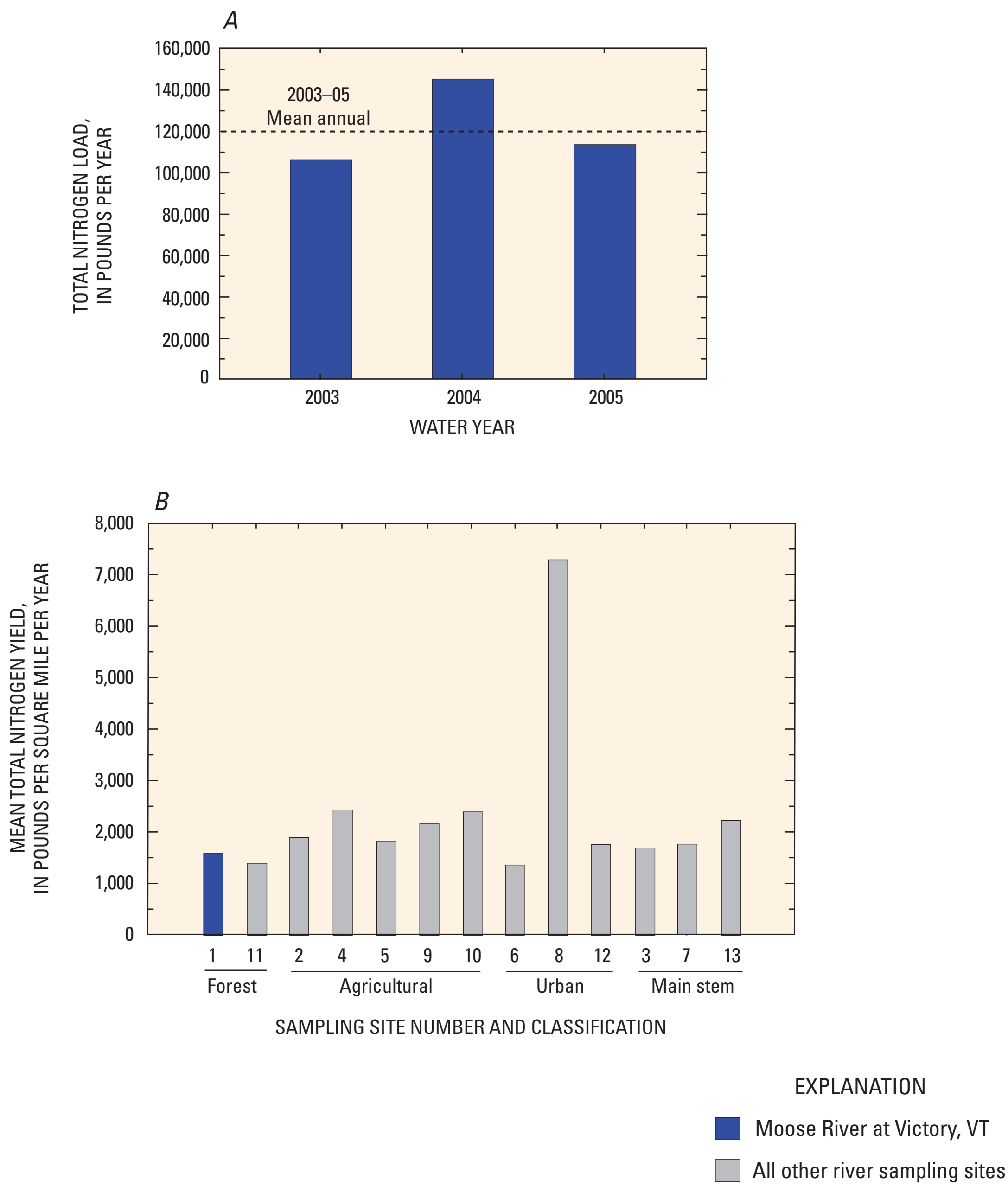


Figure 5. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Moose River near Victory, VT, station 01134500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Passumpsic River at Passumpsic, VT, Station 01135500

Passumpsic River at Passumpsic, VT, is classified as an agricultural site in the study area and represents potential effects on water quality from agricultural land use. The contributing drainage basin upstream from the site encompasses 436 mi^2 and is about 80 percent forested, 11 percent agriculture, 2 percent urban, and about 7 percent wetlands and barren (fig. 6). Annual streamflow for 1980–2002 averaged 572,000 acre-feet, with considerable year-to-year variation (fig. 7A). Annual streamflow for the data-collection period for water years 2003–05 averaged 554,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of the study, greater than the long-term mean for the second year, and slightly less than the long-term mean for the third year (fig. 7A).

Daily mean streamflow and time distribution for 43 water-quality samples are shown in figure 7B. The minimum streamflow at which the water samples were collected was 152 ft^3/s, and the maximum streamflow at which samples were collected was 3,820 ft^3/s.

The minimum concentration of dissolved oxygen at this site (8.0 mg/L) was above the State of Vermont water-quality criterion for dissolved oxygen (7.0 mg/L; Vermont Water Resources Board, 2000). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 8). Concentrations of dissolved nitrite plus nitrate ranged from 0.064 to 0.515 mg/L, and showed no apparent relation to streamflow (fig. 8A). Total ammonia plus organic nitrogen ranged from 0.13 to 0.67 mg/L and generally showed no relation to streamflow for lower flow samples; however, concentrations increased at streamflows greater than 2,500 ft^3/s (fig. 8B). One exception was the maximum concentration of total ammonia plus organic nitrogen (0.67 mg/L) that was in a sample collected at a streamflow of about 1,600 ft^3/s, when streamflow was rising as a result of snowmelt (fig. 8B). Concentrations of total nitrogen ranged from 0.25 to 1.2 mg/L (fig. 8C). Concentrations of total phosphorus ranged from 0.008 to 0.155 mg/L and increased with an increase in streamflow (fig. 8D). Instantaneous loads of total nitrogen ranged from 210 to 23,800 lb/d (fig. 8E). Ranges of concentrations or values for water-quality constituents not shown in figure 8 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	74	182	197	302
pH	6.3	7.7	7.6	9.0
Water temperature	.0	9.1	6.2	24.4
Dissolved oxygen	8.0	11.3	11.9	14.5
Dissolved nitrite	<.008	—	<.008	<.008
Dissolved ammonia	.005	.032	.019	.208
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	.02
Dissolved orthophosphate (WY 2005)	<.003	—	.005	.022
Suspended sediment	1	24	4	358

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 9A). The mean annual total nitrogen load was 822,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 4.2 percent (table 2, fig. 9A). An estimated 48 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen was 1,890 (lb/mi^2)/yr (fig. 9B).

Passumpsic River at Passumpsic, VT, Station 01135500

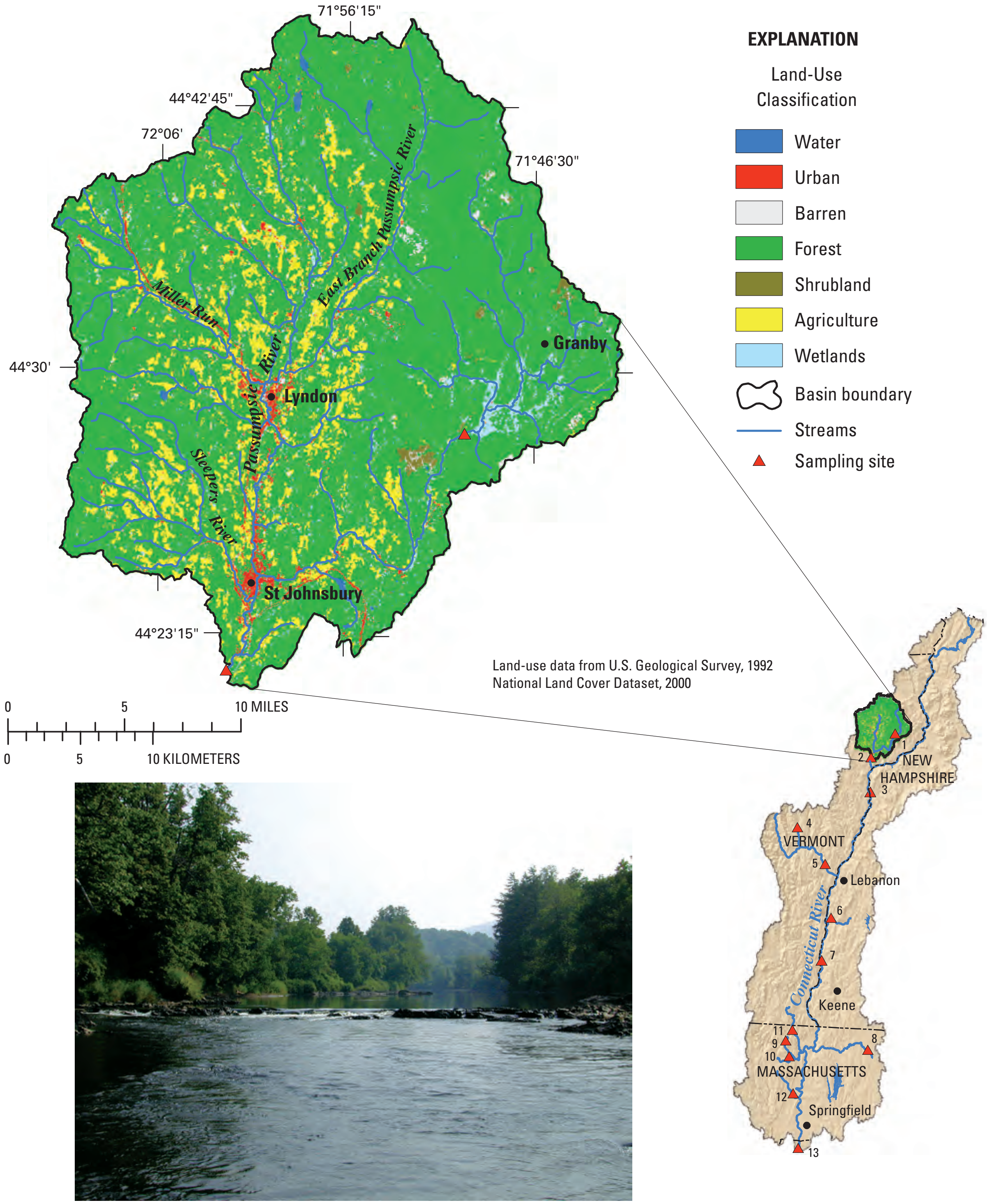


Figure 6. Location, land-use classification, and photograph of sampling site for Passumpsic River at Passumpsic, VT, station 01135500. (Refer to table 1 and figure 1 for additional site information.)

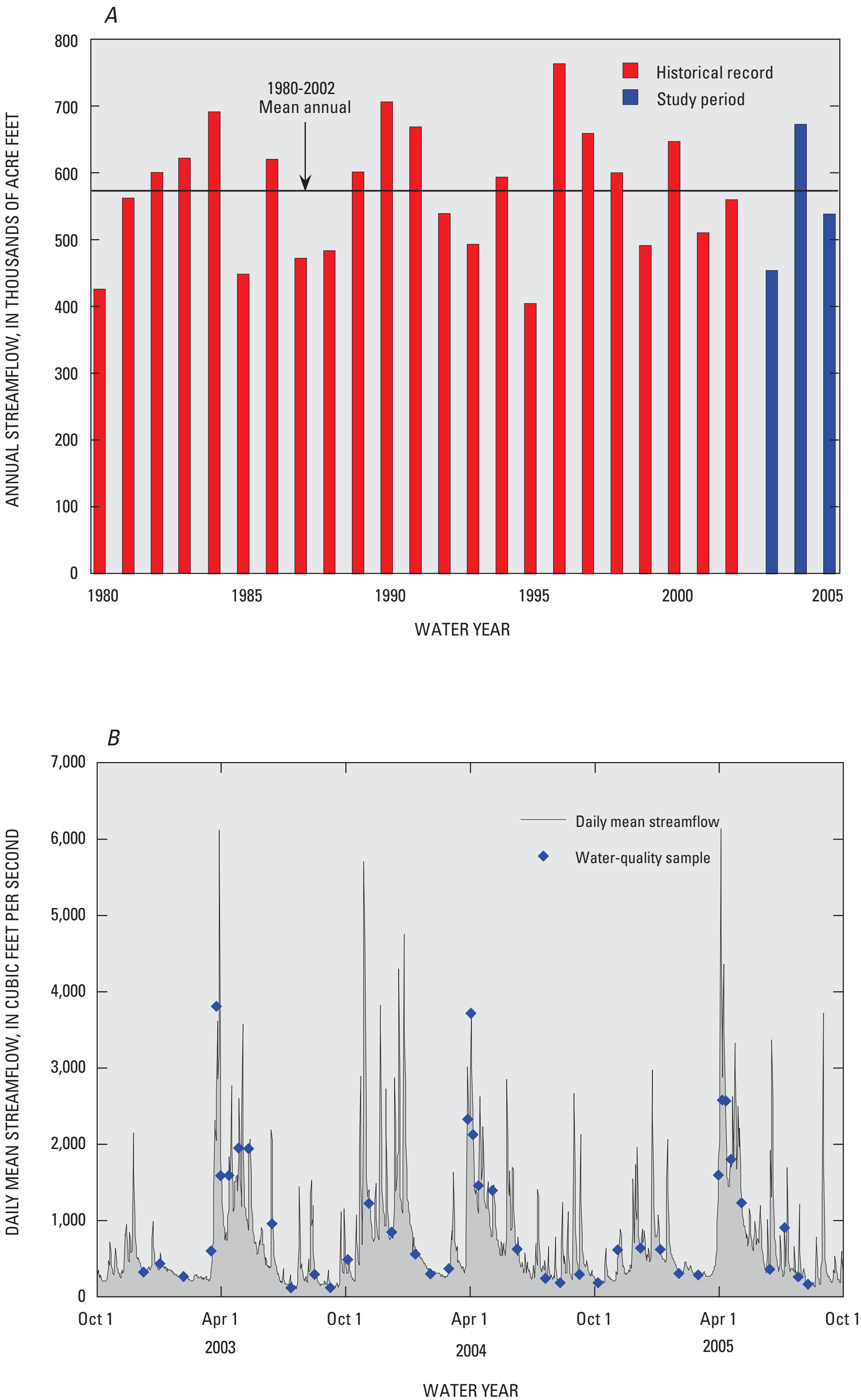


Figure 7. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Passumpsic River at Passumpsic, VT, station 01135500.

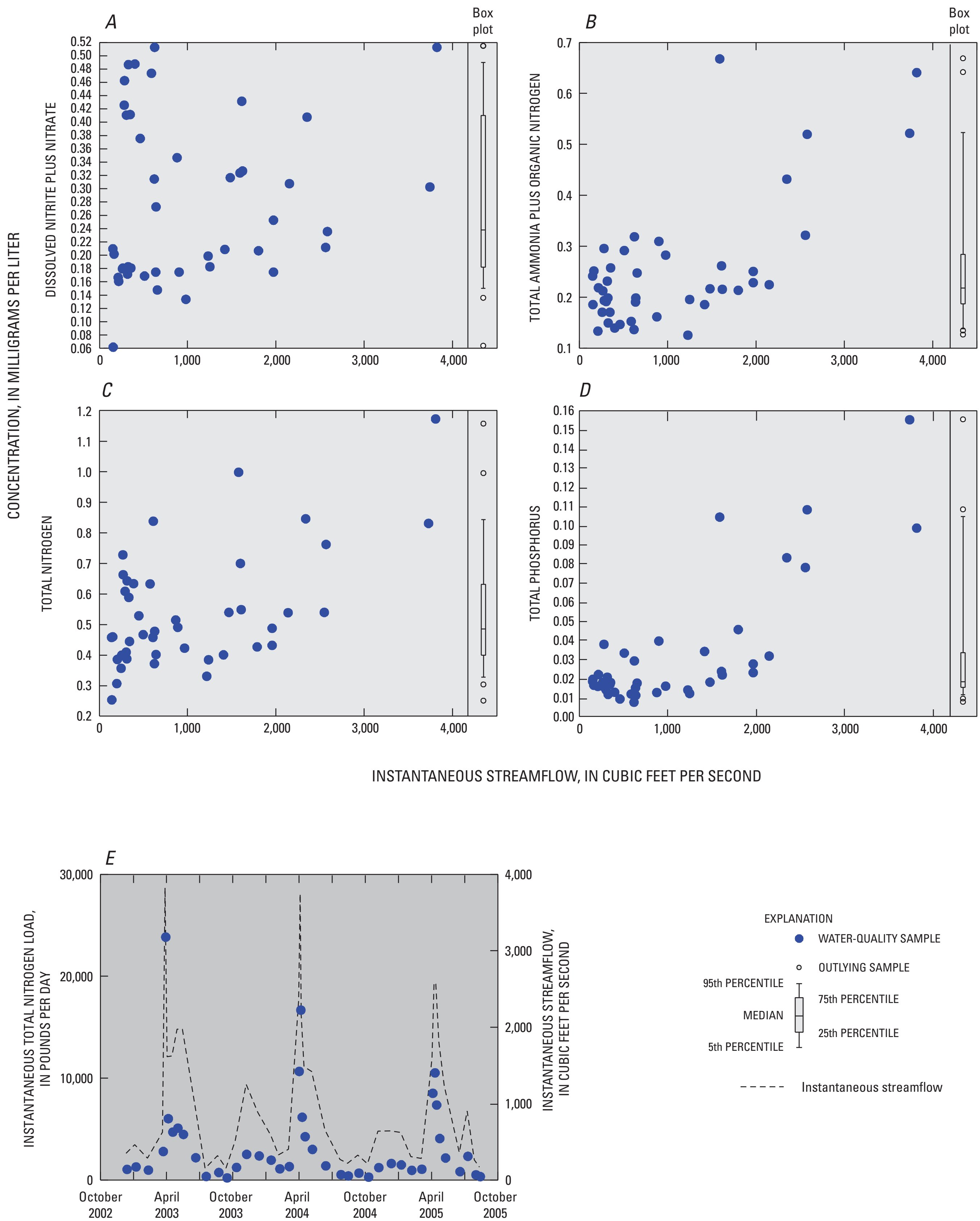


Figure 8. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and E, Instantaneous total nitrogen load relative to time for Passumpsic River at Passumpsic, VT, station 01135500. (Refer to table 1 and figure 1 for station location.)

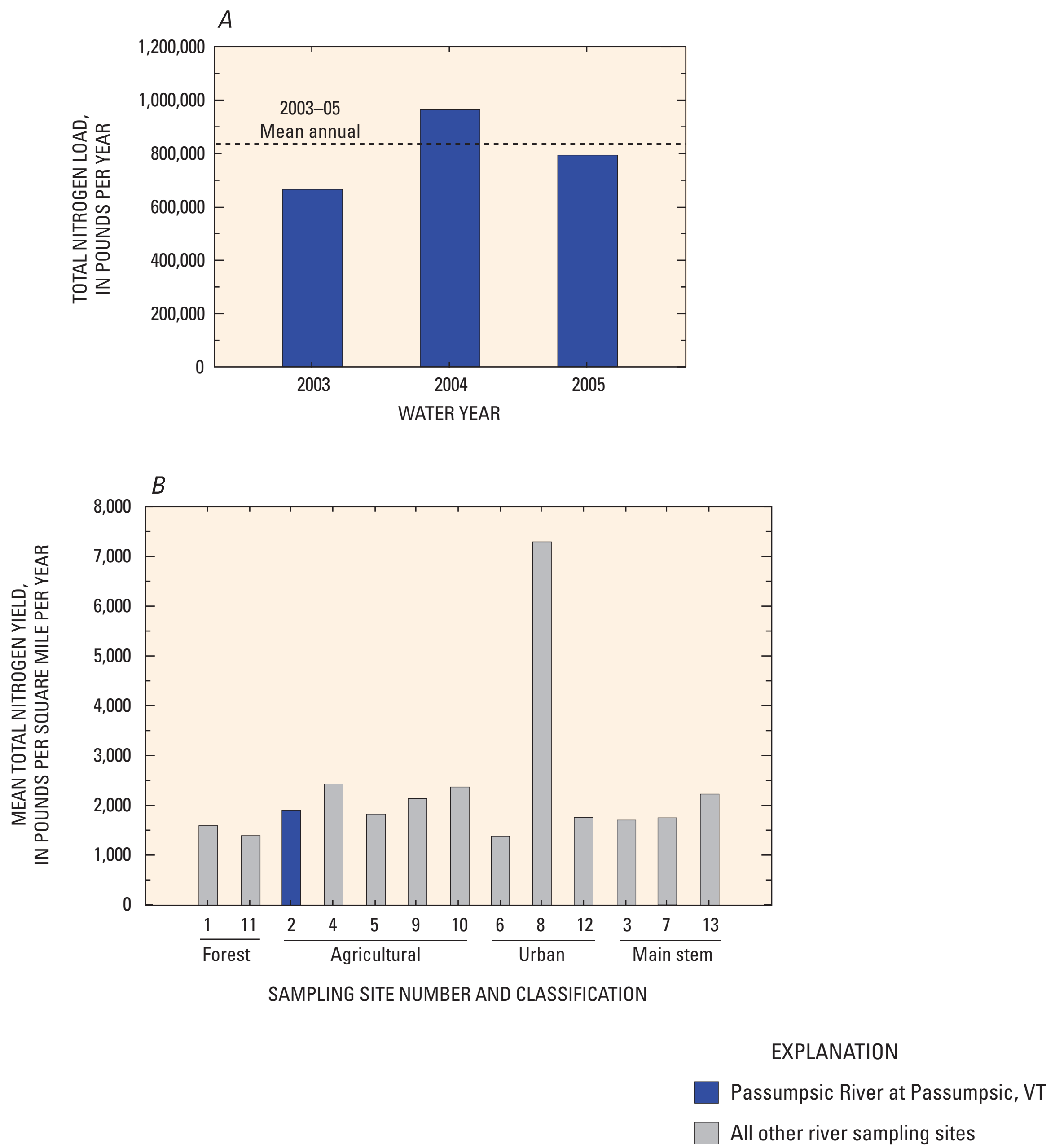


Figure 9. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Passumpsic River at Passumpsic, VT, station 01135500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Connecticut River at Wells River, VT, Station 01138500

Connecticut River at Wells River, VT, represents a main stem site in the study area and is located on the Connecticut River where there are potential effects on water quality from a mix of land uses. The contributing drainage basin upstream from this site encompasses 2,644 mi^2 and is about 84 percent forested, 6 percent agriculture, 2 percent urban, and 8 percent wetlands and barren (fig. 10). Annual streamflow for 1980–2002 averaged 3,750,000 acre-feet, with considerable year-to-year variation (fig. 11A). Annual streamflow for the data-collection period for water years 2003–05 averaged 3,560,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of the study, greater than the long-term mean for the second year, and slightly less than the long-term mean for the third year (fig. 11A).

Daily mean streamflow and the time distribution for 43 water-quality samples are shown in figure 11B. The minimum streamflow at which water samples were collected was 1,310 ft^3/s, and the maximum streamflow at which samples were collected was 22,600 ft^3/s.

The minimum concentration of dissolved oxygen at this site (7.6 mg/L) was above the State of Vermont water-quality criterion for dissolved oxygen (7.0 mg/L; Vermont Water Resources Board, 2000). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 12). Concentrations of dissolved nitrite plus nitrate ranged from 0.110 to 0.370 mg/L and showed scatter or a poorly defined relation to streamflow (fig. 12A). Total ammonia plus organic nitrogen ranged from 0.15 to 0.46 mg/L and generally showed an increase with an increase in streamflow (fig. 12B). However, a sample that was collected at a streamflow of about 4,500 ft^3/s during snowmelt had the second highest concentration of total ammonia plus organic nitrogen (0.40 mg/L; fig. 12B). Concentrations of total nitrogen ranged from 0.30 to 0.74 mg/L (fig. 12C). Concentrations of total phosphorus ranged from 0.007 to 0.112 mg/L and generally showed some scatter but also a slight increase with an increase in streamflow (fig. 12D). The sample that was collected at about 4,500 ft^3/s when streamflow was rising during snowmelt also had the second highest concentration of total phosphorus (0.110 mg/L; fig. 12D). Instantaneous loads of total nitrogen ranged from 2,300 to 71,900 lb/d (fig. 12E). Ranges of concentrations or values for water-quality constituents not shown in figure 12 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	58	87	87	119
pH	6.4	7.1	7.1	7.7
Water temperature	.0	8.3	5.5	23.2
Dissolved oxygen	7.6	11.3	11.6	15.2
Dissolved nitrite	<.004	—	<.004	.005
Dissolved ammonia	.007	.021	.017	.080
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.006
Suspended sediment	1	24	5	337

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 13A). The mean annual load of total nitrogen was 4,470,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 2.2 percent (table 2, fig. 13A). An estimated 45 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (1,690 (lb/mi^2)/yr) was similar to the yield of total nitrogen at Connecticut River at North Walpole, NH (site 7), but less than the yield of total nitrogen at the Connecticut River at Thompsonville, CT (site 13), the site representing the outlet to the upper basin (fig. 13B).

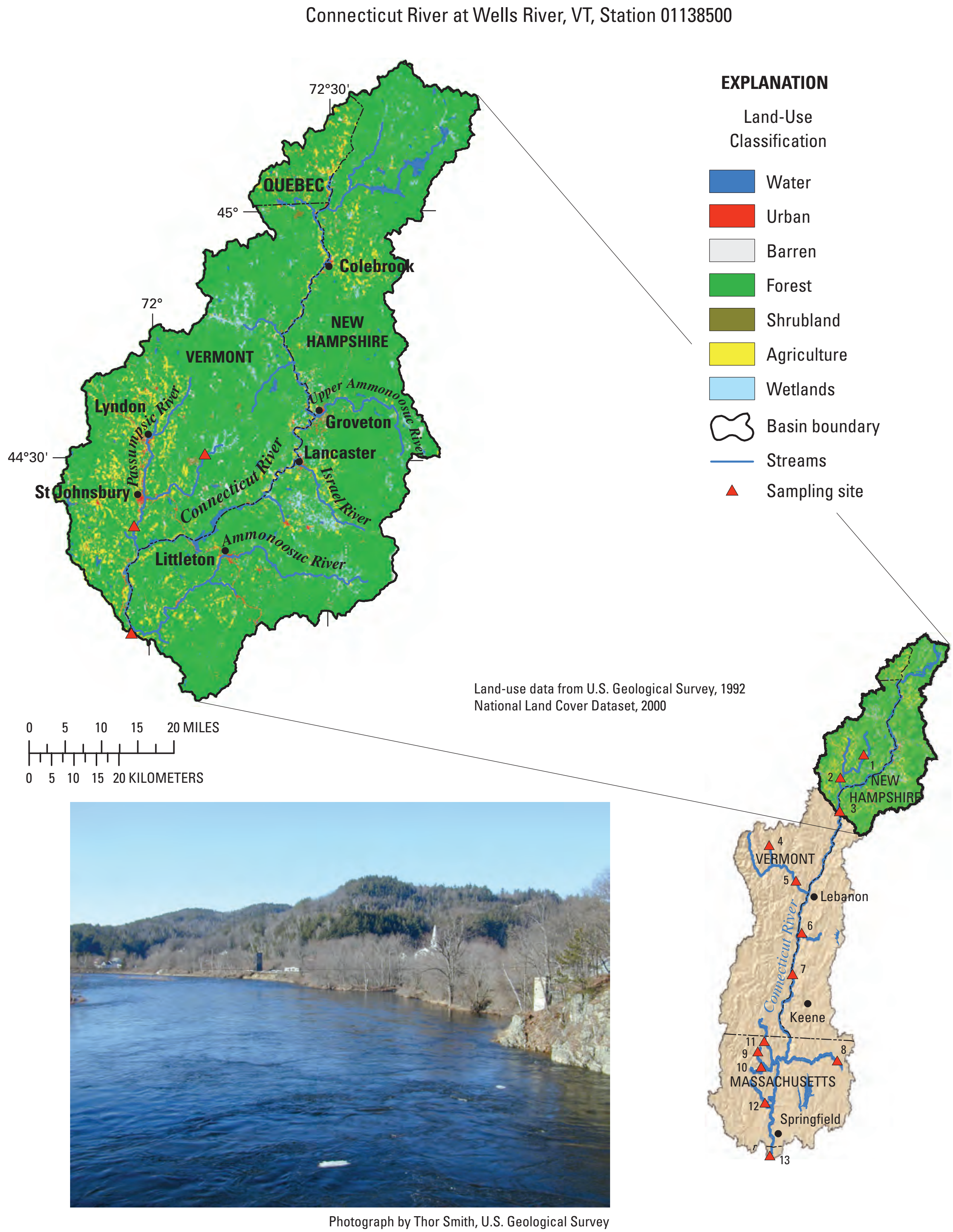


Figure 10. Location, land-use classification, and photograph of sampling site for Connecticut River at Wells River, VT, station 01138500. (Refer to table 1 and figure 1 for additional site information.)

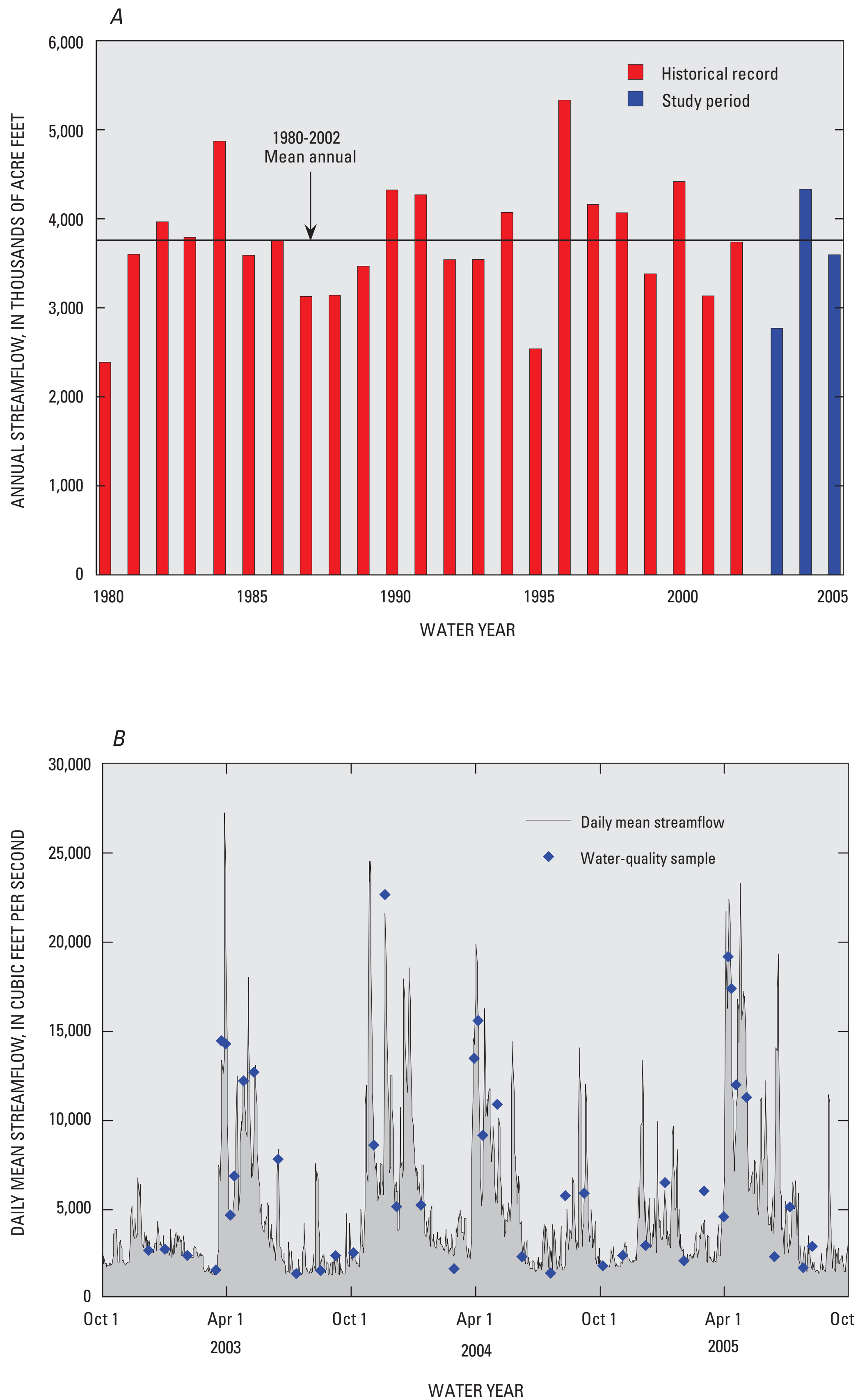


Figure 11. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Connecticut River at Wells River, VT, station 01138500.

