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Nutrient Sources and Loads in the Connecticut, Housatonic, and Thames River Basins

By ELAINE C. TODD TRENCH

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FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and policymakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for specific contamination problems; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional- and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequences of new policies.

To address these needs, the U.S. Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

- Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.
- Describe how water quality is changing over time.
- Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 59 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 59 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch

Robert M. Hirsch
Chief Hydrologist

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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
gallon per minute (gal/min)	0.06309	liter per second
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second
pound per year (lb/yr)	0.4536	kilogram per year
pound per square mile (lb/mi^2)	0.2819	kilogram per square kilometer
square mile (mi^2)	2.590	square kilometer

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

$$°F = (1.8 \times °C) + 32$$

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

$$°C = (°F - 32) / 1.8$$

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L)

VERTICAL DATUM

Altitude, as used in this report, refers to distance above or below sea level.

ABBREVIATIONS

ADAPS	U.S. Geological Survey surface-water data base
CSO	Combined sewer overflow
CTDEP	Connecticut Department of Environmental Protection
NOAA	National Oceanic and Atmospheric Administration
NADP	National Atmospheric Deposition Program
NPDES	National Pollutant Discharge Elimination System
PCS	Permit Compliance System
QWDATA	U.S. Geological Survey water-quality data base
USEPA	U.S. Environmental Protection Agency

Nutrient Sources and Loads in the Connecticut, Housatonic, and Thames River Basins

By Elaine C. Todd Trench

Abstract

Sources and loads of total nitrogen and total phosphorus in streams of the Connecticut, Housatonic, and Thames River Basins study unit were evaluated as part of the U.S. Geological Survey's (USGS) National Water-Quality Assessment Program. The study area encompasses 15,758 square miles and extends from northern New Hampshire and Vermont to coastal Connecticut.

Annual nutrient loads and yields were estimated using data from 25 USGS water-quality monitoring stations in and near New England. Major sources of nutrients include atmospheric deposition, agricultural fertilizer and manure, urban nonpoint runoff, and municipal wastewater discharges. Nutrient yields for drainage basins with relatively homogenous land use, along with data on point-source loads, were used to estimate nutrient yields for general categories of forested, agricultural, and urban land in selected basins.

Yields of total nitrogen in undeveloped forested drainage basins, for which data are limited, are generally less than about 2,000 pounds per square mile per year (lb/mi^2/yr), and yields of total phosphorus are generally less than about 100 lb/mi^2/yr. Nutrient yields are somewhat higher in forested drainage basins that have larger percentages of developed land or that receive point-source discharges, with total nitrogen yields generally less than 4,000 lb/mi^2/yr and total phosphorus yields generally less than 400 lb/mi^2/yr.

Nonpoint agricultural sources, including fertilizer and manure, constitute substantial nutrient inputs in some drainage basins but do not always result in high stream nutrient loads. Average basin yields of total nitrogen for three agricultural drainage basins were generally less than 4,000 lb/mi^2/yr, similar to forested basins, and total phosphorus yields were generally less than 300 lb/mi^2/yr. Total nitrogen yields for the small Broad Brook Basin, however, exceeded 10,000 lb/mi^2/yr, similar to nitrogen yields in urban basins in Connecticut that receive point discharges. Conditions in the Broad Brook Basin may not be representative of typical agricultural areas.

Municipal wastewater discharges are major sources of stream nutrient loads in urban areas of Massachusetts and Connecticut. Point-source discharges are the most important source of nutrient loads in four highly urban basins—the Pequabuck, Hockanum, Quinnipiac, and Naugatuck River Basins in Connecticut—even though 46 to 67 percent of the land in these drainage basins is undeveloped. These findings emphasize the importance of point discharges in urban coastal areas as sources of nutrients to Long Island Sound.

As wastewater flows increase in proportion to streamflow in urban basins, basin yields of total nitrogen and total phosphorus increase. The largest total nitrogen and total phosphorus yields were found in the Pequabuck, Hockanum, Quinnipiac, and Naugatuck River Basins, where wastewater discharges constitute from 9 to 19 percent of the

annual mean streamflow in a median flow year. Basin yields of total nitrogen generally ranged from 8,000 to 14,000 lb/mi^2/yr, and basin yields of total phosphorus generally ranged from 1,000 to 1,400 lb/mi^2/yr.

Nutrient yields from urban drainage basins with no point sources cannot be adequately characterized with the limited amount of monitoring data available, but yields appear to span a wide range, based on different types and intensities of urban land use. Yields for two urban basins that receive no point discharges were much smaller than yields in drainage basins that receive point discharges.

Although yields are moderately low in large, primarily forested drainage basins, rivers draining these large basins transport most of the nutrient load. The Connecticut River, measured at the Thompsonville station, transports about two-thirds of the total nitrogen exported from the major monitored drainage basins and about three-fifths of the total phosphorus.

The major sources of nutrients differ in the northern and southern parts of the study area. Forested land accounts for most of the stream nutrient load in northern areas, whereas municipal wastewater discharges are the dominant source of nutrients in urban areas of Massachusetts and Connecticut.

Export of total nitrogen from the major monitored drainage basins in the study area has ranged from about 32,000,000 to 63,000,000 lb/yr during the 1980's and 1990's, and in recent years has typically been about 37,000,000 lb/yr. Export of total phosphorus from major monitored basins during the 1980's and 1990's ranged from about 2,300,000 to 4,700,000 lb/yr and in recent years has typically been about 2,400,000 lb/yr. Historical maximum loads of total phosphorus do not represent currently expected maximum conditions because of the observed downward trends in phosphorus concentrations on many streams.

Although the 25 drainage basins represent about 86 percent of the study area, the load from these basins probably represents considerably less than 86 percent of the total nutrient load because (1) the monitored area contains only 55 percent of the population in the study area, (2) the monitored area includes essentially all of the least developed land with low nutrient yields, and (3) many point discharges in urban coastal areas are either in unmonitored basins or discharge directly to Long Island Sound.

INTRODUCTION

Nitrogen and phosphorus are essential nutrients for aquatic plant growth. Nitrogen availability rarely limits aquatic plant growth in freshwater, whereas phosphorus concentrations are generally low enough to limit plant growth. Excessive phosphorus concentrations in freshwater promote aquatic plant growth and eutrophic conditions (Hem, 1985, p. 126). In the saltwater environment of estuaries, such as Long Island Sound, nitrogen is considered the limiting nutrient for aquatic plant growth (Novotny and Chesters, 1981, p. 56).

The quality of freshwater streams of the Connecticut, Housatonic, and Thames River Basins and adjacent coastal drainage basins affects Long Island Sound, which is the receiving water for all streams in these drainage basins.The movement of these nutrients, especially nitrogen, into Long Island Sound is a major regional concern (U.S. Environmental Protection Agency, 1994, p. 11–13). The waters of Long Island Sound are affected by streamflow, point discharges, and nonpoint discharges from Westchester County, New York; the New York City area; the northern part of Long Island, New York; the Connecticut, Housatonic, and Thames River Basins, and coastal Connecticut drainage basins. High nitrogen concentrations in Long Island Sound promote excessive growth of aquatic algae. When these algae die, they decompose, consuming the oxygen in the water and contributing to a condition called hypoxia, or low dissolved oxygen. Hypoxia adversely affects the fish and invertebrates of the Sound in various ways. The land uses and waste-disposal practices that contribute nutrients to streams, ground water, and estuaries are fairly well known; however, the quantities of nutrients that different geographic areas and land uses contribute to Long Island Sound have not been fully identified.

State and local water managers and planners are responsible for implementing management plans and practices to reduce the amounts of nitrogen and phosphorus discharged to streams and estuaries from both point and nonpoint sources. Informed management decisions require information on the sources of these nutrients, the pathways they follow to reach freshwater streams, the proportion of nutrients that actually reaches a stream from a particular source, the loads transported by specific streams, instream attenuation of nutrient loads, and the relation of stream nutrient loads to drainage basin conditions and characteristics.

Purpose and Scope

This report evaluates nitrogen and phosphorus loads in the streams of the Connecticut, Housatonic, and Thames River Basins study unit of the U.S. Geological Survey's (USGS) National Water-Quality Assessment (NAWQA) Program. The major objective of this report is to quantify nutrient loads for selected streams. Additional objectives are to evaluate nutrient sources, and quantify them, where possible, for selected drainage basins; evaluate annual variability of loads; determine relative load contributions from point and nonpoint nutrient sources in selected basins; identify additional data needs for quantifying nutrient inputs; and relate nutrient loads to major nutrient sources. Nutrient load estimates are based on stream discharge and water-quality data collected by the USGS from 1970 to 1995.

Nitrogen and phosphorus load estimates are presented for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins NAWQA study unit. The study area encompasses the drainage basins of all streams flowing into Long Island Sound from the coast of Connecticut. The study area includes the multi-state Connecticut, Housatonic, and Thames River Basins as well as small drainage basins in coastal Connecticut.

Previous Investigations

Estimates of total nitrogen and total phosphorus loads for six drainage basins were made as part of a retrospective analysis of existing nutrient data for the Connecticut, Housatonic, and Thames River Basins study unit (Zimmerman and others, 1996, p. 102–113). The Connecticut Department of Environmental Protection (CTDEP) has estimated total nitrogen loads for State-defined management zones in Connecticut using USGS discharge and water-quality data (P.E. Stacey, Connecticut Department of Environmental Protection, written commun., 1996). Nationally, the USGS has estimated nitrate and total phosphorus yields for 14 water-resources regions in the conterminous United States as part of a summary of water-quality conditions and trends during the 1980's (Smith and others, 1993, p. 129).

Nutrient yields estimated for various land uses, and methods for estimating nutrient sources in different land-use categories, have been reported by Novotny and Chesters (1981) in a national study of nonpoint-source pollution. Nutrient yields for urban, agricultural, and forested land have been estimated by Frink (1991, table 2, p. 722) as part of a study of 33 lakes in Connecticut. Nutrient yields were estimated by relating measured concentrations of nitrogen and phosphorus in lakes to land use in their watersheds. This study also included a literature survey of nitrogen and phosphorus yield estimates for various land uses (Frink, 1991, table 1, p. 719).

The National Oceanic and Atmospheric Administration (NOAA) has compiled estimates of all point and nonpoint pollutant loads to Long Island Sound from coastal counties in Connecticut and New York, and estimates of loads for streams that flow into the coastal study area (Farrow and others, 1986). HydroQual, Inc. (1996) has estimated point and nonpoint loads of nutrients to Long Island Sound from the coastal zone in Connecticut and New York for use in a Long Island Sound water-quality model.

Acknowledgments

Water-quality data used for the nutrient load estimates in this report were collected as part of USGS Connecticut District water-quality projects in cooperation with the CTDEP, the NAWQA program, and the USGS New Hampshire–Vermont District program.

David K. Mueller and Patrick J. Phillips of the USGS and Paul E. Stacey of the CTDEP reviewed the report and provided many helpful comments and suggestions on the analysis and interpretation of nutrient loads. Timothy A. Cohn of the USGS

provided a helpful perspective on the analysis of nutrient loads in relation to concentration trends. Charles J. Patton of the USGS provided information on changes in laboratory methods.

DESCRIPTION OF THE STUDY AREA

The Connecticut, Housatonic, and Thames River Basins study area encompasses 15,758 mi^2 and extends from coastal Connecticut to Canada (fig. 1). The study area includes almost all of Connecticut, large areas of west-central Massachusetts, eastern Vermont, and western New Hampshire, and small areas of New York, Rhode Island, and the Province of Quebec, Canada. In addition to the multistate drainage basins of the Connecticut, Housatonic, and Thames Rivers, the study area also includes several small coastal drainage basins in Connecticut.

Physiography, Geology, and Climate

The study area is in the New England physiographic province (Fenneman, 1938), a plateau-like upland that rises gradually from sea level and includes numerous mountain ranges and individual peaks. Altitudes 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. The major environmental settings have been described by Zimmerman and others (1996, p. 9–11) on the basis of physiography and bedrock geology.

The major bedrock types, based on the relative abundance of carbonate minerals, are noncarbonate crystalline, arkosic, carbonate, and calcareous bedrock (Grady and Mullaney, 1998). Unconsolidated glacial deposits (till, coarse-grained stratified drift, and fine-grained glacial lake sediments) overlie fractured bedrock, except for small areas where bedrock is exposed at land surface.

The study area lies in the path of prevailing westerly winds that alternately transport cool, dry, continental-polar air masses and warm, moist, maritime-tropical air masses into the region, resulting in frequent weather changes. The climate is generally temperate and humid. Average annual temperature ranges from less than 40°F in the northern mountainous areas to about 50°F in southwestern coastal Connecticut. Average annual precipitation ranges from about 34 in. in parts of the northern Connecticut River valley to more than 65 in. in adjacent mountainous regions (Knox and Nordenson, 1955). Mean annual precipitation for the study area averages about 43 in. Total annual precipitation is highly variable and commonly fluctuates by as much as 20 in/yr from the mean (Zimmerman and others, 1996, p. 12).

Land Use and Land Cover

Landsat satellite imagery (thematic mapper) data from two periods in 1995 have been interpreted to develop a land-use and land-cover data set for the study area (P.A. Steeves, U.S. Geological Survey, written commun., 1997). The 1995 land-use data have been aggregated into categories of forested, agricultural, and urban land, according to the Level I categories described by Anderson and others (1976). Data from the unpublished 1995 data set have been used in the analyses presented in this report (table 1). A previously published land-use analysis provides a generalized picture of the distribution of major land uses (fig. 2).

Land uses vary from forested wilderness areas in the north to densely developed metropolitan areas in the south (fig. 2). Urban centers in the southern part of the study area include some of the country's oldest industrial areas. Southwestern coastal areas and major river valleys contain the most densely developed urban land. Since the 1950's, substantial land development has taken place in formerly agricultural and forested areas, particularly in Connecticut. In many areas, the pattern of forested, agricultural, and urban land use resembles a patchwork with small pieces of each land-use type, and most monitored drainage basins encompass heterogeneous mixtures of land use.

Overall, 78 percent of the land is classified as forested. The northern part of the study area, including areas in New Hampshire, Vermont, and northern Massachusetts, is heavily forested. Forests cover 85 percent of the Connecticut River Basin upstream from a point near the State line between Massachusetts and Connecticut. By contrast, the southern part of the study area, including the Connecticut River Basin south of Massachusetts, and the Thames, Housatonic, and adjacent coastal basins, is about 67 percent forested.

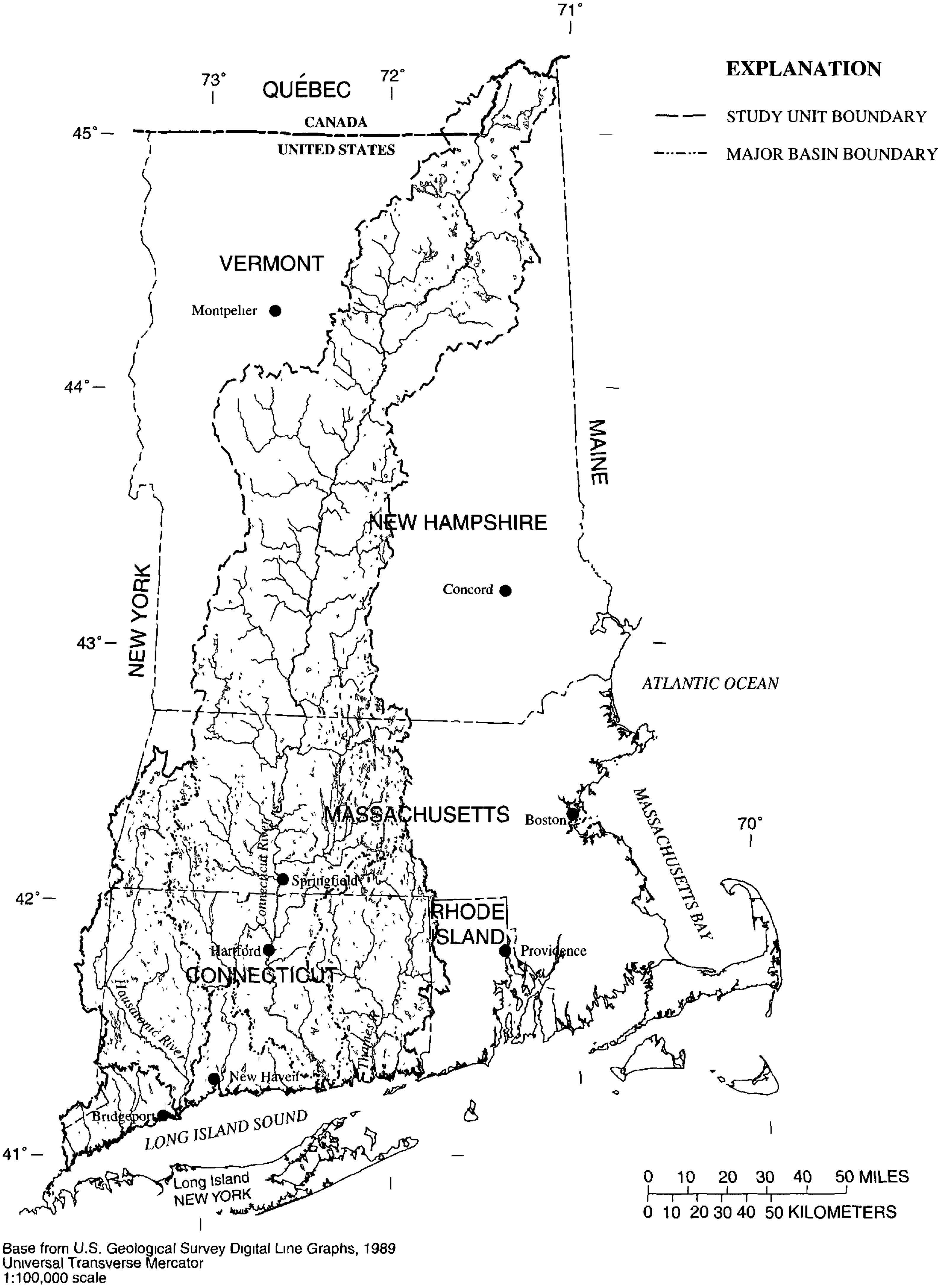


Figure 1. Political boundaries, major streams, and major drainage basins, Connecticut, Housatonic, and Thames River Basins study area.