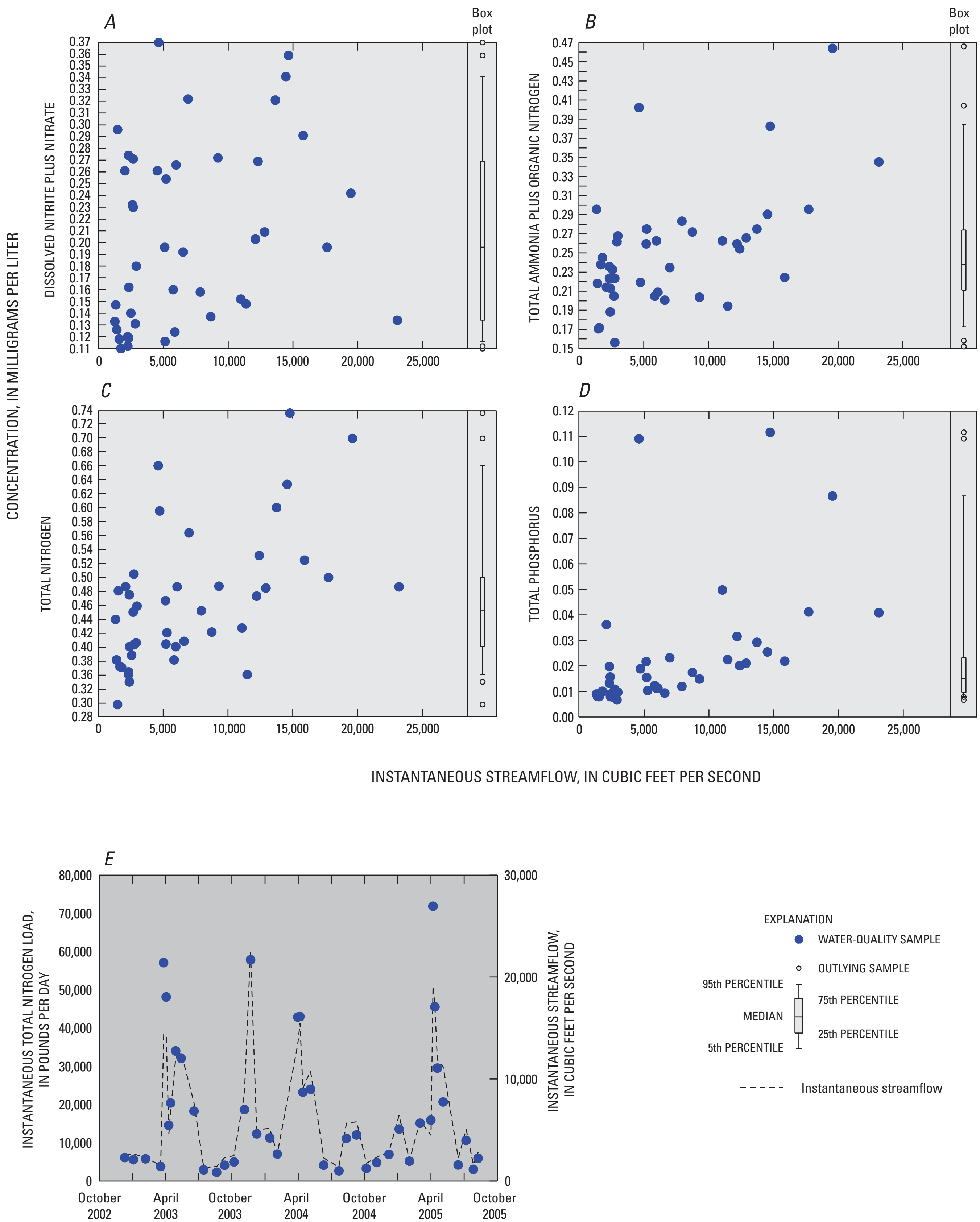


Figure 12. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Connecticut River at Wells River, VT, station 01138500. (Refer to table 1 and figure 1 for station location.)

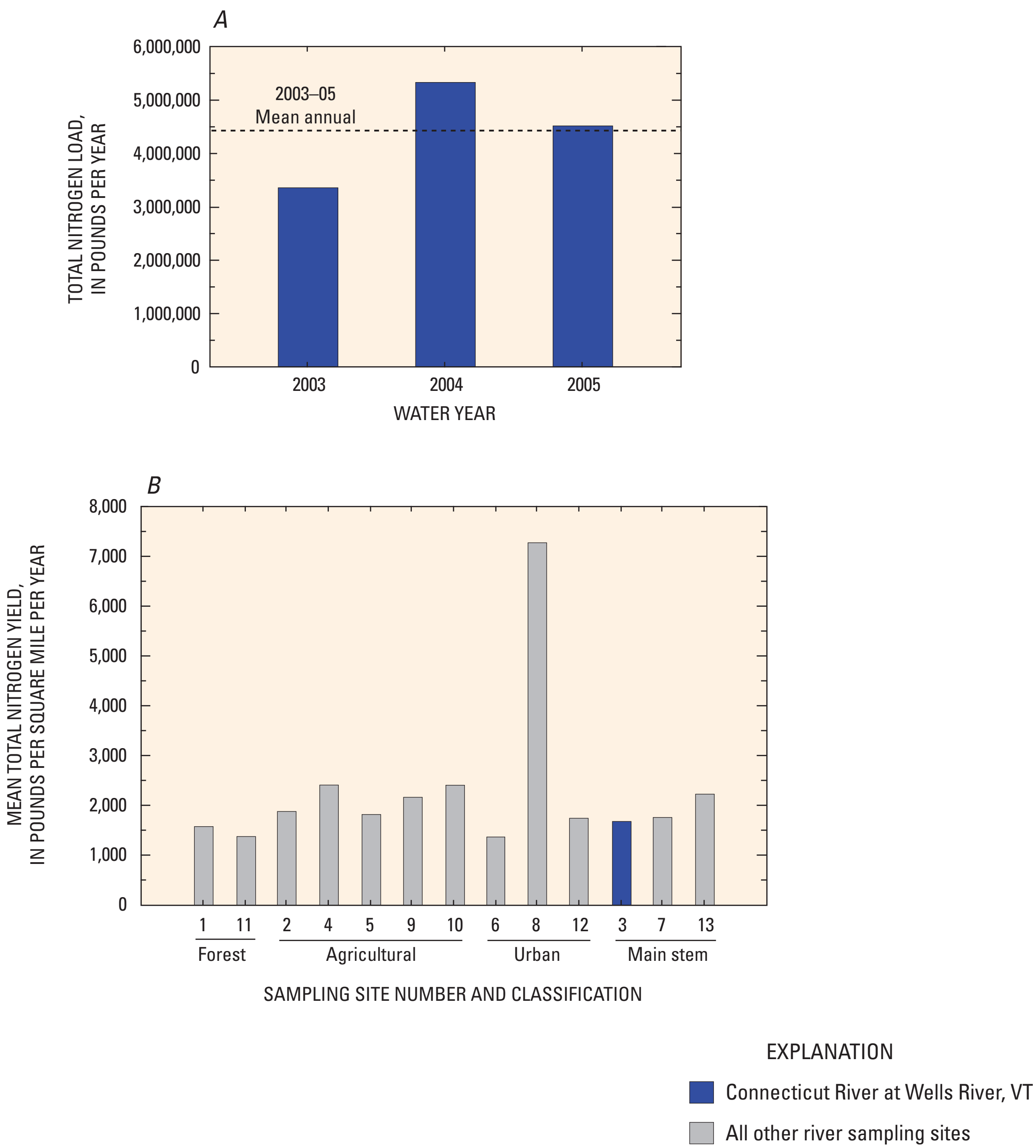


Figure 13. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Connecticut River at Wells River, VT, station 01138500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Ayers Brook at Randolph, VT, Station 01142500

Ayers Brook at Randolph, VT, represents an agricultural site in the study area. The contributing drainage basin upstream from the site encompasses 31 mi^2 and is about 73 percent forested, 21 percent agriculture, 1 percent urban, and 5 percent wetlands and barren (fig. 14). Annual streamflow for 1980–2002 averaged 37,300 acre-feet, with considerable year-to-year variation (fig. 15A). Annual streamflow for the data-collection period for water years 2003–05 averaged 38,200 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of the study, greater than the long-term mean for the second year, and slightly greater than the long-term mean for the third year (fig. 15A).

Daily mean streamflow and time distribution for 43 water-quality samples are shown in figure 15B. The minimum streamflow at which water samples were collected was 10 ft^3/s, and the maximum streamflow at which samples were collected was 310 ft^3/s.

The minimum concentration of dissolved oxygen at this site (8.2 mg/L) was above the State of Vermont water-quality criterion for dissolved oxygen (7.0 mg/L; Vermont Water Resources Board, 2000). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 16). Concentrations of dissolved nitrite plus nitrate ranged from 0.291 to 0.733 mg/L and showed scatter or a poorly defined relation to streamflow (fig. 16A). Total ammonia plus organic nitrogen ranged from an estimated 0.06 to 1.3 mg/L and showed a slight variation with an increase in streamflow (fig. 16B). Concentrations of total nitrogen ranged from 0.39 to 1.8 mg/L and also showed a slight variation with streamflow (fig. 16C). Concentrations of total phosphorus ranged from an estimated concentration of 0.003 to 0.708 mg/L and increased with an increase in streamflow, especially at streamflows greater than about 100 ft^3/s (fig. 16D). Instantaneous loads of total nitrogen ranged from 27 to 2,760 lb/d (fig. 16E). Ranges of concentrations or values for water-quality constituents not shown in figure 16 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	127	210	209	293
pH	6.3	7.5	7.6	8.2
Water temperature	.0	7.9	6.5	22
Dissolved oxygen	8.2	11.6	11.7	15.0
Dissolved nitrite	<.004	—	<.004	.006
Dissolved ammonia	.005	.016	.011	.111
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.004
Suspended sediment	1	73	5	776

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 17A). The mean annual load of total nitrogen was 74,900 lb/yr, with a ratio of the standard error of prediction to the mean load of 3.5 percent (table 2, fig. 17A). An estimated 51 percent of the load of total nitrogen was transported during the spring (appendix A-2). The mean yield of total nitrogen (2,450 $(lb/mi^2)/yr$) was greater than the yield of total nitrogen at all other sites, with the exception of one urban site that was directly affected by wastewater (site 8; fig. 17B).

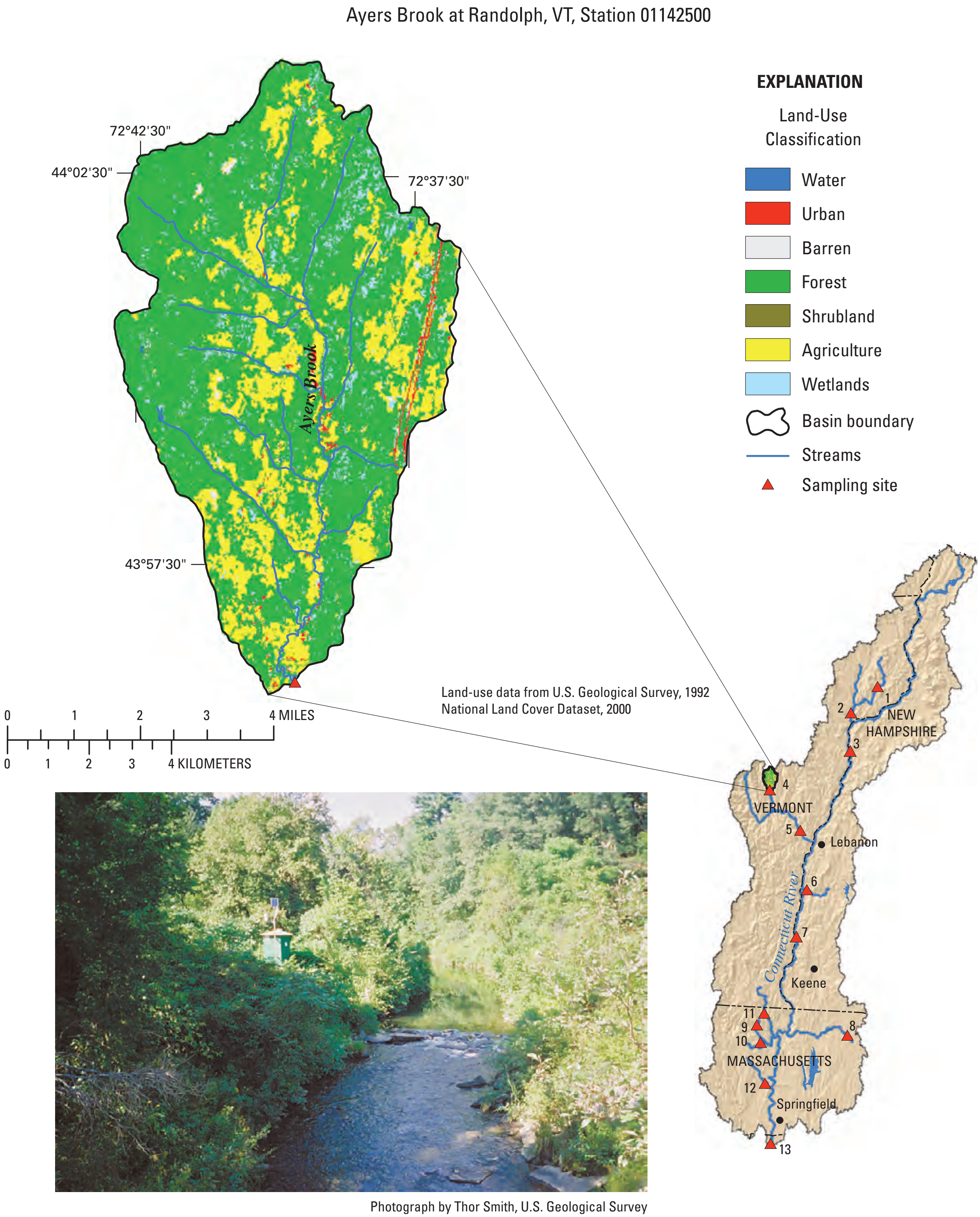
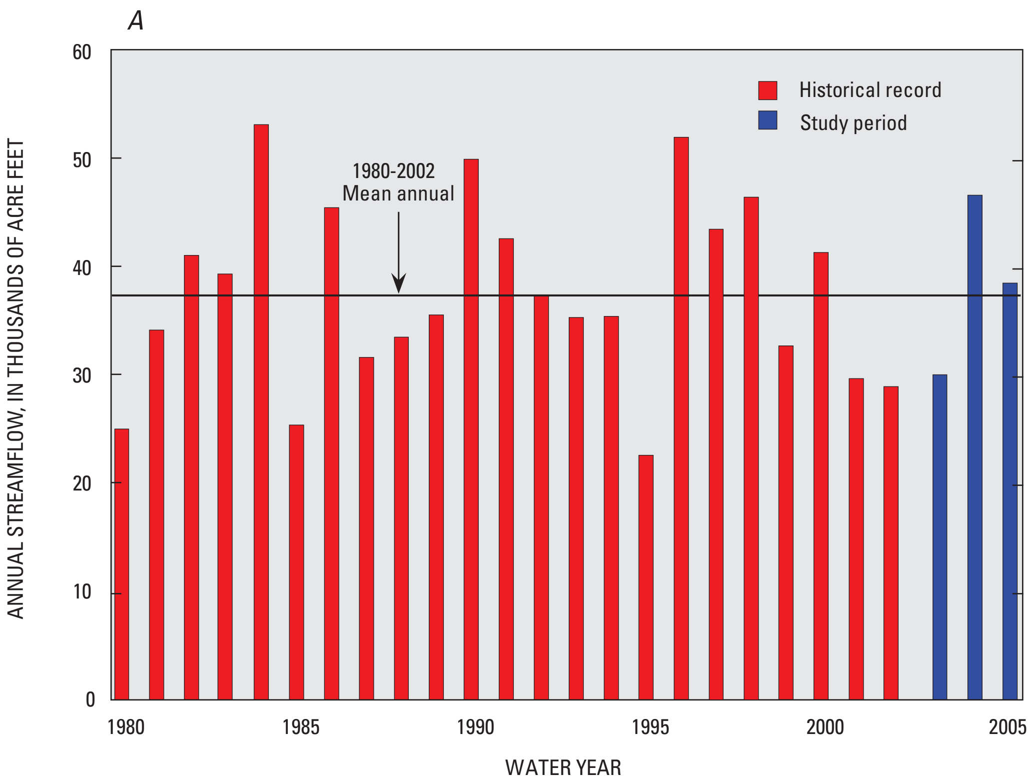


Figure 14. Location, land-use classification, and photograph of sampling site for Ayers Brook at Randolph, VT, station 01142500. (Refer to table 1 and figure 1 for additional site information.)



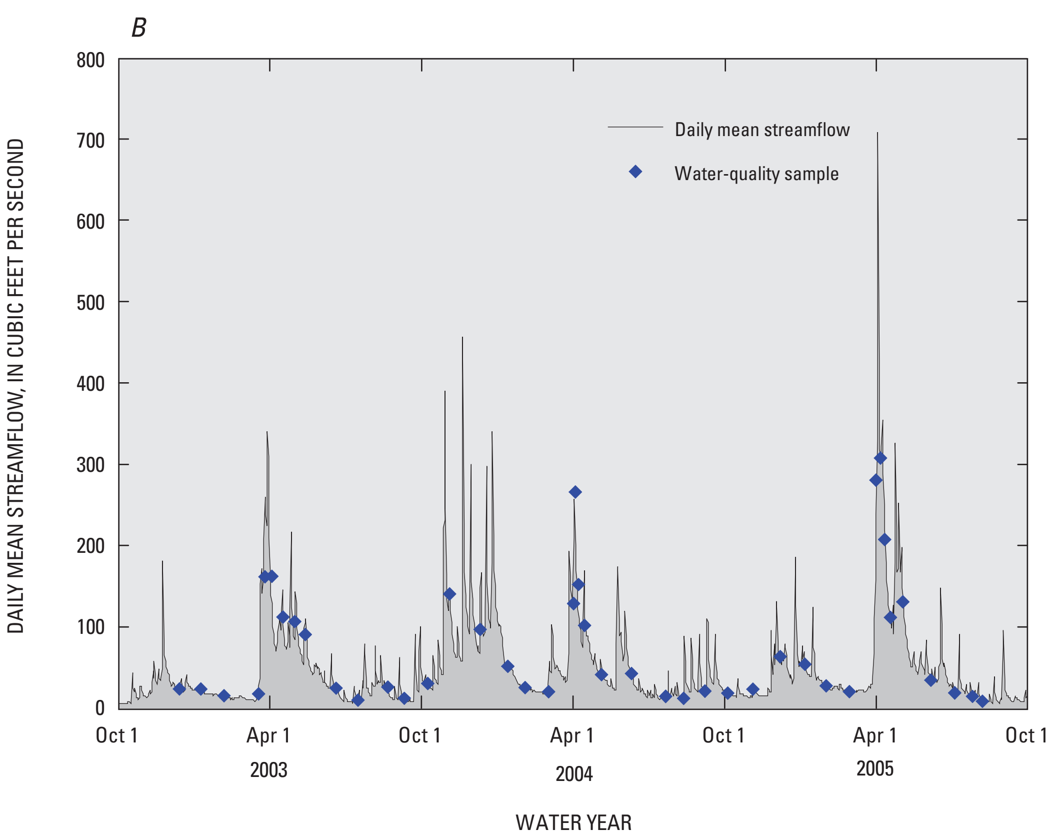


Figure 15. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Ayers Brook at Randolph, VT, station 01142500.

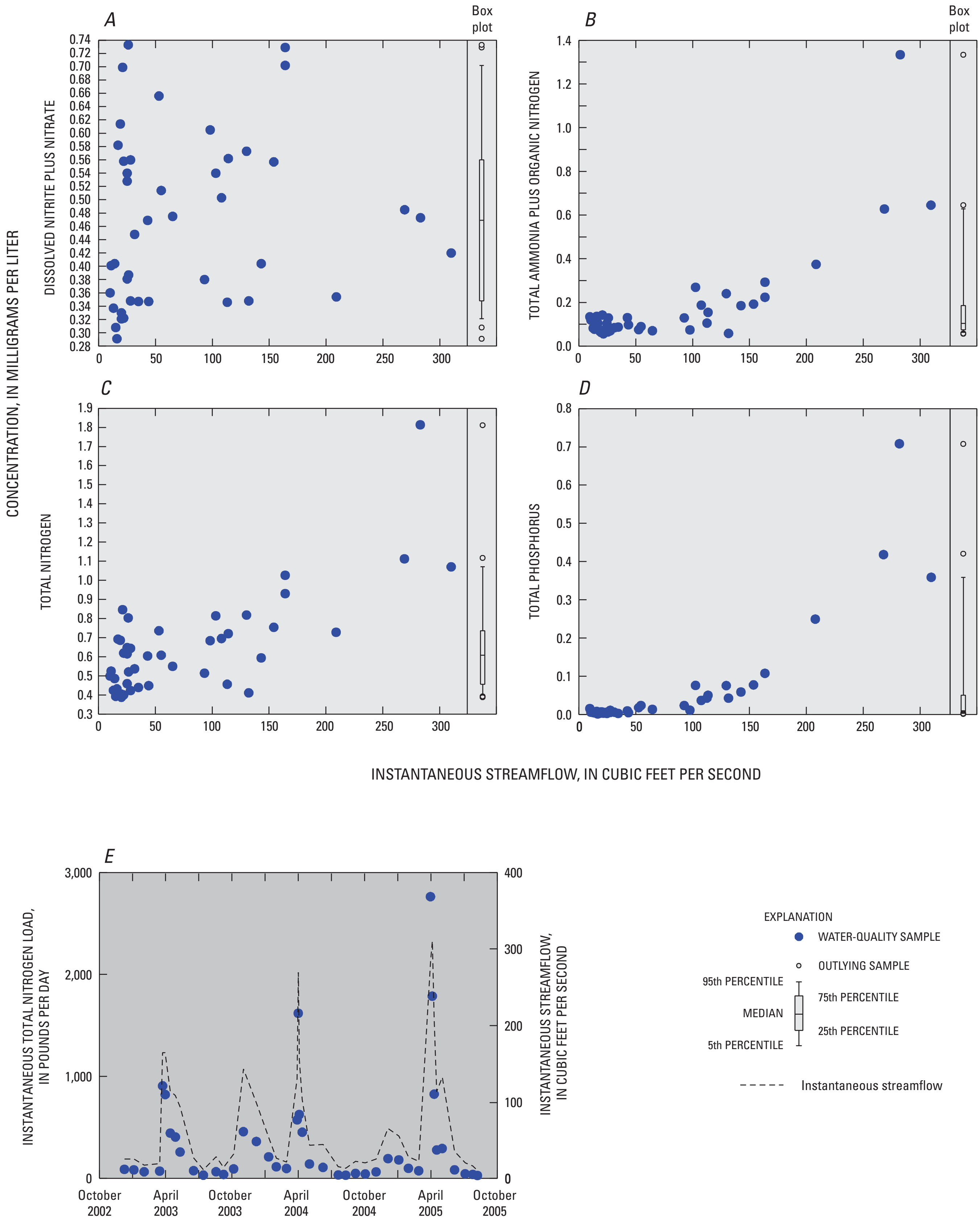


Figure 16. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Ayers Brook at Randolph, VT, station 01142500. (Refer to table 1 and figure 1 for station location.)

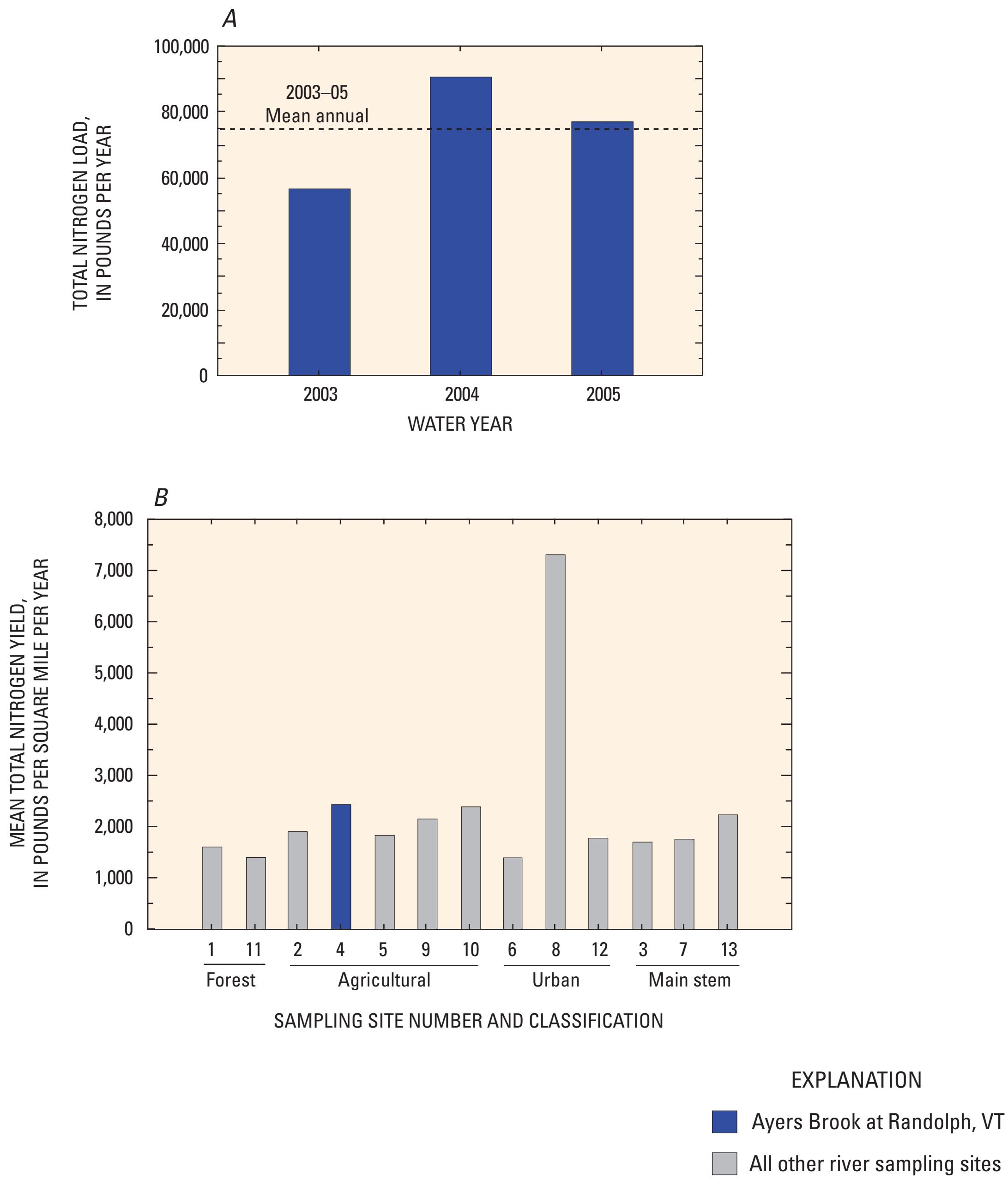


Figure 17. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Ayers Brook at Randolph, VT, station 01142500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

White River at West Hartford, VT, Station 01144000

White River at West Hartford, VT, represents an agricultural site in the study area. The contributing drainage basin upstream from this site encompasses 690 mi^2 and is about 84 percent forested, 13 percent agriculture, 1 percent urban, and 2 percent wetlands and barren (fig. 18). Annual streamflow for 1980–2002 averaged 885,000 acre-feet, with considerable year-to-year variation (fig. 19A). Annual streamflow for the data-collection period for water years 2003–05 averaged 959,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of this study, greater than the long-term mean for the second year, and about equal to the long-term mean for the third year (fig. 19A).

Daily mean streamflows and time distribution for 45 water-quality samples are shown in figure 19B. The minimum streamflow at which water samples were collected was 216 ft^3/s, and the maximum streamflow at which samples were collected was 11,600 ft^3/s.

The minimum concentration of dissolved oxygen at this site (8.0 mg/L) was above the State of Vermont water-quality criterion for dissolved oxygen (7.0 mg/L; Vermont Water Resources Board, 2000). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 20). Concentrations of dissolved nitrite plus nitrate ranged from 0.138 to 0.535 mg/L and showed scatter or a poorly defined relation to streamflow (fig. 20A). Total ammonia plus organic nitrogen ranged from an estimated 0.06 to 0.81 mg/L and generally increased as streamflow increased (fig. 20B). Concentrations of total nitrogen ranged from 0.24 to 1.1 mg/L and increased as streamflow increased (fig. 20C). Concentrations of total phosphorus ranged from an estimated 0.002 to 0.604 mg/L and also increased with an increase in streamflow, especially at streamflows greater than about 2,000 ft^3/s (fig. 20D). Instantaneous loads of total nitrogen ranged from 351 to 52,700 lb/d (fig. 20E). Ranges of concentrations or values for water-quality constituents not shown in figure 20 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	59	150	150	217
pH	6.5	7.6	7.6	8.3
Water temperature	.0	8.6	6.5	27
Dissolved oxygen	8.0	11.4	11.8	14.4
Dissolved nitrite	<.004	—	<.004	.007
Dissolved ammonia	.005	.014	.010	.077
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.008
Suspended sediment	1	72	2	752

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 21A). The mean annual load of total nitrogen was 1,260,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 2.7 percent (table 2, fig. 21A). An estimated 55 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (1,830 $(lb/mi^2)/yr$) was similar to the yield of total nitrogen at most other sites in this study (fig. 21B).

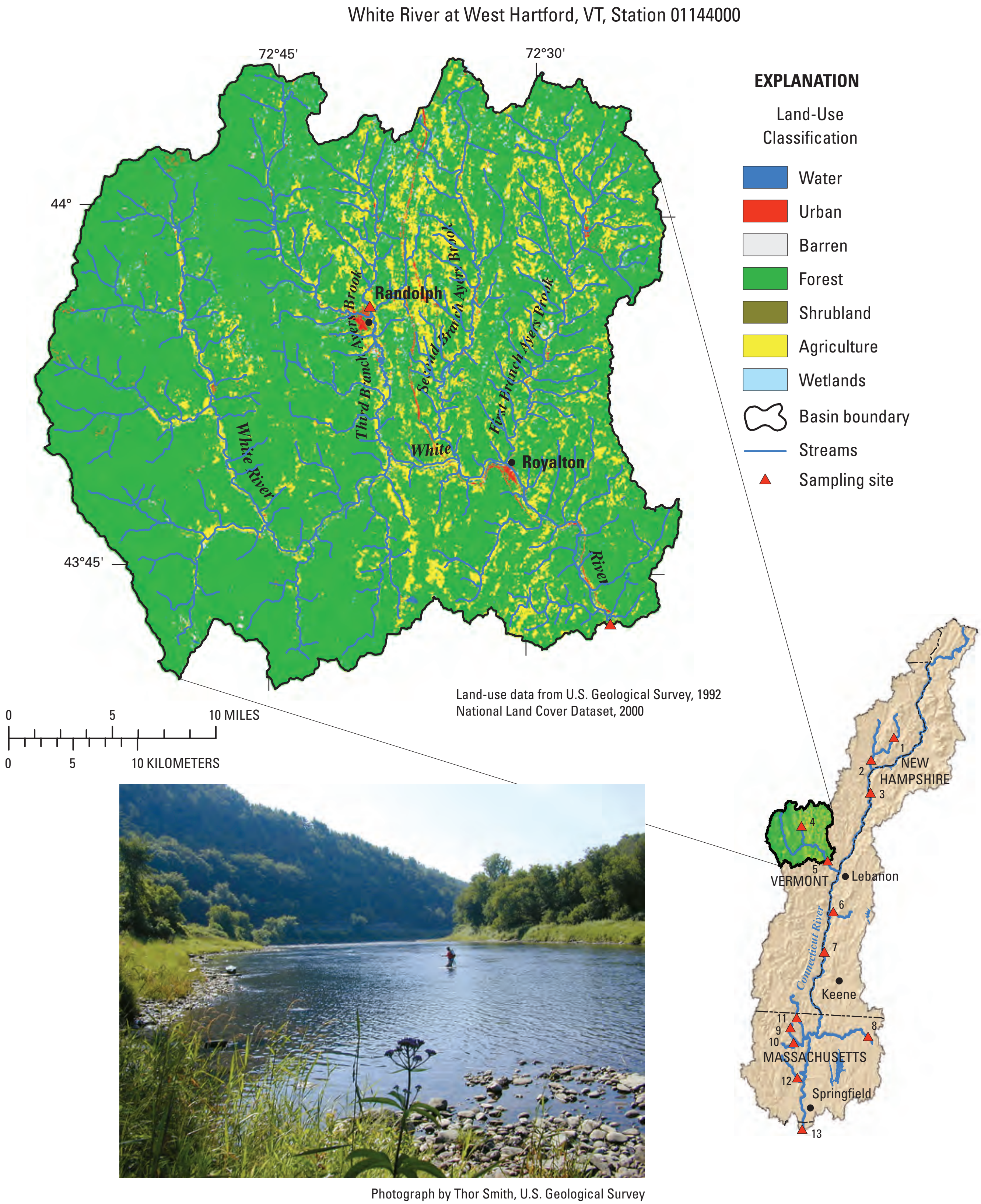
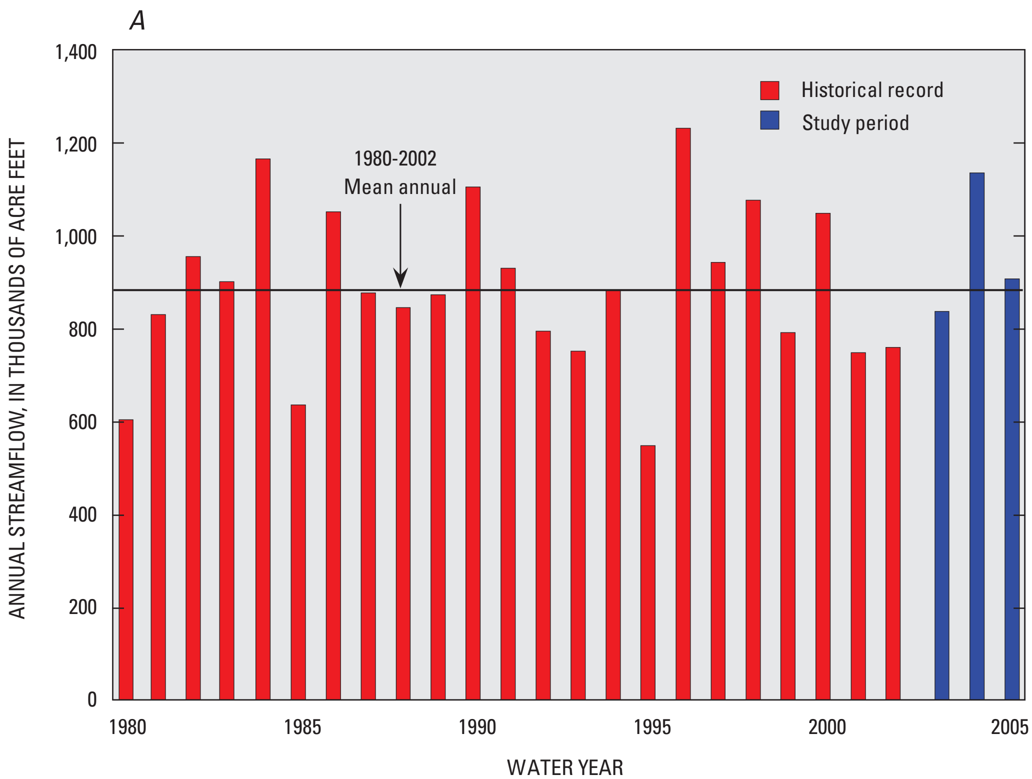


Figure 18. Location, land-use classification, and photograph of sampling site for White River at West Hartford, VT, station 01144000. (Refer to table 1 and figure 1 for additional site information.)



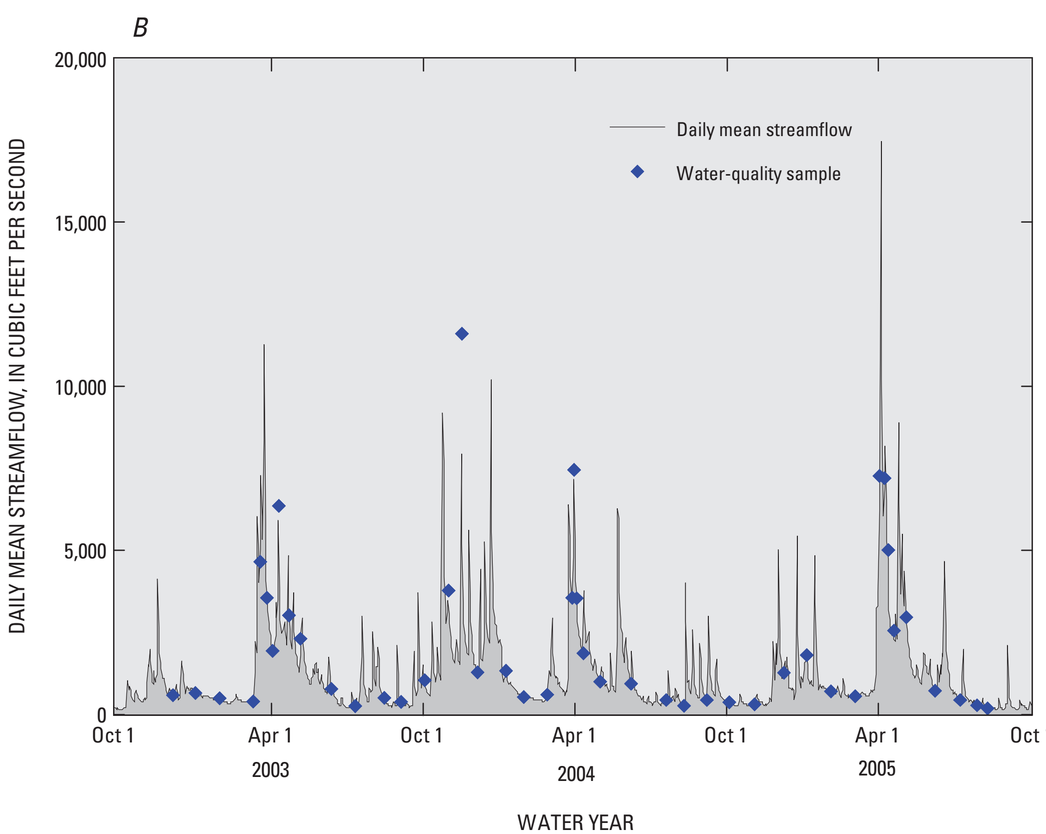


Figure 19. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for White River at West Hartford, VT, station 01144000.

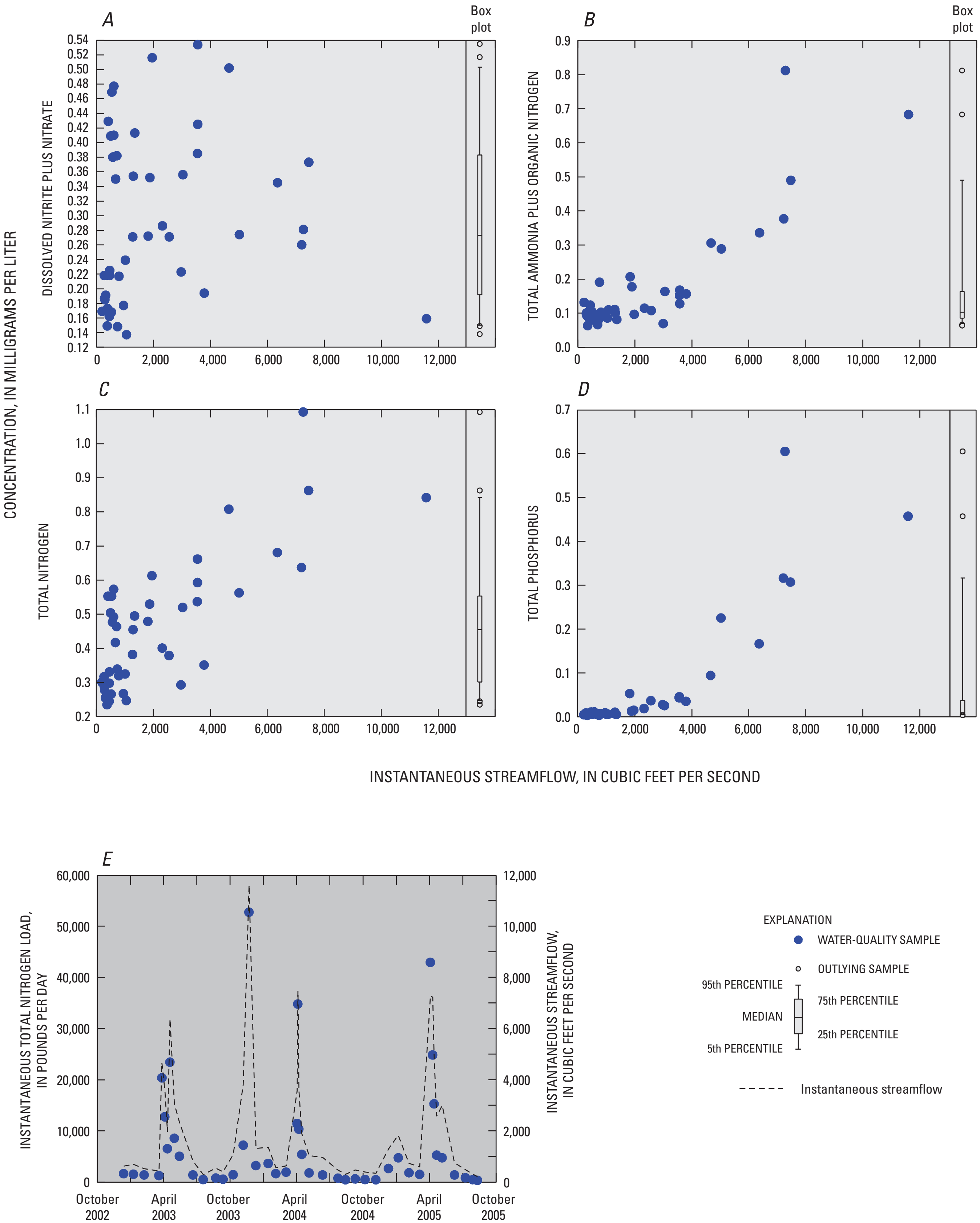


Figure 20. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for White River at West Hartford, VT, station 01144000. (Refer to table 1 and figure 1 for station location.)

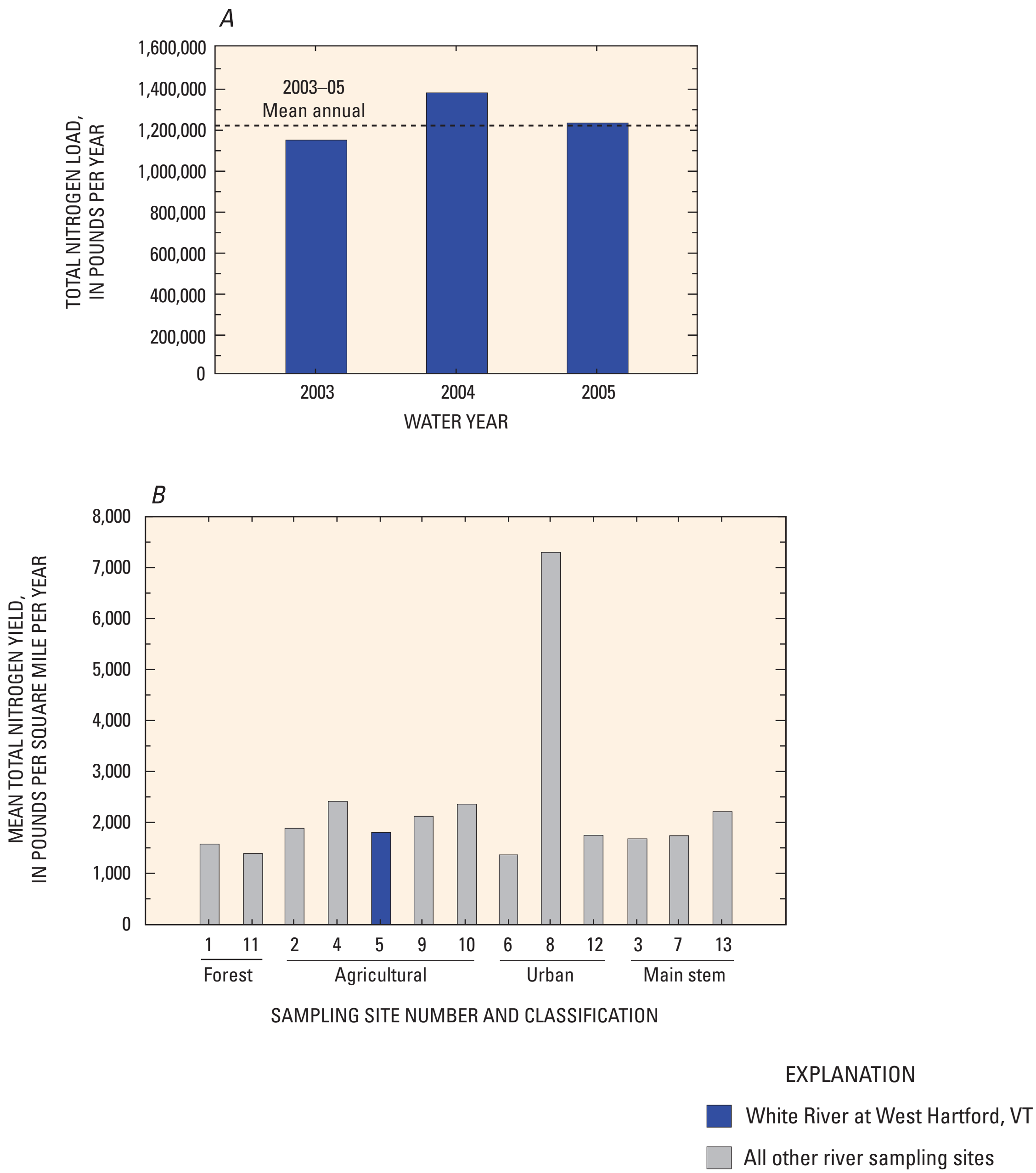


Figure 21. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for White River at West Hartford, VT, station 01144000, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Sugar River at West Claremont, NH, Station 01152500

Sugar River at West Claremont, NH, represents an urban site in the study area. A urban site represents potential effects on water quality from urban land use. The contributing drainage basin upstream from the site encompasses 269 mi^2 and is about 78 percent forested, 9 percent agriculture, 6 percent urban, and 7 percent wetlands and barren (fig. 22). Although the second predominant percentage of land use in the upstream drainage basin is agriculture, this site was selected to represent urban land use because the site is downstream from and near an urban area (fig. 22). The annual streamflow for 1980–2002 averaged 304,000 acre-feet, with considerable year-to-year variation (fig. 23A). The annual streamflow for the data-collection period for water years 2003–05 averaged 341,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of this study and greater than the long-term mean for the second and third years (fig. 23A).

Daily mean streamflow and time distribution for 43 water-quality samples are shown in figure 23B. The minimum streamflow at which water samples were collected was 73 ft^3/s, and the maximum streamflow at which samples were collected was 4,380 ft^3/s.

The minimum concentration of dissolved oxygen was 7.4 mg/L and was within the water-quality criterion for dissolved oxygen (New Hampshire Department of Environmental Services, 2004). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 24). Concentrations of dissolved nitrite plus nitrate ranged from 0.059 to 0.440 mg/L and showed some scatter but also a slight dilution effect relative to streamflow (fig. 24A). Total ammonia plus organic nitrogen ranged from an estimated 0.16 to 0.82 mg/L and generally showed no relation to streamflow; however, the maximum concentration of total ammonia plus organic nitrogen was observed at the maximum streamflow at which samples were collected (fig. 24B). Concentrations of total nitrogen ranged from 0.24 to 0.95 mg/L (fig. 24C). Concentrations of total phosphorus ranged from 0.011 to 0.275 mg/L (fig. 24D). Maximum concentrations of total nitrogen and total phosphorus also were observed at the maximum streamflow at which samples were collected. Instantaneous loads of total nitrogen ranged from 187 to 22,400 lb/d (fig. 24E). Ranges of concentrations or values for water-quality constituents not shown in figure 24 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	49	120	121	191
pH	6.1	7.0	6.8	8.7
Water temperature	.0	9.5	7.5	26
Dissolved oxygen	7.4	11.8	11.8	14.4
Dissolved nitrite	<.004	—	<.004	.005
Dissolved ammonia	.005	.038	.021	.156
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.005
Suspended sediment	1	14	2	267

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 25A). The mean annual load of total nitrogen was 372,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 3.9 percent (table 2, fig. 25A). An estimated 49 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (1,380 $(lb/mi^2)/yr$) was less than the mean yield of total nitrogen from most other sites in the study (fig. 25B).

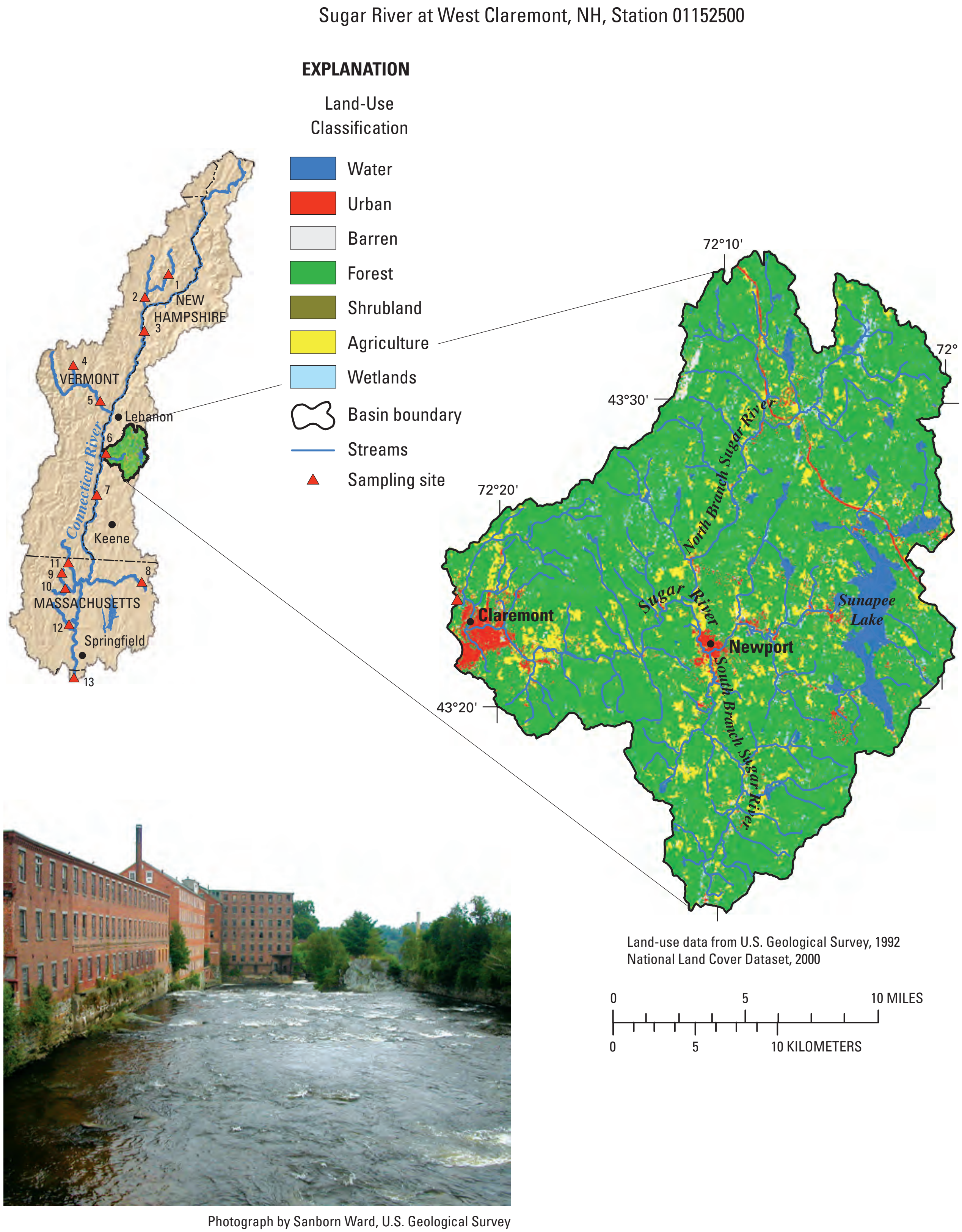


Figure 22. Location, land-use classification, and photograph of urban area upstream of sampling site for Sugar River at West Claremont, NH, station 01152500. (Refer to table 1 and figure 1 for additional site information.)

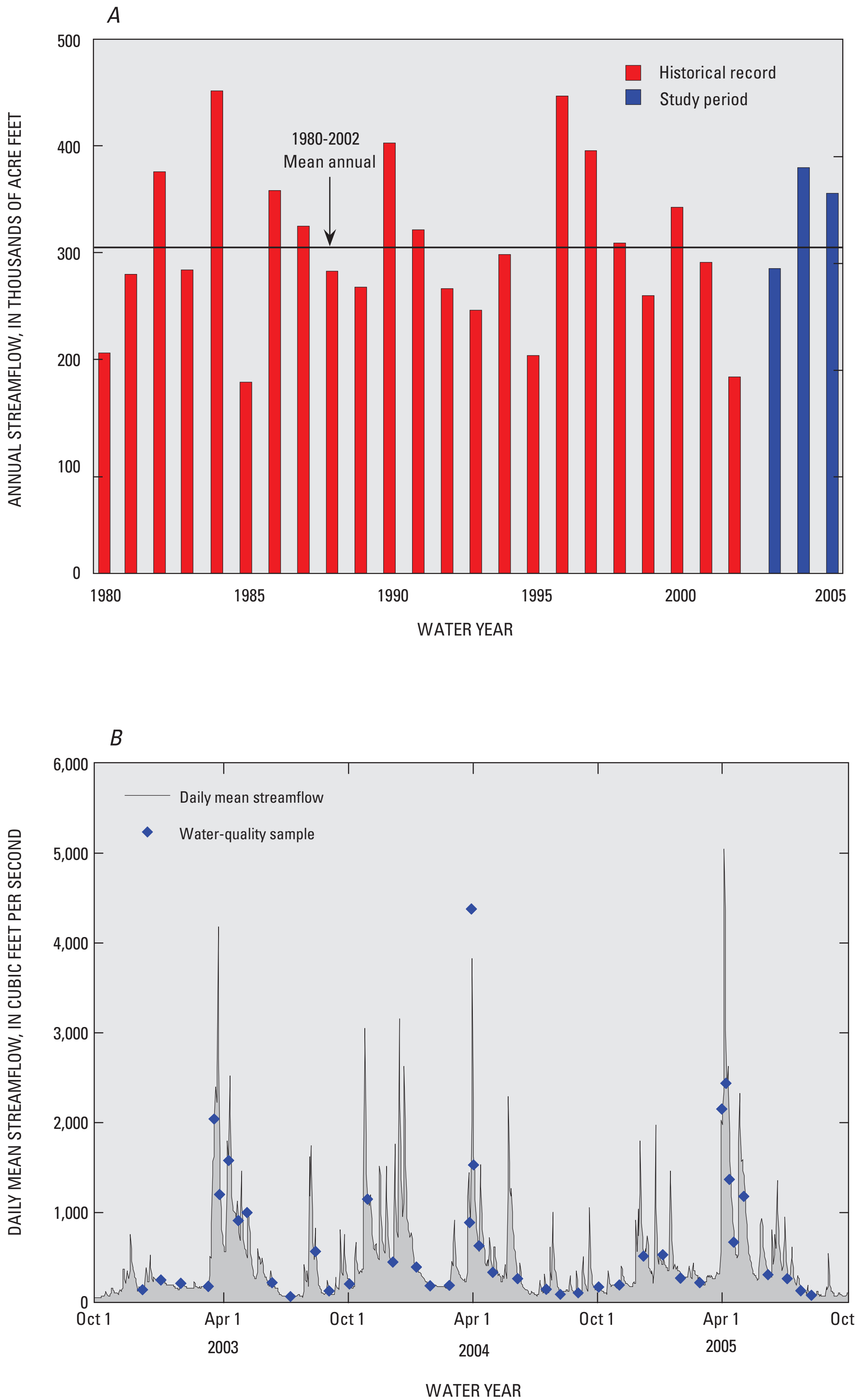


Figure 23. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Sugar River at West Claremont, NH, station 01152500.

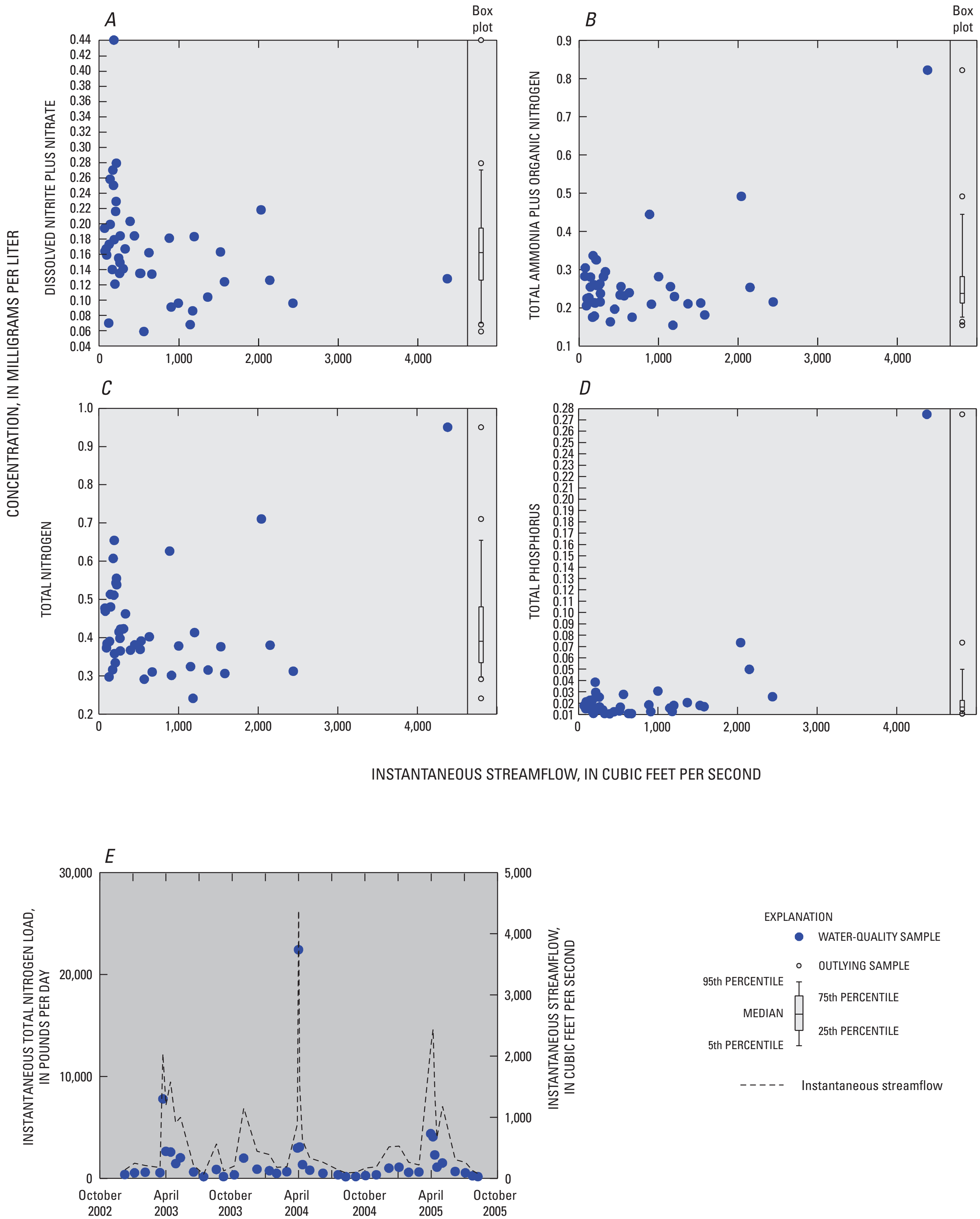


Figure 24. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Sugar River at West Claremont, NH, station 01152500. (Refer to table 1 and figure 1 for station location.)

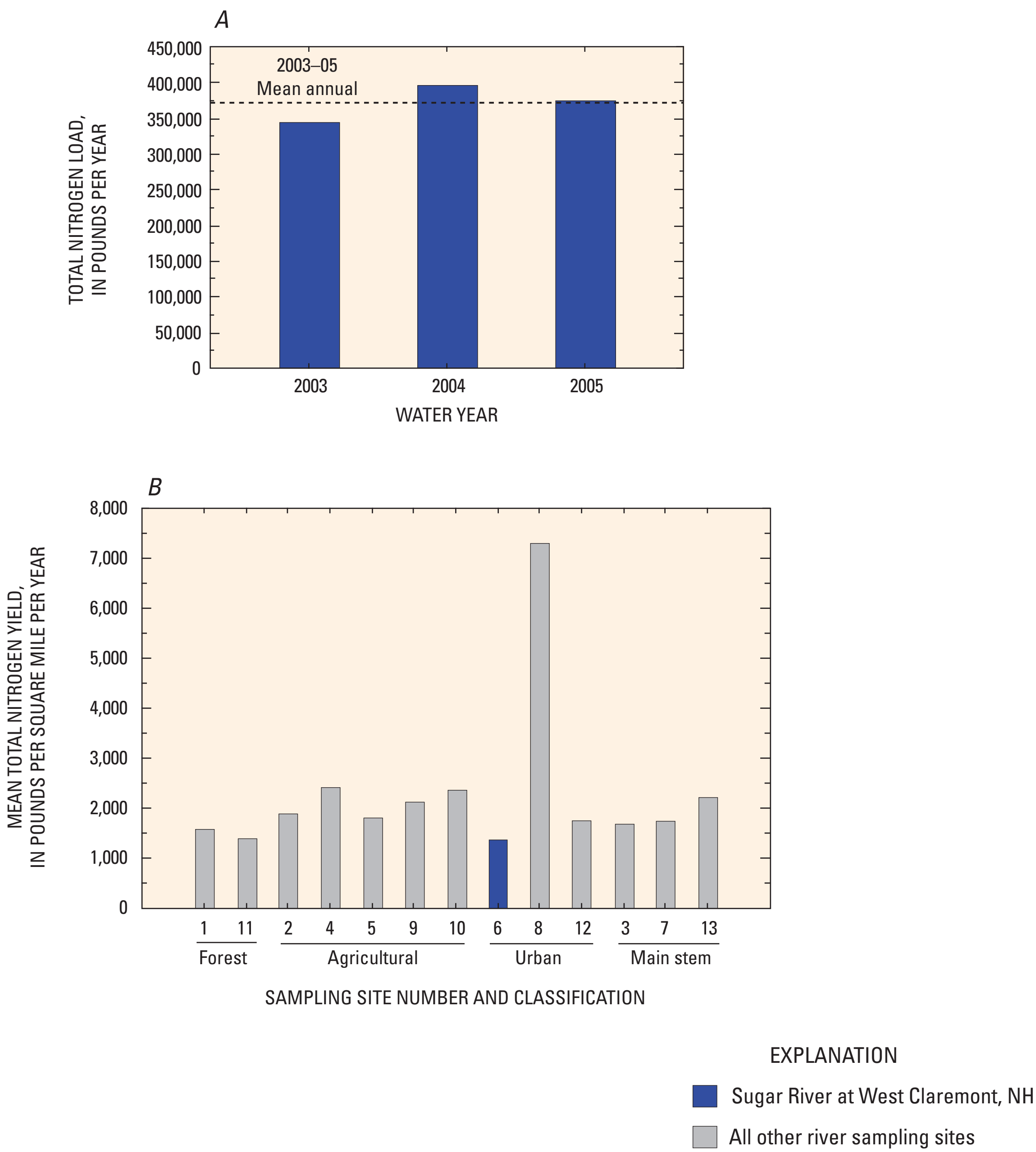


Figure 25. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Sugar River at West Claremont, NH, station 01152500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Connecticut River at North Walpole, NH, Station 01154500

Connecticut River at North Walpole, NH, represents a main-stem site for the study area. The contributing drainage basin upstream from the site encompasses 5,493 mi^2 and is about 83 percent forested, 9 percent agriculture, 2 percent urban, and 6 percent wetlands and barren (fig. 26). Annual streamflow for 1980–2002 averaged 7,160,000 acre-feet, with considerable year-to-year variation (fig. 27A). Annual streamflow for the data-collection period for water years 2003–05 averaged 7,070,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year of the study, greater than the long-term mean for the second year, and about equal to the long-term mean for the third year (fig. 27A).

Daily mean streamflow and time distribution for 44 water-quality samples are shown in figure 27B. The minimum streamflow at which water samples were collected was 1,290 ft^3/s, and the maximum streamflow at which samples were collected was 46,700 ft^3/s.

The minimum concentration of dissolved oxygen was 6.9 mg/L and was within the water-quality criterion for dissolved oxygen (New Hampshire Department of Environmental Services, 2004). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 28). Concentrations of dissolved nitrite plus nitrate ranged from 0.136 to 0.406 mg/L and showed a poorly defined relation to streamflow (fig. 28A). Total ammonia plus organic nitrogen ranged from an estimated concentration of 0.15 to 0.46 mg/L and showed a slight increase with an increase in streamflow (fig. 28B). Concentrations of total nitrogen ranged from 0.28 to 0.83 mg/L (fig. 28C) and also showed a slight variation with streamflow. Concentrations of total phosphorus ranged from 0.005 to 0.155 mg/L and increased with an increase in streamflow (fig. 28D). Instantaneous loads of total nitrogen ranged from 2,460 to 186,000 lb/d (fig. 28E). Ranges of concentrations or values for water-quality constituents not shown in figure 28 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	64	117	114	172
pH	6.2	7.3	7.3	7.8
Water temperature	.0	9.5	7.2	27
Dissolved oxygen	6.9	11.2	11.9	14.8
Dissolved nitrite	<.004	—	<.004	.006
Dissolved ammonia	.005	.021	.017	.055
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	.003
Suspended sediment	1	13	2	169

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 29A). The mean annual load of total nitrogen was 9,600,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 4.1 percent (table 2, fig. 29A). An estimated 47 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (1,750 $(lb/mi^2)/yr$) was similar to the yield of total nitrogen at the Connecticut River at Wells River, VT (site 3), but less than the yield of total nitrogen at the Connecticut River at Thompsonville, CT (site 13), the site representing the outlet to the upper basin (fig. 29B).

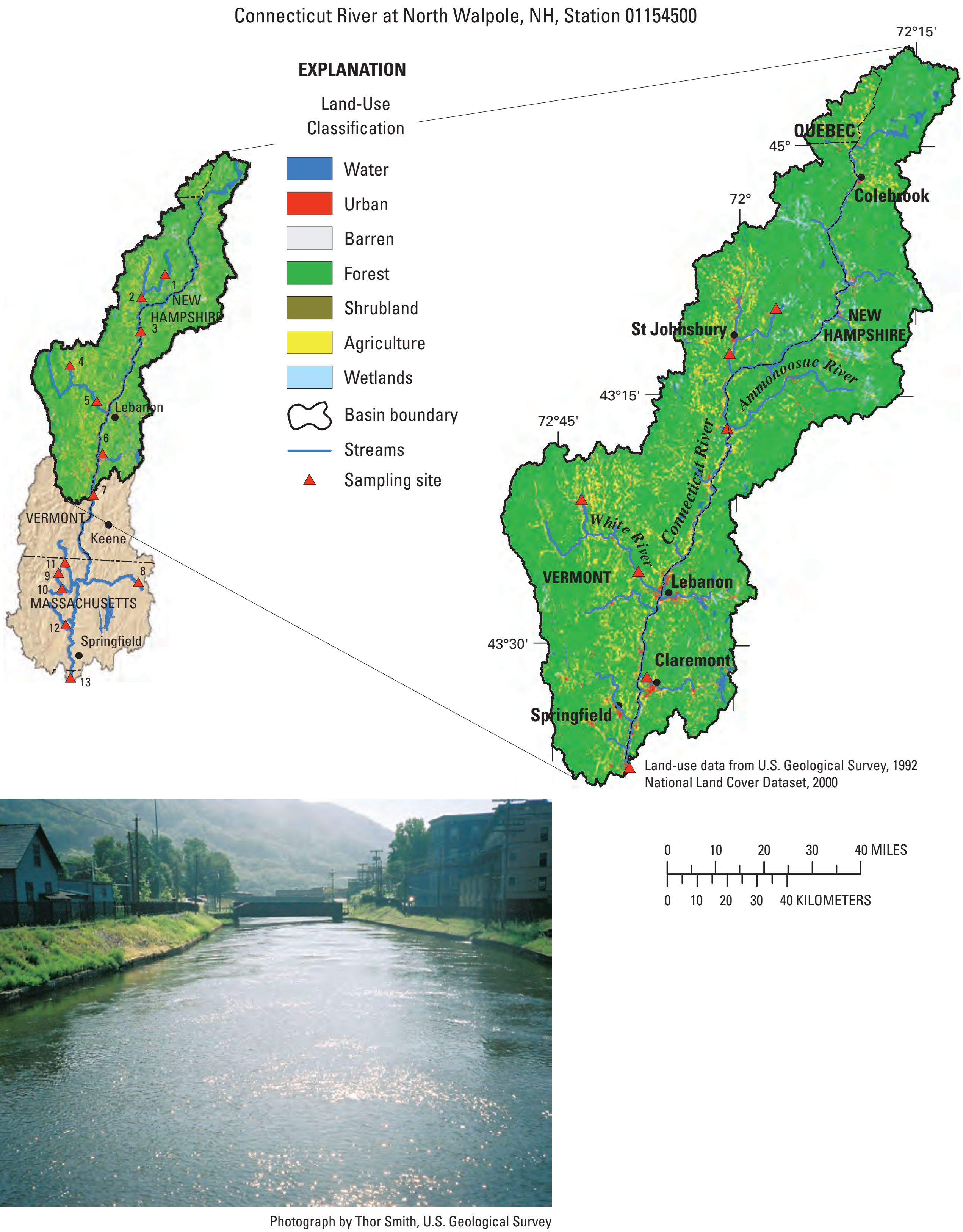


Figure 26. Location, land-use classification, and photograph of sampling site for Connecticut River at North Walpole, NH, station 01154500. (Refer to table 1 and figure 1 for additional site information.)