Table 1. Land use and population characteristics of selected drainage basins in the Connecticut, Housatonic, and Thames River Basins study area

[**Sources:** 1995 Land-use data, P.A. Steeves, U.S. Geological Survey, written commun., 1997; population data, U.S. Bureau of the Census, 1991 **Drainage basin category:** F, forested; A, agricultural; U, urbanized; USGS, U.S. Geological Survey; mi^2, square mile]

USGS station identification number	Map reference number (fig. 3)	Drainage area (mi^2)	Drainage basin category	Land use (percentage of basin)					Population	
				Urban	Agriculture	Forest	Water	Barren	Number	Density (number/ mi^2)
Thames River Basin										
01122610	1	408	F	5.6	11.5	80.5	2.2	0.1	98,613	242
01124000	2	155	F	5.5	9.0	82.1	3.4	.1	39,318	254
01127000	3	713	F	6.5	12.8	77.3	3.2	.1	171,820	241
Connecticut River Basin										
01135300	4	42.9	A	0.2	18.7	81.1	0.0	0.0	1,168	27
01137500	5	87.6	F	.1	3.8	95.9	.2	.0	1,651	19
01144000	6	690	F	1.5	14.5	83.7	.3	.0	19,971	29
01154500	7	5,493	F	1.3	10.6	86.9	1.2	.0	216,255	39
01170100	8	41.4	F	.5	4.5	94.6	.4	.0	1,030	25
01184000	9	9,660	F	3.0	10.2	84.9	1.9	.0	1,097,438	114
01184100	10	10.4	A	13.0	31.3	54.9	.8	.1	844	81
01184490	11	15.5	A	15.4	38.3	45.7	.4	.2	6,618	427
01186800	12	86.2	F	4.8	6.1	86.2	2.9	.1	13,716	159
01188000	13	4.1	A	4.4	17.9	76.8	.5	.4	443	108
01188090	14	378	F	3.6	5.0	87.1	4.3	.0	44,117	117
01189000	15	45.8	U	25.7	12.7	59.7	1.7	.3	54,161	1,183
01189995	16	577	F	8.5	8.4	79.8	3.2	.1	176,741	306
01192500	17	73.4	U	31	17.1	50	1.8	.2	97,365	1,326
01193500	18	100	F	6.2	13.6	78.7	1.4	.1	23,035	230
Quinnipiac River Basin										
01196500	19	115	U	36.6	16.2	45.7	1.3	0.2	153,068	1,331
Housatonic River Basin										
01199900	20	194	A	11.3	33.8	53.5	1.4	0.0	18,577	96
01205500	21	1,544	A	11.0	17.4	68.8	2.7	.1	328,431	231
01208500	22	260	U	17.7	13.2	67.2	1.9	.1	239,522	921
Southwestern Coastal Basins										
01208873	23	10.6	U	75.7	10.3	13	0.9	0.1	42,939	4,051
01208990	24	21.0	U	21.7	7.4	69.3	1.6	.0	5,347	255
01209710	25	33.0	U	26	7.9	65.2	.9	.1	21,734	659

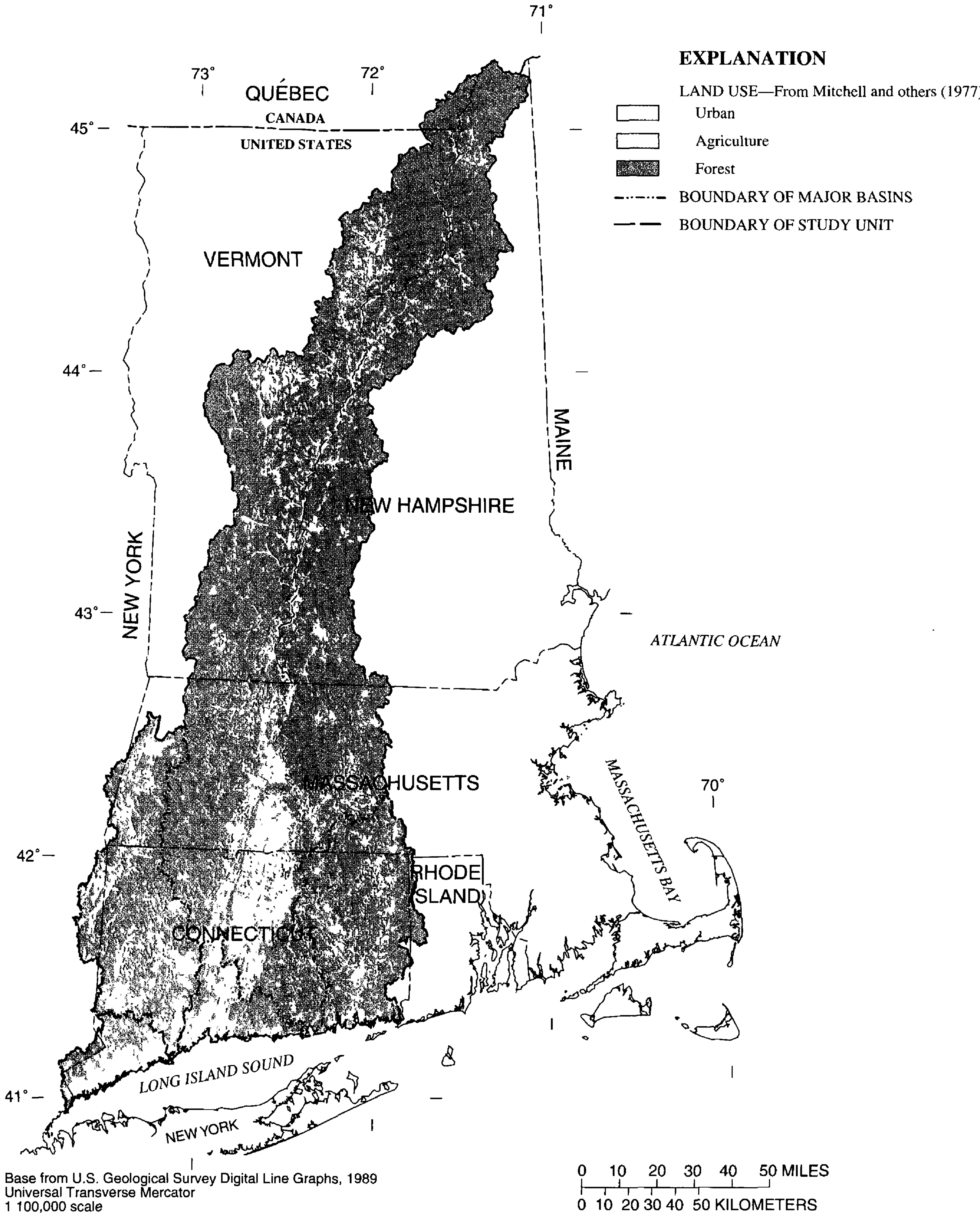


Figure 2. *Major land-use categories* (Anderson Level I) and major drainage basins, Connecticut, Housatonic, and Thames River Basins study area.

Agricultural land uses occupy 12 percent of the study area. Major crops produced are corn, potatoes, tobacco, soy beans, fruit, and vegetables, with lesser amounts of grains, ornamental shrubs, and Christmas trees. Dairy farming is declining throughout much of the region, but is still important in some areas. The deep soils derived from fine-grained glacial lake sediments in the lowland of central Connecticut and west-central Massachusetts support the most intensive agriculture in the study area.

About 8 percent of the land is classified as urban, which includes residential, commercial, industrial, institutional, transportation, and recreational land uses. The percentage and type of urban land use vary greatly among drainage basins, with basins in the southern part generally having higher percentages of urban land and higher population densities than the northern part (table 1).

In this report, monitored drainage basins have been assigned to forested, agricultural, or urban categories on the basis of dominant land use (table 1). The forested category includes basins in which 75 percent or more of the land is forested and neither urban nor agricultural land equals or exceeds 15 percent of the basin area. The agricultural category includes basins in which agricultural land covers 15 percent or more of the basin, and agricultural land exceeds urban land. The urban category includes basins in which 15 percent or more of the land is urban, and urban land exceeds agricultural land. The assignment of drainage basins to land-use categories is somewhat arbitrary because, most drainage basins, even fairly small ones, have some diversity of land use.

Population Density

In 1990, the population of the study area was about 4.5 million people, or about 2 percent of the Nation's population (U.S. Bureau of the Census, 1991). By contrast, the land area is less than one-half of 1 percent of the total area of the Nation. Thus, the study area as a whole is substantially more densely populated than the national average. Population density varies widely, however, ranging from sparsely populated rural, agricultural, and wilderness areas of Vermont and New Hampshire to densely populated urban areas of southwestern Connecticut and the south-central part of the Connecticut River valley. Population density in monitored drainage basins ranges from about 20 people per mi^2 in the largely forested Ammonoosuc River Basin in northern New Hampshire to about 4,000 people per mi^2 in the urban Rooster River Basin on the southwestern Connecticut coast (table 1).

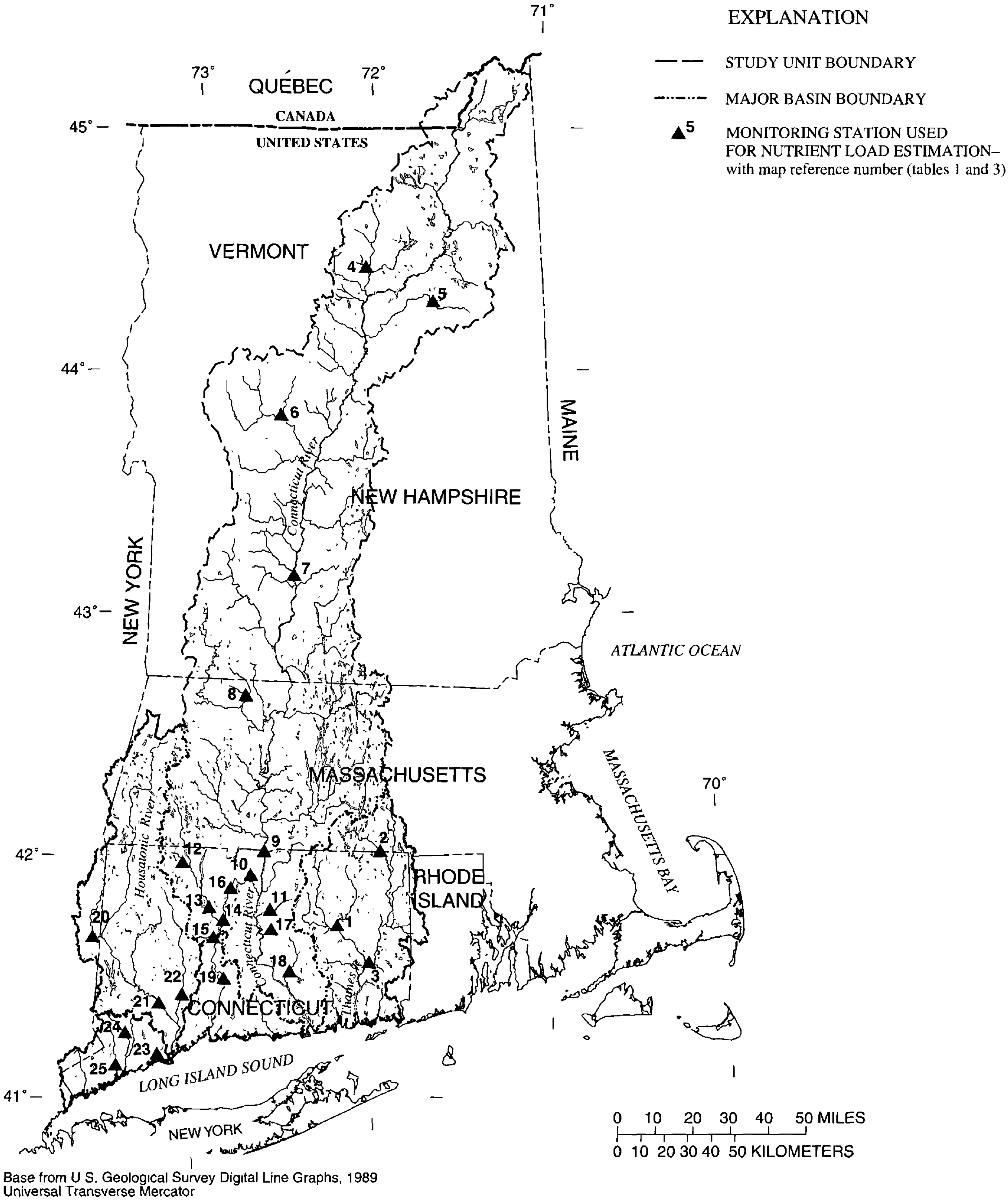
Streamflow

Major streams generally flow from north to south, and all eventually drain into Long Island Sound (fig. 1). The Connecticut River, the principal river in the study area, flows about 400 mi from its source in the Connecticut Lakes of northern New Hampshire to its mouth at Long Island Sound. The Connecticut River drains 11,260 mi^2, or about 72 percent of the study area. The Housatonic and Thames Rivers, the other major streams, together drain 3,420 mi^2, or about 20 percent of the study area. Streams that flow into Long Island Sound have tidal reaches of varying lengths. The Connecticut River is tidal for most of its length in Connecticut.

The annual mean discharge of a stream describes average streamflow conditions during a particular year. The median value of all annual mean discharges for the period of record for a stream indicates typical annual streamflow conditions. The median value for annual mean discharges at the 25 streamflow-gaging stations considered in this study (fig. 3) ranges from about 8 ft^3/s for Burlington Brook near Burlington, Connecticut (drainage area 4.1 mi^2), to about 17,500 ft^3/s for the Connecticut River at Thompsonville, Connecticut (drainage area 9,660 mi^2).

Annual mean discharges of streams differ considerably from year to year, with variations in climatic conditions. Annual mean discharges were generally high during the 1950's and 1970's, and low during a major regional drought in the 1960's. Annual mean discharges for Burlington Brook for the period 1932–95 ranged from a low of 3.5 ft^3/s in 1965 to a high of 13.2 ft^3/s in 1973. Annual mean discharges for the Connecticut River at Thompsonville for the period 1929–95 ranged from a low of 7,800 ft^3/s in 1965 to a high of 24,800 ft^3/s in 1976.

Average monthly discharge generally peaks in the spring, and there may be a secondary peak in late autumn to early winter. Low streamflow conditions generally take place from late summer to early autumn.



Base from U S. Geological Survey Digital Line Graphs, 1989
Universal Transverse Mercator
1:100,000 scale

Figure 3. Major streams and monitoring stations used for nutrient load estimation, Connecticut, Housatonic, and Thames River Basins study area.

Annual mean discharge is the primary measure of streamflow used to interpret annual nutrient loads estimated for this report. Other streamflow statistics and conditions, however, may be critical in understanding and interpreting nutrient loads. One or more major storms, for example, may transport most of the nutrient load in a year that is generally characterized by low streamflows. Thus, annual mean discharge is only one relevant discharge factor in interpreting and evaluating nutrient loads.

Water Quality

The quality of surface water ranges from the near-natural condition of streams in undeveloped forested areas to the substantially degraded condition of some streams draining highly urban areas. Streams in undeveloped forested areas are characterized by low concentrations of dissolved solids, low nutrient concentrations, low specific conductance, and concentrations of trace constituents generally below detection limits. The pH may be lowered by the effects of acidic precipitation. Streams in highly urban areas are characterized by high concentrations of dissolved solids, high nutrient concentrations, elevated specific conductance, and concentrations of some trace constituents in the parts-per-billion range (Davies and others, 1996). Water-quality conditions and trends have been summarized and interpreted by Healy and others (1994), Healy and Kulp (1995), Zimmerman and others (1996), and Trench (1996).

Nutrient data are available for selected monitoring stations for periods ranging from water years 1970–95 to water years[1] 1993–95 (table 2). Median total nitrogen concentrations range from less than 0.40 mg/L to 5.4 mg/L. Median total phosphorus concentrations range from less than the detection limit of 0.01 mg/L to 0.63 mg/L. Nutrient concentrations for the Ammonoosuc River in New Hampshire and the Green River in Massachusetts are considered to represent undeveloped, near-natural conditions (map reference numbers 5 and 8, fig. 3). Concentrations for Burlington Brook, the Salmon River, and the Farmington River at Unionville in Connecticut are considered to be typical of sparsely developed areas in Connecticut (map reference numbers 13, 18, and 14, fig. 3). Nutrient concentrations for Broad Brook indicate substantial effects from agricultural areas (map reference number 11, fig. 3); nutrient concentrations for the Pequabuck, Hockanum, Quinnipiac, and Naugatuck Rivers indicate substantial effects from urban areas (map reference numbers 15, 17, 19, and 22, fig. 3).

Nutrient concentrations are correlated with discharge in many streams. In streams draining undeveloped areas, the highest nutrient concentrations may occur during moderate to high discharges, when nutrients are transported by surface runoff during storm events (fig. 4*A*). In urban areas with substantial point-source discharges, nutrient concentrations are highest at low flows, when point-source discharges constitute a substantial percentage of streamflow; concentrations decrease at high flows because of dilution by surface runoff (fig. 4*B*). Most total nitrogen concentrations in the forested Salmon River Basin are less than the lowest concentrations in the urban Pequabuck River Basin (fig. 4).

[1]A water year is the 12-month period from October 1 through September 30. The water year is designated by the calendar year in which it ends. For example, the year beginning October 1, 1985, and ending September 30, 1986, is called the "1986 water year."

METHODS FOR NUTRIENT LOAD ESTIMATION

The stream load of a constituent is the amount or quantity of the constituent transported by the stream in a given length of time, such as the instantaneous load during a storm or the annual load for a water year. Water-quality and stream discharge data were used to estimate the annual loads of total nitrogen and total phosphorus presented in this report.

Selection of Stations and Data for Nutrient Load Estimation

Nutrient loads were estimated using data from 25 water-quality monitoring stations (fig. 3). The drainage basins for these monitoring stations range in size from 4.1 to 9,660 mi^2 (table 3). Although most of the monitoring stations are in Connecticut, most of the drainage area monitored is in Massachusetts, Vermont, and New Hampshire. The station on the Connecticut River at Thompsonville, Connecticut, monitors the largest drainage area—9,660 mi^2, or about 61 percent of the study area.

Table 2. Summary statistics for nitrogen and phosphorus constituents, Connecticut, Housatonic, and Thames River Basins study area

[**Drainage basin category:** F, forested; A, agricultural; U, urbanized. Total nitrogen data are unavailable from QWDATA for the Sleepers, Ammonoosuc, White, and Green Rivers. Total nitrogen values can be estimated for these streams by adding the values for total ammonia-plus-organic nitrogen and dissolved nitrite-plus-nitrate nitrogen. Summary statistics were not calculated for total ammonia-plus-organic nitrogen for the Ammonoosuc and Green Rivers because there were too few values above the detection limit of 0.2 mg/L. e, estimated value; USGS, U.S. Geological Survey; mg/L, milligram per liter]

USGS water-quality station name and location	Map reference number	Drainage basin category	Period of record	Number of samples	Concentration percentiles (mg/L)		
					25th	50th (median)	75th
			Total Nitrogen				
Shetucket River at South Windham, Conn.	1	F	7/74 – 3/96	255	0.70	0.90	1.1
Quinebaug River at Quinebaug, Conn.	2	F	10/80 – 3/96	153	.68	.86	1.2
Quinebaug River at Jewett City, Conn.	3	F	7/72 – 3/96	284	.86	1.0	1.3
Connecticut River at North Walpole, N.H.	7	F	10/80 – 7/94	46	.51	.62	.86
Connecticut River at Thompsonville, Conn.	9	F	8/69 – 4/96	326	.64	.80	1.0
Stony Brook near West Suffield, Conn.	10	A	10/80 – 9/94	78	.97	1.2	1.6
Broad Brook at Broad Brook, Conn.	11	A	3/93 – 9/95	40	3.8	4.2	5.0
Still River at Riverton, Conn.	12	F	8/71 – 9/91	195	.65	.95	1.6
Burlington Brook near Burlington, Conn.	13	A	7/72 – 4/96	146	.33	.43	.60
Farmington River at Unionville, Conn.	14	F	10/83 – 2/96	19	.33	.40	.47
Pequabuck River at Forestville, Conn.	15	U	3/93 – 9/95	40	3.0	5.4	7.6
Farmington River at Tariffville, Conn.	16	F	7/72 – 2/96	253	.94	1.2	1.4
Hockanum River near East Hartford, Conn.	17	U	10/91 – 4/96	57	3.0	4.1	4.5
Salmon River near East Hampton, Conn.	18	F	7/72 – 2/96	229	.42	.57	.78
Quinnipiac River at Wallingford, Conn.	19	U	7/72 – 4/96	290	2.5	3.3	4.1
Tenmile River at S. Dover near Wingdale, N.Y.	20	A	10/91 – 9/95	32	.74	.91	1.1
Housatonic River at Stevenson, Conn.	21	A	7/72 – 3/96	268	.71	.86	1.0
Naugatuck River at Beacon Falls, Conn.	22	U	7/74 – 3/96	262	2.1	3.4	5.2
Rooster River at Fairfield, Conn.	23	U	3/93 – 8/95	21	1.6	2.1	2.4
Saugatuck River near Redding, Conn.	24	U	7/72 – 2/96	231	.37	.49	.63
Norwalk River at Winnipauk, Conn.	25	U	10/80 – 2/96	214	.68	.90	1.1
			Total Ammonia-plus-Organic Nitrogen				
Sleepers River near St. Johnsbury, Vt.	4	A	3/93 – 9/95	33	e.02	e.05	e.14
White River at West Hartford, Vt.	6	F	3/93 – 9/95	35	e.01	e.03	e.08
			Dissolved Nitrite-plus-Nitrate Nitrogen				
Sleepers River near St. Johnsbury, Vt.	4	A	3/93 – 9/95	33	.12	.23	.41
Ammonoosuc River at Bethlehem Junction, N.H.	5	F	3/93 – 9/95	33	e.09	e.12	e.16
White River at West Hartford, Vt.	6	F	3/93 – 9/95	35	.19	.23	.34
Green River near Colrain, Mass.	8	F	3/93 – 9/95	35	e.06	e.08	e.12
			Total Phosphorus				
Shetucket River at South Windham, Conn.	1	F	7/74 – 3/96	262	.03	.05	.09
Quinebaug River at Quinebaug, Conn.	2	F	10/80 – 3/96	161	.04	.08	.21
Quinebaug River at Jewett City, Conn.	3	F	10/71 – 3/96	299	.05	.07	.13
Sleepers River near St. Johnsbury, Vt.	4	A	3/93 – 9/95	33	e.001	e.003	e.01
Ammonoosuc River at Bethlehem Junction, N.H.	5	F	3/93 – 9/95	33	e.003	e.005	e.009
White River at West Hartford, Vt.	6	F	3/93 – 9/95	35	e.001	e.004	e.01
Connecticut River at North Walpole, N.H.	7	F	10/80 – 7/94	56	e.005	e.01	e.02
Green River near Colrain, Mass.	8	F	3/93 – 9/95	35	e.003	e.006	e.01
Connecticut River at Thompsonville, Conn.	9	F	8/69 – 4/96	340	.04	.06	.09
Stony Brook near West Suffield, Conn.	10	A	10/80 – 9/94	77	.05	.06	.11

Table 2. Summary statistics for nitrogen and phosphorus constituents, Connecticut, Housatonic, and Thames River Basins study area—*Continued*

USGS water-quality station name and location	Map reference number	Drainage basin category	Period of record	Number of samples	Concentration percentiles (mg/L)		
					25th	50th (median)	75th
Total Phosphorus—*Continued*							
Broad Brook at Broad Brook, Conn.	11	A	3/93 – 9/95	41	0.07	0.08	0.12
Still River at Riverton, Conn.	12	F	8/71 – 9/91	198	.05	.09	.18
Burlington Brook near Burlington, Conn.	13	A	10/71 – 4/96	170	e.01	e.011	e.03
Farmington River at Unionville, Conn.	14	F	10/83 – 2/96	40	e.006	e.01	e.03
Pequabuck River at Forestville, Conn.	15	U	3/93 – 9/95	41	.36	.63	1.1
Farmington River at Tariffville, Conn.	16	F	10/71 – 2/96	267	.09	.13	.19
Hockanum River near East Hartford, Conn.	17	U	10/91 – 4/96	59	.27	.43	.63
Salmon River near East Hampton, Conn.	18	F	10/71 – 2/96	272	e.01	e.01	e.02
Quinnipiac River at Wallingford, Conn.	19	U	10/71 – 4/96	301	.27	.42	.61
Tenmile River at S. Dover near Wingdale, N.Y.	20	A	10/91 – 9/95	56	e.01	e.025	e.04
Housatonic River at Stevenson, Conn.	21	A	10/71 – 3/96	293	.03	.04	.05
Naugatuck River at Beacon Falls, Conn.	22	U	7/74 – 3/96	268	.20	.38	.66
Rooster River at Fairfield, Conn.	23	U	3/93 – 8/95	35	e.02	e.03	e.04
Saugatuck River near Redding, Conn.	24	U	10/71 – 2/96	273	e.01	e.02	e.03
Norwalk River at Winnipauk, Conn.	25	U	10/80 – 2/96	246	.03	.05	.07

Stations were selected for nutrient load estimation on the basis of length and consistency of water-quality and discharge records, geographic distribution, land-use characteristics, and significance in characterizing water-quality conditions. Stations selected include long-term water-quality monitoring stations that are part of USGS District programs and stations recently established as part of the NAWQA program. Some stations are part of both programs. Continuous-record streamflow-gaging stations are at 22 of the 25 water-quality stations. Discharge records for the other three stations are computed using a drainage-area correction factor on the discharge records for a nearby continuous-record station (table 3). Mean daily streamflow values for water years spanning the complete period of water-quality record at each station were retrieved from the USGS Automated Data Processing System (ADAPS). Nutrient data for the complete period of record at each station were retrieved from the USGS Water Quality Data Base (QWDATA).

Sample Distribution in Relation to Streamflow Conditions

The frequency of water-quality data collection varies among the 25 monitoring stations (table 3) but has not been more frequent than monthly except for a few periods of short duration. Sampling frequency at some stations has changed during the period of record. Ideally, sampling should be evenly distributed over the full range of flow conditions. Insufficient representation of high flows, which carry the largest loads of some constituents, can cause underestimates of annual loads. In a retrospective analysis of nutrient data, Zimmerman and others (1996, p. 38–41) examined sampling frequency in relation to flow duration at eight of the long-term water-quality stations included in this report. High flows (the top 10 percent of flows) were generally well represented at these stations; however, the highest streamflows may not have been sampled, and additional storm monitoring may be necessary to define nutrient transport during high flow conditions.

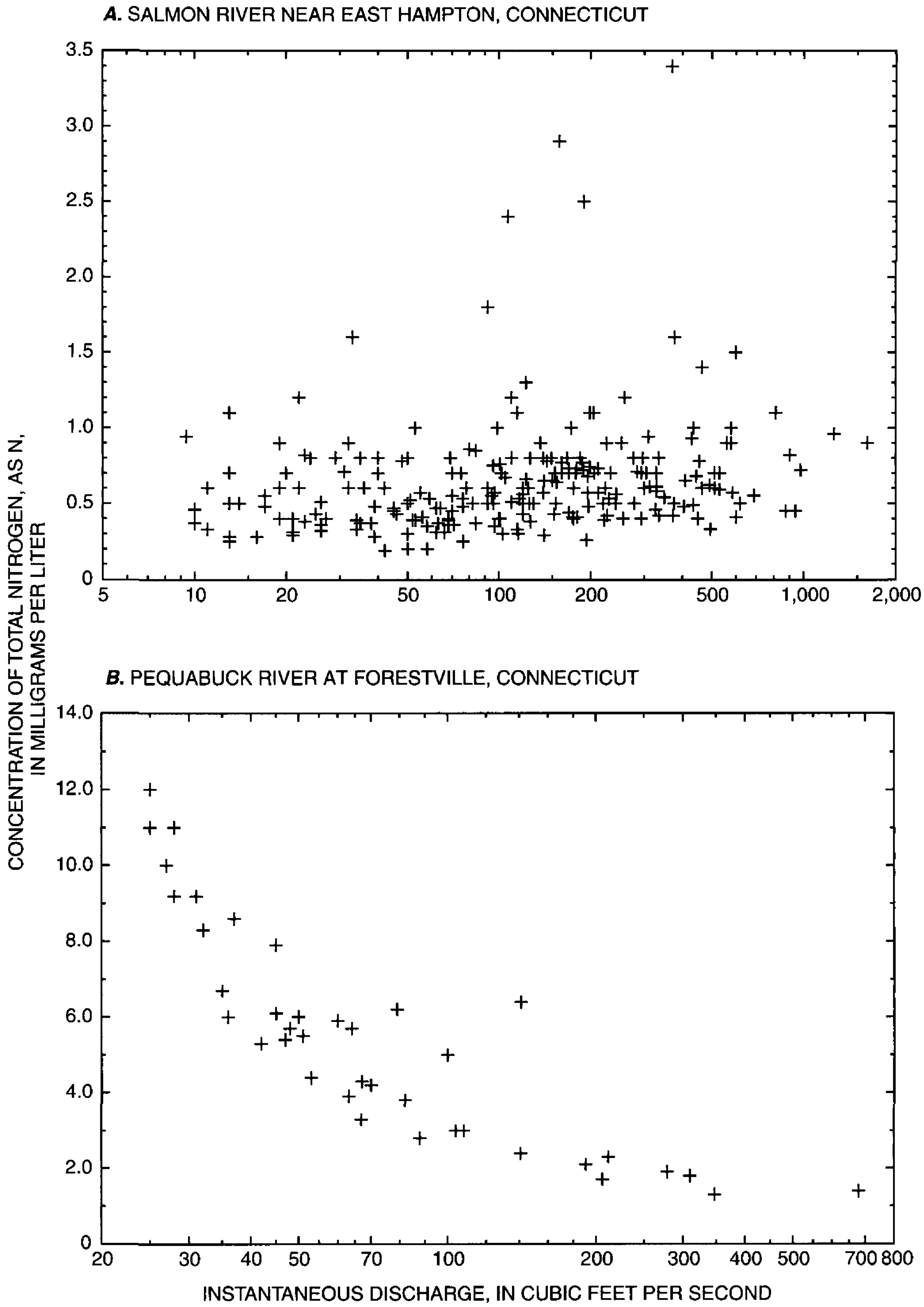


Figure 4. Total nitrogen concentrations and discharge for selected stations, Connecticut, Housatonic, and Thames River Basins study area.

Table 3. Discharge and water-quality sampling information for selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area

[**Sampling frequency:** Sampling frequency changed from monthly to 8 times per year at some stations starting in 1993. M, monthly or 8 times per year; BM, bimonthly; Q, quarterly. **Latitude and Longitude:** °, degrees; ′, minutes; ″, seconds; USGS, U.S. Geological Survey]

USGS water-quality station number	Source of discharge data	Map reference number (fig. 3)	Water-quality station name and location	Drainage area (square miles)	Latitude ° ′ ″	Longitude ° ′ ″	Period of water-quality record (water years)	Sampling frequency
			Thames River Basin					
01122610	1.01 x 01122500	1	Shetucket River at South Windham, Conn.	408	41 40 56	72 09 59	1974–95	M
01124000	01124000	2	Quinebaug River at Quinebaug, Conn.	155	42 01 20	71 57 22	1980–95	M
01127000	01127000	3	Quinebaug River at Jewett City, Conn.	713	41 35 52	71 59 05	1968–95	M
			Connecticut River Basin					
01135300	01135300	4	Sleepers River near St. Johnsbury, Vt.	42.9	44 26 04	72 02 22	1993–95	M
01137500	01137500	5	Ammonoosuc River at Bethlehem Junction, N.H.	87.6	44 16 08	71 37 52	1993–95	M
01144000	01144000	6	White River at West Hartford, Vt.	690	43 42 51	72 25 07	1993–95	M
01154500	01154500	7	Connecticut River at North Walpole, N.H.	5,493	43 07 34	72 26 14	1981–94	Q
01170100	01170100	8	Green River near Colrain, Mass.	41.4	42 42 12	72 40 16	1993–95	M
01184000	01184000	9	Connecticut River at Thompsonville, Conn.	9,660	41 59 14	72 36 21	1966–95	M
01184100	01184100	10	Stony Brook near West Suffield, Conn.	10.4	41 57 38	72 42 39	1982–91	BM
01184490	01184490	11	Broad Brook at Broad Brook, Conn.	15.5	41 54 50	72 33 00	1993–95	M
01186800	01186500	12	Still River at Riverton, Conn.	86.2	41 57 34	73 01 12	1974–91	M
01188000	01188000	13	Burlington Brook near Burlington, Conn.	4.1	41 47 10	72 57 55	1968–95	Q
01188090	01188090	14	Farmington River at Unionville, Conn.	378	41 45 21	72 53 14	1984–95	M
01189000	01189000	15	Pequabuck River at Forestville, Conn.	45.8	41 40 23	72 54 04	1993–95	M
01189995	01189995	16	Farmington River at Tariffville, Conn.	577	41 54 30	72 45 40	1972–95	M
01192500	01192500	17	Hockanum River near East Hartford, Conn.	73.4	41 46 59	72 35 16	1992–95	M
01193500	01193500	18	Salmon River near East Hampton, Conn.	100	41 33 08	72 26 59	1968–95	M
			Quinnipiac River Basin					
01196500	01196500	19	Quinnipiac River at Wallingford, Conn.	115	41 26 58	72 50 29	1968–95	M
			Housatonic River Basin					
01199900	0.95 x 01200000	20	Tenmile River at South Dover near Wingdale, N.Y.	194	41 39 46	73 33 35	1992–95	M
01205500	01205500	21	Housatonic River at Stevenson, Conn.	1,544	41 23 02	73 10 05	1968–95	M
01208500	01208500	22	Naugatuck River at Beacon Falls, Conn.	260	41 26 32	73 03 47	1974–95	M
			Southwestern Coastal Basins					
01208873	01208873	23	Rooster River at Fairfield, Conn.	10.6	41 10 47	73 13 10	1993–95	M
01208990	01208990	24	Saugatuck River near Redding, Conn.	21.0	41 17 40	73 23 44	1968–95	M
01209710	1.1 x 01209700	25	Norwalk River at Winnipauk, Conn.	33.0	41 08 07	73 25 36	1981–95	M

Effects of Changes in Laboratory Methods on Historic Nutrient Data

Reported concentrations of total nitrogen may have been affected by the laboratory method used to analyze Kjeldahl nitrogen (ammonia-plus-organic nitrogen) prior to October 1, 1991. Total nitrogen is not an analyzed constituent. It is calculated in QWDATA by adding the analytical value for nitrite-plus-nitrate to the analytical value for Kjeldahl nitrogen. A change in the digestion step that is part of the method used to analyze Kjeldahl nitrogen was implemented on October 1, 1991, at the USGS National Water Quality Laboratory. Statistical analysis of paired data for about 1,500 samples during validation of the new method revealed a bias of about 0.1 mg/L of nitrogen in Kjeldahl nitrogen samples analyzed prior to implementation of the new method (C.J. Patton, U.S. Geological Survey, written commun., 1999). That is, Kjeldahl nitrogen concentrations, and consequently total nitrogen concentrations, determined prior to this date are biased high by about 0.1 mg/L. For urban streams with high total nitrogen concentrations, this bias represents a small percentage of the concentration and may not have a significant effect on estimated total nitrogen loads. For streams with low total nitrogen concentrations, this bias represents a larger percentage of the total nitrogen concentration, and load estimates prior to the 1992 water year may be overestimated by an unknown amount. Because variability in stream discharge and changes in agricultural practices and wastewater treatment also have affected historic total nitrogen concentrations, the relative importance of the laboratory method change on estimates of total nitrogen loads is uncertain. Additional information on changes in laboratory analytical methods for nutrients has been summarized by Zimmerman and others (1996, p. 29–30).

Use of the ESTIMATOR Program for Load Estimation

The ESTIMATOR program was developed in 1988 to assist USGS personnel in estimating stream nutrient loads entering Chesapeake Bay through its major tributaries (T.A. Cohn, U.S. Geological Survey, written commun., 1994). The program was subsequently used to estimate loads for other constituents, including toxic organic substances and trace metals. The ESTIMATOR program implements the Minimum Variance Unbiased Estimator method, based on a simple log linear model that relates constituent concentrations to discharge and time (Cohn and others, 1989; Gilroy and others, 1990; Cohn and others, 1992a). The applicability of this model for estimating fluvial transport of nutrients and sediment was tested using data for Chesapeake Bay tributaries with drainage areas of 70 mi^2 or larger (Cohn and others, 1992a). The ESTIMATOR program also implements the Adjusted Maximum Likelihood Estimator method for data sets that contain values below a detection limit (Cohn, 1988; Cohn and others, 1992b).

Model Selection

The ESTIMATOR program requires the user to define the concentration model used in load estimation for each station and constituent. For most stations and constituents, the following equation was chosen:

$$\ln[C] = B_0 + B_1\ln[Q] + B_2\ln^2[Q] + B_3T + B_4T^2 + B_5\sin[2\pi T] + B_6\cos[2\pi T] + e\,, \qquad (1)$$

where ln[ ] denotes the natural logarithm function, C = constituent concentration, Q = discharge, T = time measured in years, the sine and cosine terms remove the effects of annual seasonal variability, $\pi = 3.14159$, B_0 is a constant and $B_1...B_6$ are coefficients estimated from the data, and e is an independent random error. In studies of fluvial transport of nutrients to Chesapeake Bay, Cohn and others (1992a) found that this seven-parameter model satisfactorily described much of the variability in constituent concentrations. Streamflow and water-quality data required for the ESTIMATOR program were retrieved from USGS ADAPS and QWDATA data bases for this report.

For some NAWQA stations with a short water-quality record (less than three years), a small number of constituent observations, and a high percentage of censored observations, the data were insufficient to use the seven-parameter model (equation 1). For these stations, one of the following equations was chosen:

$$\ln[C] = B_0 + B_1\ln[Q] + e \quad \text{or} \qquad (2)$$

$$\ln[C] = B_0 + B_1\ln[Q] + B_2\ln^2[Q] + e\,. \qquad (3)$$

For each constituent modeled, the ESTIMATOR program provides an output file with regression diagnostics for the selected model, diagnostic plots, and computed loads for the period of time selected by the user. Estimated monthly and annual mean daily loads, in units of kilograms per day, are calculated by the program for each calendar year and water year, along with the standard error and standard error of prediction for each mean daily load estimate. Estimated mean daily loads for each water year of record have been converted to units of pounds per year for data presentations in this report. Annual loads and confidence intervals calculated from the standard error of prediction are reported in table 15 (at the back of this report) for total nitrogen and total phosphorus for all stations and years evaluated for this report.

Adequacy of Data for Nutrient Load Estimation

About 2.5 years of monthly water-quality data are available from recently established NAWQA stations in the study area. Load estimates are reported for these short-term stations with the cautionary note that error percentages are high in some cases, and additional years of water-quality data are necessary to confirm the accuracy of these estimates.

Modifications to the total nitrogen data retrieved from QWDATA were necessary to create a representative data set for load estimation at some stations. As noted previously, total nitrogen concentrations are calculated by adding analyzed values for nitrite-plus-nitrate and Kjeldahl nitrogen. If either of these two constituents is censored, a total nitrogen value is not calculated by the QWDATA program. For streams with high nutrient concentrations, this does not significantly affect the distribution of values in the data set. For streams with low nutrient concentrations, the absence of calculated total nitrogen values at low concentrations may bias the data set toward high concentrations that are not fully representative of the water quality.

The total nitrogen data were modified to set the total nitrogen concentration equal to that of the detected component constituent where one of the two component constituents was detected and one was censored, and where the detected value exceeded the higher of the two reporting limits. Where both were censored, or where the detected value was less than the higher reporting limit, total nitrogen was defined as a nondetected value at the higher reporting limit of the two. This approach modified less that 4 percent of the total nitrogen values for 14 stations, from 4 to 42 percent of the values for 7 stations, and 82 to 86 percent of the values for 2 stations—the Sleepers and White Rivers in Vermont (map reference numbers 4, 6, fig. 3).

The approach described previously did not provide a sufficient number of detected total nitrogen values to use in the ESTIMATOR program for two stations—the Ammonoosuc River in New Hampshire and the Green River in Massachusetts—because of the very high percentage of censored values in Kjeldahl nitrogen and nitrite-plus-nitrate. The alternative approach for these two stations (map reference numbers 5, 8, fig. 3) was to estimate the maximum concentration of total nitrogen by substituting the detection limit for all censored values of constituents used in the calculation of total nitrogen. Setting numerous values equal to the detection limit has the effect of reducing concentration variability, and consequently, artificially reduces the standard error of the load estimates (D.K. Mueller, U.S. Geological Survey, oral commun., 1999). As a result, the confidence interval for these load estimates is underestimated by an unknown amount. These provisional load estimates are included in this report, but additional years of water-quality data will be required for validation.

NUTRIENT SOURCES AND TRANSPORT PROCESSES

Nitrogen and phosphorus constituents in streams are derived from natural sources and from many human uses of land and water resources (fig. 5). Nutrients are transported to streams by ground-water inflow and surface runoff. Sources of nitrogen include atmospheric deposition, decaying plants, animal wastes, fertilizers, septic systems, and municipal and industrial wastewater. Weathering products from certain types of igneous rocks and soil minerals are minor sources. Sources of phosphorus include weathering and erosion of phosphorus-bearing minerals in rocks and soil, decaying plants, animal wastes, fertilizers, detergents, and municipal and industrial wastewater. Atmospheric deposition contributes substantially less phosphorus than nitrogen.

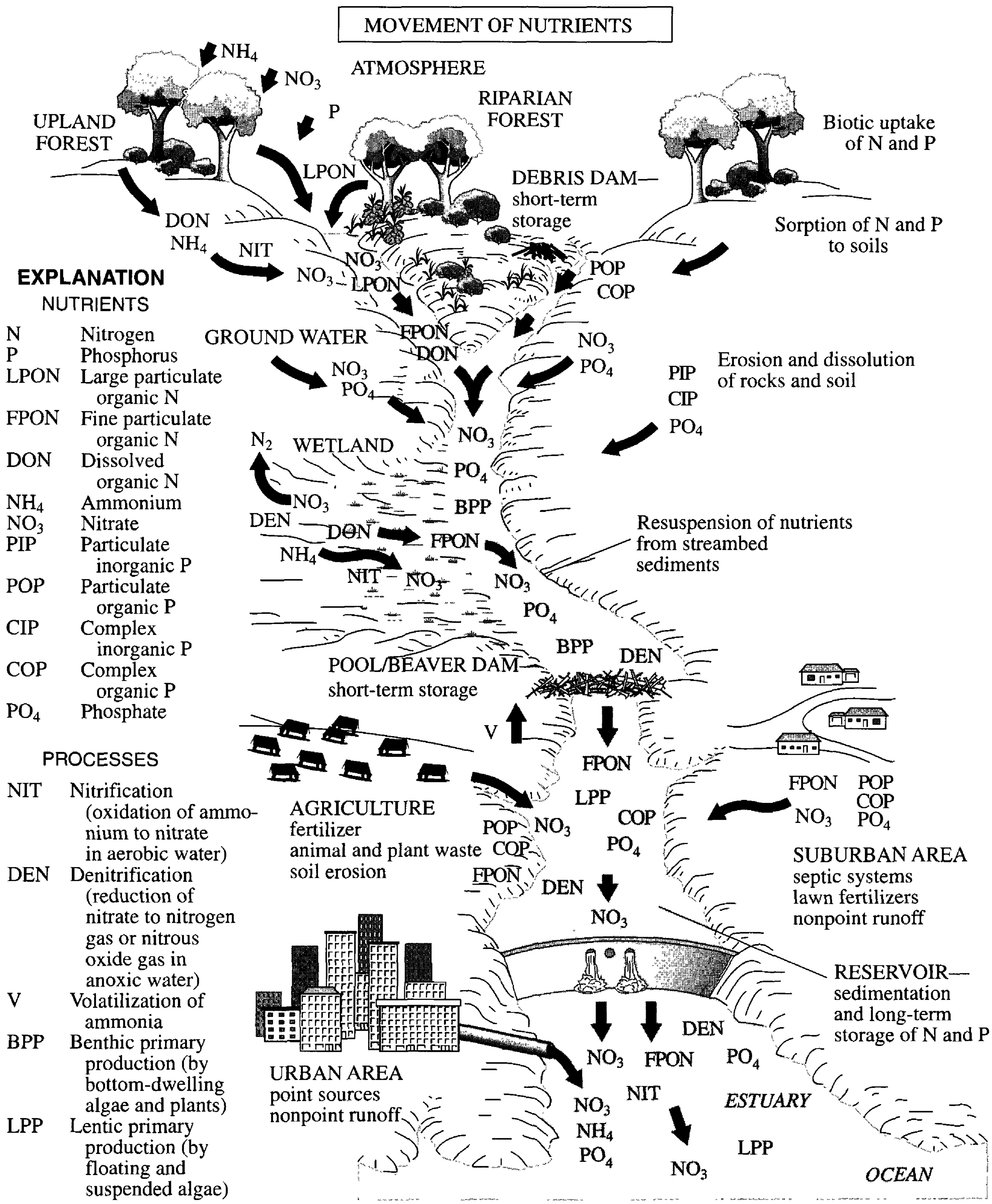


Figure 5. Movement of nutrients from watersheds to rivers and the ocean, Connecticut, Housatonic, and Thames River Basins study area (modified from Puckett and Triska, 1996).