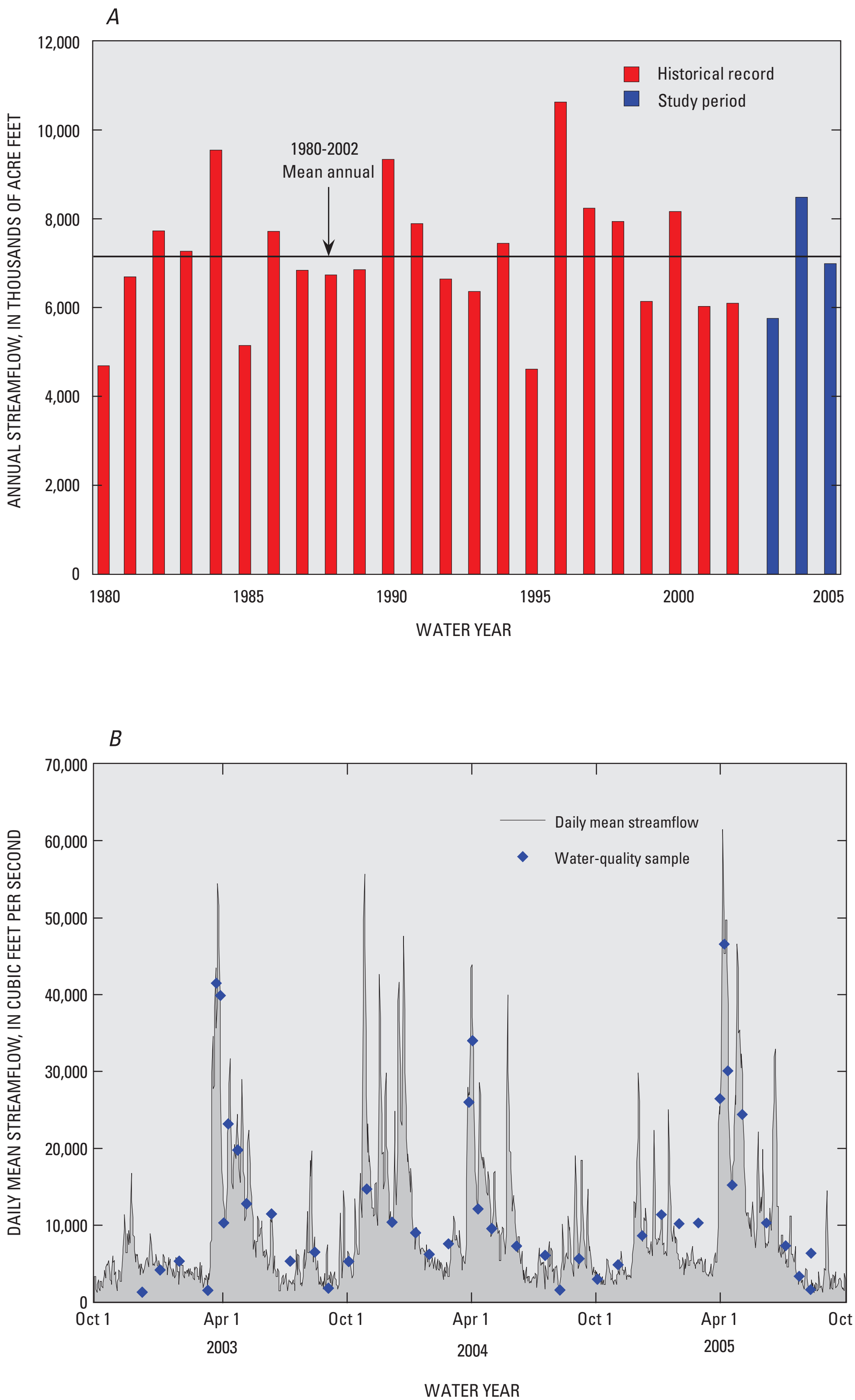


Figure 27. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Connecticut River at North Walpole, NH, station 01154500.

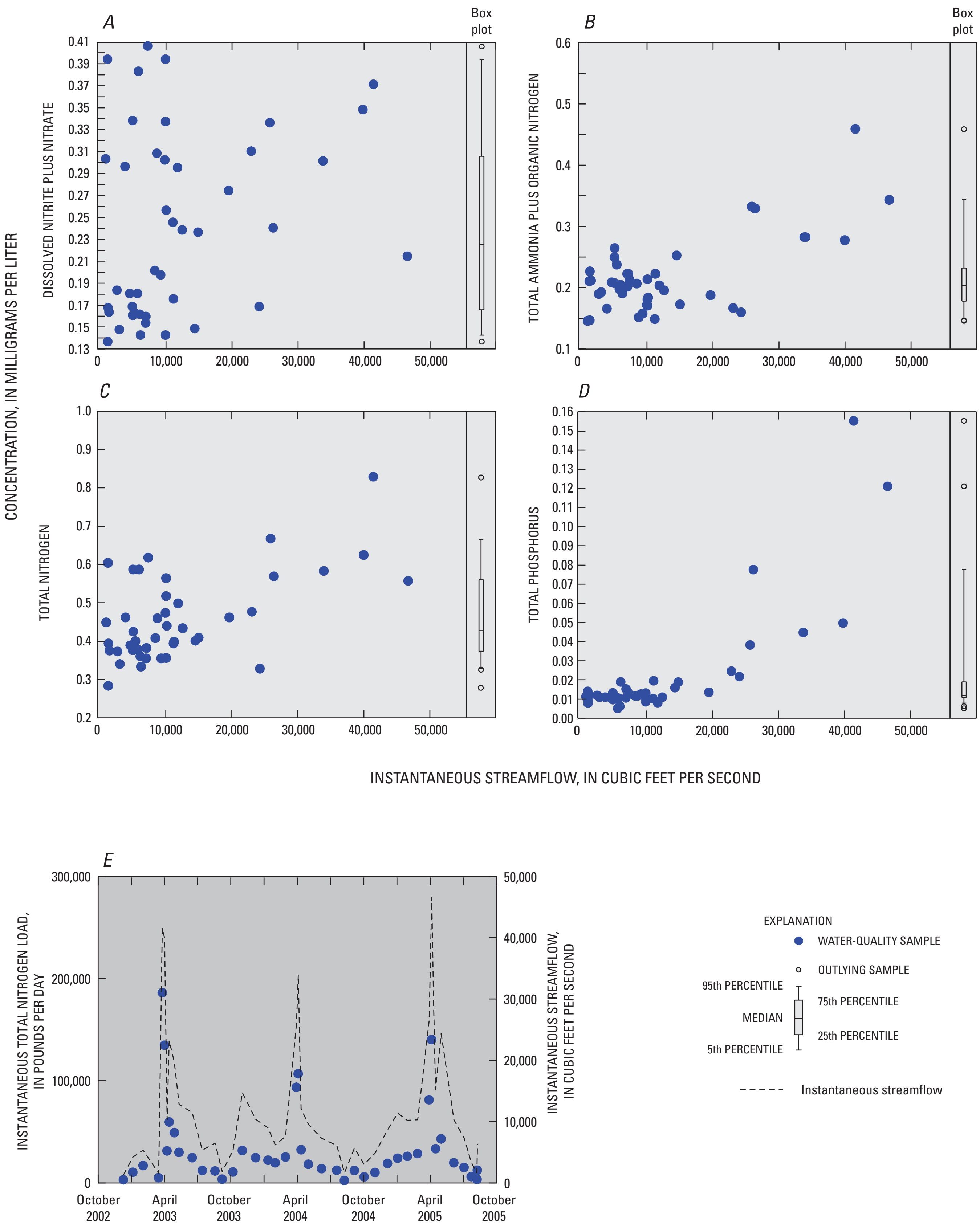


Figure 28. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Connecticut River at North Walpole, NH, station 01154500. (Refer to table 1 and figure 1 for station location.)

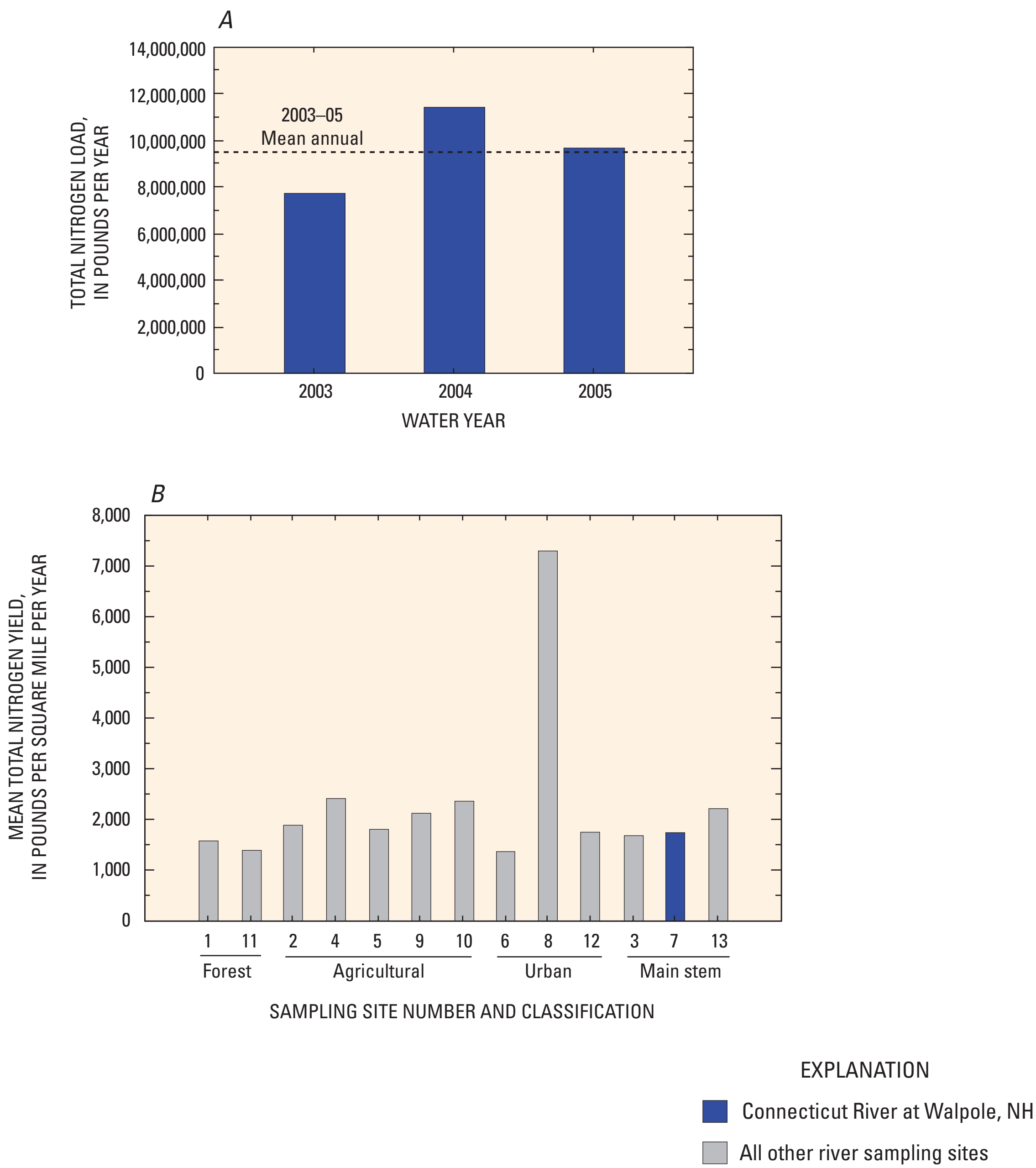


Figure 29. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Connecticut River at North Walpole, NH, station 01154500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Otter River at Otter River, MA, Station 01163200

Otter River at Otter River, MA, represents a urban site in the study area. The contributing drainage basin upstream from the site encompasses about 34 mi^2 and is about 58 percent forested, 6 percent agriculture, 22 percent urban, and 14 percent wetlands and barren (fig. 30). The annual streamflow for 1980–2002 averaged 45,300 acre-feet, with considerable year-to-year variation (fig. 31A). Annual streamflow for the data-collection period for water years 2003–05 averaged 53,400 acre-feet (table 1). Streamflow was greater than the long-term mean for all 3 years of the study (fig. 31A).

Daily mean streamflow and time distribution for 42 water samples are shown in figure 31B. The minimum streamflow at which samples were collected was 6.4 ft^3/s, and the maximum streamflow was 348 ft^3/s.

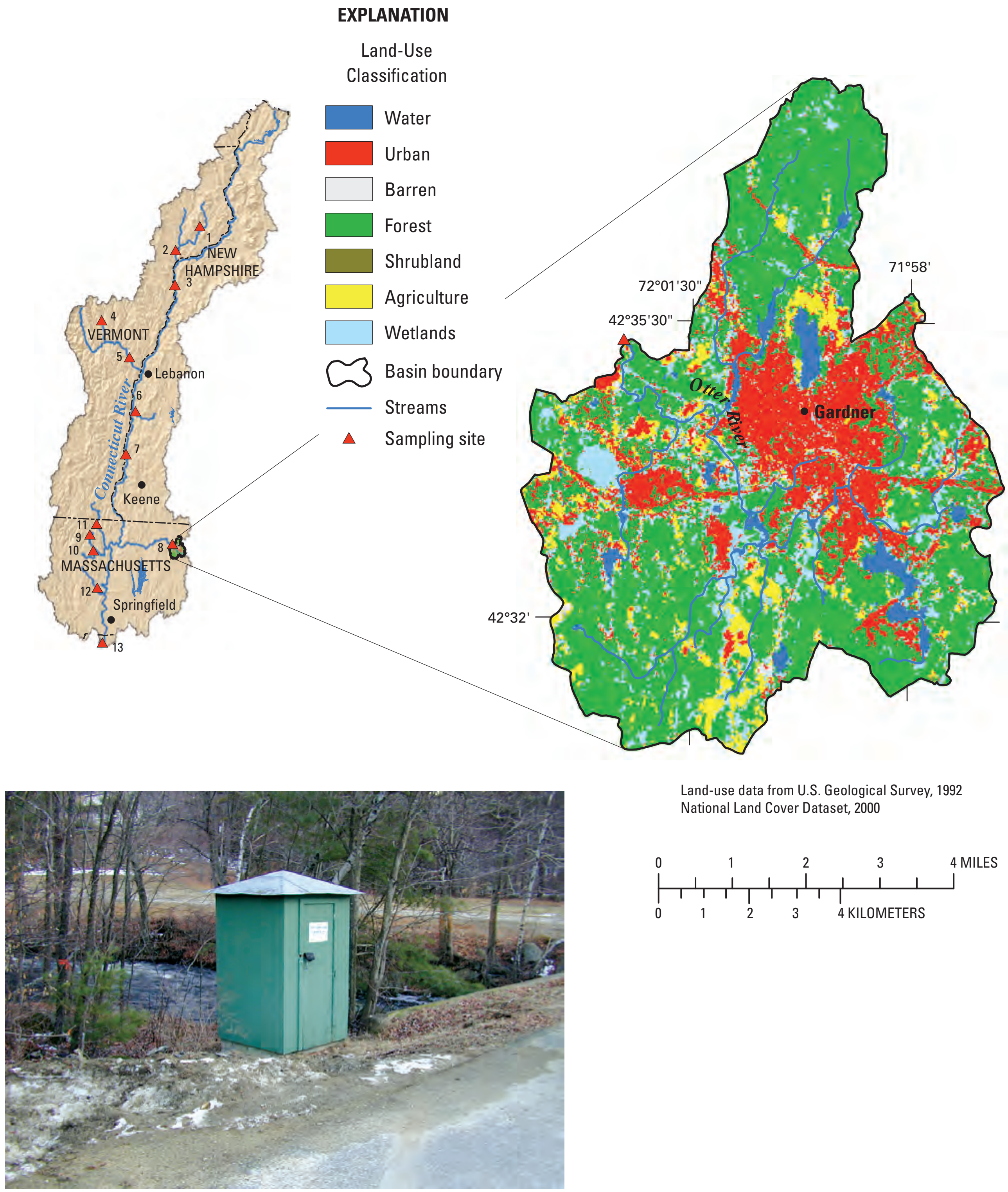
The minimum concentration of dissolved oxygen was 6.6 mg/L and was within the Massachusetts water-quality criterion for dissolved oxygen (Massachusetts Department of Environmental Protection, 2005). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 32). Concentrations of dissolved nitrite plus nitrate ranged from 0.226 to 9.66 mg/L and showed a typical dilution curve relative to streamflow (fig. 32A). Total ammonia plus organic nitrogen ranged from an estimated 0.33 to 1.1 mg/L and showed a decrease in concentrations with an increase in streamflow with the exception of the sample collected at a streamflow of 348 ft^3/s. This sample was collected just prior to the first peak in maximum daily mean streamflow during snowmelt in water year 2005 (fig. 32B). Concentrations of total nitrogen ranged from 0.59 to 10 mg/L and also showed a well-defined relation with streamflow (fig. 32C). The water quality at this site is dominated by effluent and most of the total nitrogen is in the form of dissolved nitrite plus nitrate. This relation is typical of dilution curves found at sites that may be dominated by wastewater-treatment effluent. Concentrations of total phosphorus ranged from 0.023 to 0.337 mg/L (fig. 32D). Instantaneous loads of total nitrogen ranged from 268 to 2,140 lb/d (fig. 32E). Ranges of concentrations or values for water-quality constituents not shown in figure 32 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	209	378	362	765
pH	5.7	6.3	6.3	7.0
Water temperature	.0	10.1	8.6	24.9
Dissolved oxygen	6.6	9.8	9.3	14.7
Dissolved nitrite	.004	.024	.016	.214
Dissolved ammonia	<.020	.165	.104	.710
Dissolved orthophosphate (WY 2003–05)	.01	.06	.03	.21
Suspended sediment	2	6	6	16

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen was similar during the first and second year of the study and slightly greater during the third year (appendix A-1; fig. 33A). The mean annual load of total nitrogen was 249,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 3.9 percent (table 2, fig. 33A). An estimated 29 and 22 percent of the total nitrogen load was transported in the spring and summer, respectively. The load of total nitrogen at this site was similar among seasons (appendix A-2). The mean yield of total nitrogen (7,300 $(lb/mi^2)/yr$) was greater than at all other sites (fig. 33B). Trench (1999) reported similar results in that basins receiving effluent from wastewater-treatment facilities generally are greater in yields of total nitrogen than other basins.

Otter River at Otter River, MA, Station 01163200



Photograph by Tim Driskell, U.S. Geological Survey

Figure 30. Location, land-use cover classification, and photograph of sampling site for Otter River at Otter River, MA, station 01163200. (Refer to table 1 and figure 1 for additional site information.)

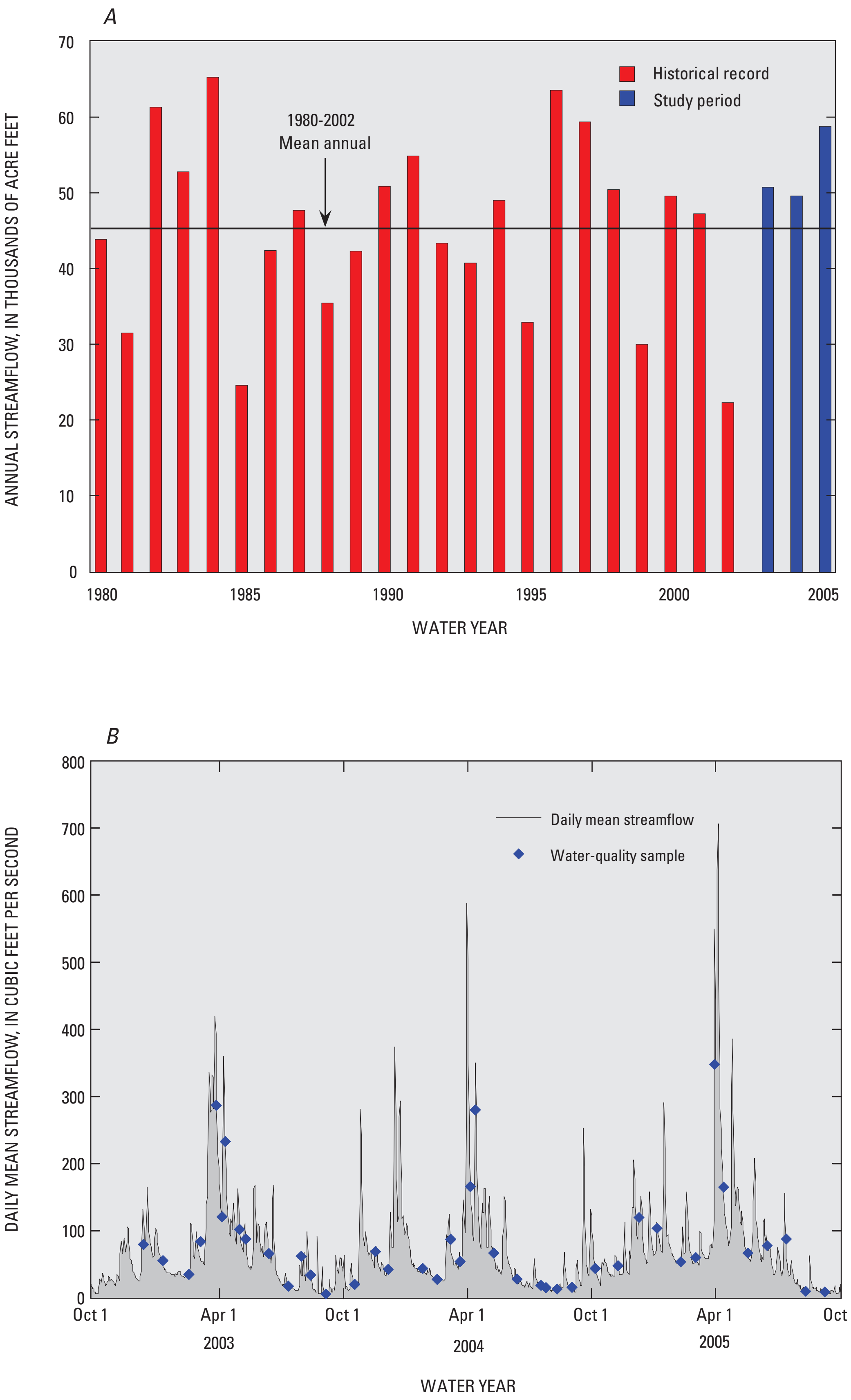


Figure 31. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Otter River at Otter River, MA, station 01163200.

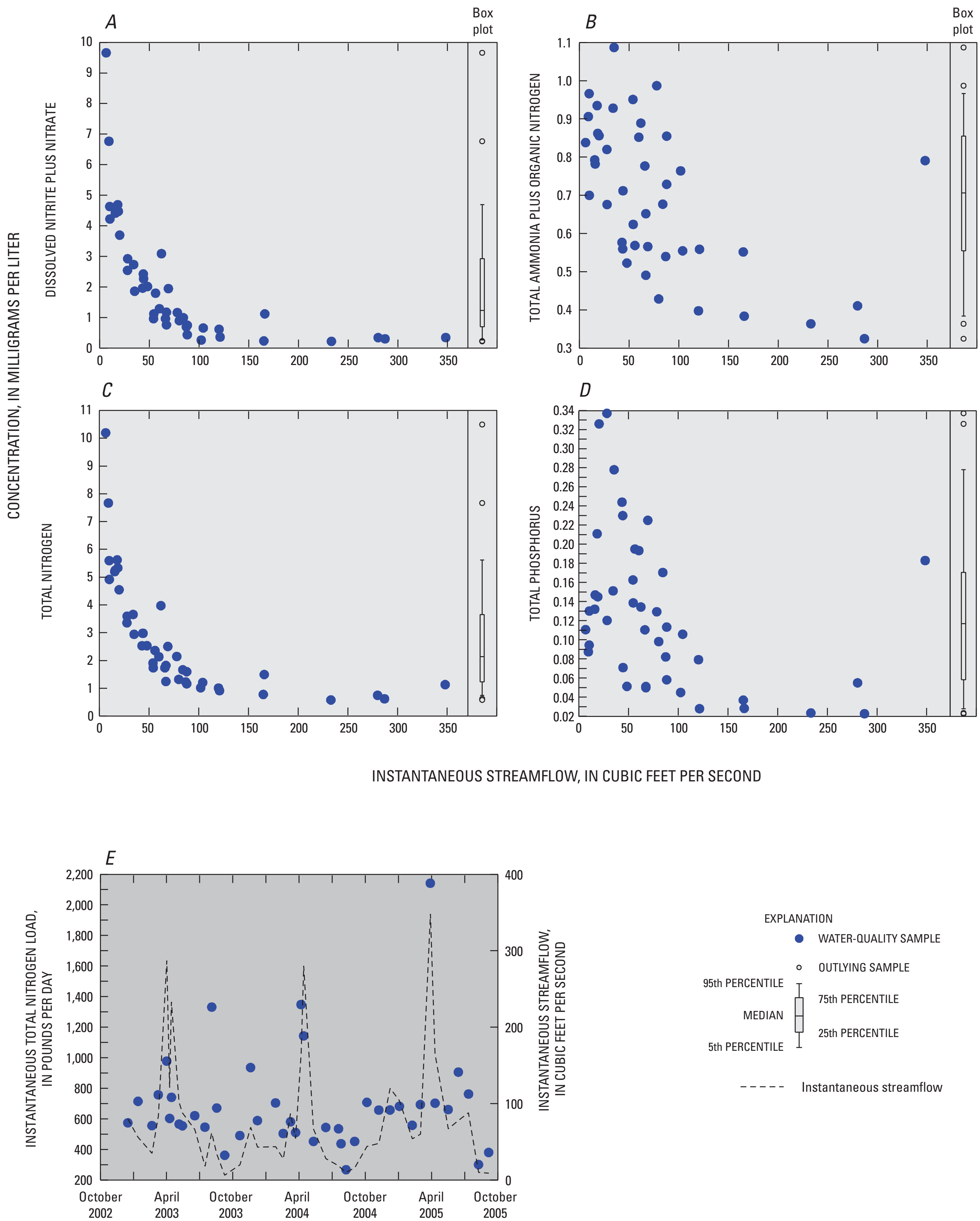


Figure 32. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and E, Instantaneous total nitrogen load relative to time for Otter River at Otter River, MA, station 01163200. (Refer to table 1 and figure 1 for station location.)

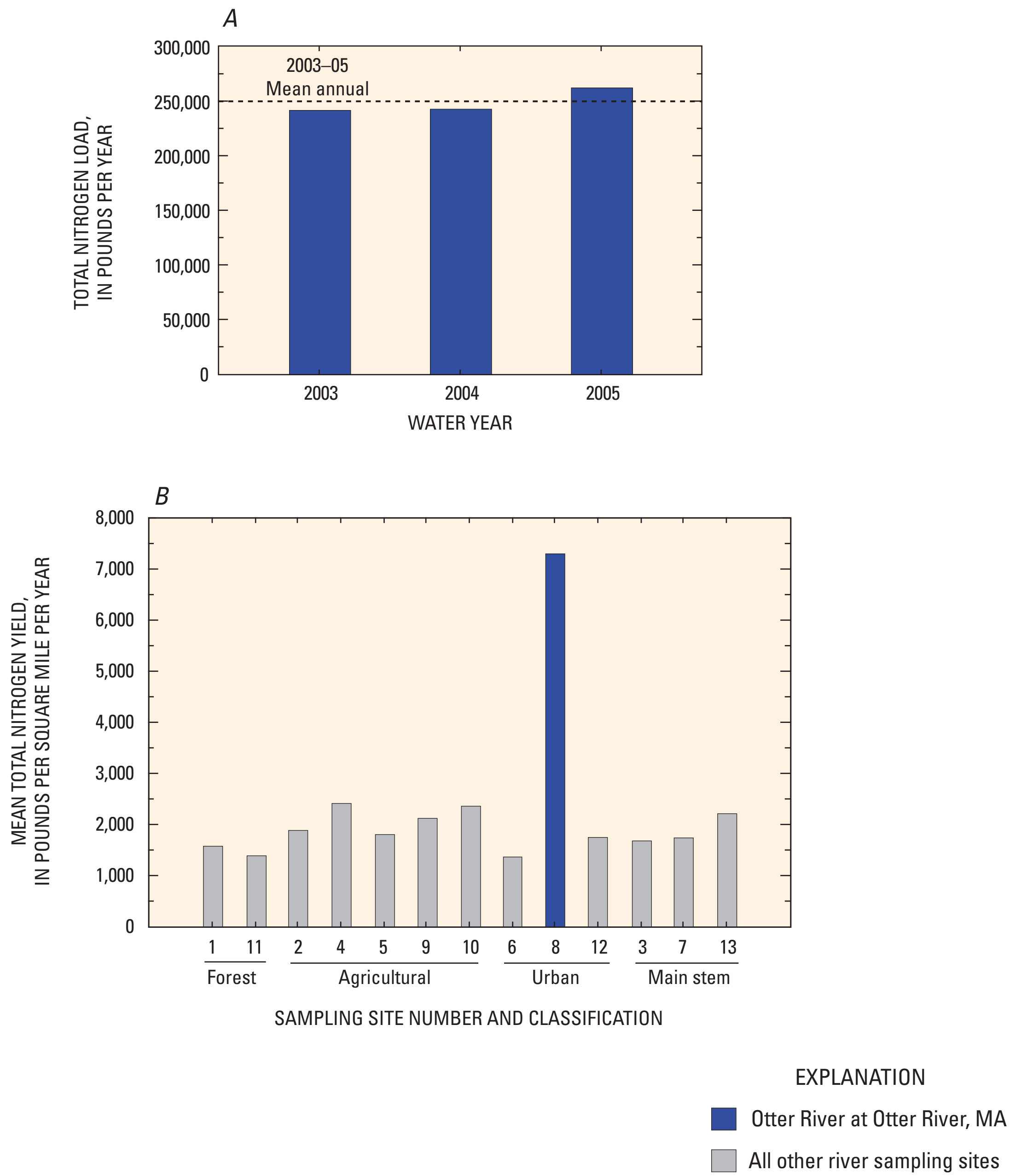


Figure 33. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Otter River at Otter River, MA, station 01163200, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

North River at Shattuckville, MA, Station 01169000

North River at Shattuckville, MA, represents an agricultural site in the study area. The contributing drainage basin upstream from the site encompasses about 89 mi^2 and is about 84 percent forested, 9 percent agriculture, 2 percent urban, and 5 percent wetlands and barren (fig. 34). Annual streamflow for 1980–2002 averaged 138,000 acre-feet, with considerable year-to-year variation (fig. 35A). Annual streamflow for the data-collection period for water years 2003–05 averaged 167,000 acre-feet (table 1). Streamflow was greater than the long-term mean for all 3 years of the study (fig. 35A).

Daily mean streamflows and the time distribution for 41 water samples are shown in figure 35B. The minimum streamflow at which water samples were collected was 22 ft^3/s, and the maximum streamflow at which samples were collected was 2,030 ft^3/s.

The minimum concentrations of dissolved oxygen was 8.0 mg/L and was within the Massachusetts water-quality criterion for dissolved oxygen (Massachusetts Department of Environmental Protection, 2005). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 36). Concentrations of dissolved nitrite plus nitrate ranged from 0.082 to 1.35 mg/L and generally showed a slight variation (dilution) in relation to streamflow (fig. 36A). Total ammonia plus organic nitrogen ranged from an estimated 0.07 to 0.47 mg/L and generally showed at slight dilution with an increase in streamflow; however, an increase in total ammonia plus organic nitrogen was observed in samples collected at streamflows greater than about 500 ft^3/s (fig. 36B). An increase in concentration of suspended sediment relative to the other samples also was observed for the three samples collected at streamflows greater than 500 ft^3/s. Concentrations of total nitrogen ranged from 0.25 to 1.7 mg/L (fig. 36C). Concentrations of total phosphorus ranged from 0.007 to 0.199 mg/L (fig. 36D). Concentrations of total phosphorus generally followed a similar pattern as concentrations of total ammonia plus organic nitrogen and likely were affected by an increase in concentrations of suspended sediment at greater streamflows. Instantaneous loads of total nitrogen ranged from 47 to 6,590 lb/d (fig. 36E). Ranges of concentrations or values for water-quality constituents not shown in figure 36 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	47	107	105	212
pH	6.6	7.5	7.4	8.7
Water temperature	.0	9.4	7.7	22.5
Dissolved oxygen	8.0	11.7	11.6	15.8
Dissolved nitrite	<.004	—	<.004	.036
Dissolved ammonia	<.005	—	<.005	.092
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	.13
Dissolved orthophosphate (WY 2005)	<.003	—	.007	.065
Suspended sediment	1	10	2	184

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study period (appendix A-1; fig. 37A). The mean annual load of total nitrogen was 194,000 lb/yr, with a ratio of the standard error of prediction to the mean load of 7.0 percent (table 2, fig. 37A). An estimated 43 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (2,180 (lb/mi^2)/yr) was greater than yield of total nitrogen at two of the agricultural sites in Vermont and less than the yield of total nitrogen at the other agricultural site in Massachusetts (fig. 37B).

North River at Shattuckville, MA, Station 01169000

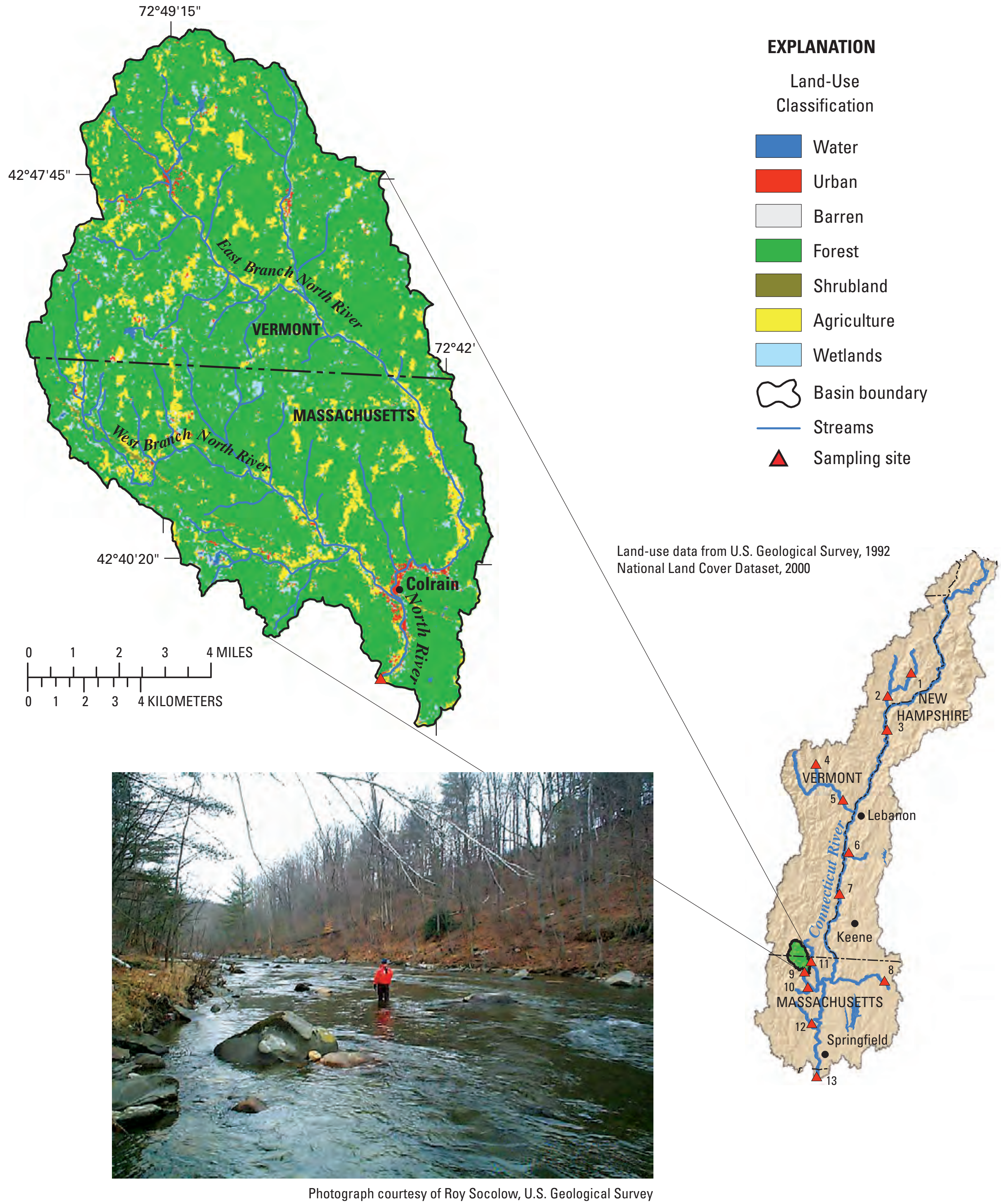
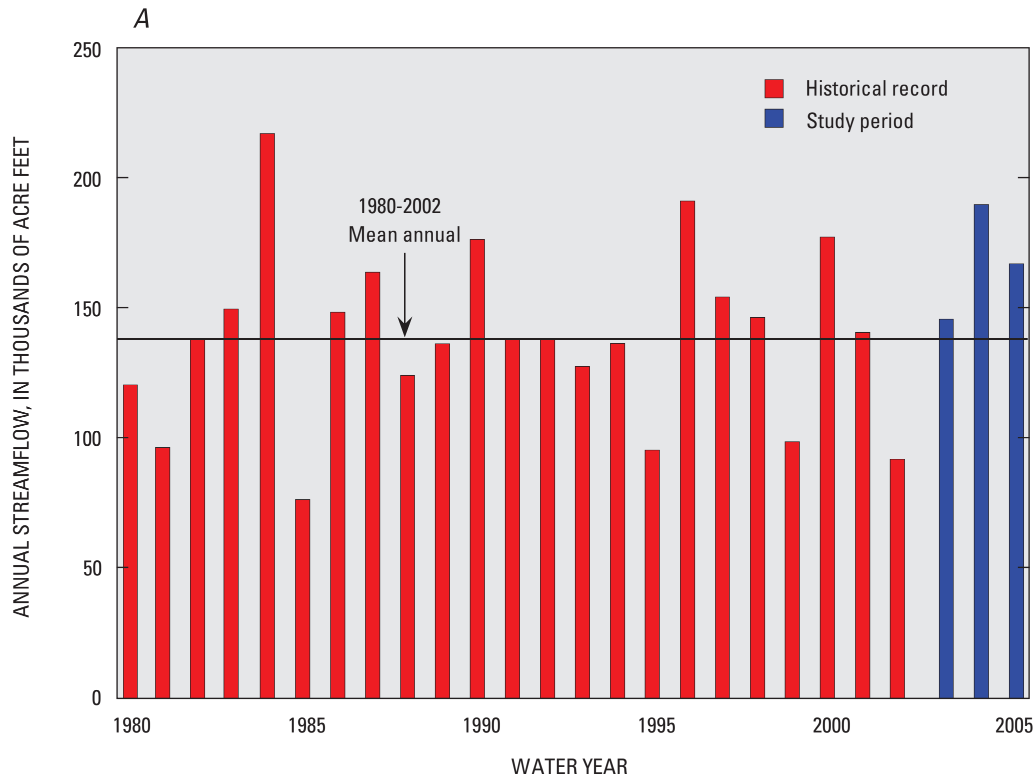


Figure 34. Location, land-use classification, and photograph of sampling site for North River at Shattuckville, MA, station 01169000. (Refer to table 1 and figure 1 for additional site information.)



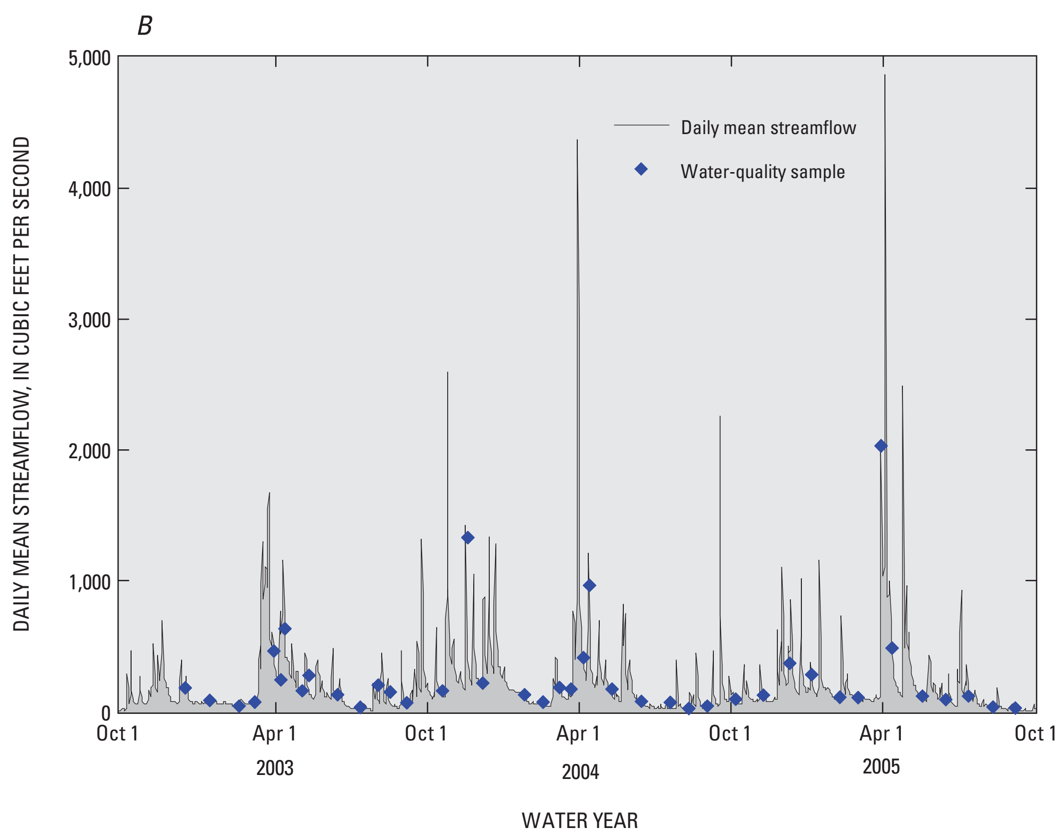


Figure 35. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for North River at Shattuckville, MA, station 01169000.

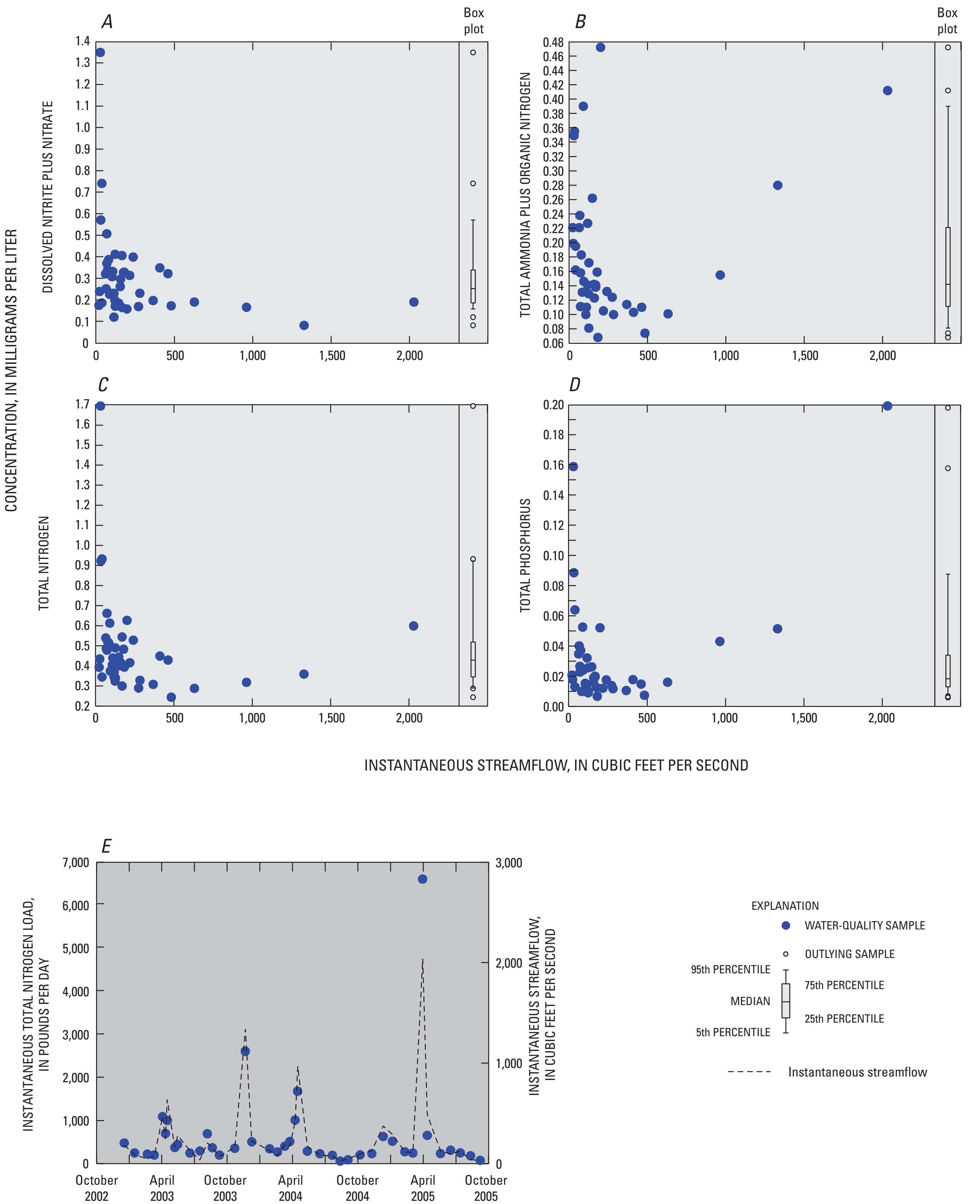


Figure 36. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for North River at Shattuckville, MA, station 01169000. (Refer to table 1 and figure 1 for station location.)

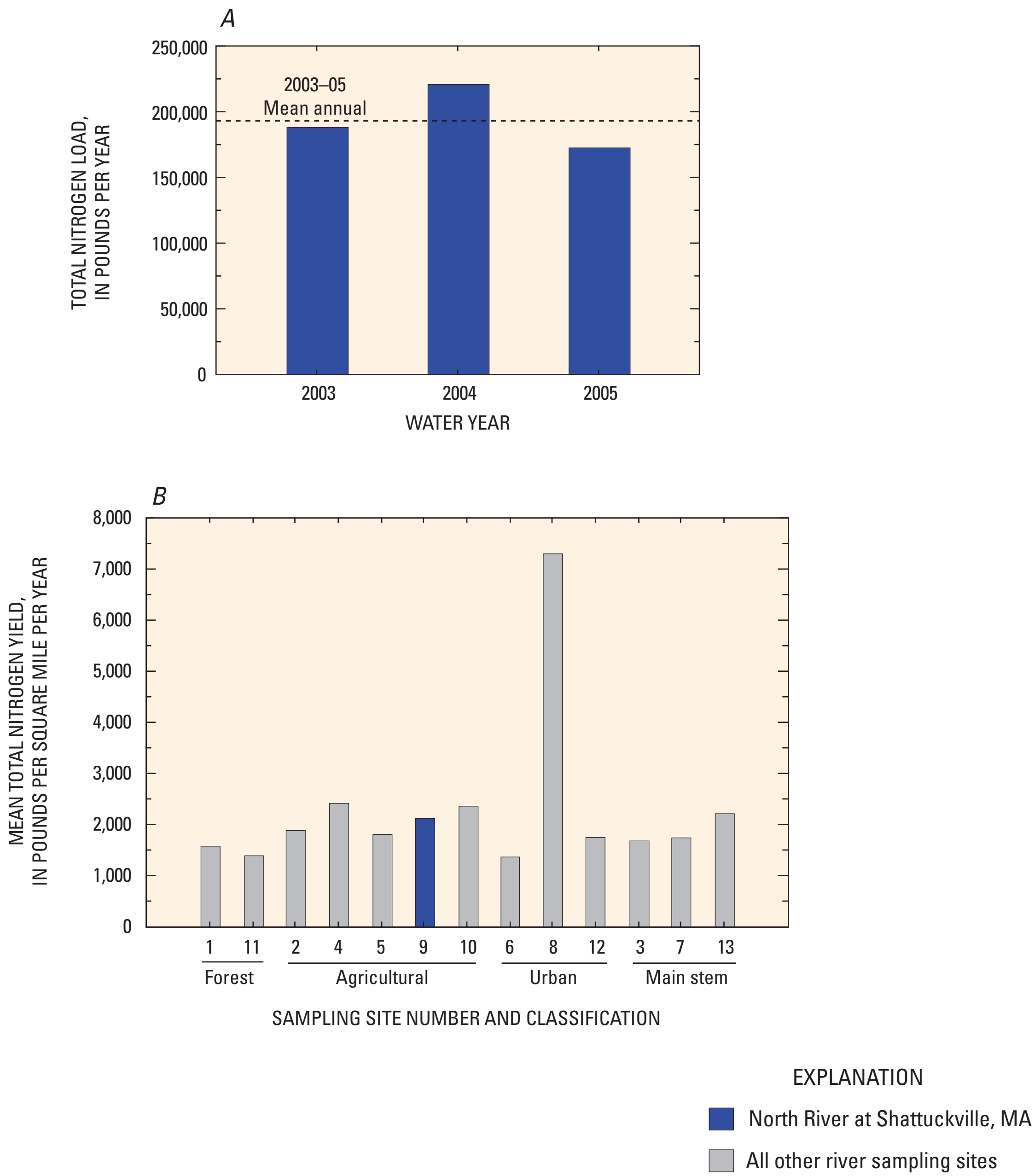


Figure 37. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for North River at Shattuckville, MA, station 01169000, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

South River near Conway, MA, Station 01169900

South River near Conway, MA, represents an agricultural site in the study area. The contributing drainage basin upstream from the site encompasses about 24 mi^2 and is about 81 percent forested, 10 percent agriculture, 4 percent urban, and 5 percent wetlands and barren (fig. 38). Annual streamflow for 1980–2002 averaged 37,100 acre-feet, with considerable year-to-year variation (fig. 39A). Annual streamflow for the data-collection period for water years 2003–05 averaged 48,100 acre-feet (table 1). Streamflow was greater than the long-term mean for all 3 years of the study (fig. 39A).

Daily mean streamflows and time distribution for 41 water-quality samples are shown in figure 39B. The minimum streamflow at which water samples were collected was 5 ft^3/s, and the maximum streamflow at which samples were collected was 197 ft^3/s.

The minimum concentration of dissolved oxygen was 7.9 mg/L and was within the Massachusetts water-quality criterion for dissolved oxygen (Massachusetts Department of Environmental Protection, 2005). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 40). Concentrations of dissolved nitrite plus nitrate ranged from 0.175 to 0.635 mg/L and showed no relation to streamflow (fig. 40A). Total ammonia plus organic nitrogen ranged from an estimated 0.05 to 0.31 mg/L and showed no relation to streamflow (fig. 40B). The maximum concentration of 0.31 mg/L was in a sample collected at a streamflow of about 70 ft^3/s during a small increase in streamflow that resulted from rain in August 2003. The concentration of suspended sediment in this sample was one of the highest concentrations relative to other samples collected at the site. Concentrations of total nitrogen ranged from 0.26 to 1.0 mg/L (fig. 40C). Concentrations of total phosphorus ranged from an estimated 0.002 to 0.050 mg/L (fig. 40D). Instantaneous loads of total nitrogen ranged from 11 to 525 lb/d (fig. 40E). Ranges of concentrations or values for water-quality constituents not shown in figure 40 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	103	161	157	218
pH	6.7	7.4	7.4	8.5
Water temperature	.0	9.2	7.4	24
Dissolved oxygen	7.9	11.2	11.3	14.4
Dissolved nitrite	<.004	—	<.004	.123
Dissolved ammonia	<.005	—	<.005	.020
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	<.003
Suspended sediment	1	5	2	49

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study (appendix A-1; fig. 41A). The mean annual load of total nitrogen was 53,700 lb/yr, with a ratio of the standard error of prediction to the mean load of 4.4 percent (table 2, fig. 41A). An estimated 31 and 39 percent of the total nitrogen load was transported during the winter and spring, respectively (appendix A-2). The mean yield of total nitrogen (2,230 $(lb/mi^2)/yr$) was greater than at most of the other agricultural sites (fig. 41B).

South River near Conway, MA, Station 01169900

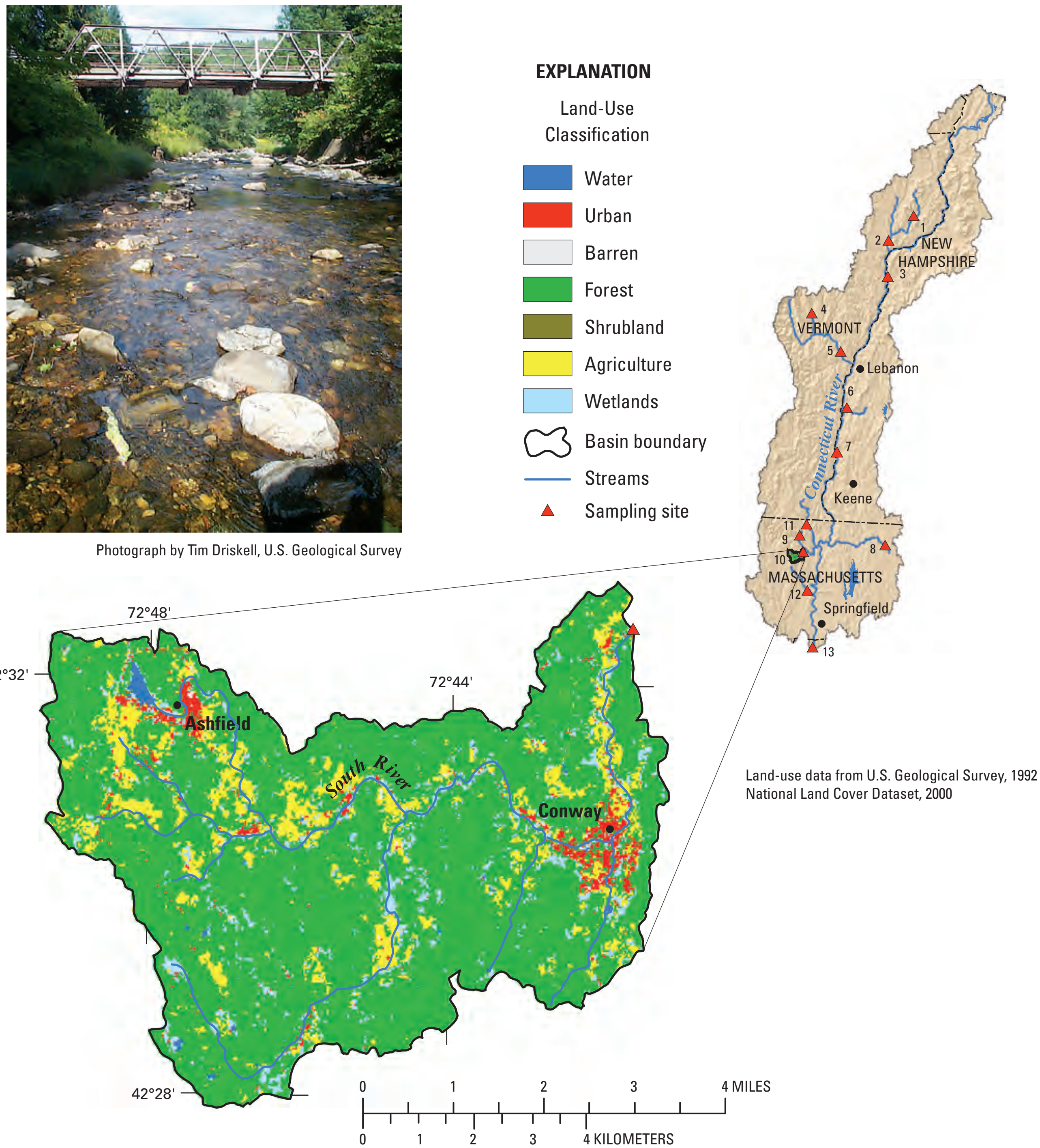


Figure 38. Location, land-use classification, and photograph of sampling site for South River near Conway, MA, station 01169900. (Refer to table 1 and figure 1 for additional site information.)

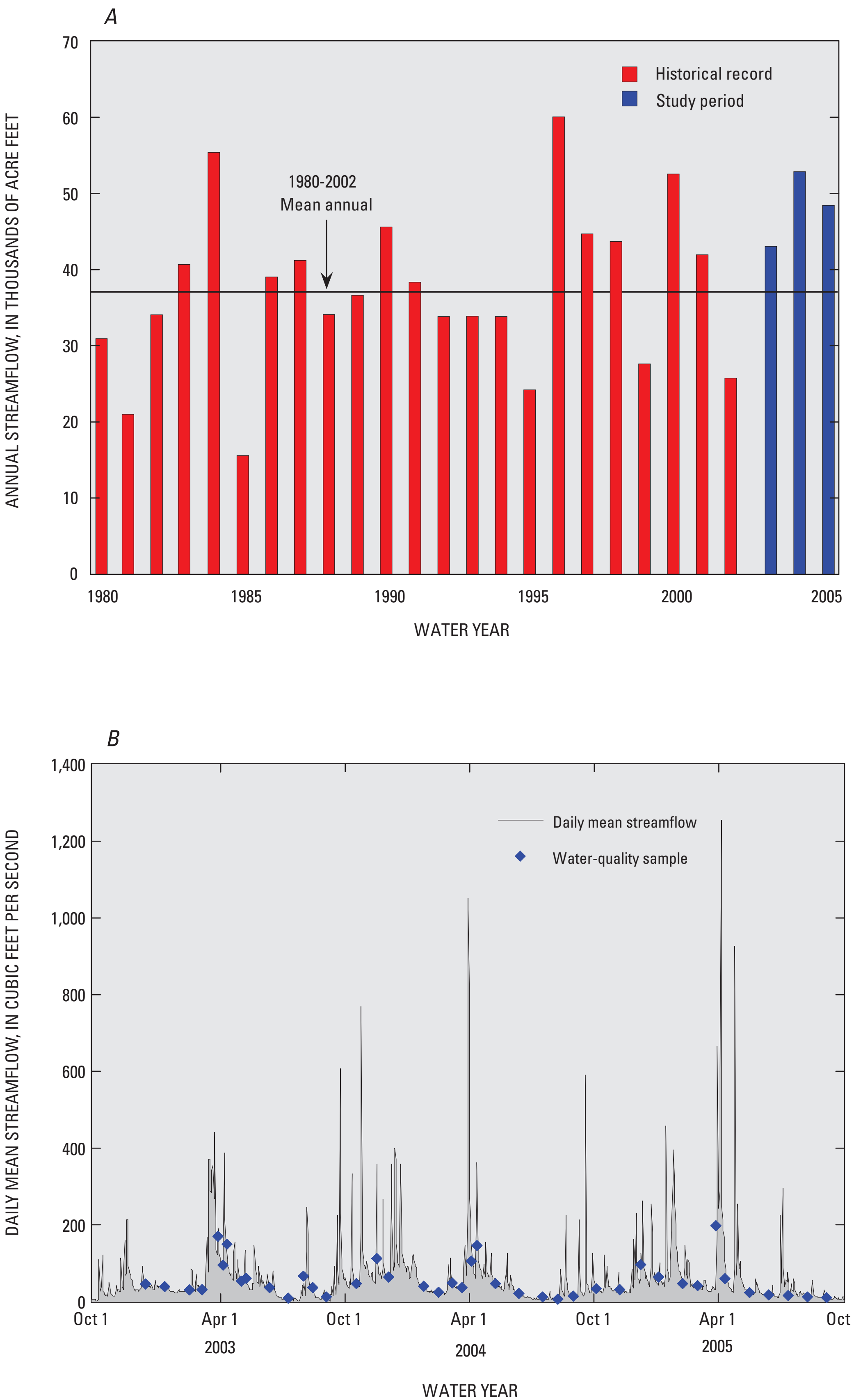


Figure 39. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for South River near Conway, MA, station 01169900.

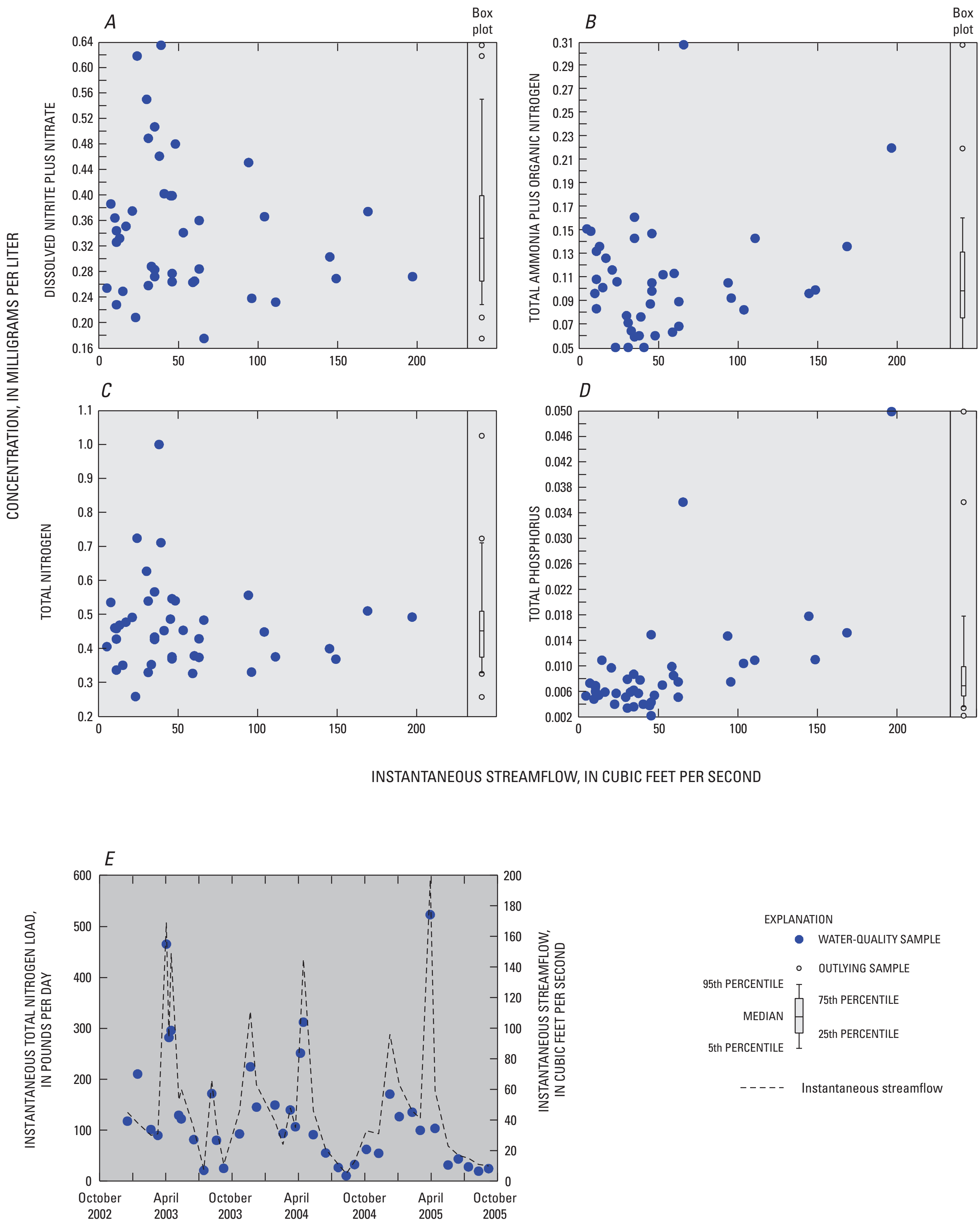


Figure 40. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for South River near Conway, MA, station 01169900. (Refer to table 1 and figure 1 for station location.)

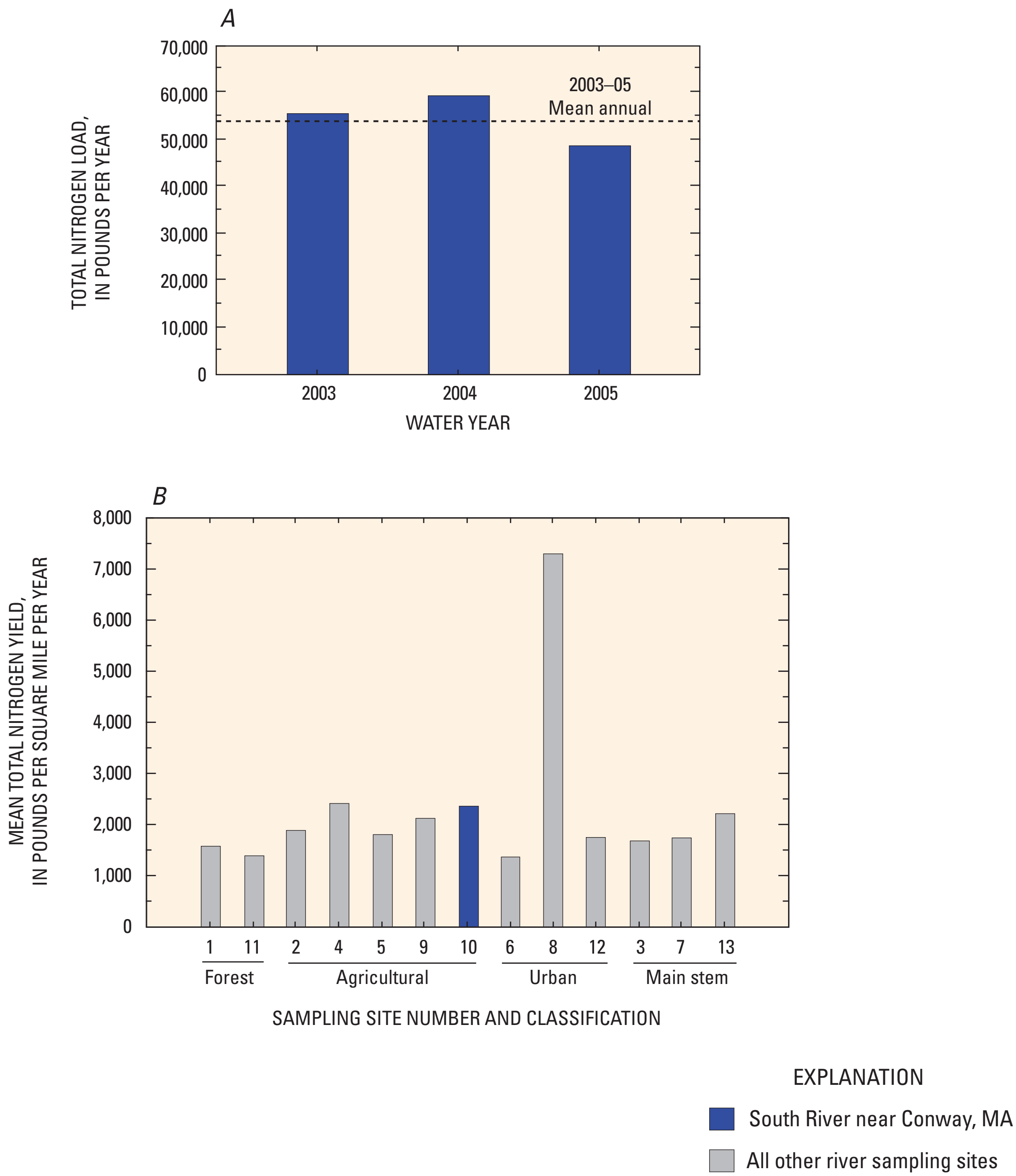


Figure 41. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for South River near Conway, MA, station 01169900, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Green River near Colrain, MA, Station 01170100

Green River near Colrain, MA, represents a forested site in the study area. The contributing drainage basin upstream from the site encompasses about 41 mi^2 and is about 92 percent forested, 5 percent agriculture, 1 percent urban, and about 2 percent wetlands and barren (fig. 42). Annual streamflow for 1980–2002 averaged 61,400 acre-feet, with considerable year-to-year variation (fig. 43A). Annual streamflow for the data-collection period for water years 2003–05 averaged 74,400 acre-feet (table 1). Streamflow was greater than the long-term mean for all 3 years of the study (fig. 43A).