Conceptual Model of Nutrient Sources and Transport

Minimally Developed or Forested Drainage Basins

In undeveloped basins, the sources of nitrogen constituents are presumed to be decomposing plant and animal matter and atmospheric deposition. The sources of phosphorus constituents are presumed to be decomposing plant and animal matter, mineral decomposition, and, to a lesser extent, atmospheric deposition (fig. 5). Concentrations of nitrogen and phosphorus constituents are low in surface water and ground water. Completely natural conditions are not present because of atmospheric transport of nitrate and other substances from developed areas.

Biogeochemical processes determine the amount of nitrogen and phosphorus transported to streams. Oxidized forms of nitrogen may be transported without much attenuation under many circumstances; an example is the conservative transport of nitrate in ground water that contains dissolved oxygen. Uptake of nitrogen by terrestrial or aquatic plants and denitrification in some riparian zones and streambed sediments, however, reduce nitrogen loads transported by streams. Phosphorus constituents are generally more likely to be sorbed by soil and aquifer particles than are nitrogen constituents. Very little phosphorus is transported by ground water to streams, and stream concentrations of phosphorus may be reduced by various reactions during transport. Consequently, the total loads of nitrogen and phosphorus leaving a drainage basin are substantially less than the total nitrogen and phosphorus inputs to the basin. The amounts of nitrogen and phosphorus that may be stored in a drainage basin for later release are unknown. Nutrient retention in forested areas includes uptake by plants and sorption to soils. In a study of nitrate in the Catskill Mountains, Murdoch and Stoddard (1992, p. 2718) have noted that forests near maturation have a low demand for nitrogen and may not be able to retain all of the atmospheric nitrogen entering the watersheds. It is not known whether forested areas in the study area are near or have reached a point of nitrogen saturation.

Concentrations of nitrogen and phosphorus constituents are relatively low at low flows and increase somewhat at higher flows in forested drainage basins, presumably because of contributions from surface runoff at higher flows. Under low-flow conditions, the nutrient load represents the ground-water contribution to the stream. Low-flow nutrient concentrations in the stream may be similar to concentrations in ground water. However, denitrification along some stream reaches may substantially decrease the nitrate concentration of discharging ground water, and uptake by aquatic plants during the growing season may substantially decrease the nitrate concentration of surface water.

Total nitrogen loads for winter or spring months (from December to a period varying from March to May) generally exceed loads for low-flow months (June to October), sometimes by an order of magnitude. These higher monthly loads in winter are attributed to higher discharges and to storm runoff carrying particulate and dissolved material.

Agricultural Drainage Basins

Less is known about the effects of this land-use category on nutrient loads than other land uses, because parcels of agricultural land are generally small and are mixed with other land uses in many monitored basins. Nitrogen and phosphorus are contributed primarily from nonpoint sources, including crop fertilizers and animal wastes (fig. 5). A substantial amount of the ammonia nitrogen in manure may be volatilized before the manure is returned to agricultural fields, but this is unquantified (Jaworski and others, 1992).

Stream concentrations of nutrients are generally higher in agricultural areas than in forested areas. Concentrations of nitrite-plus-nitrate in ground water beneath tilled agricultural land in Connecticut are significantly higher than in undeveloped areas (Grady, 1994, fig. 7, p. B28). Concentrations of orthophosphate, however, are low in ground water beneath agricultural land (Grady, 1994, p. B27).

High-flow events generally deliver the bulk of the nitrogen and phosphorus to streams, from surface runoff, erosion, transport of organic and inorganic particulates, and resuspension of streambed sediments. Low flows carry nitrogen and phosphorus that have infiltrated to the water table and entered the ground-water-flow system. The relative proportions of base-flow nutrient contributions from ground water and high-flow contributions from surface runoff vary depending on local soils and geology and on the location of agricultural land relative to the ground-water-flow system and discharge areas.

If land has been used for agriculture for a long time, a substantial amount of nitrogen may be present in the ground water.

Developed or Urban Drainage Basins

Developed areas contribute nutrients to streams from nonpoint and point sources. Different types of nonpoint and point-source nutrient loads are transmitted to streams in different ways that affect the magnitude and consistency of the water-quality effects. Nonpoint-source pollution in urban streams results from material washed off the land surface during storms, as well as from constituents transported by ground-water discharge (fig. 5). In addition to nutrients contributed by vegetation in urban areas, urban nonpoint sources include atmospheric deposition, urban runoff, construction runoff, domestic and commercial fertilizer use, waste-disposal sites, leaking sewer lines, and septic systems in unsewered areas. The relative proportions of nutrients contributed from surface runoff and from ground-water discharge are not fully known, although the contribution from surface runoff is considered to predominate.

Most nutrients that reach impervious surfaces are transported to storm drains and eventually to streams by surface runoff. Nonpoint-source runoff is highly episodic, with most nutrient transport taking place intermittently during a few days of the year. The intermittent, large pollutant load delivered by storm water during a short time span represents a shock loading to the receiving water (Novotny and Chesters, 1981, p. 314). Combined sewer overflows (CSOs), although considered point sources, have the episodic, shock-loading characteristics of nonpoint storm runoff.

Ground-water discharge is a relatively constant nutrient source throughout the year. Nutrients (primarily nitrogen) on permeable surfaces such as lawns, and nutrients from waste sources within the unsaturated zone, may infiltrate to ground water and eventually be transported to streams with ground-water discharge (fig. 5). The addition of nutrients may vary seasonally, but the effects of this variability may not be apparent in the quality of ground-water discharge because of retention and attenuation in the soil, the length of the ground-water-flow path, and mixing of ground water from several sources.

Substantial amounts of nitrogen and phosphorus are contributed to streams by point sources in urban drainage basins. Point sources include municipal discharges, industrial discharges, and CSOs. Permitted municipal and industrial effluents discharge directly to the receiving water and provide a relatively constant contribution of nitrogen and phosphorus throughout the year. There is some diurnal variation in loads, but the effects on the quality of the receiving water are relatively constant, in comparison to other sources. The effects of point sources may mask natural sources of nitrogen and phosphorus and other nonpoint sources related to various human activities.

Concentrations of nitrogen and phosphorus are much higher at low flows than at high flows in urban drainage basins, indicating that point sources dominate the transport of nutrients in this environment. Point discharges produce high stream nutrient concentrations at low flows, when wastewater discharges constitute a large proportion of the streamflow (fig. 4b). At high flows, nutrient concentrations in streams are diluted by storm runoff that has lower nutrient concentrations than the wastewater discharges.

Concentrations and loads at low flows represent the total of the point-source load plus the ground-water contribution (no nonpoint surface runoff). Concentrations and loads at high flows represent the total of the point-source load, the ground-water contribution, nonpoint storm runoff, and CSOs (if present). Despite the large and fairly constant point-source contribution in urban basins, monthly loads in winter are still substantially larger than monthly loads during low-flow conditions in summer and fall, because of increased streamflow in winter.

Nonpoint-Source Contributions

Nonpoint sources of pollution are discussed in detail by Novotny and Chesters (1981). Data on atmospheric deposition, agricultural fertilizer, animal manure, and urban nonpoint sources are considered to have large margins of error because of gaps in available data, the geographic distribution of the data, or assumptions made in apportioning nutrients to particular drainage basins.

Available literature estimates and data for the study area were used to develop a basis for quantifying nutrient inputs. Estimates of nonpoint-source contributions discussed in the following sections were used to describe nutrient inputs in selected drainage basins. The following information does not fully characterize all areas but helps to indicate where further investigation is needed to quantify nutrient sources more accurately.

Atmospheric Deposition

Data from the National Atmospheric Deposition Program (NADP) and the University of Connecticut indicate a range in rates of atmospheric nutrient deposition. The wet deposition data from NADP include nitrate and ammonia nitrogen, but do not include dry deposition, and therefore do not represent the total atmospheric deposition of nitrogen. Rates of wet deposition of total nitrogen at seven NADP stations in or near the study area ranged from 2,700 to 4,300 lb/mi^2/yr in 1994 and 1995 (fig. 6, table 4). National maps showing the spatial variability of wet deposition rates of nitrate and total nitrogen indicate that, in general, deposition rates of nitrate and total nitrogen are similar to rates in New Jersey and eastern New York and are higher than rates in northern and eastern Maine and eastern Massachusetts (National Atmospheric Deposition Program/National Trends Network, 1996). Wet deposition rates for nitrate and total nitrogen in the more undeveloped northern areas generally equal, and in some cases exceed, deposition rates in the more developed southern areas.

Data from six NADP stations have previously been used by Zimmerman and others (1996, p. 109–112) to estimate atmospheric deposition of inorganic nitrogen for several drainage basins (table 5). Estimates were based on wet deposition data from the NADP stations and include estimates for dry deposition as well as adjustments for urban and altitudinal effects. These estimates indicate total annual deposition of atmospheric nitrogen ranging from 4,600 to 5,600 lb/mi^2/yr in rural drainage basins and from 6,300 to 9,400 lb/mi^2/yr in urban areas of central and southwestern Connecticut. Estimation methods, based on data for 1980–91, are described by Zimmerman and others (1996, p. 33, 36–37).

Researchers at the University of Connecticut collected data on wet and dry deposition of inorganic nitrogen and phosphorus at three locations in Connecticut from 1991 through 1993 (Chen and others, 1994; Yang and others, 1996). Two monitoring stations were on the southwestern and central coast, and the third was in an inland upland area (fig. 6). Annual deposition of total nitrogen ranged from 4,600 to 4,900 lb/mi^2, including both wet and dry deposition, and annual deposition of total phosphorus ranged from 22 to 27 lb/mi^2 (Yang and others, 1996, p. 3808, table 1). Although two of the stations are near urban areas, all three stations are in State parks that include forested areas, and presumably the data do not represent total atmospheric deposition of nutrients in highly urban areas. Atmospheric deposition of nutrients is a strongly episodic phenomenon (Yang and others, 1996, p. 3808–3809).

Estimates of annual wet and dry deposition of total nitrogen reported by Yang and others (1996) are similar to estimates made by Zimmerman and others (1996) for rural drainage basins, but substantially lower than estimates made by Zimmerman and others (1996) for total nitrogen deposition in urban areas of central and southwestern Connecticut (table 5). Estimates made by Zimmerman and others (1996) (table 5) include estimates for dry deposition as well as adjustments for urban and altitudinal effects; these estimates may be more representative of the range of conditions in the study area than the unadjusted NADP data or the data reported by Yang and others (1996). Because urban and altitudinal adjustments to the wet deposition data are based on data for the eastern United States, however, these ranges may not fully represent local conditions. Further investigation of rates of atmospheric deposition of nutrients is needed, particularly in urban areas. Estimates made by Zimmerman and others (1996) were used in analyses presented in this report.

Agricultural Manure and Fertilizer

Nitrogen and phosphorus in animal manure and fertilizer are major sources of the nitrogen and phosphorus loads in streams draining agricultural areas. County-level data for nitrogen and phosphorus from animal manure and fertilizer were compiled in a National data set (L.J. Puckett, U.S. Geological Survey, written commun., 1997). Data for counties that are entirely or mostly within the study area were compiled from this source (table 6). Counties with less than about 50 percent of their land area in the study area were not included.

Use of county-level data has some limitations in its application. Agricultural land, and therefore manure and fertilizer sources, are not evenly distributed within

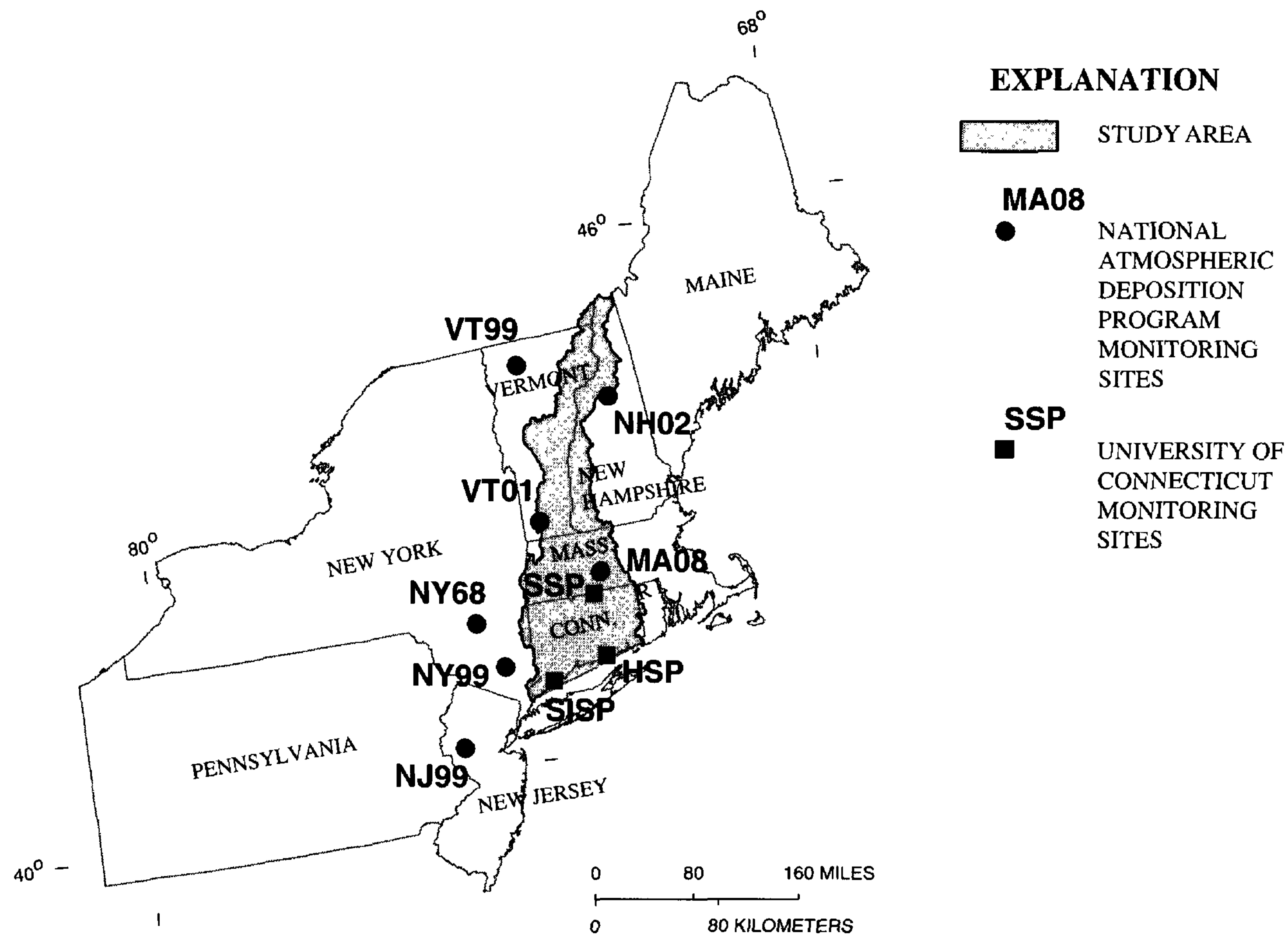


Figure 6. Locations of monitoring stations for atmospheric deposition, northeastern United States.

counties. Along the Connecticut River, and especially in the central lowland of Connecticut and west-central Massachusetts, agricultural land use is concentrated in the valley lowlands and sparse in the adjacent upland areas of the same counties. Thus, application rates averaged for a county do not adequately represent either the intensive agriculture of the lowlands or the more sparse agriculture of the uplands. In general, use of county-level data is more readily applicable to large drainage basins that encompass whole counties than to the generally small monitored basins in the study area, most of which encompass small parts of one or a few counties. For this reason, estimates of agricultural manure and fertilizer inputs have only been made for the whole study area and the Connecticut River Basin (table 6). Inputs in the Connecticut River Basin are discussed in the section of this report entitled "Comparison of Nutrient Sources and Loads in the Connecticut River Basin."

Animal manure contributed roughly 30,700,000 lb of nitrogen and 6,200,000 lb of phosphorus to the study area in 1992 (table 6), an average of about 1,900 lb/mi^2/yr of nitrogen and 390 lb/mi^2/yr of phosphorus. Agricultural land encompasses about 12 percent of the study area, or about 1,900 mi^2. If nutrient inputs from manure are applied to the agricultural land, the contributions are 16,000 lb/mi^2/yr of nitrogen and 3,300 lb/mi^2/yr of phosphorus. Actual nitrogen inputs to the land are probably lower because of volatilization.

Fertilizer contributions of nutrients in 1992 were similar in magnitude to those of manure, with roughly 26,900,000 lb of nitrogen and 5,200,000 lb of phosphorus applied (table 6). These contributions average about 1,700 lb/mi^2/yr of nitrogen and 320 lb/mi^2/yr of phosphorus throughout the study area. If nutrient inputs from fertilizer are applied only to agricultural land, nutrient contributions from fertilizer are about 14,000 lb/mi^2/yr of nitrogen and 2,700 lb/mi^2/yr of phosphorus. If fertilizer inputs are applied to urban land as well as agricultural land, with a higher input rate assumed on agricultural land, then fertilizer contributes about 10,000 lb/mi^2/yr of nitrogen and 1,800 lb/mi^2/yr of phosphorus to agricultural land.

Table 4. Wet atmospheric deposition of total nitrogen at selected National Atmospheric Deposition Program stations, northeastern United States

[Source: National Atmospheric Deposition Program (NRSP-3) /National Trends Network, 02/11/97, NADP/NTN Coordination Office, Illinois State Water Survey, 2204 Griffith Dr., Champaign, IL 61820]

National Atmospheric Deposition Program station	Calendar year	Total nitrogen (pounds per square mile)
MA08	1994	4,200
MA08	1995	3,000
NH02	1994	3,000
NH02	1995	3,200
NJ99	1994	4,300
NJ99	1995	2,900
NY68	1994	4,000
NY68	1995	3,500
NY99	1994	3,900
NY99	1995	2,700
VT01	1994	3,200
VT01	1995	3,500
VT99	1994	3,700
VT99	1995	2,900

Agricultural land includes fallow fields that do not receive fertilizer and manure; consequently, input rates may be higher than these averages in some areas.

A National summary of nutrient information from 20 NAWQA study units indicates that stream nitrogen yields were generally less than or equal to about one-half of the total nonpoint inputs of nitrogen from commercial fertilizer and manure. Stream phosphorus yields were generally less than or equal to about one-sixth of the total phosphorus inputs from commercial fertilizer and manure (U.S. Geological Survey, 1999, p. 46). These or lower ratios applied to the study area indicate that agricultural land may contribute 4,000 to 13,000 lb/mi^2/yr of nitrogen to streams, depending on the amount of volatilization from manure, and 200 to 800 lb/mi^2/yr of phosphorus to streams. These ranges are in the same order of magnitude as nutrient yield estimates made by Frink (1991, table 2, p. 722) for agricultural areas in the drainage basins of 33 Connecticut lakes. Total nitrogen yields in Frink's study ranged from 3,100 to 5,600 lb/mi^2/yr; total phosphorus yields ranged from 220 to 400 lb/mi^2/yr.

Although total nutrient contributions from manure and fertilizer are similar for the entire study area (see Totals, table 6), the relative importance of each source varies considerably in different counties. In more than half of the 22 counties, nutrient inputs from animal manure exceed inputs from fertilizer. In northeastern and northwestern Connecticut (Litchfield, Tolland, and Windham Counties, table 6), and in some Vermont counties (Orange and Windsor Counties, table 6), inputs of nitrogen and phosphorus from manure are two to four times greater than inputs from fertilizer. By contrast, inputs from fertilizer are two to three times greater than inputs from manure in counties along the Connecticut River lowland in west-central Massachusetts (Franklin, Hampden, and Hampshire Counties, table 6).

Urban Nonpoint-Source Contributions

Nonpoint sources of nutrients in urban areas include wet and dry atmospheric deposition, street refuse, plant and animal waste and debris, local motor vehicle exhaust, lawn fertilizer, and soil erosion. Nutrients from most of these sources are transported to streams by surface runoff, but some also are transported by ground-water flow. The proportions and total amounts of these sources in different types of urban areas are not well known or thoroughly quantified. Urban nonpoint nutrient sources are sometimes evaluated from the perspective of the resulting nutrient loads measured in urban streams. Several literature estimates of nonpoint nutrient contributions from urban areas are cited here to provide a context for estimates developed in this study for urban drainage basins.

A study of the quality and quantity of precipitation and storm runoff in eight urban areas of the United States indicated that rainfall was a major source of nitrogen constituents in urban storm runoff but was not generally a major source of phosphorus (Ebbert and Wagner, 1987, p. 869). The study also found that in some cases the rainfall contribution of nitrogen exceeded runoff loads, indicating some retention of nitrogen in plants or soils of urban drainage basins.

NOAA has compiled estimates of annual pollutant loads in stormwater runoff from major urban areas, including areas without CSOs, as part of an evaluation of pollutant discharges to Long Island

Table 5. Estimates of atmospheric deposition of total nitrogen in selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area

[**Source:** National Atmospheric Deposition Program data for 1980–91, interpreted in Zimmerman and others, 1996, table 22. lb/mi^2/yr, pounds per square mile per year; lb/yr, pounds per year; mi^2, square mile]

Station name	Drainage area (mi^2)	Total nitrogen deposition	
		(lb/yr)	(lb/mi^2/yr)
Shetucket River at South Windham, Conn.	408	2,030,000	5,000
Quinebaug River at Quinebaug, Conn.	155	794,000	5,100
Quinebaug River at Jewett City, Conn.	713	3,530,000	4,900
Connecticut River at North Walpole, N.H.	5,493	30,900,000	5,600
Connecticut River at Thompsonville, Conn.	9,660	52,900,000	5,500
Still River at Riverton, Conn.	86.2	397,000	4,600
Salmon River near East Hampton, Conn.	100	507,000	5,100
Quinnipiac River at Wallingford, Conn.	115	838,000	7,300
Housatonic River at Stevenson, Conn.	1,544	8,160,000	5,300
Naugatuck River at Beacon Falls, Conn.	260	1,630,000	6,300
Saugatuck River near Redding, Conn.	21.0	146,000	6,900
Norwalk River at Winnipauk, Conn.	33.0	309,000	9,400

Sound (Farrow and others, 1986, p. 25–28; appendix VI, table VI-3). Estimates were made for ten urban areas—one in New York and nine in Connecticut—based on precipitation data for 1982. Estimates of the total nitrogen delivered to streams from nonpoint stormwater runoff in areas without CSOs ranged from 4,400 to 6,600 lb/mi^2/yr, with an average of 5,400 lb/mi^2/yr for the 10 urban areas. Estimates of total phosphorus contributions from stormwater runoff ranged from 690 to 1,100 lb/mi^2/yr, with an average of 840 lb/mi^2/yr.

In urban drainage basins, as in other types of drainage basins, a few major storms may transport a large part of the annual nonpoint nutrient load. Urban storm runoff loads are affected by total storm rainfall, total contributing drainage area, peak discharge, storm runoff volume and duration, antecedent rainfall conditions, rainfall rates, percentage of impervious area in the drainage basin, land-use characteristics, mean annual climatic characteristics, and other factors (Driver, 1989; Driver and Tasker, 1990). Because of the wide range of factors affecting urban nonpoint runoff, additional information for specific locations and conditions is necessary to adequately characterize the expected range of urban nonpoint contributions to streams, and to quantify the contributions of different urban land uses.

Nutrient data from a USGS NAWQA ground-water study in the Hockanum River Basin provide information on the general range of the nutrient contribution from ground-water discharge in urban areas. Streamflow data were collected and stream samples were analyzed for nitrite-plus-nitrate nitrogen and other constituents during a low-flow period in August 1995 along a reach of the Hockanum River (Mullaney and Grady, 1997, table 15, p. 35). These data indicate that the nonpoint yield of nitrite-plus-nitrate supplied to the stream by ground-water flow from the 4.3-square-mile area draining to that stream reach is about 6,400 lb/mi^2/yr. The nonpoint yield of dissolved phosphorus from this same area is about 170 lb/mi^2/yr (J.R. Mullaney, U.S. Geological Survey, written commun., 1997). These values may be lower than the actual annual yields supplied to the stream by ground water, because ground-water discharge at other times of the year is probably higher. These values indicate that a substantial amount of the stream nitrogen load is supplied by ground-water discharge in some urban areas. The proportion of the stream phosphorus load supplied by ground-water discharge is probably smaller, because phosphorus concentrations in ground water are typically low, even in urban areas.

In a study of lakes in Connecticut, total nitrogen yields estimated by Frink (1991, table 2, p. 722) for urban land with no point sources ranged from 6,200 lb/mi^2/yr to 9,100 lb/mi^2/yr. Total phosphorus

Table 6. Estimated amounts of nitrogen and phosphorus added from animal manure and fertilizer, Connecticut, Housatonic, and Thames River Basins study area, 1992

[**Source:** L.J. Puckett, U.S. Geological Survey, written commun., 1997. (x 0.5), amount shown is half of total for county. Numbers may not add to totals because of independent rounding. lb, pound]

State	County	Animal manure		Fertilizer	
		Nitrogen (lb)	Phosphorus (lb)	Nitrogen (lb)	Phosphorus (lb)
Vermont	Caledonia	2,550,000	397,000	612,000	196,000
	Essex	141,000	21,600	172,000	55,000
	Orange	2,590,000	416,000	650,000	208,000
	Windsor	1,530,000	305,000	414,000	133,000
New Hampshire	Coos (x 0.5)	399,000	66,000	192,000	40,600
	Grafton (x 0.5)	726,000	117,000	439,000	92,900
	Sullivan	690,000	117,000	600,000	127,000
Subtotal: Connecticut River at North Walpole, N.H.		8,630,000	1,440,000	3,080,000	852,000
Vermont	Windham	1,050,000	173,000	529,000	170,000
New Hampshire	Cheshire	744,000	126,000	456,000	96,500
Massachusetts	Franklin	1,730,000	284,000	4,080,000	741,000
	Hampden	610,000	115,000	2,130,000	386,000
	Hampshire	1,240,000	260,000	3,400,000	618,000
	Worcester (x 0.5)	1,120,000	223,000	1,560,000	283,000
Subtotal: Connecticut River at Thompsonville, Conn.		15,100,000	2,620,000	15,200,000	3,150,000
Massachusetts	Berkshire	1,310,000	223,000	1,260,000	229,000
Connecticut	Fairfield	203,000	43,000	90,500	15,700
	Hartford	800,000	168,000	2,880,000	499,000
	Litchfield	2,260,000	387,000	1,060,000	184,000
	Middlesex	420,000	84,000	265,000	45,900
	New Haven	681,000	130,000	841,000	146,000
	New London	5,460,000	1,660,000	3,820,000	661,000
	Tolland	1,750,000	313,000	612,000	106,000
	Windham	2,700,000	560,000	818,000	142,000
Totals For Study Unit:		*30,700,000*	*6,190,000*	*26,900,000*	*5,170,000*

yields estimated by Frink ranged from 850 to 1,100 lb/mi^2/yr. Novotny and Chesters (1981, p. 407) reported total nitrogen yields ranging from 2,900 to 4,000 lb/mi^2/yr and total phosphorus yields ranging from 230 to 740 lb/mi^2/yr for residential areas near the Great Lakes. They also reported total nitrogen yields ranging from 1,100 to 6,300 lb/mi^2/yr and total phosphorus yields ranging from 60 to 230 lb/mi^2/yr for commercial areas (p. 413).

Point-Source Contributions

Point-source discharges to surface water are registered through the National Pollutant Discharge Elimination System (NPDES) permitting program of the U.S. Environmental Protection Agency (USEPA). Required monitoring data for NPDES discharges are stored in the USEPA's Permit Compliance System (PCS) data base. Some treatment plants monitor effluent for total phosphorus and ammonia nitrogen, but many do not, and, typically, information on total nitrogen concentrations is not available. Retrieval and evaluation of PCS data were beyond the scope of this report. Further investigation of these data, however, would yield important quantitative information on nutrient sources.

Estimates of point-source contributions of nitrogen and phosphorus were derived from several sources of information. Locations and volumes of wastewater return flows from municipal wastewater-treatment facilities in 1990 were obtained from Medalie (1996). The compilation includes data on all facilities in New England with a mean flow greater than 0.01 Mgal/d, or that served a sewered population of greater than 150 people if a mean daily flow value was not available. Most of the return flows compiled by Medalie are NPDES discharges to surface water; a few are small discharges to ground water permitted by the States. The compilation includes data for 144 municipal wastewater-treatment plants in the 25 drainage basins evaluated in this report.

Data on wastewater return flows were used in conjunction with a range of estimates for concentrations of total nitrogen and total phosphorus in wastewater to obtain estimates of nutrient loads transmitted to streams from wastewater-treatment plants in selected drainage basins (Farrow and others, 1986, p. 18; Medalie, 1996; Margo Webber, Massachusetts Department of Environmental Protection, written commun., 1996; P.E. Stacey, Connecticut Department of Environmental Protection, oral commun., 1999). Additionally, total nitrogen loads for wastewater-treatment plants in Connecticut have been compiled by the CTDEP Bureau of Water Management (P.E. Stacey, Connecticut Department of Environmental Protection, written commun., 1996). These loads, in pounds per day, also were used to estimate point-source loads in selected drainage basins. In cases where monitoring data were unavailable, the CTDEP load values are based on an estimated total nitrogen concentration of 15 mg/L in the treated effluent. Drainage basins selected for analysis in this report include the Connecticut River Basin and four highly urban basins with major point sources (table 7).

Total nitrogen concentrations in municipal wastewater effluent were assumed to be in a range of about 14 to 18 mg/L, and total phosphorus concentrations were assumed to be in a range of about 1.0 to 2.0 mg/L, for the load estimates presented in this report (table 7). Nutrient inputs to streams from municipal wastewater-treatment plant discharges have been estimated using the following equation:

$$\textit{Wastewater return flow}\ (\mathrm{ft^3/s}) \times \textit{nutrient concentration}\ (\mathrm{mg/L}) \times 5.3943\ (\textit{unit conversion factor}) \times 365\ \mathrm{d/yr} = \textit{nutrient load}\ (\mathrm{lb/yr}) \qquad (4)$$

Estimates of the total nitrogen contributed to streams from point sources range from 18,000 to 44,000 lb/mi^2/yr for urban land in the southern part of the study area (table 7). Point-source contributions of total nitrogen for urban land in the northern part of the study area range from 10,000 to 12,000 lb/mi^2/yr, based on information for the Connecticut River at North Walpole, NH. Point-source contributions of total phosphorus range from 1,600 to 5,100 lb/mi^2/yr for urban land in the southern part of the study area and are about 1,000 to 1,400 lb/mi^2/yr for urban land in the northern part of the study area.

Sixteen of the 25 drainage basins evaluated for this study receive municipal wastewater discharges (table 8). In 12 of the 16 basins, the wastewater discharges constitute less than 5 percent of the annual mean streamflow; in 4 of these 12 basins, wastewater consistently constitutes less than 1 percent of the annual mean streamflow. In the Pequabuck, Hockanum, Quinnipiac, and Naugatuck River Basins, wastewater constitutes a substantial proportion of the annual mean streamflow—from 9 to 27 percent (table 8).

Some municipal wastewater-treatment facilities receive industrial wastewater, and consequently those industrial discharges are included in the effluent data compiled for this report. Other industrial wastewater discharges are separately permitted, and information on these has not been compiled for this report. In some drainage basins, industrial discharges that are separately permitted may be substantial sources of nutrients to streams.

Table 7. Estimated point source loads for selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area

[**Sources:** Wastewater return flows, Medalie, 1996; ranges of nutrient concentrations, Farrow and others, 1986, p. 18; P.E. Stacey, Connecticut Department of Environmental Protection, written commun., 1996 and oral commun., 1999; Margo Webber, Massachusetts Department of Environmental Protection, written commun., 1996. ft^3/s, cubic foot per second; $lb/mi^2/yr$, pounds per square mile per year; lb/yr, pounds per year; mg/L, milligrams per liter; mi^2, square mile]

Station name	Drainage area (mi^2)	Urban land (mi^2)	1990 wastewater flow (ft^3/s)	Assumed total nitrogen concentration (mg/L)	Point source load of nitrogen from urban land in basin		Assumed total phosphorus concentration (mg/L)	Point source load of phosphorus from urban land in basin	
					lb/yr	$lb/mi^2/yr$		lb/yr	$lb/mi^2/yr$
Connecticut River at North Walpole, N.H.	5,493	71.4	24.9	15.0	735,000	10,000	1.5	73,500	1,000
				18.0	882,000	12,000	2.0	98,100	1,400
Connecticut River at Thompsonville, Conn.	9,660	290	214	15.0	6,320,000	22,000	1.1	463,000	1,600
				18.0	7,580,000	26,000	1.3	548,000	1,900
Connecticut River between North Walpole, N.H. and Thompsonville, Conn.	4,167	219	189	15.0	5,580,000	26,000	1.2	450,000	2,100
				18.0	6,700,000	31,000	1.3	484,000	2,200
Pequabuck River at Forestville, Conn.	45.8	11.8	18.1	13.6	485,000	41,000	1.5	53,500	4,500
				14.5	517,000	44,000	1.7	60,600	5,100
Hockanum River near East Hartford, Conn.	73.4	22.8	16.1	15.8	500,000	22,000	1.7	53,900	2,400
				17.8	564,000	25,000	2.0	63,400	2,800
Quinnipiac River at Wallingford, Conn.	115	42.1	25.4	15.2	760,000	18,000	1.5	75,000	1,800
Naugatuck River at Beacon Falls, Conn.	260	46.0	58.3	15.3	1,750,000	38,000	1.5	172,000	3,700
				17.1	1,960,000	43,000	1.7	195,000	4,200

Table 8. Municipal wastewater return flows and annual mean stream discharges for selected water years, Connecticut, Housatonic, and Thames River Basins study area

[**Sources:** Wastewater return flows from Medalie (1996); annual mean discharges from U.S. Geological Survey National Water Information System; ft^3/s, cubic feet per second; mi^2, square mile; --, no data]

Station name	Drainage area (mi^2)	1990 waste-water return flow (ft^3/s)	Annual mean discharge (ft^3/s)			Return flow as a percentage of discharge		
			1990	1994	1995	1990	1994	1995
Shetucket River at South Windham, Conn.	408	8.42	888	872	590	0.95	0.96	1.4
Quinebaug River at Quinebaug, Conn.	155	4.61	336	353	191	1.4	1.3	2.4
Quinebaug River at Jewett City, Conn.	713	21.3	1,600	1,380	933	1.3	1.5	2.3
White River at West Hartford, Vt.	690	0.65	1,530	1,220	755	.04	.05	.09
Connecticut River at North Walpole, N.H.	5,493	24.9	12,900	10,300	6,380	.19	.24	.39
Connecticut River at Thompsonville, Conn.	9,660	214	22,300	18,800	12,000	.96	1.1	1.8
Still River at Riverton, Conn.	86.2	2.65	197	175	118	1.3	1.5	2.2
Farmington River at Unionville, Conn.	378	3.53	799	694	477	.44	.51	.74
Pequabuck River at Forestville, Conn.	45.8	18.1	112	96	68	16	19	27
Farmington River at Tariffville, Conn.	577	32.6	1,340	1,230	854	2.4	2.7	3.8
Hockanum River near East Hartford, Conn.	73.4	16.1	150	144	102	11	11	16
Quinnipiac River at Wallingford, Conn.	115	25.4	293	244	174	8.7	10	15
Tenmile River at South Dover nr Wingdale, N.Y.	194	.09	--	332	237	--	.03	.04
Housatonic River at Stevenson, Conn.	1,544	47.3	3,460	3,120	2,020	1.4	1.5	2.3
Naugatuck River at Beacon Falls, Conn.	260	58.3	650	618	403	9.0	9.4	14
Norwalk River at Winnipauk, Conn.	33.0	1.45	63.7	59.8	39.9	2.3	2.4	3.6

For example, the Naugatuck River receives industrial discharges, and the point-source load calculated for the Naugatuck River is probably underestimated (P.E. Stacey, Connecticut Department of Environmental Protection, written commun., 1998).

Municipal CSOs are generally considered a point-source discharge. A management goal of the CTDEP is to eliminate the discharge of untreated wastewater through CSOs. CSOs are considered to be a major pollution source on the Connecticut and Naugatuck Rivers (Connecticut Department of Environmental Protection, 1994, p. 2; Appendix A, p. 73–75).

Estimates of annual pollutant loads in stormwater runoff from major urban areas have been compiled by NOAA for 10 urban areas, including areas with CSOs, using precipitation data for 1982 (Farrow and others, 1986, p. 25–28; appendix VI, table VI-3). The areas evaluated include one urban area in New York and nine urban areas in Connecticut. Estimates for total nitrogen contributed to streams from stormwater runoff in areas with CSOs range from 7,000 to 22,000 lb/mi^2/yr, with an average of 12,000 lb/mi^2/yr for the 10 urban areas. Estimates for total phosphorus range from 1,500 to 4,700 lb/mi^2/yr, with an average of 2,500 lb/mi^2/yr for the 10 areas. Current data on nutrient loads from CSOs would improve understanding of the relative importance of this nutrient source in urban drainage basins.

NUTRIENT LOADS IN THE CONNECTICUT, HOUSATONIC, AND THAMES RIVER BASINS

Annual total nitrogen and total phosphorus loads have been estimated using the ESTIMATOR program for 25 drainage basins. Load estimates based on monitoring stations with long periods of record are generally more reliable than estimates for stations with short periods of record. Annual loads vary depending on drainage basin size, discharge conditions, and land uses.

Stream nutrient loads have been estimated for nontidal locations. Some streams have long reaches affected by tides, including the Connecticut River for most of its length in Connecticut. The load of nitrogen or phosphorus at the farthest downstream nontidal location on a stream is likely to differ from the load that actually enters Long Island Sound because of additional nutrient inputs along tidally affected reaches and estuarine processes that affect transport of nitrogen and phosphorus.

Nutrient Load Results and Confidence Intervals

The 25 monitoring stations have water-quality records ranging in length from 2.5 to 26 years. Annual nutrient loads (in pounds per year) and yields (in pounds per square mile per year) for each station for all available years of record are reported in table 15 (at the back of this report). The 95 percent confidence interval for each estimated annual load of nitrogen or phosphorus has been calculated from the standard error of prediction provided by the ESTIMATOR program. The confidence interval is shown in pounds per year and as a percentage of the annual load (table 15).

Drainage basins with long-term water-quality records and a high percentage of detected observations typically have confidence intervals, or error ranges, of about plus-or-minus 5 to 15 percent for total nitrogen loads and about plus-or-minus 10 to 30 percent for total phosphorus loads. Error percentages are substantially greater for phosphorus than for nitrogen at most stations.

Urban drainage basins with point sources have the smallest confidence intervals. Confidence intervals are substantially larger for streams with low nitrogen and phosphorus concentrations and high percentages of censored data. For clean streams with less than 3 full years of water-quality data, confidence intervals exceed 100 percent for some load estimates; however, because the annual nutrient load estimates for these streams are very small, the absolute load remains small. Confidence intervals are largest for the Sleepers, Ammonoosuc, White, and Green River Basins (all forested basins) and for the Rooster River Basin (a nonpoint urban basin). Load estimates are reported for these stations, but a larger number of observations is necessary to improve the confidence interval for load estimates.

A large confidence interval for a load estimate may not indicate insufficient or incorrect data. For example, the confidence interval for the 1982 phosphorus load on the Salmon River (map reference number 18, fig. 3; 01193500, table 15) is 125 percent. However, the peak streamflow for a 69-year period occurred on the Salmon River on June 6, 1982, and the high annual load appears to reflect the unusually high and prolonged stream discharge associated with this event.

Relation of Nutrient Loads to Drainage Area and Discharge

Total nitrogen and total phosphorus loads are closely correlated with drainage area (fig. 7). This correlation is due in part to the strong correlation between stream discharge and drainage area. Stream discharge is used directly to calculate constituent loads; consequently, there is also a strong correlation between loads and drainage area. Annual total nitrogen loads in 1994 ranged from about 11,000 lb in the smallest drainage basin (Burlington Brook) to about 23,000,000 lb in the largest basin (Connecticut River at Thompsonville). Similarly, total phosphorus loads for these two drainage basins ranged from about 400 lb to 1,500,000 lb.

The 1994 water year was selected for analyses presented in this report because it is a complete year of sampling at the short-term NAWQA stations, and because discharge conditions in 1994, as represented by annual mean flows, were reasonably close to median conditions at most stations. Annual mean flows have been used to characterize flow conditions for load estimates presented in this report; however, this is only one measure of the streamflow conditions that affect nutrient transport. For example, a few major storms may transport a large nonpoint nutrient load in a year when the annual mean flow is lower than usual.