Daily mean streamflow and time distribution for 41 water-quality samples are shown in figure 43B. The minimum streamflow at which water samples were collected was 10 ft^3/s, and the maximum streamflow at which samples were collected was 602 ft^3/s.

The minimum concentration of dissolved oxygen was 8.4 mg/L and was within the Massachusetts water-quality criterion for dissolved oxygen (Massachusetts Department of Environmental Protection, 2005). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 44). Concentrations of dissolved nitrite plus nitrate ranged from less than 0.016 to 0.201 mg/L and showed no relation to streamflow (fig. 44A). Total ammonia plus organic nitrogen ranged from an estimated 0.05 to 0.32 mg/L and also showed no relation to streamflow (fig. 44B). Concentrations of total nitrogen ranged from 0.06 to 0.46 mg/L (fig. 44C). Concentrations of total phosphorus ranged from an estimated 0.002 to 0.067 mg/L (fig. 44D). The maximum concentration of total phosphorus was observed at the second greatest streamflow at which samples were collected; this sample had the maximum concentration of suspended sediment (61 mg/L) relative to the other samples. Instantaneous loads of total nitrogen ranged from 5.5 to 1,240 lb/d (fig. 44E). Ranges of concentrations or values for water-quality constituents not shown in figure 44 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	51	84	88	128
pH	6.6	7.4	7.5	8.4
Water temperature	.0	8.8	7.7	21.2
Dissolved oxygen	8.4	11.6	11.3	15.7
Dissolved nitrite	<.004	—	<.004	.006
Dissolved ammonia	<.005	—	<.005	.006
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	<.003	<.003
Suspended sediment	1	4	1	61

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years and was considerably less during the third year of the study (fig. 45A). The mean annual flow also was less during the third year of the study (appendix A-1). The mean annual load of total nitrogen was 49,100 lb/yr, with a ratio of the standard error of prediction to the mean load of 10 percent (table 2, fig. 45A). This site had the greatest percentage of error relative to other sites. An estimated 47 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean yield of total nitrogen (1,190 $(lb/mi^2)/yr$) was less than all of the other study sites (fig. 45B). In general, water quality at this site typifies reference conditions for this area of the basin. Concentrations of total nitrogen and other water-quality constituents generally were low.

Green River near Colrain, MA, Station 01170100

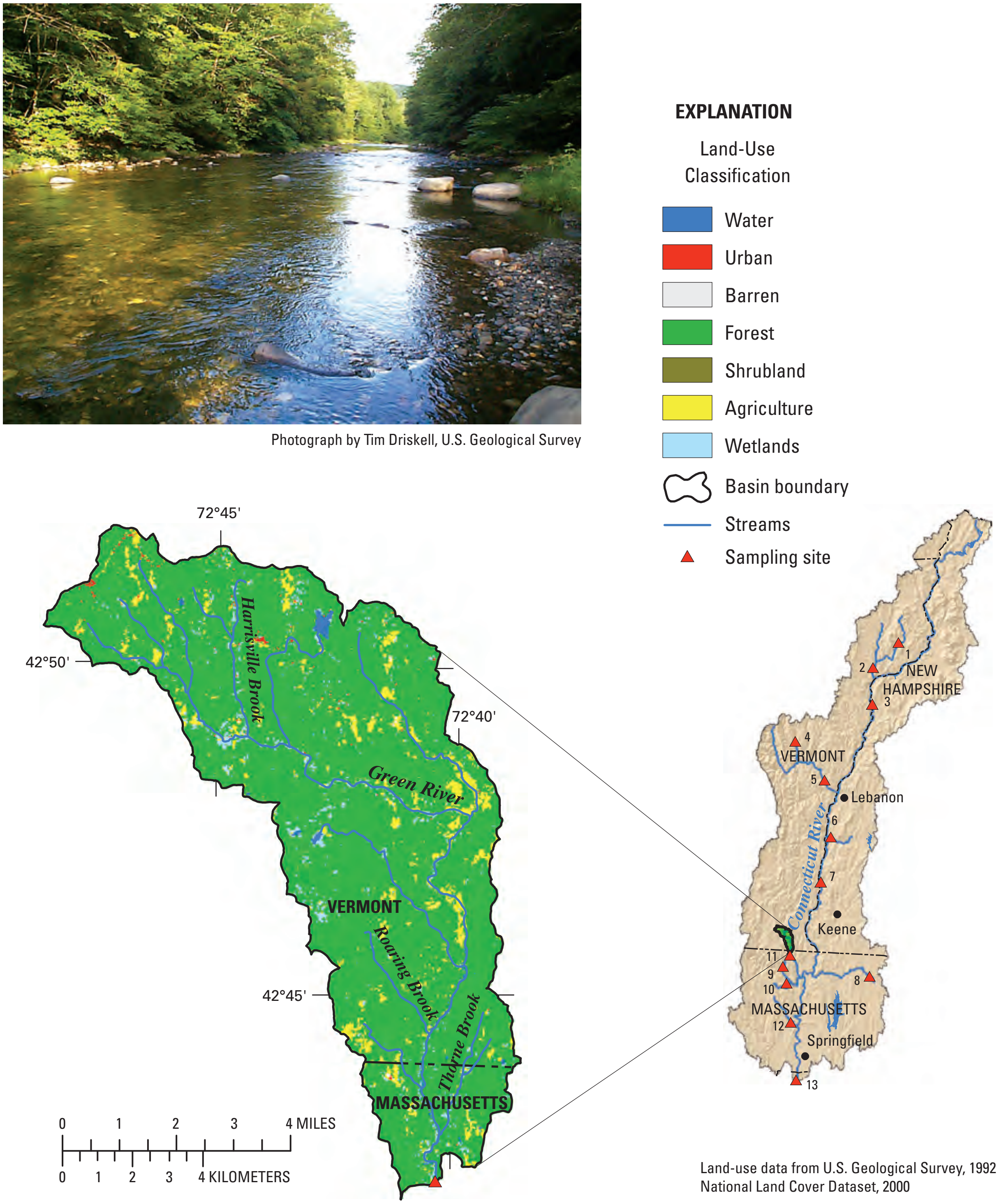
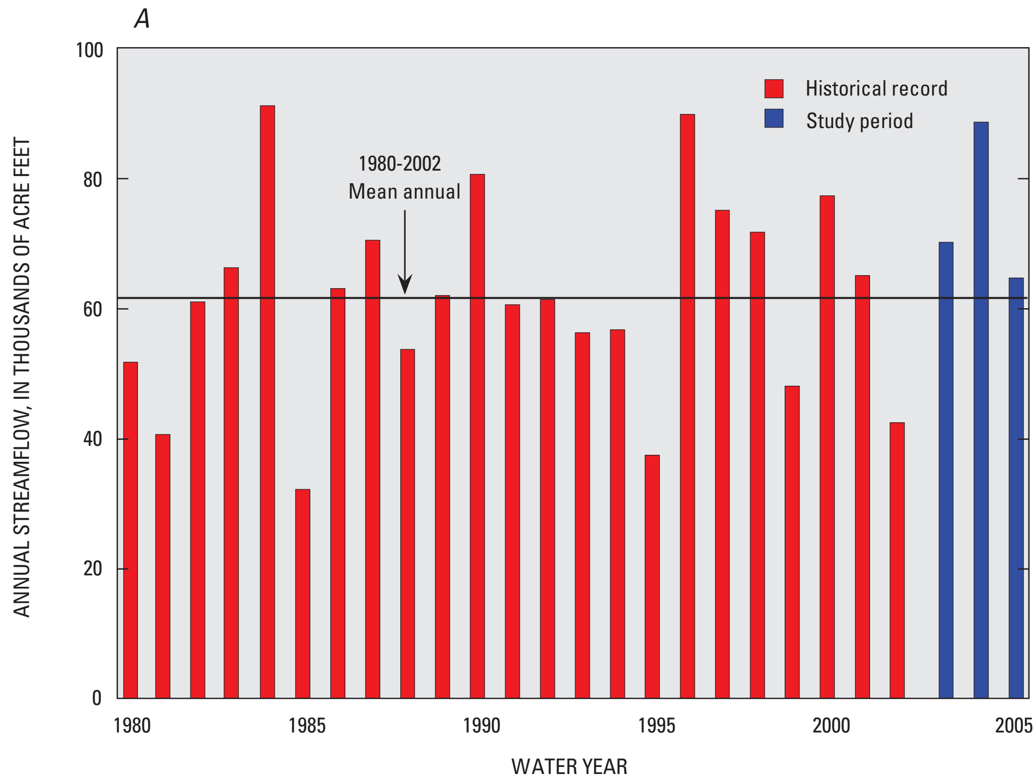


Figure 42. Location, land-use classification, and photograph of sampling site for Green River near Colrain, MA, station 01170100. (Refer to table 1 and figure 1 for additional site information.)



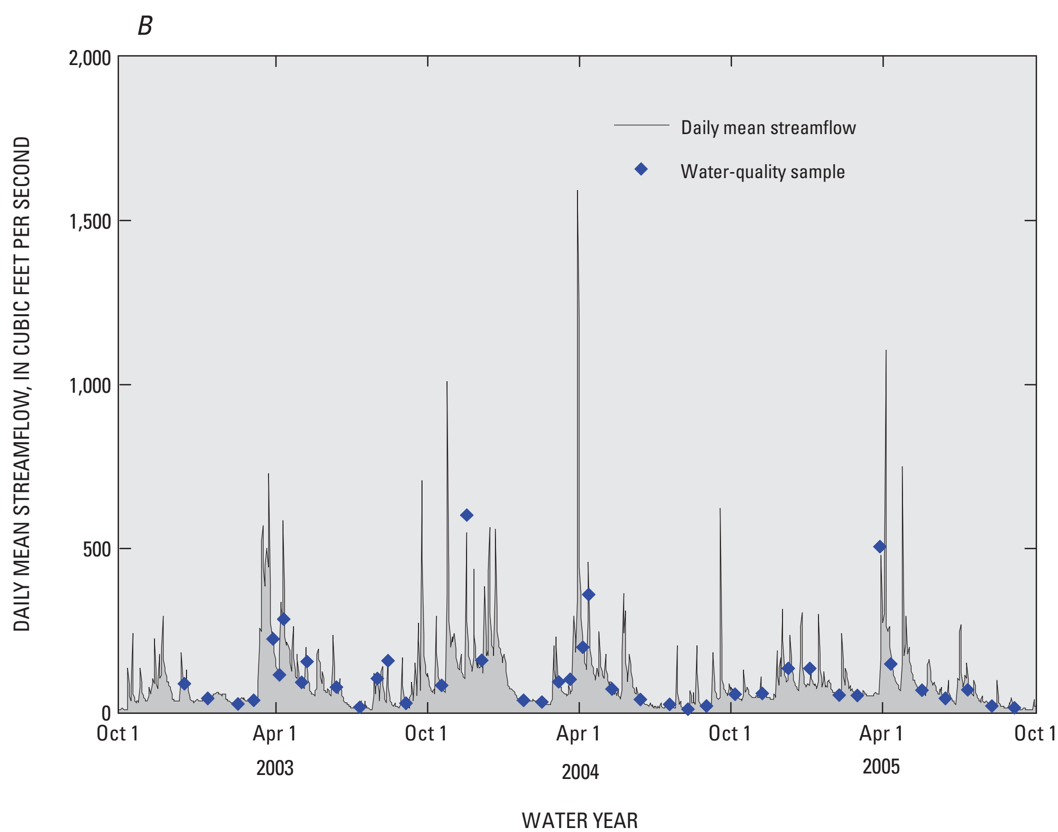


Figure 43. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Green River near Colrain, MA, station 01170100.

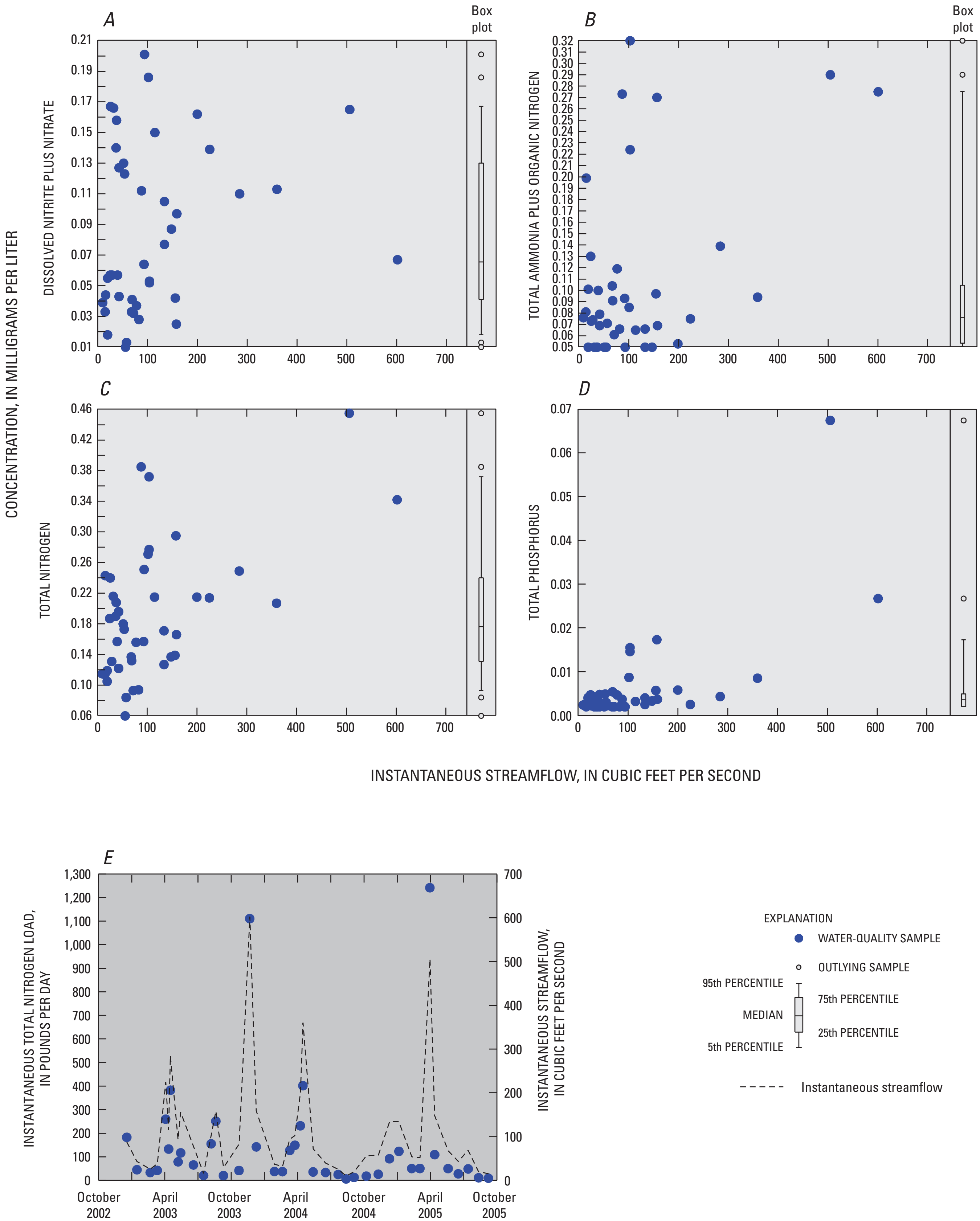


Figure 44. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Green River near Colrain, MA, station 01170100. (Refer to table 1 and figure 1 for station location.)

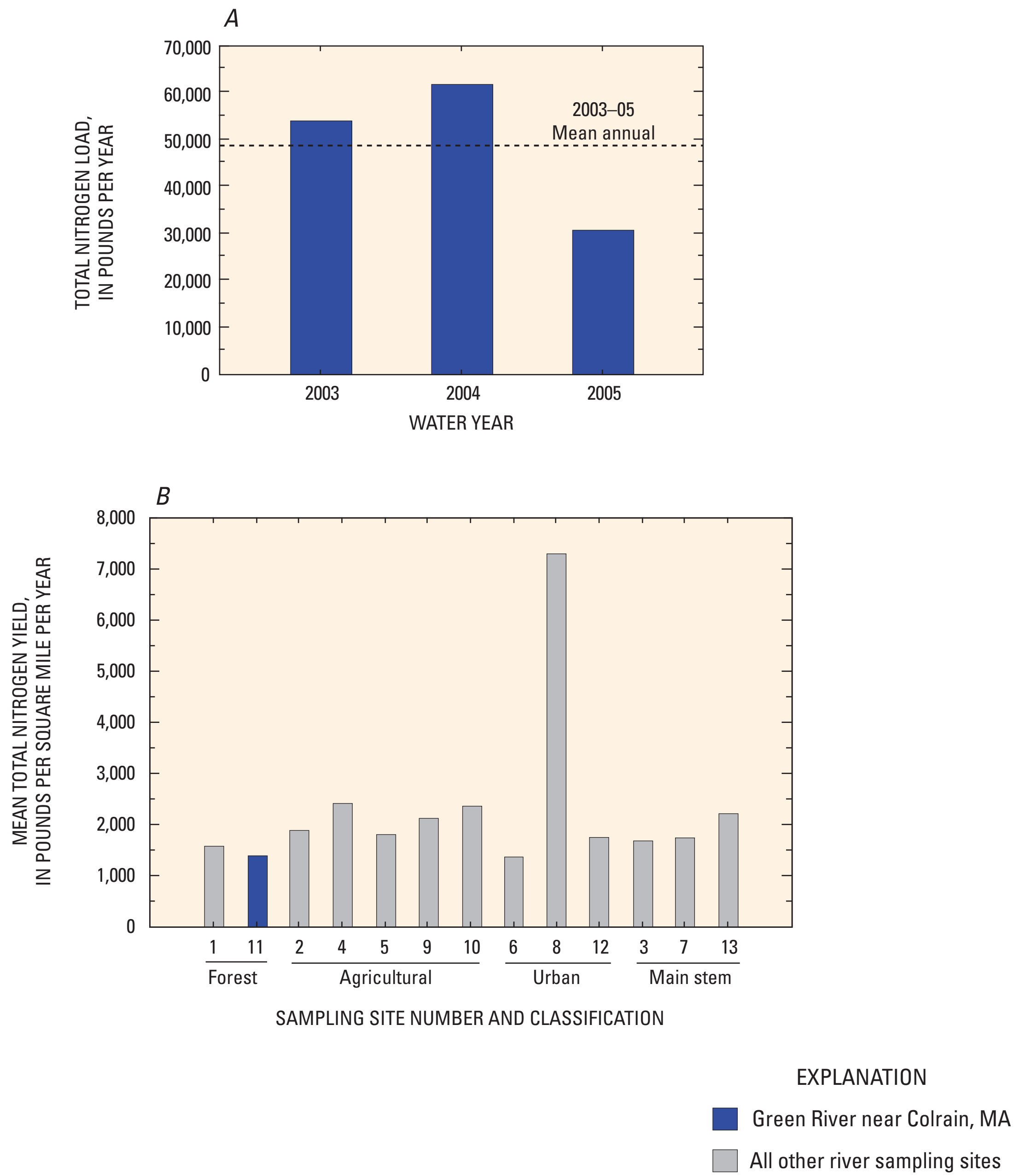


Figure 45. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Green River near Colrain, MA, station 01170100, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Mill River at Northhampton, MA, Station 01171500

Mill River at Northhampton, MA, represents an urban site in the study area. The contributing drainage basin upstream from this site encompasses about 54 mi^2 and is about 77 percent forested, 6 percent agriculture, 10 percent urban, and about 7 percent wetlands and barren (fig. 46). Annual streamflow for 1980–2002 averaged 73,000 acre-feet, with considerable year-to-year variation (fig. 47A). Annual streamflow for the data-collection period for water years 2003–05 averaged 88,400 acre-feet (table 1). Streamflow was greater than the long-term mean for all 3 years of the study (fig. 47A).

Daily mean streamflow and time distribution for 43 water samples are shown in figure 47B. The minimum streamflow at which water samples were collected was 12 ft^3/s, and the maximum streamflow at which samples were collected was 512 ft^3/s.

The minimum concentration of dissolved oxygen was 7.7 mg/L and was within the Massachusetts water-quality criterion for dissolved oxygen (Massachusetts Department of Environmental Protection, 2005). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 48). Concentrations of dissolved nitrite plus nitrate ranged from less than 0.160 to 0.570 mg/L and, although some scatter was shown, there also was a slight dilution effect relative to streamflow (fig. 48A). Total ammonia plus organic nitrogen ranged from an estimated 0.07 to 0.31 mg/L and showed no relation to streamflow (fig. 48B). Concentrations of total nitrogen ranged from 0.29 to 0.68 mg/L and showed a pattern similar to dissolved nitrite plus nitrate (fig. 48C). Most of the total nitrogen at this site was in the form of dissolved nitrite plus nitrate. Concentrations of total phosphorus ranged from an estimated 0.006 to 0.026 mg/L (fig. 48D). The maximum concentration of total phosphorus was observed at the greatest streamflow at which samples were collected which was during snowmelt. This sample also had the greatest concentration of suspended sediment (17 mg/L) relative to the other samples. Instantaneous loads of total nitrogen ranged from 39 to 958 lb/d (fig. 48E). Ranges of concentrations or values for water-quality constituents not shown in figure 48 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	65	108	107	160
pH	6.3	7.2	7.2	8.0
Water temperature	.0	10.1	8.3	22.6
Dissolved oxygen	7.7	11.2	11.2	15.1
Dissolved nitrite	<.004	—	<.004	.087
Dissolved ammonia	<.005		<.005	.022
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	<.01
Dissolved orthophosphate (WY 2005)	<.003	—	.003	.007
Suspended sediment	1	3	2	17

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen was similar during the first and second year of the study and less during the third year of the study (appendix A-1; fig. 49A). The mean annual load of total nitrogen was 95,400 lb/yr, with a ratio of the standard error of prediction to the mean load of 3.0 percent (table 2, fig. 49A). An estimated 31 and 37 percent of the total nitrogen load was transported during the winter and spring, respectively (appendix A-2). The mean yield of total nitrogen (1,770 $(lb/mi^2)/yr$) was similar to the yield of total nitrogen at other sites (fig. 49B).

Mill River at Northampton, MA, Station 01171500

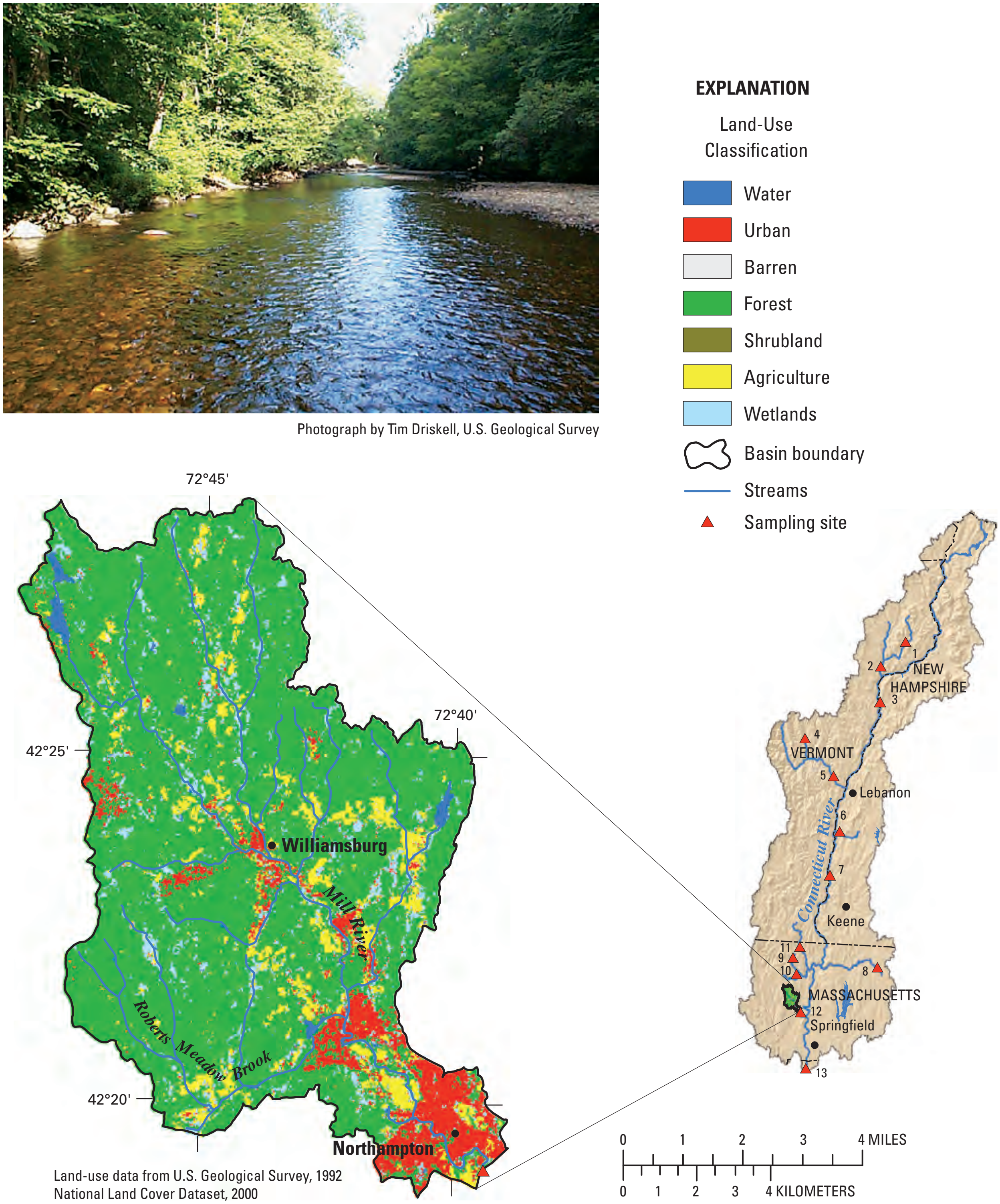
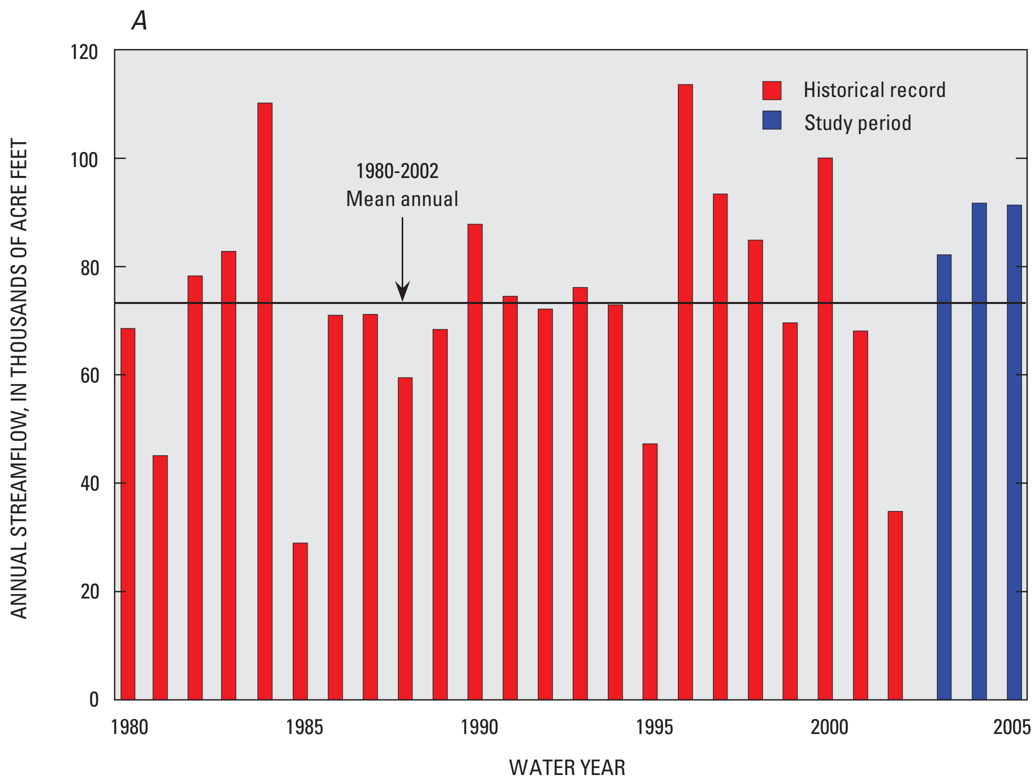


Figure 46. Location, land-use classification, and photograph of sampling site for Mill River at Northampton, MA, station 01171500. (Refer to table 1 and figure 1 for additional site information.)



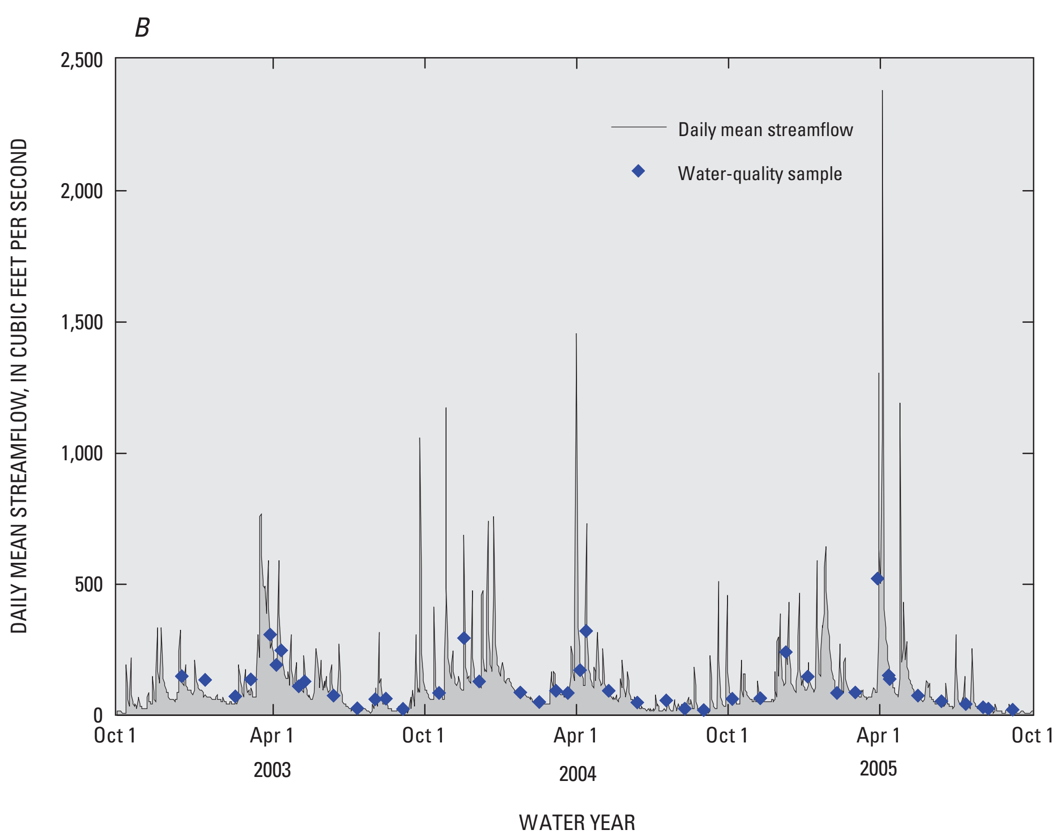


Figure 47. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Mill River at Northampton, MA, station 01171500.