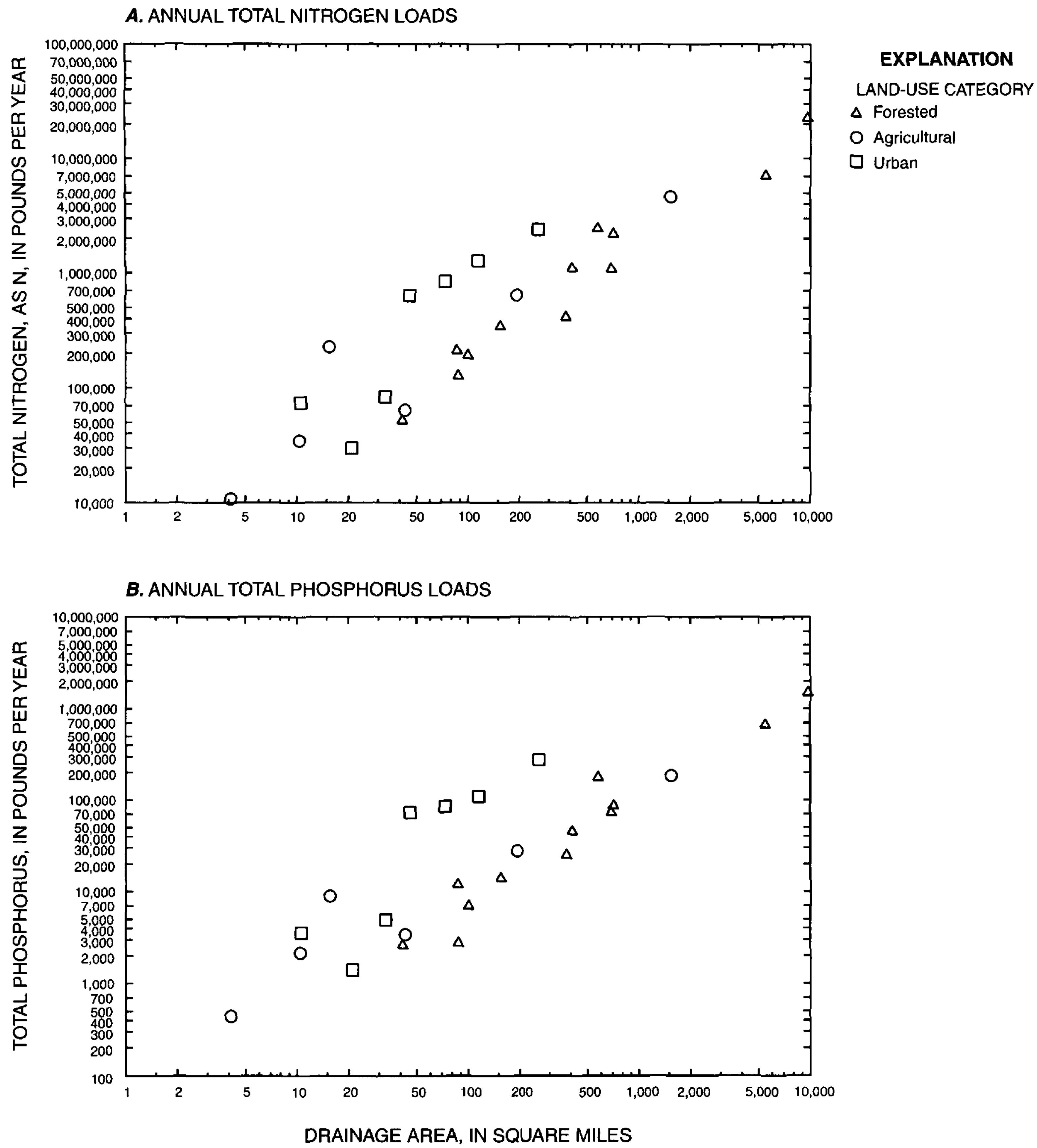


Figure 7. Annual (*A*) total nitrogen and (*B*) total phosphorus loads as a function of drainage area for 25 drainage basins, Connecticut, Housatonic, and Thames River Basins study area, water year 1994.

The water-quality record of short-term monitoring stations may not adequately represent the full range of streamflow conditions. Load estimates for these stations typically have a greater uncertainty than estimates for long-term stations.

Relation of Nutrient Loads to Predominant Land Use

The 25 basins evaluated in this study include 12 forested basins, 6 agricultural basins, and 7 urban basins. Water quality in most of these basins reflects the effects of multiple land uses to some extent. All but one of the basins have drainage areas that are at least 40 percent forested, and in four basins, the percentages of urban and agricultural land are similar (table 1).

Nutrient loads are related to land-use practices and waste discharges in each drainage basin (fig. 7). In general, urban basins have much larger nutrient loads than forested basins of a similar size. Some urban basins have nutrient loads that equal or exceed the loads of much larger forested basins. Nutrient loads in agricultural basins equal or exceed those of forested basins of a similar size and are typically less than those of urban basins.

Nutrient yields in pounds per square mile were calculated to compare the nutrient loads from basins of various sizes. Basin nutrient yields represent an average of the effects of different land-use conditions and nutrient sources within each drainage basin. Comparison of nutrient yields in 1994 for the 25 drainage basins indicates some general effects of land use and waste discharges (fig. 8*A*,*B*). The largest total nitrogen and total phosphorus yields are in basins where the total of urban and agricultural land exceeds 30 percent of the drainage basin, whereas the smallest yields are primarily in basins where more than 70 percent of the land is forested. The largest nutrient yields are generally in drainage basins where wastewater discharges constitute a large percentage of streamflow.

Annual nitrogen and phosphorus yields for all years of record at each station are summarized in boxplots (figs. 9 and 10). Stations are grouped by drainage basin size to facilitate comparison of typical yields in basins of similar size and different land uses. The stations have from 3 to 26 years of yield estimates.

Minimally Developed or Forested Drainage Basins

Total nitrogen yields are generally less than 4,000 lb/mi^2/yr in forested drainage basins (fig. 9), and total phosphorus yields are generally less than 400 lb/mi^2/yr (fig. 10). Nutrient yields are generally lowest in the forested basins with no point sources. The 12 forested drainage basins include only 3 basins that do not receive any wastewater discharges. Nutrient yields in forested basins appear to be related to the percentage of forested land, the combined percentage of urban and agricultural land, the magnitude of point discharges relative to stream discharge, and the population density.

The lowest total nitrogen and total phosphorus yields are in two relatively undeveloped drainage basins, the Green River in Massachusetts and Vermont and the Ammonoosuc River in northern New Hampshire. More than 94 percent of the land is forested in both of these drainage basins, and there are no point-source discharges. Total nitrogen yields for the limited period of record (1993–95) were less than 2,000 lb/mi^2/yr; total phosphorus yields were 100 lb/mi^2/yr or less.

Typical total nitrogen yields at stations on the Quinebaug River at Quinebaug, the Salmon River, and the Still River, all in Connecticut, substantially exceed yields on the Green and Ammonoosuc Rivers (fig. 9*A*,*B*). The Quinebaug and Still Rivers receive point discharges. The Salmon River, although it receives no point discharges, has the largest combined percentage of urban and agricultural land among the forested basins.

The median total phosphorus yield for the Salmon River is only about half the median total phosphorus yields for the Quinebaug and Still Rivers (fig. 10*B*). Less phosphorus may be delivered to the Salmon River Basin, which has no point sources, or more phosphorus may be retained than in the other two basins. For example, phosphorus from septic system effluent may be retained by soils in the Salmon River Basin, whereas nitrogen, a more conservative constituent, is delivered to streams in the form of nitrate by ground-water discharge.

All the large drainage areas are primarily forested, despite the high population density of some areas in the southern part of the study area (table 1). Nutrient yields in large forested basins may be related

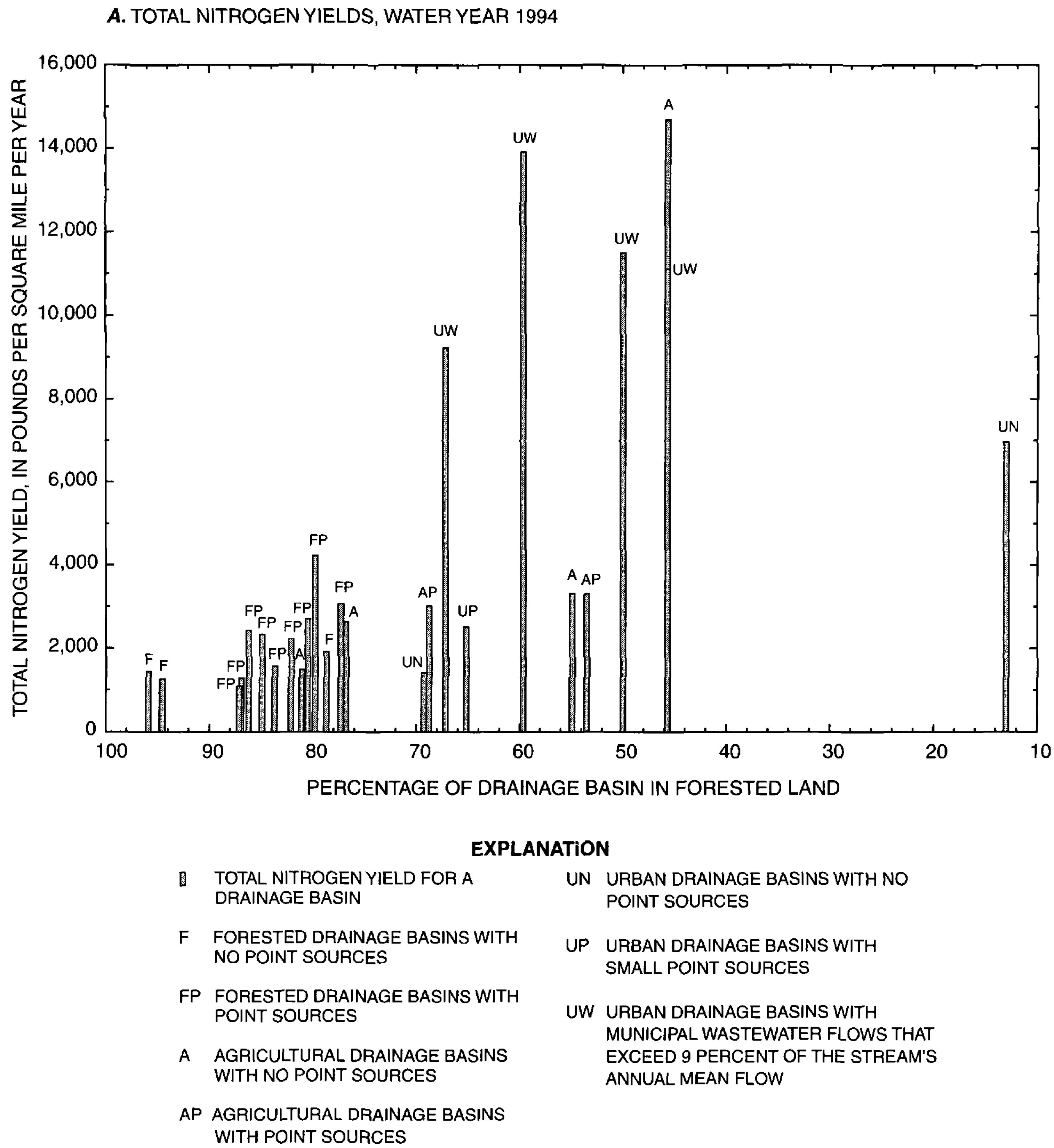
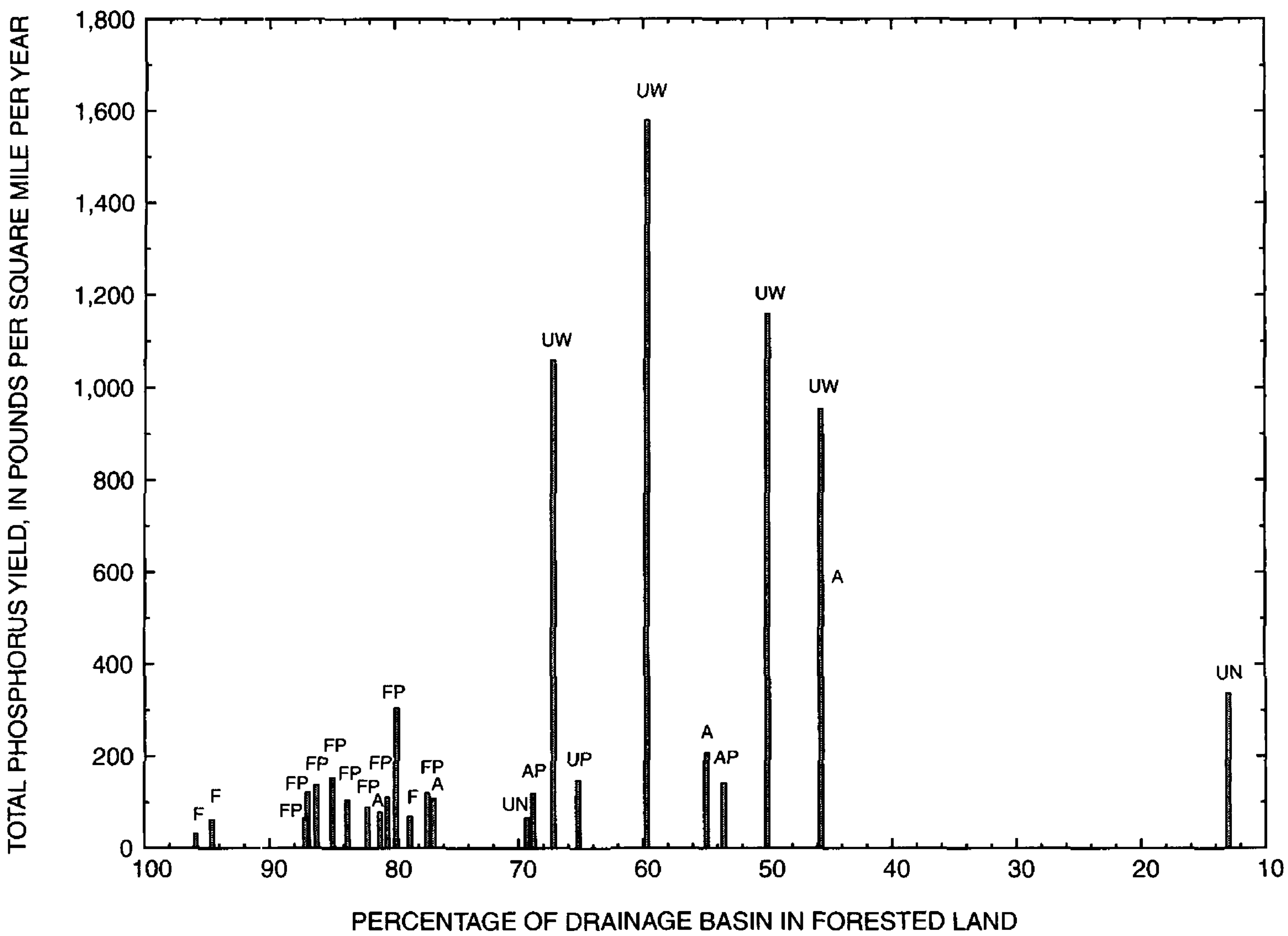


Figure 8. Yields of (*A*) total nitrogen and (*B*) total phosphorus loads for 25 drainage basins, Connecticut, Housatonic, and Thames River Basins study area, water year 1994.

to the magnitude of waste discharges relative to basin size, as indicated by basin population density (table 1) or by the magnitude of wastewater flows relative to streamflow (table 8). Wastewater discharges constitute less than 0.1 percent of the annual mean discharge on the White River, and less than 0.8 percent of the annual mean discharge on the Farmington River at Unionville, both of which have low nutrient yields (fig. 9*C*). Population density in these basins is 29/mi^2 and 117/mi^2, respectively. By contrast, the Farmington River at Tariffville, which has the largest nutrient yields among the large forested basins, also has the highest population density (306 per mi^2) and the largest wastewater discharges relative to streamflow (2.4 to 3.8 percent) among these basins.

Differences in nutrient yields between an upstream and downstream station on the Farmington River (map reference numbers 14 and 16, fig. 3; fig. 9*C*) may be explained by differences in land use and nutrient sources in the upstream and downstream

B. TOTAL PHOSPHORUS YIELDS, WATER YEAR 1994



EXPLANATION

- ▮ TOTAL PHOSPHORUS YIELD FOR A DRAINAGE BASIN
- F FORESTED DRAINAGE BASINS WITH NO POINT SOURCES
- FP FORESTED DRAINAGE BASINS WITH POINT SOURCES
- A AGRICULTURAL DRAINAGE BASINS WITH NO POINT SOURCES
- AP AGRICULTURAL DRAINAGE BASINS WITH POINT SOURCES
- UN URBAN DRAINAGE BASINS WITH NO POINT SOURCES
- UP URBAN DRAINAGE BASINS WITH SMALL POINT SOURCES
- UW URBAN DRAINAGE BASINS WITH MUNICIPAL WASTEWATER FLOWS THAT EXCEED 9 PERCENT OF THE STREAM'S ANNUAL MEAN FLOW

Figure 8. Yields of (*A*) total nitrogen and (*B*) total phosphorus loads for 25 drainage basins, Connecticut, Housatonic, and Thames River Basins study area, water year 1994—*Continued.*

parts of the drainage basin. As noted previously, wastewater discharges constitute less than 1 percent of streamflow in the Farmington River at Unionville and about 87 percent of the drainage basin is forested. Water quality on the Farmington River at Tariffville is affected by its urban tributary, the Pequabuck River (map reference number 15, fig. 3), which enters the Farmington River downstream from Unionville, and which has some of the highest nutrient yields of all 25 monitored basins (figs. 9*A*, 10*A*). Also, agricultural land in the Farmington River Basin is primarily along the downstream reaches of the river, in the lowlands of central Connecticut, and probably contributes to the increased nutrient load at Tariffville. Agricultural land constitutes only 5 percent of the drainage area of the Farmington River upstream from Unionville. Agricultural land constitutes about 8 percent of the entire drainage area for the Farmington River at Tariffville, but about 12 percent of the drainage area between the Unionville and Tariffville stations.

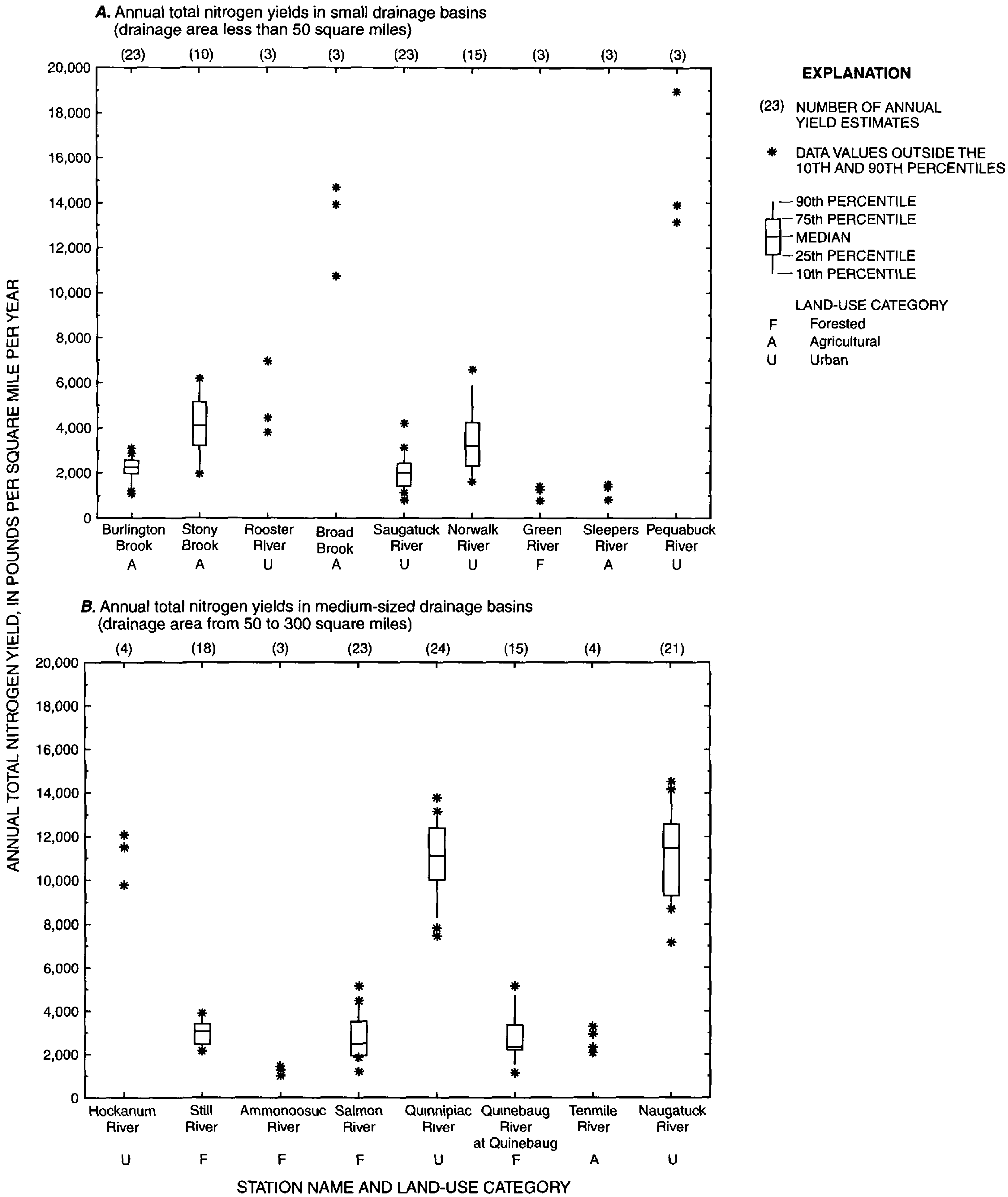


Figure 9. Total nitrogen yields in (*A*) small, (*B*) medium-sized, and (*C*) large drainage basins drainage basins, Connecticut, Housatonic, and Thames River Basins study area.

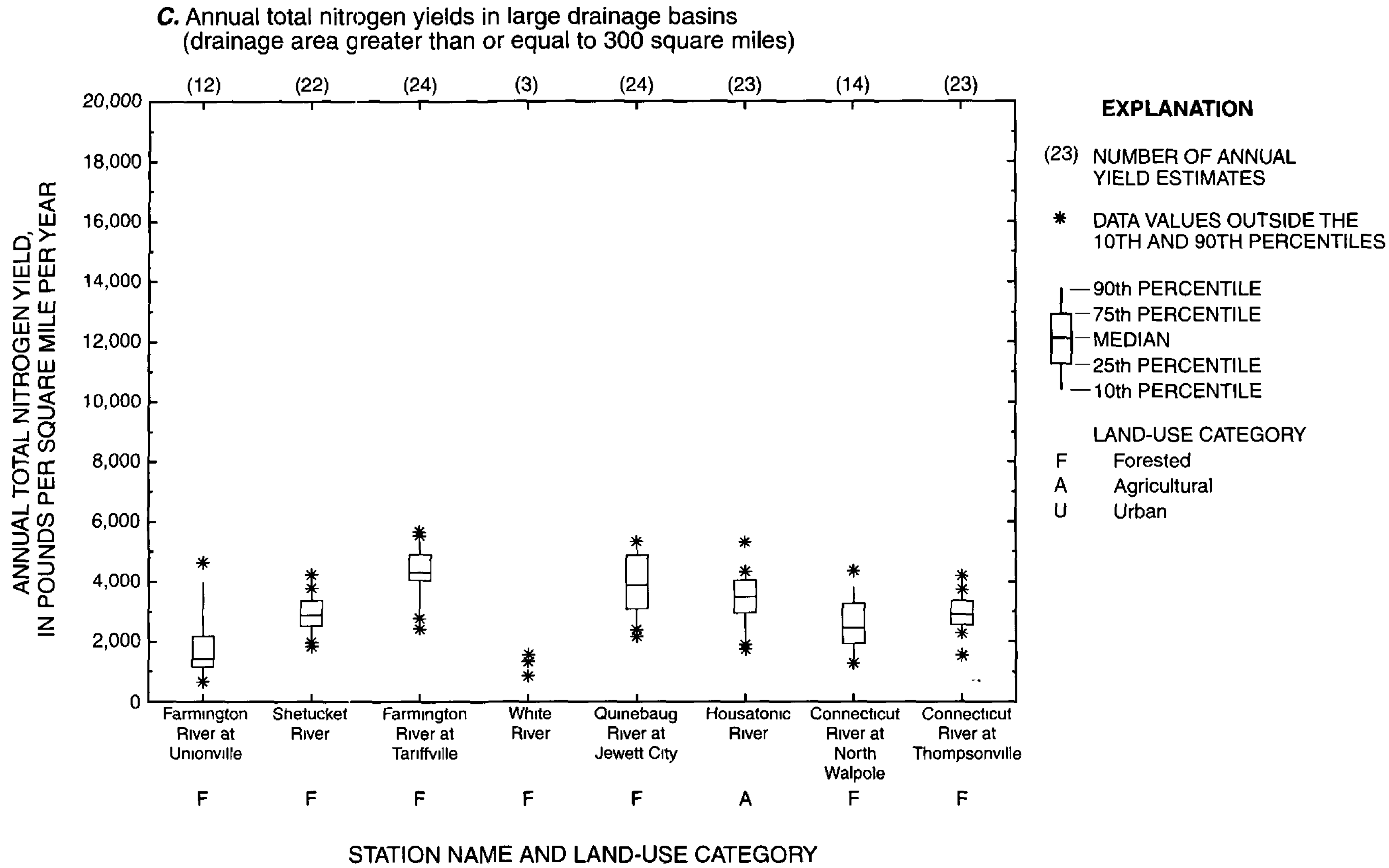


Figure 9. Total nitrogen yields in (*A*) small, (*B*) medium-sized, and (*C*) large drainage basins, Connecticut, Housatonic, and Thames River Basins study area—*Continued.*

Nutrient yields for the drainage basins of the Farmington River at Unionville and the Connecticut River at Thompsonville may be somewhat higher than those estimated from discharges measured at the monitoring stations, because of upstream diversions of water for large municipal supplies in Massachusetts and Connecticut. The exported discharge includes some of the nutrient load of the drainage basin; however, the exported water is assumed to have low nutrient concentrations and may not constitute a significant percentage of the stream load.

Total nitrogen yields for the Connecticut River at North Walpole in New Hampshire (fig. 9*C*) appear high relative to the low density of population (only 39/mi^2), the low ratio of wastewater discharge to streamflow (less than 0.4 percent), and the large amount of forested land (87 percent). The city of Lebanon, N.H., about 35 mi upstream from the North Walpole monitoring station, has CSOs that occasionally discharge during wet weather to the Connecticut River and tributaries (New Hampshire Department of Environmental Services, 1996, p. II-2-15), and the CSOs may contribute to the relatively high total nitrogen yields. Additionally, four counties bordering the Connecticut River in New Hampshire and Vermont have substantial farm animal populations (Battaglin and Goolsby, 1995, p. 18, fig. 10). Additional information is necessary to interpret nitrogen yields for this drainage basin.

Agricultural Drainage Basins

Six drainage basins, with agricultural land use ranging from 17 to 38 percent of the basin, are considered agricultural. Total nitrogen yields for four of these basins (Sleepers, Tenmile, and Housatonic Rivers, and Burlington Brook) are generally less than 4,000 lb/mi^2/yr, and total phosphorus yields are generally less than 300 lb/mi^2/yr, similar to forested basins (figs. 9, 10). The similarity to forested drainage basins indicates that agricultural land use in these four basins is not intensive enough to have a substantial effect on nutrient loads.

The highest nutrient yields among agricultural basins are in the Stony Brook and Broad Brook Basins (figs. 9*A*, 10*A*). Total nitrogen yields for Broad Brook exceed 10,000 lb/mi^2/yr, similar to yields of urban

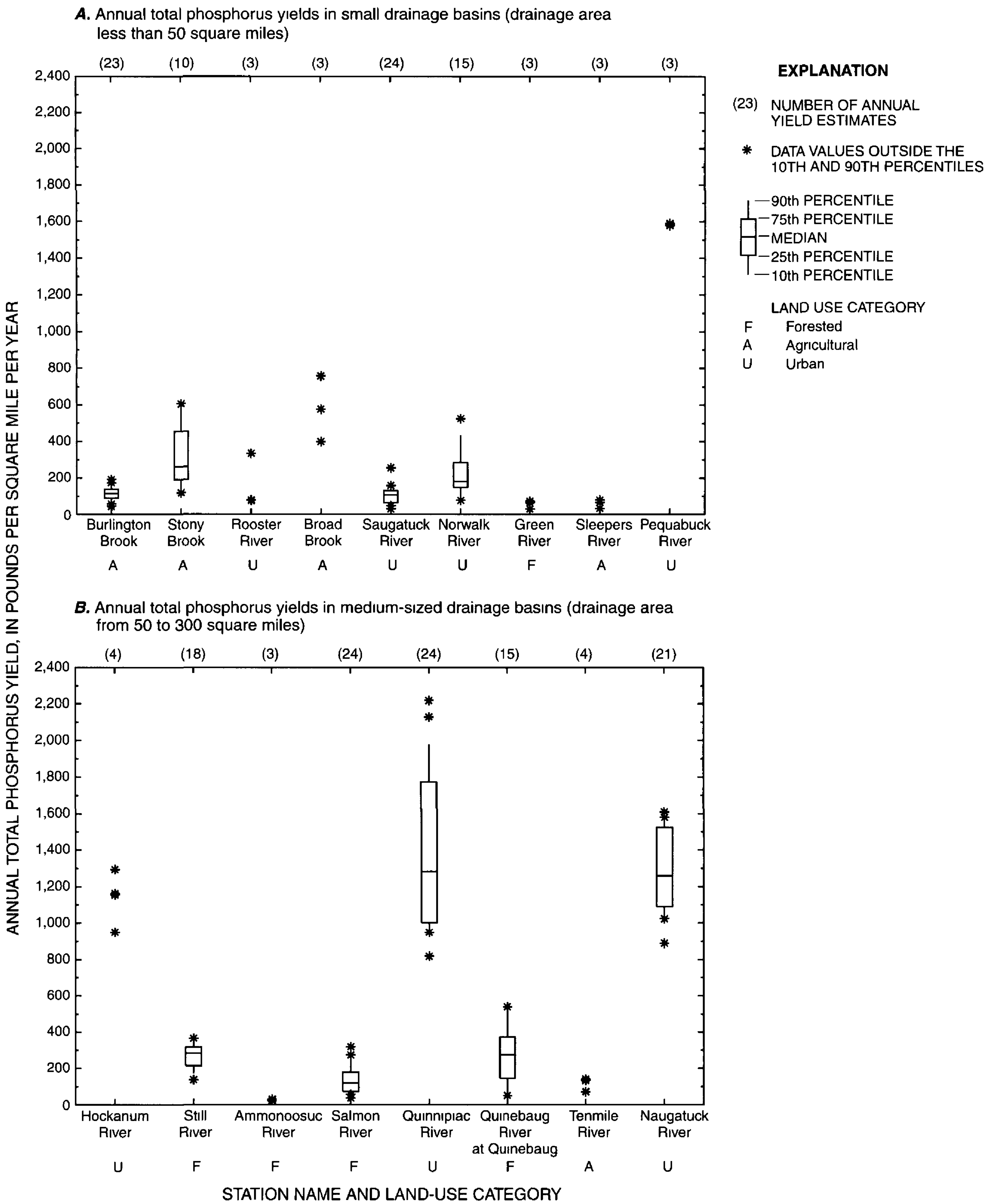


Figure 10. Total phosphorus yields in (*A*) small, (*B*) medium-sized, and (*C*) large drainage basins, Connecticut, Housatonic, and Thames River Basins study area.

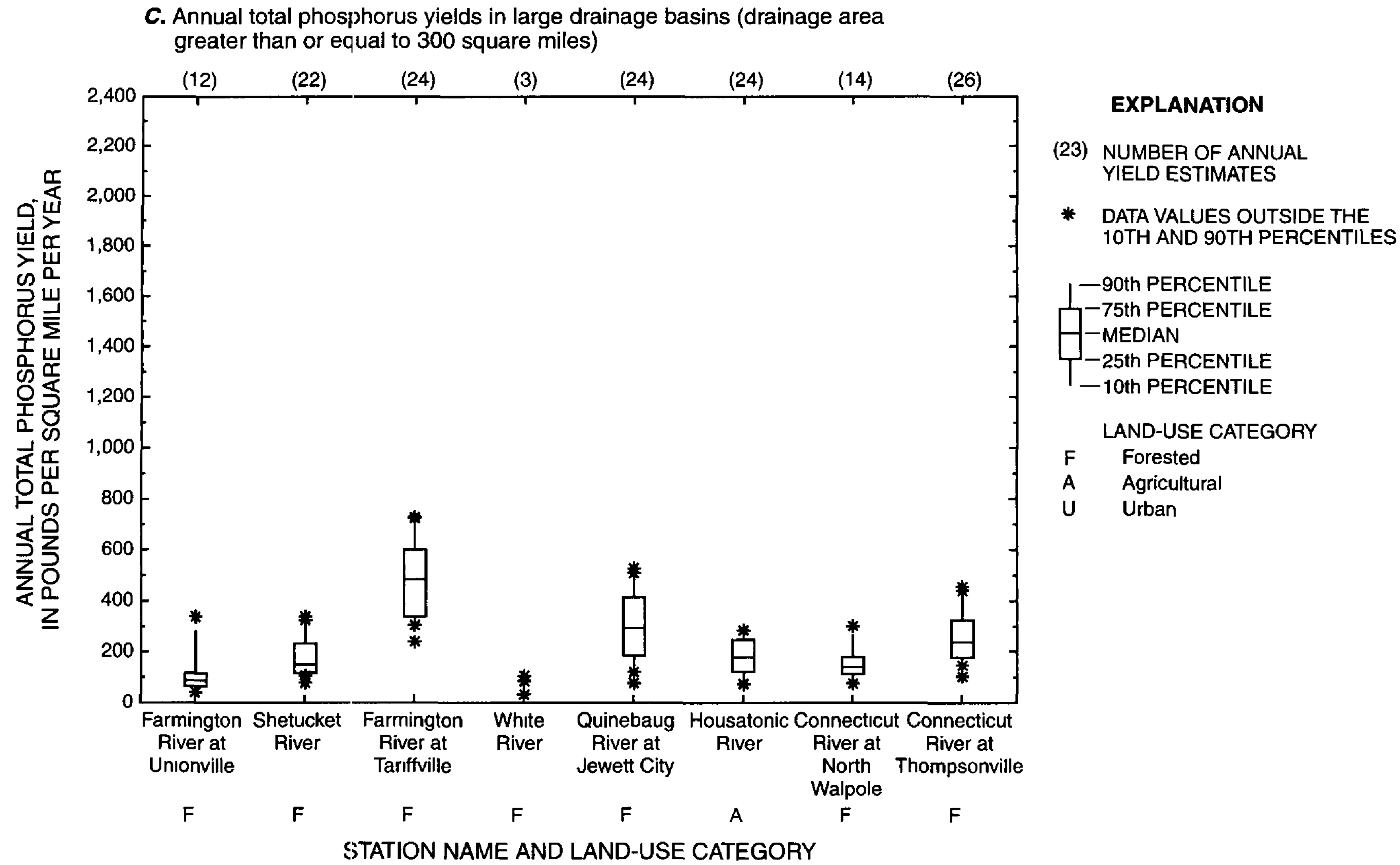


Figure 10. Total phosphorus yields in (*A*) small, (*B*) medium-sized, and (*C*) large drainage basins, Connecticut, Housatonic, and Thames River Basins study area—*Continued.*

drainage basins where wastewater discharges constitute a large percentage of streamflow (fig. 9). Total phosphorus yields for Broad Brook are generally less than yields for urban basins with major point sources, but substantially higher than yields for most forested drainage basins (fig. 10).

Both Stony Brook and Broad Brook are in the extensive stratified-drift deposits overlying sedimentary bedrock in the central lowlands of Connecticut, whereas the other four agricultural basins are underlain by crystalline bedrock terrains. The permeability, erodibility, and composition of the surficial materials may be a factor in the transport of nutrients by ground water and surface water. Also, soils developed in the central lowlands of Connecticut support more intensive agricultural land use than the less easily farmed terrain of the upland areas.

Four of the six agricultural basins have drainage areas that are less than 50 mi^2. They are among the smallest drainage basins evaluated in this study. Nutrient yields for a small drainage basin may be substantially affected by localized agricultural practices and conditions, such as the presence of large populations of farm animals.

Developed or Urban Drainage Basins

Total nitrogen and total phosphorus yields are generally highest in urban drainage basins (figs. 9, 10). Seven drainage basins, with urban land use ranging from 18 to 76 percent of the basin, are considered developed or urban basins. Factors that affect the magnitude of total nitrogen and total phosphorus yields include the presence or absence of point discharges, the magnitude of the point discharges, the percentage of urban land in the drainage basin, and the type and location of urban land.

Effects of Nonpoint Sources

The Saugatuck and Rooster River Basins in southwestern Connecticut are two small urban basins with no point sources. Although 22 percent of the Saugatuck River Basin is classified as urban based on the land-use data used in this study, much of the urban land is low- or medium-density residential development. Total nitrogen and total phosphorus yields in the Saugatuck River Basin are similar to nutrient yields in forested basins (figs. 9 and 10).

The Rooster River Basin, by contrast, is about 76 percent urban. Only 13 percent of the land is forested. Total nitrogen yields generally exceed those of forested drainage basins, but total phosphorus yields are similar to yields of forested basins (figs. 9 and 10). Although data for this basin are limited, yield estimates indicate a possible range for nonpoint-source contributions of nutrients resulting from urban runoff in densely developed urban areas under median or near-median flow conditions.

Total nitrogen and total phosphorus yields for high-density urban areas without point sources may exceed current estimates based on data for the Rooster River Basin, which has a short period of record that does not include high-flow years. Additionally, combined sanitary and storm sewers in parts of the Rooster River Basin may transport some storm runoff out of the basin, resulting in stream nutrient loads that may be lower than the loads produced in the basin.

Effects of Point Discharges

The largest median total nitrogen and total phosphorus yields are found in the Naugatuck, Quinnipiac, Pequabuck, and Hockanum River Basins, which have large point discharges relative to the size of the streams (table 8). Total nitrogen yields for these basins generally exceed 8,000 $lb/mi^2/yr$ and are substantially larger than yields of forested drainage basins (fig. 9). Total phosphorus yields for these urban basins are an order of magnitude larger than yields in forested basins with no point discharges (fig. 10).

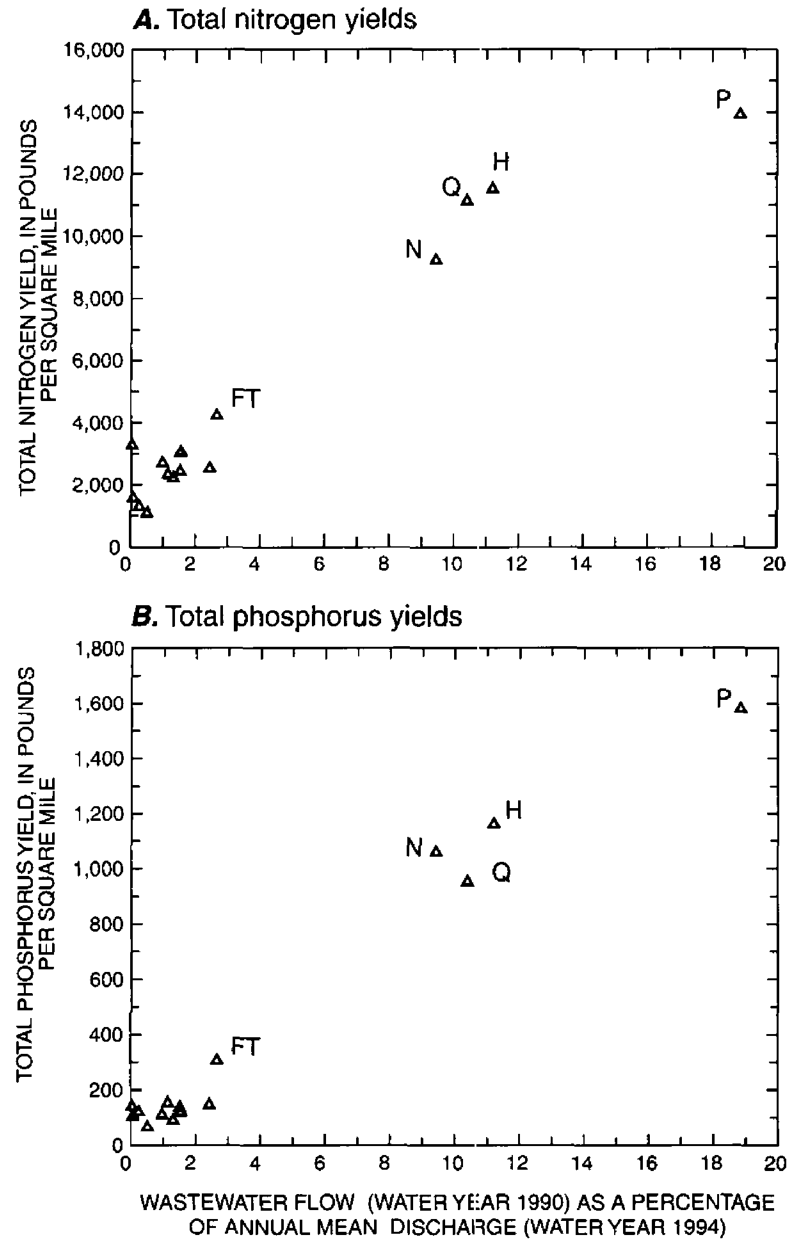
The magnitude of the point discharges relative to the drainage basin size appears to be an important factor affecting stream nutrient yields from urban basins. Magnitude of point discharges is determined, in part, by the number of people served by wastewater-treatment plants. The Naugatuck, Quinnipiac, Pequabuck, and Hockanum River Basins, for example, have sewered population densities ranging from about 740 $/mi^2$ to 1,400$/mi^2$, whereas the Norwalk River Basin, which has substantially lower nutrient yields than these four basins, has a sewered population density of only about 150$/mi^2$.

As wastewater flows increase in proportion to streamflow, total nitrogen and total phosphorus yields increase. Streams in 16 of the 25 drainage basins (including basins classified as forested, agricultural, and urban) receive municipal point discharges. These discharges range in magnitude from 0.01 Mgal/d to 48 Mgal/d, and represent varying percentages of the natural streamflow. To compare the significance of wastewater discharges in basins of different sizes, average annual wastewater flows were expressed as a percentage of each stream's annual mean flow (table 8). Total nitrogen and total phosphorus yields for 1994 are plotted as a function of this percentage for the 16 drainage basins in figure 11. (Yields for one station with a shorter record are for 1991, a comparable year in terms of streamflow.)