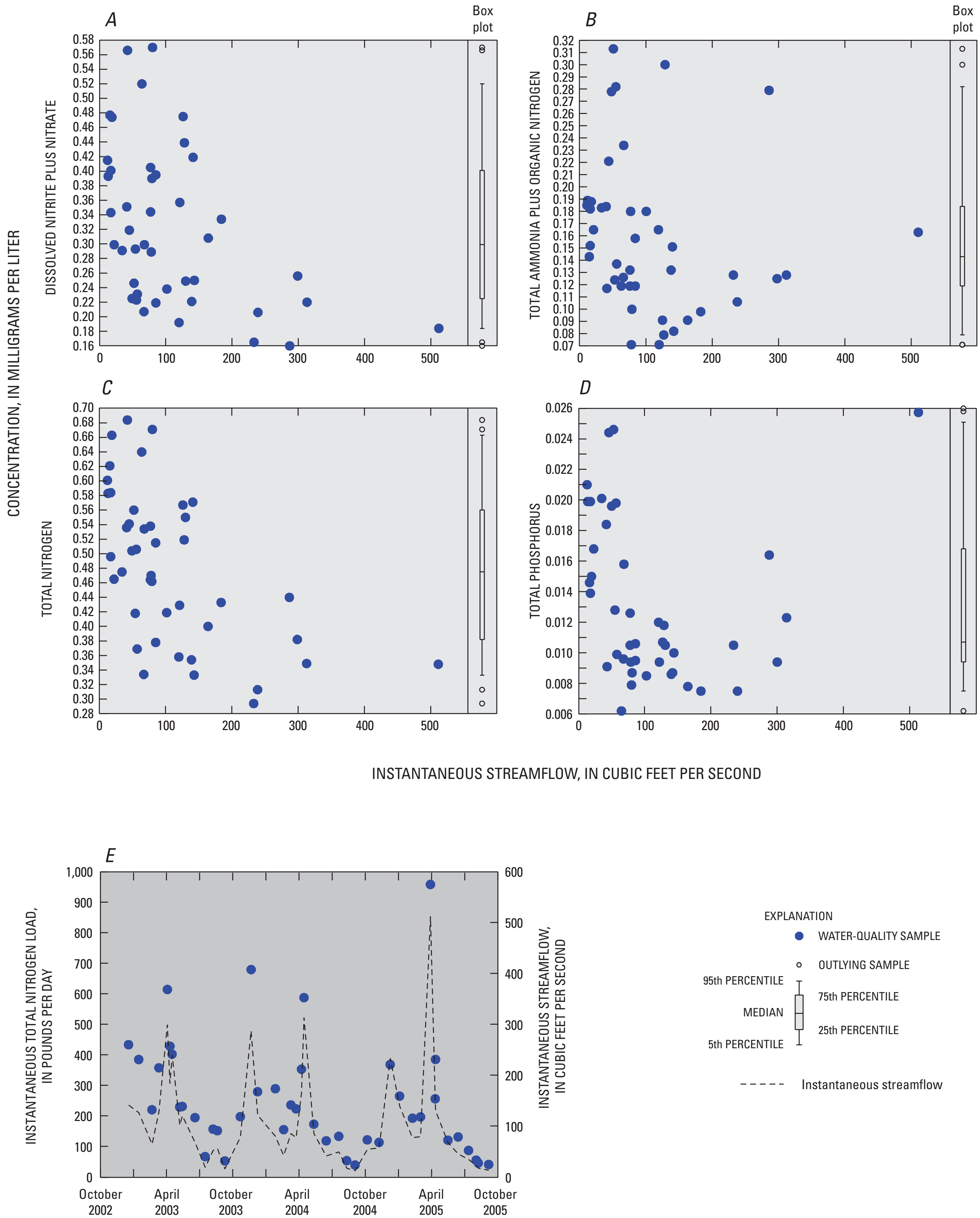


Figure 48. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Mill River at Northampton, MA, station 01171500. (Refer to table 1 and figure 1 for station location.)

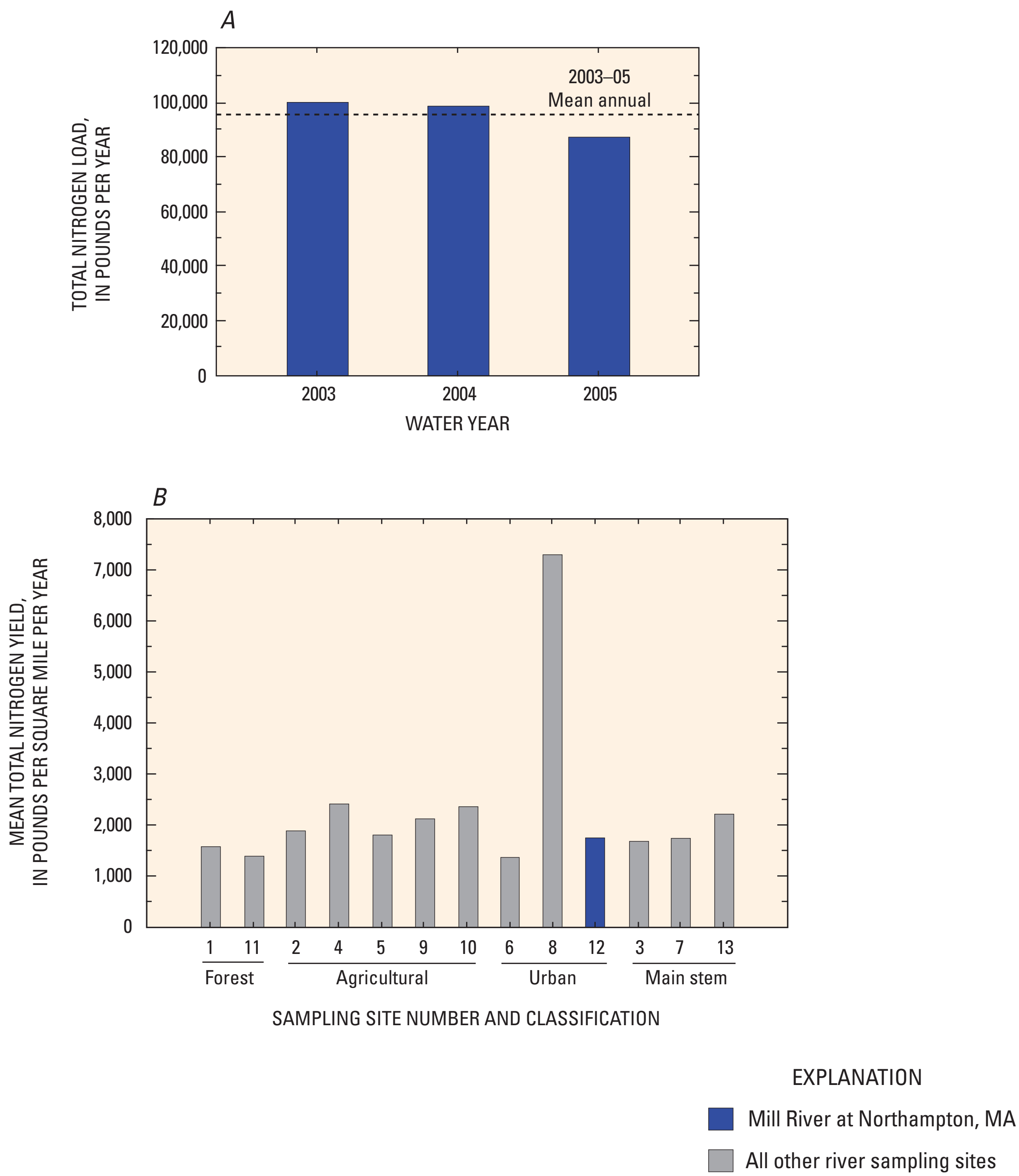


Figure 49. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Mill River at Northampton, MA, station 01171500, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Connecticut River at Thompsonville, CT, Station 01184000

Connecticut River at Thompsonville, CT, represents a main-stem site in the study area and serves as the outlet site to the upper Connecticut River Basin. The contributing drainage basin upstream from the site encompasses about 9,660 mi^2 and is about 80 percent forested, 9 percent agriculture, 4 percent urban, and about 6 percent wetlands and barren (fig. 50). Annual streamflow for 1980–2002 averages 12,700,000 acre-feet, with considerable year-to-year variation (fig. 51A). Annual streamflow for the data-collection period for water years 2003–05 averaged 13,000,000 acre-feet (table 1). Streamflow was less than the long-term mean for the first year and greater than the long-term mean for the second year and about average for the third year of the study (fig. 51A).

Daily mean streamflows and the time distribution of the collection of 41 water-quality samples are shown in figure 51B. The minimum streamflow at which water samples were collected was 4,930 ft^3/s, and the maximum streamflow at which samples were collected was 77,200 ft^3/s.

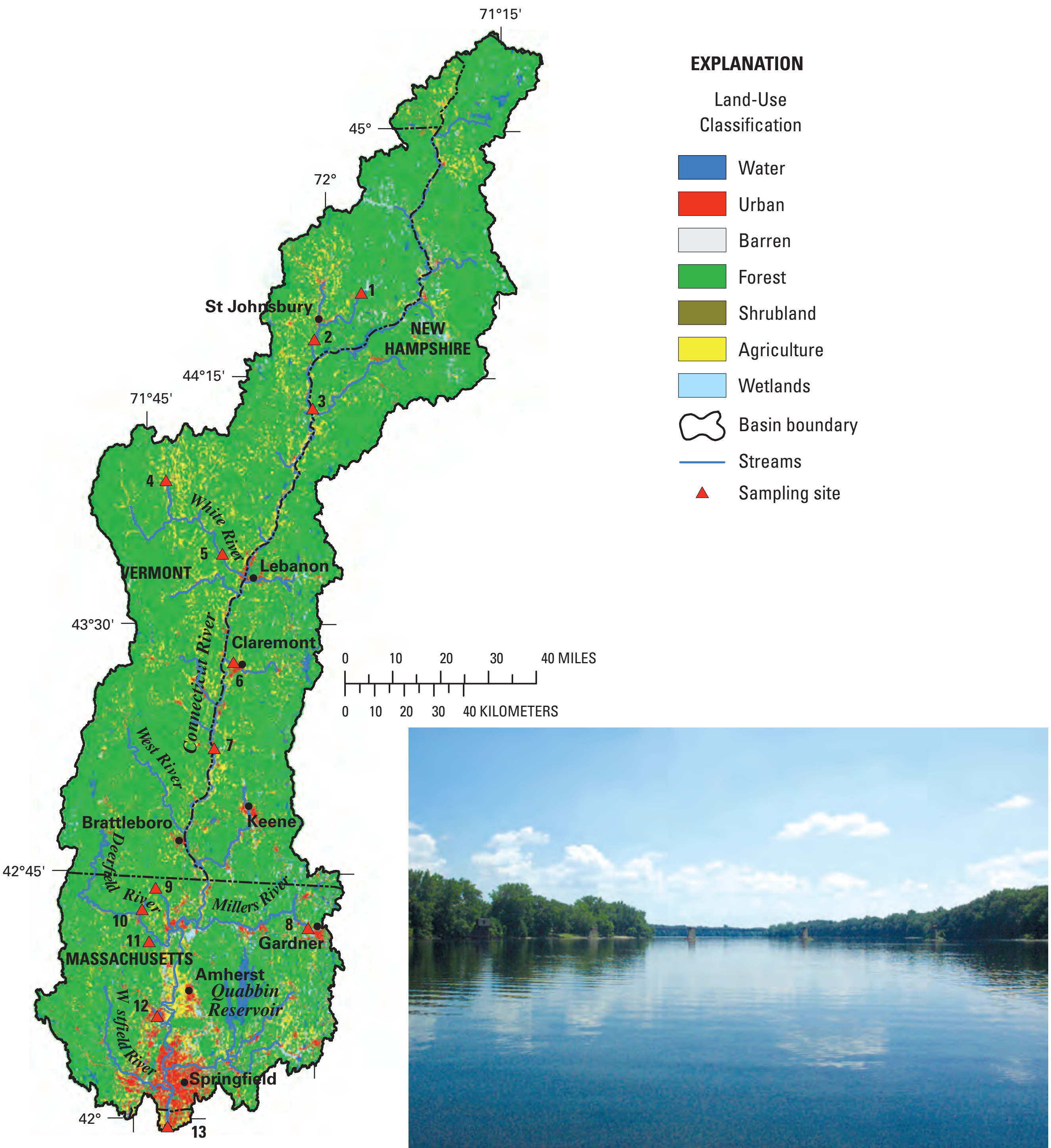
The minimum concentration of dissolved oxygen was 6.7 mg/L and was within the Connecticut water-quality criterion for dissolved oxygen (Connecticut Department of Environmental Protection, 2002). Concentrations of selected water-quality constituents were plotted relative to streamflow (fig. 52). Concentrations of dissolved nitrite plus nitrate ranged from less than 0.126 to 0.632 mg/L and showed a slight dilution relative to streamflow except at extreme high streamflows (fig. 52A). Total ammonia plus organic nitrogen ranged from 0.22 to 0.46 mg/L and showed no apparent relation to streamflow (fig. 52B). Concentrations of total nitrogen ranged from 0.44 to 1.0 mg/L (fig. 52C). Concentrations of total phosphorus ranged from 0.021 to 0.122 mg/L (fig. 52D). The maximum concentration of total phosphorus was observed at the maximum streamflow at which samples were collected. This sample also had the greatest concentration of suspended sediment (135 mg/L) relative to the other samples. Instantaneous loads of total nitrogen ranged from 14,300 to 288,000 lb/d (fig. 52E). Ranges of concentrations or values for water-quality constituents not shown in figure 52 are listed below.

Water-quality constituent[a]	<, less than; —, not calculated			
	Minimum	Mean	Median	Maximum
Specific conductance	85	142	141	230
pH	6.8	7.4	7.4	7.7
Water temperature	.0	13.3	14.5	27
Dissolved oxygen	6.7	10.7	10.4	14.6
Dissolved nitrite	<.004	—	.007	.031
Dissolved ammonia	.020	.057	.041	.227
Dissolved orthophosphate (WY 2003–04)	<.01	—	<.01	.094
Suspended sediment	1	12	3	135

[a]All constituents are reported as milligrams per liter except for specific conductance, which is reported as microsiemens per centimeter at 25 degrees Celsius; pH, which is reported as standard units; and water temperature, which is reported as degrees Celsius; WY, water year.

The estimated load of total nitrogen varied among years during the study period (appendix A-1; fig. 53A). The mean annual load of total nitrogen was 21,600,000 lb/yr with a ratio of the standard error of prediction to the mean load of 3.0 percent (table 2, fig. 53A). An estimated 41 percent of the total nitrogen load was transported during the spring (appendix A-2). The mean load estimate at this site represents the cumulative load of total nitrogen leaving the upper Connecticut River Basin. The mean yield of total nitrogen (2,230 $lb/mi^2/yr$) was greater than the yield at other main-stem sites and at most agricultural and urban sites (fig. 53B).

Connecticut River at Thompsonville, CT, Station 01184000



Land-use data from U.S. Geological Survey, 1992 National Land Cover Dataset, 2000

Photograph courtesy of John Mullaney, U.S. Geological Survey

Figure 50. Location, land-use classification, and photograph of sampling site for Connecticut River at Thompsonville, CT, station 01184000. (Refer to table 1 and figure 1 for additional site information.)

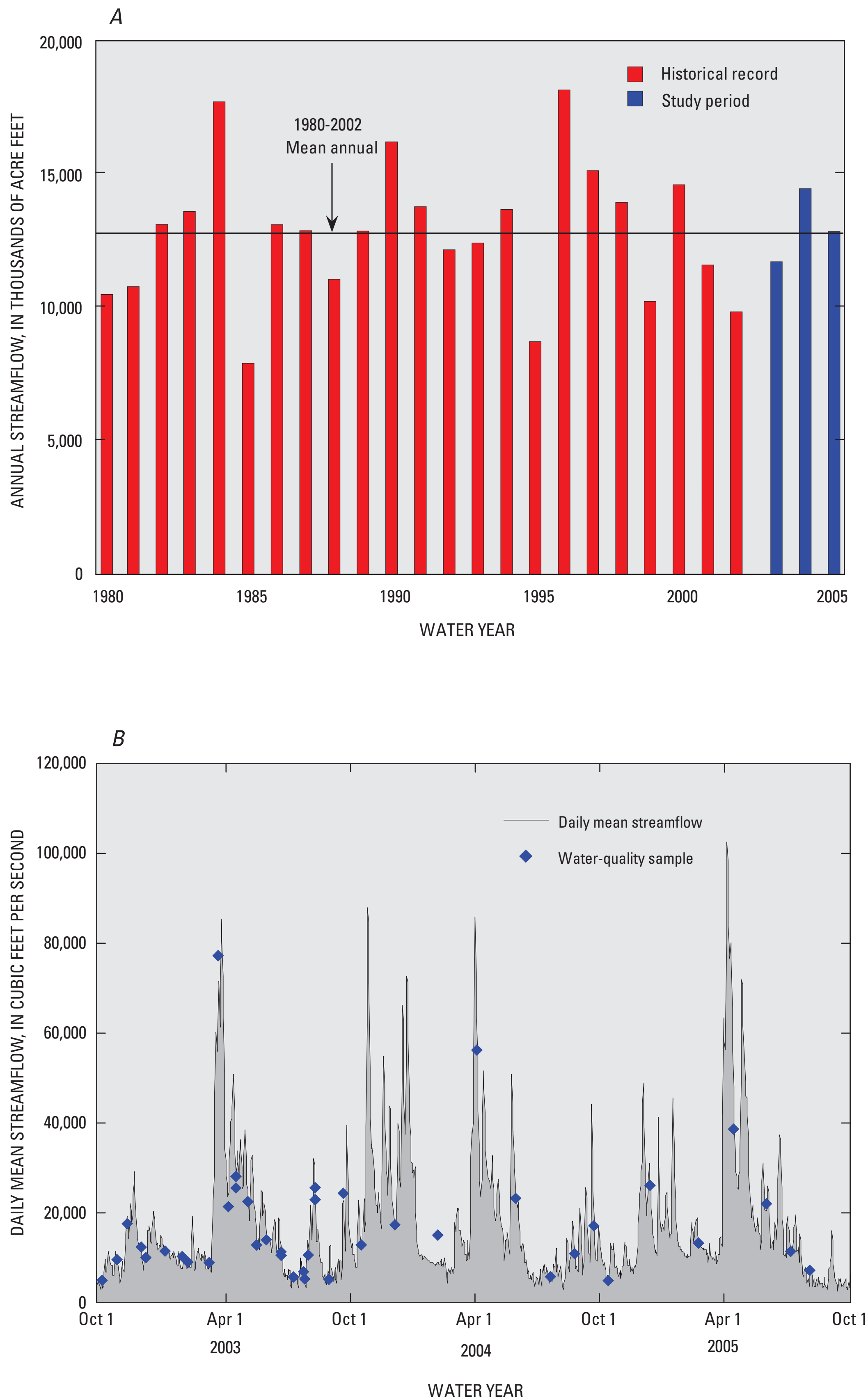


Figure 51. *A*, Historical and study-period annual streamflow, and *B*, Daily mean streamflow and time distribution of water-quality samples for Connecticut River at Thompsonville, CT, station 01184000.

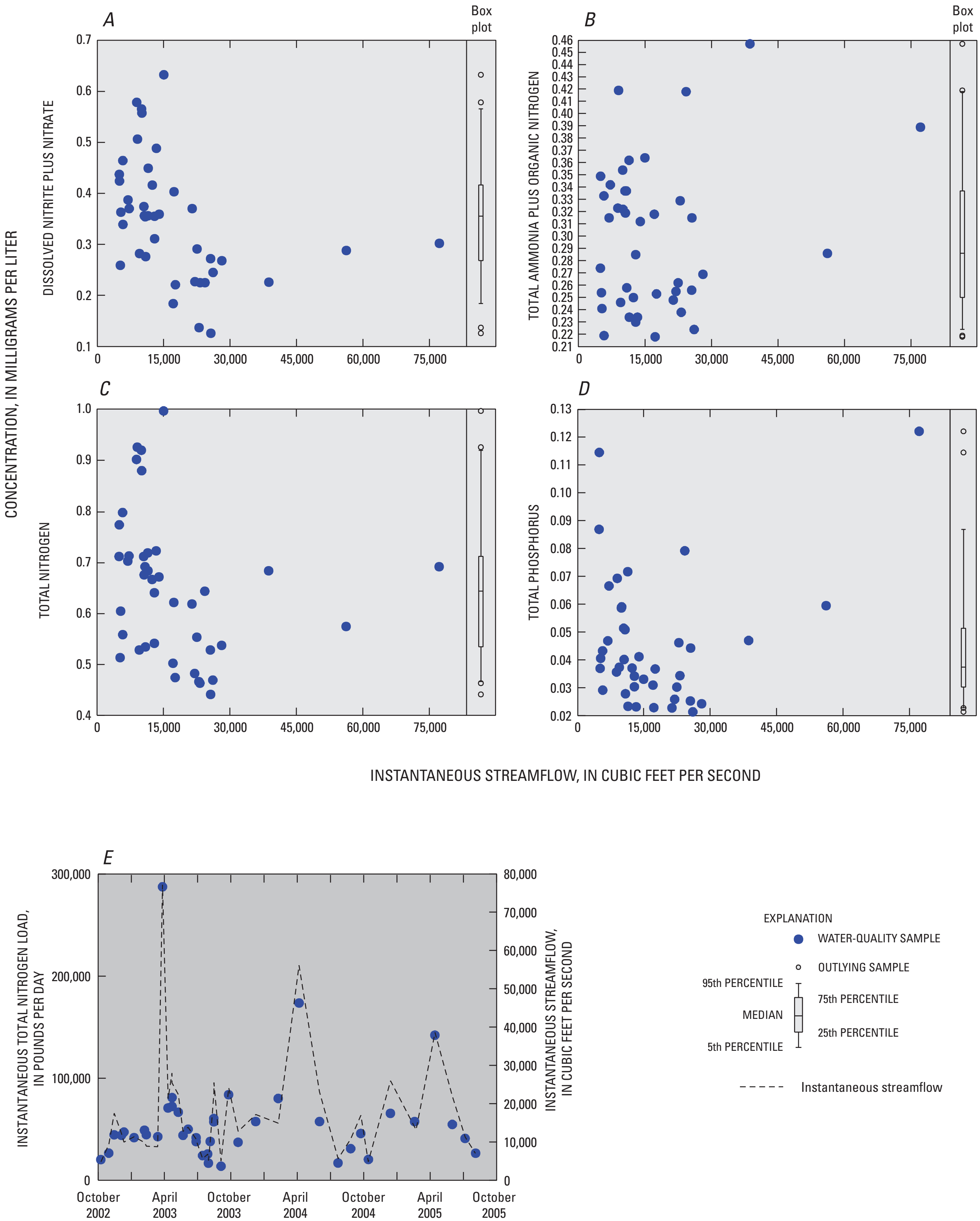


Figure 52. Distribution of *A*, Dissolved nitrite plus nitrate, *B*, Total ammonia plus organic nitrogen, *C*, Total nitrogen, *D*, Total phosphorus concentrations relative to streamflow, and *E*, Instantaneous total nitrogen load relative to time for Connecticut River at Thompsonville, CT, station 01184000. (Refer to table 1 and figure 1 for station location.)

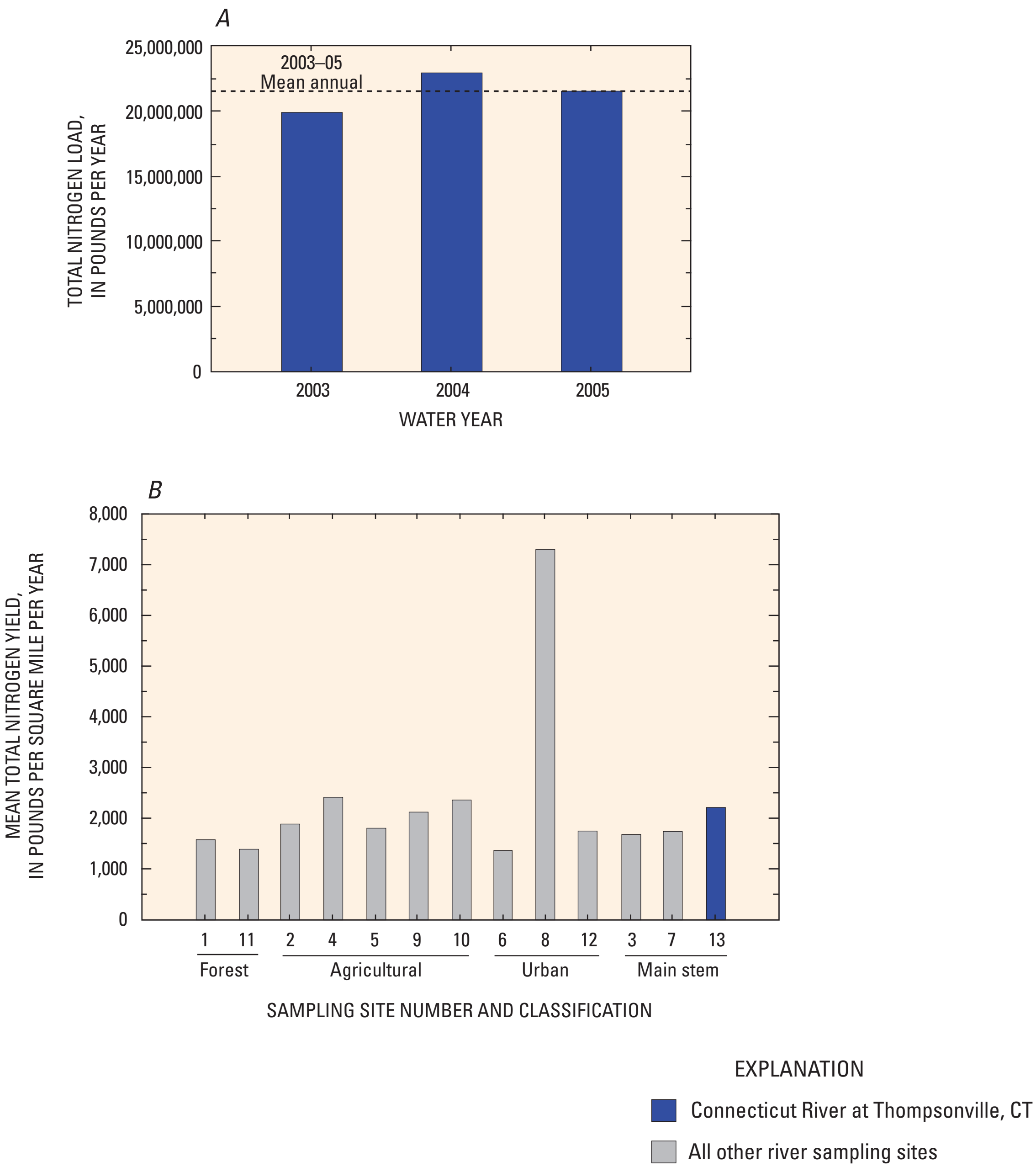


Figure 53. *A*, Total nitrogen load, by year, and *B*, Mean annual total nitrogen yield (2003–05) for Connecticut River at Thompsonville, CT, station 01184000, in relation to all other river sampling sites. (Refer to table 1 and figure 1 for site names and locations.)

Characterization of Total Nitrogen at Wastewater-Treatment Sampling Sites

Data collected for this study were used to characterize the spatial distribution and variability of total nitrogen among 19 wastewater-treatment sampling sites. Sixteen sampling sites were located at municipal wastewater-treatment facilities. Three sampling sites were located at paper mill wastewater-treatment facilities. Summary statistics concentrations and instantaneous loads of total nitrogen are listed in table 3.

Mean concentrations of total nitrogen ranged from 4.4 to 30 mg/L at wastewater-treatment sampling sites (table 3; fig. 54A). The concentrations of dissolved nitrite plus nitrate and total ammonia plus organic nitrogen, the constituents, which are summed to calculate total nitrogen, varied among wastewater-treatment sampling sites (fig. 54A). Ranges in mean concentrations of total nitrogen at wastewater-treatment sampling sites (4.4 to 30 mg/L) were greater than the ranges in mean concentrations of total nitrogen at river sampling sites (0.19 to 2.8 mg/L).

Instantaneous mean loads of total nitrogen from municipal wastewater-treatment sampling sites ranged from 36 to 1,780 lb/d (table 3; fig. 54B). Instantaneous mean loads of total nitrogen at the three paper mill wastewater-treatment sampling sites ranged from 96 to 160 lb/d (table 3; fig. 54B). Based on the sites and data for this study, the paper mill wastewater-treatment facilities were contributing less total nitrogen load than the municipal wastewater-treatment facilities.

Table 3. Selected characteristics and summary statistics for concentrations of total nitrogen and instantaneous loads of total nitrogen for the wastewater-treatment sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[USGS, U.S. Geological Survey; ft^3/s, cubic feet per second; mg/L, milligrams per day; lb/d, pounds per day; Min, minimum; Max, maximum; WWTF, wastewater-treatment facility]

Site number (fig. 1)	USGS station number	Station name	Number of samples	Mean instantaneous flow (ft^3/s)	Total nitrogen (mg/L)			Instantaneous total nitrogen load (lb/d)		
					Min	Mean	Max	Min	Mean	Max
14[a]	443558071303001	Wasau Paper WWTF, NH	12	7.1	1.1	4.4	16	44	160	521
15	442906071354401	Lancaster WWTF, NH	10	2.1	4.7	8.8	13	38	106	221
16	442436072010001	St, Johnsbury WWTF, VT	19	2.3	4.5	12	21	54	146	318
17	441827071473701	Littleton WWTF, NH	10	1.7	3.3	10	18	31	88	131
18	440835072022501	Woodsville WWTF, NH	13	0.4	4.6	16	59	4	36	119
19	434145072175601	Hanover WWTF, NH	17	3.1	19	30	38	201	498	697
20	433844072185501	Hartford/White River Junction WWTF, VT	10	1.7	23	30	35	130	267	376
21	433813072192001	Lebanon WWTF, NH	17	3.4	12	19	29	194	346	658
22	432359072234001	Claremont WWTF, NH	14	2.5	4.1	14	22	55	185	330
23	431648072280801	Springfield WWTF, VT	14	2.1	8.4	12	21	57	145	293
24	430745072263701	Bellows Falls WWTF, VT	10	1.4	12	21	32	73	147	262
25[a]	425322072323701	Fibermark Products WWTF, VT	10	2.5	2.3	7.3	11	31	96	150
26	425029072325901	Brattleboro WWTF, VT	12	3.2	13	20	35	200	330	636
27[a]	423542072031001	Seaman Paper WWTF, MA	11	1.4	3.3	14	50	21	97	262
28	423413072011201	Gardner WWTF, MA	10	6.2	9.5	22	28	478	702	914
29	421132072365001	Holyoke WWTF, MA	11	12.8	1.9	5.6	12	150	339	621
30	420908072373301	Chicopee WWTF, MA	15	17.3	13	18	24	1,080	1,640	5,330
31	420702072435601	Westfield WWTF, MA	11	6.4	13	19	26	500	654	822
32	420508072351401	Springfield WWTF, MA	14	66.5	3.2	5.0	6.3	1,290	1,780	2,150

[a] Paper mill.

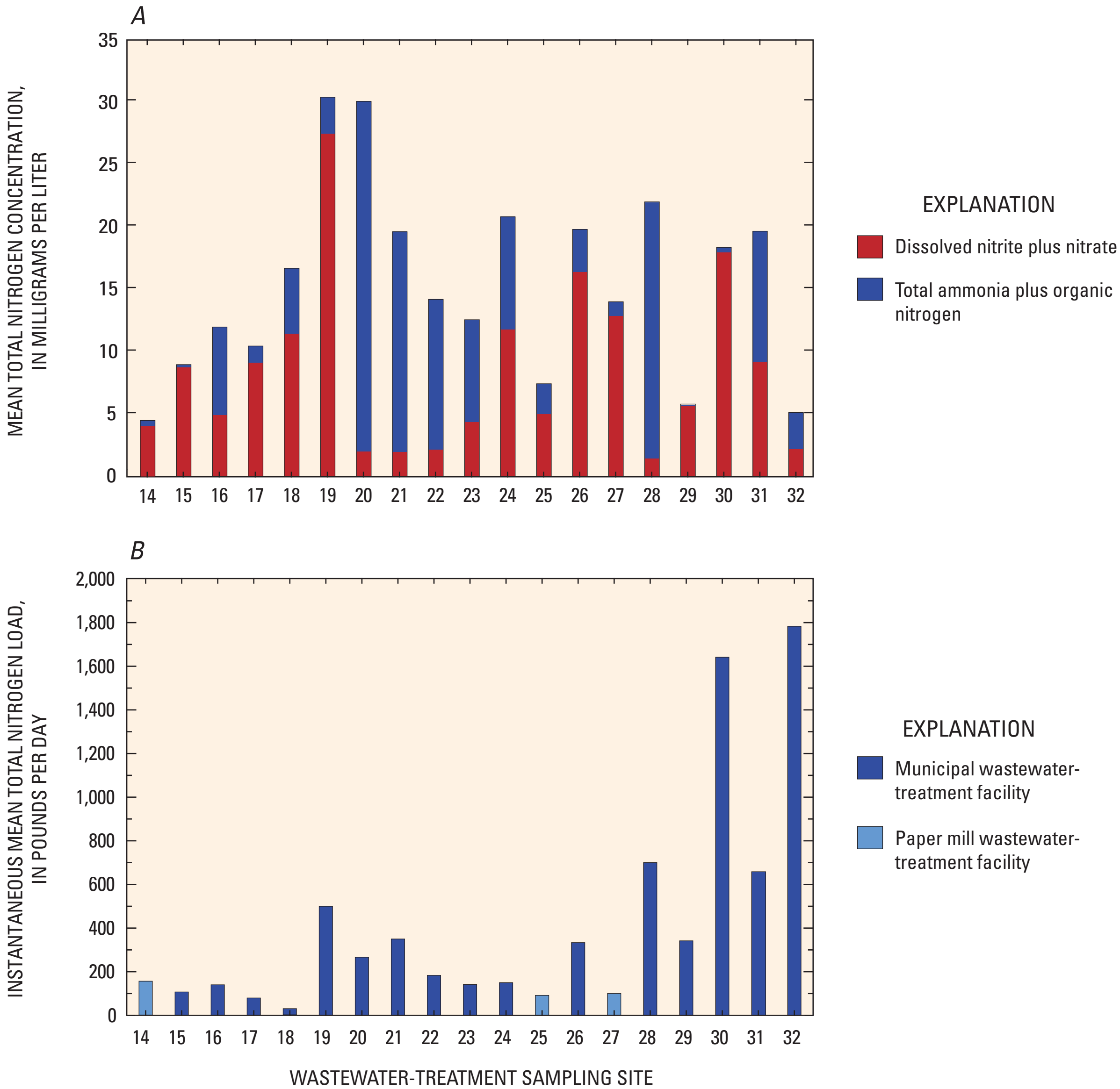


Figure 54. *A*, Mean total nitrogen concentration, and *B*, Instantaneous mean total nitrogen load for wastewater-treatment sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts. (Refer to table 1 and figure 1 for site names and locations.)

Comparison of Total Nitrogen Concentrations and Yields Among Site Types

The sampling sites were grouped to compare concentrations and yields of total nitrogen among site types. The five site types were forested, agricultural, urban, main stem, and wastewater treatment. Forest was the predominant land use at all sites in the basin. Sites that were selected to represent agricultural and urban land use in this study generally had agriculture and urban land use as the second predominant land use in the basin.

The median concentration of total nitrogen was 0.24 mg/L at forested sites, 0.48 mg/L at agricultural sites, 0.54 mg/L at urban sites, 0.48 mg/L at main-stem sites, and 14 mg/L at wastewater-treatment sites (fig. 55). Comparison of concentrations of total nitrogen among the site types indicated significant differences. Concentrations of total nitrogen at forested sites were significantly less than at all other site types ($p<0.05$). Concentrations of total nitrogen at agricultural, urban, and main-stem sites were not significantly different among each other ($p>0.05$), but were significantly greater ($p<0.05$) than at forested sites and significantly less than concentrations at wastewater-treatment sites ($p<0.05$). Concentrations of total nitrogen at wastewater-treatment sites were significantly different from those at all other site types ($p<0.05$).

Nitrogen yields at forested sites generally were less than yields at agricultural and urban sites; however, nitrogen yields at agricultural sites generally were greater than yields at urban sites. Annual yields of total nitrogen ranged from 732 to 1,920 $(lb/mi^2)/yr$ at forested sites; 1,550 to 2,980 $(lb/mi^2)/yr$ at agricultural sites; 1,280 to 1,860 $(lb/mi^2)/yr$ at urban sites that were not directly affected by wastewater effluent; 7,090 to 7,700 $(lb/mi^2)/yr$ at a urban site directly affected by wastewater effluent; and 1,300 to 2,390 $(lb/mi^2)/yr$ at main-stem sites (appendix A-1).

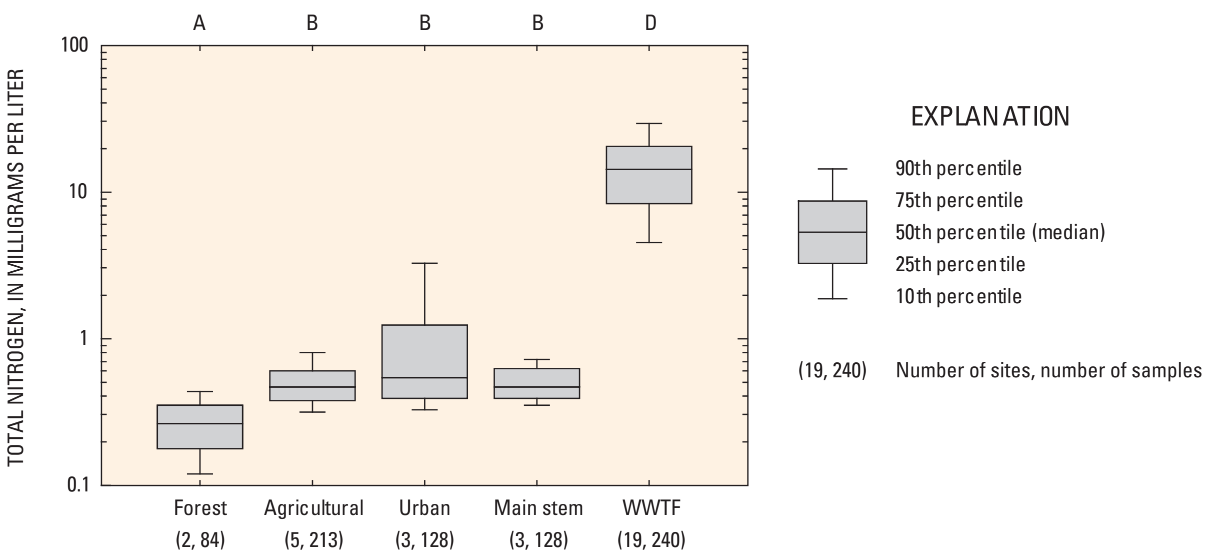


Figure 55. Total nitrogen concentrations among site types in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts. (WWTF, wastewater-treatment facility; results of Tukey's multiple comparison test [Helsel and Hirsch, 1992] among sites are presented as letters, and concentrations with at least one letter in common do not differ significantly.)

Summary and Conclusions

Low concentrations (less than 3.5 milligrams per liter (mg/L)) of dissolved oxygen (hypoxia) caused by nitrogen enrichment often occur during the summer in the western part of Long Island Sound (LIS). Excess nitrogen levels lead to the enhanced growth of algae, which eventually die and decay, consuming oxygen in the process. The ensuing hypoxic conditions have resulted in the exceedance of dissolved-oxygen water-quality standards in Long Island Sound (LIS) during the summer. As a result, Connecticut and New York developed a Total Maximum Daily Load (TMDL) for dissolved oxygen that specifies the maximum amount of nitrogen that can be discharged to LIS without exceeding water-quality standards for dissolved oxygen. According to the TMDL analysis, an annual baseline load of about 53,300 tons of nitrogen is delivered to LIS from all sources in Connecticut and New York combined. An additional estimated 13,600 tons of nitrogen reach LIS annually from the portion of the watershed originating north of Connecticut. Of this total load, an estimated 12,500 tons of nitrogen are delivered to LIS by way of the Connecticut River.

To better define loads in the upper Connecticut River Basin, the U.S. Geological Survey (USGS), in cooperation with the New England Interstate Water Pollution Control Commission, designed and operated a surface-water quality monitoring network from December 2002 to September 2005 to collect water-quality and streamflow data and to use these data to determine the current concentrations, loads, and yields of nitrogen from selected sites in the upper Connecticut River Basin.

A study was conducted at 13 river sites in the upper Connecticut River Basin. Ten sites were selected to represent contributions of nitrogen from forested, agricultural, and urban land. Forest was the predominant land use at all sites in the basin. Sites that were selected to represent agricultural and urban land use in this study generally had agriculture and urban land use as the second predominant land use in the basin. Three sites were distributed spatially on the main stem of Connecticut River to assess the cumulative loads of total nitrogen. To further improve the understanding the sources and concentrations and loads of total nitrogen in the upper Connecticut River Basin, ambient water-quality sampling at river sites was supplemented with sampling and analysis of effluent from wastewater treatment at 19 municipal and paper mill wastewater-treatment facilities.

Mean concentrations of total nitrogen ranged from 0.19 to 2.8 milligrams per liter (mg/L) at river sampling sites. Instantaneous mean loads of total nitrogen ranged from 162 to 58,300 pounds per day (lb/d). Estimated mean annual loads of total nitrogen at river sampling sites ranged from 49,100 to 21.6 million pounds per year (lb/yr) with about 30 to 55 percent being transported during the spring. The estimated mean annual yields of total nitrogen ranged from 1,190 to 7,300 pounds per square mile per year (lb/mi^2)/yr.

Mean concentrations of total nitrogen ranged from 4.4 to 30 mg/L at wastewater-treatment sampling sites. Instantaneous mean loads of total nitrogen from municipal wastewater-treatment facilities ranged from 36 to 1,780 lb/d. Instantaneous mean loads of total nitrogen from three paper mill wastewater-treatment facilities ranged from 96 to 160 lb/d.

Sampling sites were grouped to compare concentrations and yields of total nitrogen among forested, agricultural, urban, main stem, and wastewater-treatment site types. The median concentration of total nitrogen was 0.24 mg/L at forested sites, 0.48 mg/L at agricultural sites, 0.54 mg/L at urban sites, 0.48 mg/L at main-stem sites, and 14 mg/L at wastewater-treatment sites. Concentrations of total nitrogen at forested sites were significantly less than at all other site types ($p<0.05$). Concentrations of total nitrogen at agricultural, urban, and main-stem sites were not significantly different among each other ($p>0.05$) but were significantly greater ($p<0.05$) than at forested sites and significantly less than concentrations at wastewater-treatment sites ($p<0.05$). Concentrations of total nitrogen at wastewater-treatment sites were significantly different from all other site types ($p<0.05$).

Nitrogen yields at forested sites generally were less than yields at agricultural and urban sites; however, nitrogen yields at agricultural sites generally were greater than yields at urban sites. Annual yields of total nitrogen ranged from 732 to 1,920 (lb/mi^2)/yr at forested sites; 1,550 to 2,980 (lb/mi^2)/yr at agricultural sites; 1,280 to 1,860 (lb/mi^2)/yr at urban sites that were not directly affected by wastewater effluent; 7,090 to 7,700 (lb/mi^2)/yr at a urban site directly affected by wastewater effluent; and 1,300 to 2,390 (lb/mi^2)/yr at main-stem sites.

In this study, the mean annual load and yield of total nitrogen at the Connecticut River at Wells River, VT, was estimated at 4.47 million lb/yr and 1,690 (lb/mi^2)/yr, respectively. The mean annual load and yield of total nitrogen at the Connecticut River at North Walpole, NH, was estimated at 9.60 million lb/yr and 1,750 (lb/mi^2)/yr, respectively. The mean annual load and yield of total nitrogen leaving the upper Connecticut River Basin, as estimated at the Connecticut River at Thompsonville, CT, was 21.6 million lb/yr and 2,230 (lb/mi^2)/yr, respectively.

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Appendix A: Supplemental Data

Table A-1. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/yr, pounds per year; (lb/mi^2)/yr, pounds per square mile per year]

Site number (table 1; fig. 1)	USGS station number	Water year	Station name	Mean streamflow (in thousands of acre-feet)	Total nitrogen Load (lb/yr)	Total nitrogen Yield (lb/mi^2)/yr	Total nitrogen 95-percent confidence interval Lower (lb/yr)	Total nitrogen 95-percent confidence interval Upper (lb/yr)	Total phosphorus Load (lb/yr)	Total phosphorus Yield (lb/mi^2)/yr	Total phosphorus 95-percent confidence interval Lower (lb/yr)	Total phosphorus 95-percent confidence interval Upper (lb/yr)
1	01134500	2003	Moose River at Victory, VT	87	106,000	1,410	91,300	122,000	6,500	86	3,910	10,200
1	01134500	2004	Moose River at Victory, VT	126	145,000	1,920	129,000	162,000	9,640	128	6,310	14,100
1	01134500	2005	Moose River at Victory, VT	109	113,000	1,500	96,800	130,000	8,790	117	5,690	13,000
2	01135500	2003	Passumpsic River at Passumpsic, VT	453	677,000	1,550	625,000	733,000	45,900	105	30,900	65,800
2	01135500	2004	Passumpsic River at Passumpsic, VT	672	981,000	2,250	881,000	1,090,000	92,200	211	66,500	124,000
2	01135500	2005	Passumpsic River at Passumpsic, VT	538	808,000	1,850	740,000	880,000	86,600	199	57,600	125,000
3	01138500	2003	Connecticut River at Wells River, VT	2,769	3,400,000	1,300	3,290,000	3,610,000	172,000	65	137,000	212,000
3	01138500	2004	Connecticut River at Wells River, VT	4,326	5,400,000	2,040	5,100,000	5,680,000	274,000	104	217,000	342,000
3	01138500	2005	Connecticut River at Wells River, VT	3,594	4,600,000	1,720	4,340,000	4,780,000	258,000	98	202,000	325,000
4	01142500	2003	Ayers Brook at Randolph, VT	30	56,600	1,860	51,600	61,900	6,130	201	3,800	9,380
4	01142500	2004	Ayers Brook at Randolph, VT	46	90,800	2,980	83,100	99,100	20,500	672	11,600	33,600
4	01142500	2005	Ayers Brook at Randolph, VT	38	77,200	2,530	69,100	85,900	94,500	3,100	32,100	218,000
5	01144000	2003	White River at West Hartford, VT	837	1,160,000	1,680	1,080,000	1,250,000	170,000	246	96,600	277,000
5	01144000	2004	White River at West Hartford, VT	1,135	1,390,000	2,020	1,310,000	1,480,000	231,000	334	153,000	333,000
5	01144000	2005	White River at West Hartford, VT	904	1,240,000	1,800	1,140,000	1,350,000	651,000	943	247,000	1,410,000

Table A-1. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.—Continued

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/yr, pounds per year; (lb/mi^2)/yr, pounds per square mile per year]

Site number (table 1; fig. 1)	USGS station number	Water year	Station name	Mean streamflow (in thousands of acre-feet)	Total nitrogen				Total phosphorus			
					Load (lb/yr)	Yield (lb/mi^2)/yr	95-percent confidence interval Lower (lb/yr)	95-percent confidence interval Upper (lb/yr)	Load (lb/yr)	Yield (lb/mi^2)/yr	95-percent confidence interval Lower (lb/yr)	95-percent confidence interval Upper (lb/yr)
6	01152500	2003	Sugar River at West Claremont, NH	285	344,000	1,280	307,000	384,000	24,100	90	18,300	31,000
6	01152500	2004	Sugar River at West Claremont, NH	380	397,000	1,480	362,000	435,000	28,300	105	22,800	34,700
6	01152500	2005	Sugar River at West Claremont, NH	356	376,000	1,400	335,000	419,000	26,100	97	19,000	34,900
7	01154500	2003	Connecticut River at North Walpole, NH	5,756	7,800,000	1,410	7,200,000	8,340,000	437,000	79	349,000	539,000
7	01154500	2004	Connecticut River at North Walpole, NH	8,475	11,400,000	2,070	10,200,000	12,600,000	751,000	137	604,000	921,000
7	01154500	2005	Connecticut River at North Walpole, NH	6,990	9,760,000	1,780	8,960,000	10,600,000	692,000	126	535,000	881,000
8	01163200	2003	Otter River at Otter River, MA	51	242,000	7,090	224,000	261,000	14,400	422	11,700	17,400
8	01163200	2004	Otter River at Otter River, MA	50	243,000	7,130	224,000	263,000	14,500	425	11,700	17,700
8	01163200	2005	Otter River at Otter River, MA	59	262,000	7,700	241,000	285,000	16,000	469	12,800	19,700
9	01169000	2003	North River at Shattuckville, MA	145	189,000	2,120	161,000	221,000	12,300	138	8,690	16,800
9	01169000	2004	North River at Shattuckville, MA	190	221,000	2,480	187,000	258,000	25,700	289	11,100	51,100
9	01169000	2005	North River at Shattuckville, MA	167	173,000	1,940	142,000	207,000	24,800	278	9,380	53,700
10	01169900	2003	South River near Conway, MA	43	55,800	2,320	50,300	61,800	2,770	115	1,430	4,850
10	01169900	2004	South River near Conway, MA	53	57,800	2,400	52,100	64,000	5,480	227	1,730	13,200
10	01169900	2005	South River near Conway, MA	48	47,400	1,970	41,700	53,700	6,190	257	1,600	16,700

Table A-1. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.—Continued

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/yr, pounds per year; (lb/mi^2)/yr, pounds per square mile per year]

Site number (table 1; fig. 1)	USGS station number	Water year	Station name	Mean streamflow (in thousands of acre-feet)	Total nitrogen				Total phosphorus			
					Load (lb/yr)	Yield (lb/mi^2)/yr	95-percent confidence interval Lower (lb/yr)	95-percent confidence interval Upper (lb/yr)	Load (lb/yr)	Yield (lb/mi^2)/yr	95-percent confidence interval Lower (lb/yr)	95-percent confidence interval Upper (lb/yr)
11	01170100	2003	Green River near Colrain, MA	70	54,200	1,310	43,300	67,000	1,980	48	1,280	2,940
11	01170100	2004	Green River near Colrain, MA	89	62,800	1,520	47,800	80,900	3,770	91	1,750	7,140
11	01170100	2005	Green River near Colrain, MA	65	30,300	732	24,300	37,500	1,500	36	876	2,370
12	01171500	2003	Mill River at Northhampton, MA	82	100,000	1,860	93,400	108,000	2,810	52	2,370	3,360
12	01171500	2004	Mill River at Northhampton, MA	92	98,500	1,820	92,200	105,000	3,480	64	2,860	4,200
12	01171500	2005	Mill River at Northhampton, MA	91	87,600	1,620	80,700	95,300	3,650	68	2,850	4,710
13	01184000	2003	Connecticut River at Thompsonville, CT	11,653	20,000,000	2,070	18,800,000	21,200,000	1,540,000	159	1,280,000	1,840,000
13	01184000	2004	Connecticut River at Thompsonville, CT	14,398	23,100,000	2,390	21,600,000	24,700,000	1,980,000	205	1,580,000	2,430,000
13	01184000	2005	Connecticut River at Thompsonville, CT	12,805	21,600,000	2,240	20,300,000	23,000,000	1,860,000	192	1,450,000	2,350,000

Table A-2. Estimates of seasonal total nitrogen load for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/season, pounds per season; (lb/mi^2)/season, pounds per square mile per season; Winter, December–February; Spring, March–May; Summer, June–August; Fall, September–November]

Site number (table 1, fig. 1)	USGS station number	Season	Total nitrogen load (lb/season)	Percent of load	Total nitrogen yield (lb/mi^2)/season	Lower 95th percent confidence interval	Upper 95th percent confidence interval	Standard error of prediction
				Moose River at Victory, VT				
1	01134500	Winter	74,300	15	988	67,300	81,800	3,700
1	01134500	Spring	228,000	47	3,040	201,000	258,000	14,700
1	01134500	Summer	70,100	15	932	62,800	77,900	3,850
1	01134500	Fall	110,000	23	1,460	97,200	124,000	6,880
				Passumpsic River at Passumpsic, VT				
2	01135500	Winter	758,000	23	1,740	669,000	857,000	47,800
2	01135500	Spring	1,580,000	48	3,620	1,420,000	1,740,000	82,500
2	01135500	Summer	385,000	12	882	342,000	431,000	22,600
2	01135500	Fall	561,000	17	1,290	468,000	668,000	51,100
				Connecticut River at Wells River, VT				
3	01138500	Winter	4,130,000	23	1,560	3,840,000	4,430,000	150,000
3	01138500	Spring	7,950,000	45	3,000	7,460,000	8,440,000	249,000
3	01138500	Summer	2,550,000	14	959	2,370,000	2,710,000	8,100
3	01138500	Fall	3,230,000	18	1,220	2,950,000	3,500,000	141,000
				Ayers Brook at Randolph, VT				
4	01142500	Winter	68,600	23	2,250	62,800	74,800	3,060
4	01142500	Spring	151,000	51	4,970	138,000	166,000	7,060
4	01142500	Summer	24,100	8	789	22,100	26,100	1,030
4	01142500	Fall	54,700	18	1,790	47,900	62,300	3,680
				White River at West Hartford, VT				
5	01144000	Winter	1,100,000	22	1,600	1,020,000	1,190,000	43,400
5	01144000	Spring	2,760,000	55	3,990	2,560,000	2,970,000	104,000
5	01144000	Summer	435,000	9	631	401,000	472,000	18,300
5	01144000	Fall	756,000	15	1,100	682,000	835,000	39,100
				Sugar River at West Claremont, NH				
6	01152500	Winter	356,000	24	1,320	316,000	399,000	21,200
6	01152500	Spring	727,000	49	2,700	654,000	805,000	38,300
6	01152500	Summer	179,000	12	665	159,000	200,000	10,500
6	01152500	Fall	224,000	15	834	193,000	260,000	17,200
				Connecticut River at North Walpole, NH				
7	01154500	Winter	8,960,000	24	1,630	7,990,000	10,000,000	533,000
7	01154500	Spring	18,500,000	47	3,370	16,700,000	20,400,000	946,000
7	01154500	Summer	4,520,000	12	820	4,100,000	4,900,000	232,000
7	01154500	Fall	6,540,000	18	1,190	5,550,000	7,650,000	536,000

Table A-2. Estimates of seasonal total nitrogen load for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.—Continued

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/season, pounds per season; (lb/mi^2)/season, pounds per square mile per season; Winter, December–February; Spring, March–May; Summer, June–August; Fall, September–November]

Site number (table 1, fig. 1)	USGS station number	Season	Total nitrogen load (lb/season)	Percent of load	Total nitrogen yield (lb/mi^2)/season	Lower 95th percent confidence interval	Upper 95th percent confidence interval	Standard error of prediction
Otter River at Otter River, MA								
8	01163200	Winter	257,000	26	7,530	226,000	290,000	16,300
8	01163200	Spring	293,000	29	8,600	263,000	326,000	16,200
8	01163200	Summer	212,000	22	6,210	189,000	236,000	12,100
8	01163200	Fall	234,000	23	6,860	202,000	269,000	17,100
North River at Shattuckville, MA								
9	01169000	Winter	169,000	22	1,900	151,000	190,000	9,890
9	01169000	Spring	331,000	43	3,720	267,000	404,000	35,000
9	01169000	Summer	93,000	12	1,050	83,700	103,000	4,970
9	01169000	Fall	182,000	23	2,050	159,000	209,000	12,800
South River near Conway, MA								
10	01169900	Winter	66,700	31	2,770	59,800	74,100	3,620
10	01169900	Spring	84,200	39	3,490	74,500	94,700	5,160
10	01169900	Summer	20,600	10	856	18,500	22,900	1,120
10	01169900	Fall	43,200	20	1,790	37,200	49,900	3,230
Green River near Colrain, MA								
11	01170100	Winter	39,000	20	943	33,600	45,100	2,930
11	01170100	Spring	92,200	47	2,230	68,300	122,000	13,700
11	01170100	Summer	17,000	9	410	14,900	19,200	1,090
11	01170100	Fall	47,800	24	1,150	38,800	58,100	4,940
Mill River at Northhampton, MA								
12	01171500	Winter	120,000	31	2,220	111,000	130,000	4,710
12	01171500	Spring	141,000	37	2,610	130,000	152,000	5,520
12	01171500	Summer	43,700	11	810	40,600	47,000	1,630
12	01171500	Fall	78,300	20	1,450	70,500	86,800	4,170
Connecticut River at Thompsonville, CT								
13	01184000	Winter	22,900,000	27	2,370	20,900,000	25,000,000	1,040,000
13	01184000	Spring	35,100,000	41	3,640	32,200,000	38,300,000	1,580,000
13	01184000	Summer	12,600,000	15	1,300	11,700,000	13,500,000	448,000
13	01184000	Fall	15,600,000	18	1,610	14,200,000	17,000,000	726,000

Table A-3. Estimates of seasonal total phosphorus load for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/season, pounds per season; (lb/mi^2)/season, pounds per square mile per season; Winter, December–February; Spring, March–May; Summer, June–August; Fall, September–November]

Site number (table 1, fig. 1)	USGS station number	Season	Total phosphorus load (lb/season)	Percent of load	Total phosphorus yield (lb/mi^2)/season	Lower 95th percent confidence interval	Upper 95th percent confidence interval	Standard error of prediction
				Moose River at Victory, VT				
1	01134500	Winter	3,300	10	44	2,510	4,260	445
1	01134500	Spring	17,700	53	235	11,100	26,900	4,070
1	01134500	Summer	3,730	11	50	2,710	5,010	588
1	01134500	Fall	8,390	25	112	4,740	13,800	2,330
				Passumpsic River at Passumpsic, VT				
2	01135500	Winter	46,500	16	107	34,300	61,600	7,000
2	01135500	Spring	161,000	54	369	110,000	227,000	30,000
2	01135500	Summer	27,900	9	64	22,400	34,300	3,060
2	01135500	Fall	63,500	21	146	41,900	92,200	12,900
				Connecticut River at Wells River, VT				
3	01138500	Winter	168,000	18	64	126,000	220,000	23,900
3	01138500	Spring	534,000	57	202	408,000	688,000	71,500
3	01138500	Summer	102,000	11	39	76,600	134,000	14,600
3	01138500	Fall	130,000	14	49	88,100	186,000	25,100
				Ayers Brook at Randolph, VT				
4	01142500	Winter	6,630	4	217	4,050	10,200	1,590
4	01142500	Spring	135,000	84	4,410	48,900	299,000	65,700
4	01142500	Summer	770	1	25	610	960	91
4	01142500	Fall	18,600	11	610	8,960	34,400	6,580
				White River at West Hartford, VT				
5	01144000	Winter	114,000	8	166	60,300	198,000	35,500
5	01144000	Spring	1,120,000	80	1,620	499,000	2,170,000	433,000
5	01144000	Summer	22,200	2	32	16,800	28,700	3,040
5	01144000	Fall	141,000	10	204	86,200	218,000	33,900
				Sugar River at West Claremont, NH				
6	01152500	Winter	19,300	18	72	15,900	23,200	1,860
6	01152500	Spring	58,800	56	219	44,100	76,900	8,410
6	01152500	Summer	9,730	9	36	8,350	11,300	741
6	01152500	Fall	16,700	16	62	13,400	20,600	1,850
				Connecticut River at North Walpole, NH				
7	01154500	Winter	414,000	17	75	342,000	500,000	40,200
7	01154500	Spring	1,470,000	59	267	1,160,000	1,860,000	181,000
7	01154500	Summer	181,000	7	33	157,000	208,000	13,100
7	01154500	Fall	435,000	17	79	343,000	548,000	52,200

Table A-3. Estimates of seasonal total phosphorus load for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.—Continued

[Numbers have been independently rounded; USGS, U.S. Geological Survey; lb/season, pounds per season; (lb/mi^2)/season, pounds per square mile per season; Winter, December–February; Spring, March–May; Summer, June–August; Fall, September–November]

Site number (table 1, fig. 1)	USGS station number	Season	Total phosphorus load (lb/season)	Percent of load	Total phosphorus yield (lb/mi^2)/season	Lower 95th percent confidence interval	Upper 95th percent confidence interval	Standard error of prediction
				Otter River at Otter River, MA				
8	01163200	Winter	21,700	36	636	16,000	28,800	3,280
8	01163200	Spring	18,300	31	536	14,000	23,400	2,410
8	01163200	Summer	7,780	13	228	5,750	10,300	1,160
8	01163200	Fall	12,100	20	356	8,360	17,100	2,230
				North River at Shattuckville, MA				
9	01169000	Winter	8,340	10	94	5,540	12,100	1,670
9	01169000	Spring	54,100	65	608	20,500	117,000	25,300
9	01169000	Summer	6,770	8	76	4,820	9,260	1,140
9	01169000	Fall	14,100	17	158	7,260	24,800	4,520
				South River near Conway, MA				
10	01169900	Winter	2,460	13	102	1,330	4,170	734
10	01169900	Spring	12,500	65	518	3,270	33,500	8,100
10	01169900	Summer	832	4	35	533	1,240	183
10	01169900	Fall	3,420	18	142	1,220	7,670	1,690
				Green River near Colrain, MA				
11	01170100	Winter	1,120	12	27	745	1,640	230
11	01170100	Spring	5,290	55	128	2,380	10,200	2,040
11	01170100	Summer	628	7	15	456	840	99
11	01170100	Fall	2,600	27	63	1,370	4,480	803
				Mill River at Northhampton, MA				
12	01171500	Winter	3,020	23	56	2,530	3,570	266
12	01171500	Spring	5,500	41	102	4,060	7,300	829
12	01171500	Summer	1,710	13	32	1,470	1,970	128
12	01171500	Fall	3,100	23	58	2,420	3,920	383
				Connecticut River at Thompsonville, CT				
13	01184000	Winter	1,520,000	21	157	1,280,000	1,780,000	126,000
13	01184000	Spring	3,300,000	46	342	2,390,000	4,450,000	526,000
13	01184000	Summer	944,000	13	98	826,000	1,070,000	63,100
13	01184000	Fall	1,390,000	19	144	1,160,000	1,650,000	125,000

Table A-4. Regression equations for estimates of total nitrogen load and total phosphorus load for river sampling sites in the upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts.

[USGS, U.S. Geological Survey; ln, natural logarithm; Q, centered streamflow, in cubic feet per second; sin, sine; cos, cosine; π, pi; dtime, centered decimal time]

Site number (table 1, fig. 1)	USGS station number	Station name	Total nitrogen regression equations	Coefficient of determination (R^2)
1	01134500	Moose River at Victory, VT	$4.64 + 1.12 \ln(Q) – 0.09 (dtime)$	0.96
2	01135500	Passumpsic River at Passumpsic, VT	$6.69 + 1.02 \ln(Q) + 0.09 \ln(Q)^2 – 0.27 \sin(2\pi dtime) + 0.19 \cos(2\pi dtime)$	.97
3	01138500	Connecticut River at Wells River, VT	$8.60 + 1.07 \ln(Q) – 0.12 \sin(2\pi dtime) + 0.13 \cos(2\pi dtime)$	.98
4	01142500	Ayers Brook at Randolph, VT	$4.24 + 1.10 \ln(Q) + 0.19 \ln(Q)^2 – 0.27 \sin(2\pi dtime) + 0.14 \cos(2\pi dtime) – 0.08 (dtime) – 0.06 (dtime)^2$	.99
5	01144000	White River at West Hartford, VT	$7.13 + 1.11 \ln(Q) + 0.15 \ln(Q)^2 – 0.31 \sin(2\pi dtime) + 0.25 \cos(2\pi dtime) – 0.07 (dtime)$	.99
6	01152500	Sugar River at West Claremont, NH	$5.99 + 0.88 \ln(Q) + 0.12 \ln(Q)^2 – 0.17 \sin(2\pi dtime) + 0.19 \cos(2\pi dtime) – 0.06 (dtime)$	.96
7	01154500	Connecticut River at North Walpole, NH	$8.99 + 1.04 \ln(Q) + 0.05 \ln(Q)^2 – 0.17 \sin(2\pi dtime) + 0.10 \cos(2\pi dtime) – 0.06 (dtime)$	.98
8	01163200	Otter River at Otter River, MA	$5.64 + 0.40 \ln(Q) + 0.07 \sin(2\pi dtime) – 0.14 \cos(2\pi dtime)$	.65
9	01169000	North River at Shattuckville, MA	$5.17 + 0.83 \ln(Q) + 0.09 \ln(Q)^2 – 0.13 (dtime)$	.90
10	01169900	South River near Conway, MA	$3.62 + 0.84 \ln(Q) – 0.20 \sin(2\pi dtime) + 0.09 \cos(2\pi dtime) – 0.14 (dtime)$	.96
11	01170100	Green River near Colrain, MA	$3.40 + 1.17 \ln(Q) + 0.09 \ln(Q)^2 – 0.22 (dtime)$	.92
12	01171500	Mill River at Northhampton, MA	$4.37 + 0.75 \ln(Q) – 0.13 \sin(2\pi dtime) + 0.02 \cos(2\pi dtime) – 0.11 (dtime)$	.97
13	01184000	Connecticut River at Thompsonville, CT	$10.1 + 0.77 \ln(Q) + 0.03 \sin(2\pi dtime) + 0.21 \cos(2\pi dtime)$	.94
			Total phosphorus regression equations	
1	01134500	Moose River at Victory, VT	$1.06 + 1.26 \ln(Q) + 0.27 \ln(Q)^2$	0.89
2	01135500	Passumpsic River at Passumpsic, VT	$3.39 + 1.49 \ln(Q) + 0.46 \ln(Q)^2 + 0.16 (dtime)$	.92
3	01138500	Connecticut River at Wells River, VT	$5.17 + 1.42 \ln(Q) + 0.19 \ln(Q)^2 – 0.13 \sin(2\pi dtime) + 0.31 \cos(2\pi dtime)$	.89
4	01142500	Ayers Brook at Randolph, VT	$0.44 + 2.33 \ln(Q) + 0.59 \ln(Q)^2 + 0.13 (dtime)$	.97
5	01144000	White River at West Hartford, VT	$3.63 + 2.27 \ln(Q) + 0.48 \ln(Q)^2$	.97
6	01152500	Sugar River at West Claremont, NH	$2.81 + 1.24 \ln(Q) + 0.32 \ln(Q)^2 – 0.14 (dtime)$	.92
7	01154500	Connecticut River at North Walpole, NH	$5.34 + 1.56 \ln(Q) + 0.38 \ln(Q)^2$	.95
8	01163200	Otter River at Otter River, MA	$2.70 + 0.56 \ln(Q) – 0.14 \ln(Q)^2 – 0.34 \sin(2\pi dtime) – 0.08 \cos(2\pi dtime)$	.62
9	01169000	North River at Shattuckville, MA	$2.00 + 1.02 \ln(Q) + 0.29 \ln(Q)^2 + 0.30 \sin(2\pi dtime) + 0.08 \cos(2\pi dtime)$	.78
10	01169900	South River near Conway, MA	$-0.68 + 1.44 \ln(Q) + 0.22 \ln(Q)^2 + 0.26 \sin(2\pi dtime) + 0.03 \cos(2\pi dtime)$	.88
11	01170100	Green River near Colrain, MA	$-0.40 + 1.61 \ln(Q) + 0.20 \ln(Q)^2 + 0.40 \sin(2\pi dtime) – 0.15 \cos(2\pi dtime)$	.89
12	01171500	Mill River at Northhampton, MA	$0.66 + 1.06 \ln(Q) + 0.07 \ln(Q)^2 – 0.37 \sin(2\pi dtime) – 0.05 \cos(2\pi dtime) + 0.08 (dtime)$	.91
13	01184000	Connecticut River at Thompsonville, CT	$7.18 + 0.93 \ln(Q) + 0.44 \ln(Q)^2$	.77

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Deacon, J.R., and others—**Assessment of Total Nitrogen in the Upper Connecticut River Basin in New Hampshire, Vermont, and Massachusetts, December 2002–September 2005**—USGS Scientific Investigations Report 2006–5144