Wastewater flow appears to be the most important factor affecting nutrient yields (fig. 11). Four of the five largest total nitrogen and total phosphorus yields in 1994 were in the Naugatuck, Quinnipiac, Pequabuck, and Hockanum River Basins, where wastewater constituted from 9 to 19 percent of the annual mean streamflow in the years selected for analysis (table 8; four bars labeled "uw" in fig. 8; fig. 11). In the 12 basins where wastewater flows are small (from 0.03 to 2.7 percent of the average annual streamflow, table 8), nutrient yields are similar to or somewhat greater than yields in forested basins. These 12 drainage basins include small and medium-sized basins with small wastewater flows, as well as large basins with large wastewater flows that are substantially diluted by streamflow from forested tributary basins.

NUTRIENT YIELD ESTIMATES FOR LAND-USE CATEGORIES

The nutrient yield for a drainage basin usually represents a composite, or average, of different yields from more than one land use. Additional insight into possible nutrient management targets can be gained by examining and estimating nutrient yields for the forested, agricultural, and urban land areas within each drainage basin. Nutrient yields for specific land-use categories have been estimated by using a combination of information on land-use percentages in drainage basins, nutrient inputs to drainage basins, nutrient



EXPLANATION

FT FARMINGTON RIVER AT TARIFFVILLE
H HOCKANUM RIVER
N NAUGATUCK RIVER
P PEQUABUCK RIVER
Q QUINNIPIAC RIVER

Figure 11. (*A*) Total nitrogen and (*B*) total phosphorus yields in water year 1994 as a function of wastewater return flow (expressed as a percentage of annual mean discharge), Connecticut, Housatonic, and Thames River Basins study

yields from drainage basins in the study area with relatively homogeneous land use, and published estimates of land-use yields of nutrients.

The following assumptions and limitations apply when evaluating the land-use yield estimates in this report:

- Annual nutrient loads for water year 1994 from the ESTIMATOR program provide the basic data for the following analysis. Nutrient loads are apportioned to different land uses so that they total to the annual load calculated by the ESTIMATOR program for 1994.
- The total nutrient load in each drainage basin is apportioned to the three major land-use categories on the basis of the percentage of each land use in a drainage basin; thus, nutrient yield estimates for land-use categories are limited, in part, by the accuracy of the land-use data. For example, rural areas classified as forested land could include low-density residential development in some drainage basins.
- Nutrient inputs from municipal wastewater-treatment plant discharges in urban basins have been estimated on the basis of a range of effluent concentrations and data on wastewater return flows, as described in the section "Point-Source Contributions" and shown in table 7. Total nitrogen concentrations in municipal wastewater effluent were assumed to be in a range of about 14 to 18 mg/L, and total phosphorus concentrations were assumed to be in a range of about 1.0 to 2.0 mg/L. In the following analysis, nutrient loads from municipal wastewater effluent were assumed to reach the monitoring station without instream attenuation. This assumption may overestimate the relative contribution of point sources at some locations, especially for phosphorus.
- Industrial point sources or CSOs could constitute a significant percentage of a station's total nutrient load in a few drainage basins. Information on nutrient loads from industrial sources and CSOs was not compiled for this analysis but may be necessary to assign nutrient yields to land uses more accurately at a few locations.
- Different yield estimates for the three major land uses can be obtained by making different assumptions about effluent concentrations or the typical nutrient yield of a particular land use. The land use yield estimates shown here are not unique solutions for a drainage basin and are a function of many necessary assumptions.
- Annual mean flows in water year 1994 were slightly to moderately above median for the period of record in most monitored drainage basins but were below median in some drainage basins in the northern part of the study area. Total basin loads will differ in high-flow or low-flow years, and the apportionment of nutrient loads to land-use categories may change under different flow conditions.

The following approach was taken to estimate land-use yields for selected drainage basins. Nutrient yields for forested land use were based on the 1994 yields from forested drainage basins in which agricultural and urban effects are minimal or absent. Nutrient yields for urban land use were selected from a range of published estimates discussed in the section "Urban Nonpoint-Source Contributions." Point-source loads, where applicable, were derived from calculations shown in table 7. Agricultural yields were determined from the residual load after the loads for forested and urban land (and point sources, where applicable) were subtracted from the total 1994 load estimate for a drainage basin.

The total nitrogen yield for forested land was assumed to be 1,200 lb/mi^2/yr, and the total phosphorus yield for forested land was assumed to be 60 lb/mi^2/yr, based on information for forested basins in the study area. These estimates are similar to those reported for forested areas by Frink (1991, table 2, p. 722) in a study relating nutrients in 33 Connecticut lakes to land use in their drainage basins. The study reported total nitrogen yields ranging from 1,100 lb/mi^2/yr to 1,700 lb/mi^2/yr and total phosphorus yields ranging from 40 to 74 lb/mi^2/yr.

Published estimates for nonpoint nutrient yields from urban land cover a wide range (Novotny and Chesters, 1981; Farrow and others, 1986; Frink, 1991; Mullaney and Grady, 1997). Estimated total nitrogen yields generally range from 3,000 to 9,000 lb/mi^2/yr, and may be as high as 13,000 lb/mi^2/yr, if separate estimates for ground-water contributions and stormwater runoff are added. Estimated total phosphorus yields generally range from 200 to 1,000 lb/mi^2/yr.

Experimentation with apportionment of nutrient yields to land uses in drainage basins indicated that a single number for nitrogen and phosphorus yields from urban land would not result in reasonable estimates in many drainage basins. Consequently, on the assumption that nutrient yields for urban land are higher in the more intensively developed drainage basins, two levels of urban nutrient yields were selected, based on the extent and type of urbanization in a drainage basin. In basins classified as urban, and in the drainage basin of the Connecticut River at Thompsonville, Connecticut, which has major urban areas along the lower reaches of the river, the total nitrogen yield for urban land was assumed to be 8,000 lb/mi^2/yr and the total phosphorus yield was assumed to be 400 lb/mi^2/yr. Urban land in forested and agricultural basins was assumed to have a total nitrogen yield of 4,000 lb/mi^2/yr and a total phosphorus yield of 200 lb/mi^2/yr.

Application of either the lower or upper urban yield rates to urban land in the Saugatuck River Basin resulted in loads for urban land that exceeded the 1994 nutrient loads for the entire basin. The Saugatuck River Basin, although classified as an urban drainage basin in this study, has generally low-density development, and nutrient yields for the basin are similar to those of forested basins. Consequently, a total nitrogen yield of 2,000 lb/mi^2/yr and a total phosphorus yield of 100 lb/mi^2/yr was applied to urban land in this basin.

Additional investigation is necessary to determine sources of nutrients in specific drainage basins and to determine nutrient yields for different types and intensities of agricultural and urban land use. The nutrient yield estimates shown in table 9 provide possible ranges for major land uses. Results of the effort to apportion basin loads to land uses in specific basins show considerable variability in nutrient yields in each land-use category, particularly for the agricultural and urban categories.

Minimally Developed or Forested Land

Although all forested land was assumed to have the same nutrient yield, forested land in the more developed parts of the study area is likely to contain some low-density development. Consequently, nutrient yields from forested areas in the southern part of the study area may exceed nutrient yields from the more undeveloped forested areas in the north. Forested yields for some urban drainage basins (table 9) may be underestimated. Nutrient yields for the Saugatuck River Basin, which is classified as urban, were among the lowest in the study area in 1994, and the assumed yields for forested land appear to be appropriate for this drainage basin (table 9).

Table 9. Nutrient loads and yields from major land uses in selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area, 1994

[Category: F, Forested; A, Agricultural; U, Urban. Method for estimating point source loads shown in table 7. Numbers may not add to totals because of independent rounding. DA, drainage area; lb, pound; lb/mi²/yr, pounds per square mile per year; lb/yr, pounds per year; mi², square mile; <, actual value is less than value shown]

Major land uses			Nutrient loads and yields		
Category	Area (mi^2)	Percentage of basin	Yield ($lb/mi^2/yr$)	Load (lb/yr)	Percentage of annual load
Salmon River near East Hampton, Conn.: DA = 100 mi^2					
Total Nitrogen: 1994 load = 192,000 lb; Average yield = 1,920 lb/mi^2					
F	78.7	78.7	1,200	94,400	49
A	13.6	13.6	5,350	72,800	38
U	6.2	6.2	4,000	24,800	13
Total Phosphorus: 1994 load = 6,910 lb; Average yield = 69 lb/mi^2					
F	78.7	78.7	60	4,700	68
A	13.6	13.6	70	950	14
U	6.2	6.2	200	1,240	18
Sleepers River near St. Johnsbury, Vt.: DA = 42.9 mi^2					
Total Nitrogen: 1994 load = 64,000 lb; Average yield = 1,490 lb/mi^2					
F	35.7	81.1	1,200	42,800	67
A	8.2	18.7	2,500	20,800	32
U	.1	.2	4,000	400	< 1
Total Phosphorus: 1994 load = 3,390 lb; Average yield = 79 lb/mi^2					
F	35.7	81.1	60	2,140	63
A	8.2	18.7	150	1,230	36
U	.1	.2	200	20	< 1
Tenmile River at South Dover near Wingdale, N.Y.: DA = 194 mi^2					
Total Nitrogen: 1994 load = 640,000 lb; Average yield = 3,300 lb/mi^2					
F	103.8	53.5	1,200	125,000	20
A	65.6	33.8	6,500	428,000	67
U	21.9	11.3	4,000	87,600	14
Total Phosphorus: 1994 load = 27,600 lb; Average yield = 140 lb/mi^2					
F	103.8	53.5	60	6,230	23
A	65.6	33.8	260	17,000	62
U	21.9	11.3	200	4380	16
Broad Brook at Broad Brook, Conn.: DA = 15.5 mi^2					
Total Nitrogen: 1994 load = 228,000 lb; Average yield = 14,700 lb/mi^2					
F	7.1	45.7	1,200	8,520	4
A	5.9	38.3	35,600	210,000	92
U	2.4	15.4	4,000	9,600	4
Total Phosphorus: 1994 load = 8,960 lb; Average yield = 580 lb/mi^2					
F	7.1	45.7	60	430	5
A	5.9	38.3	1,360	8,050	90
U	2.4	15.4	200	480	5
Saugatuck River near Redding, Conn.: DA = 21 mi^2					
Total Nitrogen: 1994 load = 29,800 lb; Average yield = 1,420 lb/mi^2					
F	14.6	69.3	1,200	17,500	59
A	1.6	7.4	1,920	3,080	10
U	4.6	21.7	2,000	9,200	31
Total Phosphorus: 1994 load = 1,400 lb; Average yield = 67 lb/mi^2					
F	14.6	69.3	60	876	63
A	1.6	7.4	40	64	5
U	4.6	21.7	100	460	33
Rooster River at Fairfield, Conn.: DA = 10.6 mi^2					
Total Nitrogen: 1994 load = 73,800 lb; Average yield = 6,960 lb/mi^2					
F	1.38	13.0	1,200	1,660	2
A	1.09	10.3	7,320	7,980	11
U	8.02	75.7	8,000	64,200	87
Total Phosphorus: 1994 load = 3,560 lb; Average yield = 336 lb/mi^2					
F	1.38	13.0	60	83	2
A	1.09	10.3	250	270	8
U	8.02	75.7	400	3,210	90

Table 9. Nutrient loads and yields from major land uses in selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area, 1994—*Continued*

Major land uses			Nutrient loads and yields		
Category	Area (mi^2)	Percentage of basin	Yield ($lb/mi^2/yr$)	Load (lb/yr)	Percentage of annual load
Pequabuck River at Forestville, Conn.: DA = 45.8 mi^2					
Total Nitrogen: 1994 load = 637,000 lb; Average yield = 13,900 lb/mi^2					
F	27.3	59.7	1,200	32,800	5
A	5.8	12.7	4,200	24,400	4
U (nonpoint)	11.8	25.7	8,000	94,400	15
U (point)	11.8	25.7	41,100	485,000	76
Total Phosphorus: 1994 load = 72,600 lb; Average yield = 1,580 lb/mi^2					
F	27.3	59.7	60	1,640	2
A	5.8	12.7	980	5,660	8
U (nonpoint)	11.8	25.7	400	4,720	6
U (point)	11.8	25.7	5,100	60,600	83

Major land uses			Nutrient loads and yields		
Category	Area (mi^2)	Percentage of basin	Yield ($lb/mi^2/yr$)	Load (lb/yr)	Percentage of annual load
Hockanum River near East Hartford, Conn.: DA = 73.4 mi^2					
Total Nitrogen: 1994 load = 844,000 lb; Average yield = 11,500 lb/mi^2					
F	36.7	50.0	1,200	44,000	5
A	12.6	17.1	9,330	118,000	14
U (nonpoint)	22.8	31.0	8,000	182,000	22
U (point)	22.8	31.0	22,000	500,000	59
Total Phosphorus: 1994 load = 84,800 lb; Average yield = 1,160 lb/mi^2					
F	36.7	50.0	60	2,200	3
A	12.6	17.1	800	10,100	12
U (nonpoint)	22.8	31.0	400	9,120	11
U (point)	22.8	31.0	2,780	63,400	75

Agricultural Land

Nonpoint-source nutrient yields for agricultural areas were determined as a residual after subtracting the forested and urban loads from the total drainage basin load. Total nitrogen yields for agricultural land in all but one of the drainage basins shown in table 9 range from about 1,900 to 9,300 $lb/mi^2/yr$, and total phosphorus yields range from about 40 to 980 $lb/mi^2/yr$. In the agricultural drainage basins of the Sleepers River in Vermont and Tenmile River in New York, total nitrogen yields for agricultural land range from 2,500 to 6,500 $lb/mi^2/yr$, and total phosphorus yields range from 150 to 260 $lb/mi^2/yr$.

In the small Broad Brook Basin in central Connecticut, the total nitrogen yield from agricultural land was estimated to be about 36,000 $lb/mi^2/yr$ in 1994, and the total phosphorus yield was about 1,400 $lb/mi^2/yr$ (table 9). Independent of the attempt to apportion nutrient yields to land uses, the total nutrient yield of the Broad Brook Basin is very high. This drainage basin may be an exception and may not be representative of agricultural areas; however, additional information on conditions in this and other agricultural basins and a longer monitoring record may be necessary to determine the extent to which the conditions in the Broad Brook Basin are representative or unusual. Results for this basin point out the importance of further investigation to determine the types and locations of agricultural areas that contribute the largest nutrient loads. Intensively farmed areas and areas with large animal populations may have high nitrogen yields, especially when these areas are in flood plains along streams.

Some of the highest nutrient yields for agricultural land, with the exception of the Broad Brook Basin, were calculated for urban drainage basins that receive substantial point-source loads (table 9). This result may mean that nutrient yields for other sources in those drainage basins, including forested land, urban land, and point sources, have been underestimated, or, in the case of industrial discharges, may be unaccounted for.

Based on information presented in the section "Agricultural Manure and Fertilizer," including a national summary of information on ratios of nutrient yield to nutrient input in agricultural areas, the nutrient yields for agricultural land in most of the drainage basins shown in table 9 appear reasonable. Total phosphorus yields for agricultural land in the Salmon and Saugatuck River Basins are lower than would be expected. Total nitrogen yields for agricultural land in the Rooster and Hockanum Rivers are at the high end of the likely range, and total phosphorus yields for the Pequabuck and Hockanum Rivers are higher than expected. Total phosphorus yields for agricultural land in the Broad Brook Basin are higher than expected, and total nitrogen yields are about three times the expected maximum yield.

Developed or Urban Land

Total nitrogen yields derived from point-source effluents range from about 22,000 to 41,000 lb/mi^2/yr in the highly urban Hockanum and Pequabuck Basins in Connecticut (table 9). Point-source inputs are estimated to account for 59 to 76 percent of the total nitrogen load in these drainage basins. Total phosphorus yields derived from point-source effluents in these drainage basins range from about 2,800 to 5,100 lb/mi^2/yr. Point-source inputs account for 75 to 83 percent of the total phosphorus load in these drainage basins.

The nutrient yields of small or medium-sized drainage basins with major point sources are typically dominated by those point sources. The apportionment of nonpoint nutrient loads to land uses is affected significantly by the choice of effluent concentration for the point sources. More accurate data on effluent concentrations for specific wastewater-treatment plants are needed to apportion nonpoint nutrient yields accurately, and data on nutrient loads from industrial discharges need to be compiled for some drainage basins. It is also possible that all land-use categories in highly urban basins encompass more development, and more intense development, than less urban basins, resulting in higher nonpoint nutrient yields for all categories. Instream attenuation of point sources and nonpoint sources also needs to be considered in developing a more accurate understanding of the nutrient contributions of different sources.

COMPARISON OF NUTRIENT SOURCES AND LOADS IN THE CONNECTICUT RIVER BASIN

Percentages of stream nutrient loads supplied by major nutrient sources have been estimated for the nontidal section of the Connecticut River Basin and compared to basin inputs of nutrients. All quantities and percentages discussed in the following section are based on estimates of nutrient sources and loads; additional investigation is necessary for accurate quantification in many instances.

The drainage basins of two monitoring stations on the Connecticut River—at North Walpole, New Hampshire, and Thompsonville, Connecticut—constitute 61 percent of the study area. The North Walpole drainage area is within the drainage area of the Thompsonville station (fig. 3) and accounts for about 57 percent of the Thompsonville drainage area. Comparing nutrient import and export at these stations aids in understanding these relations throughout the study area and illustrates changes in predominant sources of nutrients between forested northern drainage areas and urban southern drainage areas.

Estimated inputs of total nitrogen from atmospheric deposition (table 5), agricultural fertilizer and manure (table 6), and municipal wastewater discharges (table 7) were compiled for these two drainage basins and compared to the estimated amounts of total nitrogen contributed to stream loads by the three major land uses and by point sources (table 10). Stream nutrient loads were apportioned to point sources and major land uses on the basis of procedures and assumptions described in previous sections of this report (tables 7, 9). Nutrient yields were assigned to forested and urban land as previously described, with the exception that a total nitrogen yield of 1,000 lb/mi^2/yr was applied to forested land in the North Walpole drainage area. The estimates in table 10 are considered very approximate, because of the varying assumptions and periods of record used, but are presented to give a general picture of total nitrogen inputs and loads.

Total nitrogen loads on the Connecticut River are about 16 percent of the total nitrogen inputs to the drainage basin at the North Walpole station and about 25 percent of the total nitrogen inputs to the drainage basin at the Thompsonville station (table 10). These proportions indicate that a substantial amount of nitrogen is retained and processed within the drainage basin and its streams. The total nitrogen load at Thompsonville is three times the load at North Walpole, although the North Walpole station encompasses more than half of the drainage area.

Table 10. Comparison of total nitrogen inputs and total nitrogen loads in the Connecticut River Basin

[Land-use percentages shown in table 1. Estimated inputs from atmospheric deposition, agricultural fertilizer and manure, and point sources shown in tables 5, 6, and 7, respectively. Stream loads apportioned to land uses and point sources as demonstrated in table 9. Numbers may not add to totals because of independent rounding. Annual loads are for water year 1994. DA, drainage area; lb/yr, pounds per year; mi^2, square mile]

Total nitrogen inputs			Total nitrogen loads		
Source	Estimated input (lb/yr)	Estimated input (percent)	Source	Estimated stream load (lb/yr)	Estimated stream load (percent)
Connecticut River at North Walpole, New Hampshire DA = 5,493 mi^2					
Atmospheric deposition (1980–91)	30,900,000	71	Forested land	4,770,000	67
Agricultural fertilizer (1992)	3,080,000	7	Open water	65,900	1
Agricultural manure (1992)	8,630,000	20	Agricultural land	1,250,000	18
Point sources (1990)	735,000	2	Point sources	735,000	10
			Urban land (nonpoint sources)	286,000	4
Total	43,300,000	100	Total (1994)	7,110,000	100
Connecticut River at Thompsonville, Connecticut (including N. Walpole drainage area): DA = 9,660 mi^2					
Atmospheric deposition (1980–91)	52,900,000	59	Forested land	9,840,000	44
Agricultural fertilizer (1992)	15,200,000	17	Open water	221,000	1
Agricultural manure (1992)	15,100,000	17	Agricultural land	3,900,000	17
Point sources (1990)	6,320,000	7	Point sources	6,320,000	28
			Urban land (nonpoint sources)	2,320,000	10
Total	89,500,000	100	Total (1994)	22,600,000	100
Connecticut River at Thompsonville, Connecticut (minus N. Walpole drainage area): DA = 4,167 mi^2					
Atmospheric deposition (1980–91)	22,000,000	48	Forested land	5,100,000	33
Agricultural fertilizer (1992)	12,200,000	26	Open water	155,000	1
Agricultural manure (1992)	6,490,000	14	Agricultural land	2,650,000	17
Point sources (1990)	5,580,000	12	Point sources	5,580,000	36
			Urban land (nonpoint sources)	2,030,000	13
Total	46,200,000	100	Total	15,500,000	100

Atmospheric deposition is the largest source of nitrogen input (table 10). Atmospheric deposition accounts for an undetermined percentage of the nonpoint stream load of total nitrogen derived from forested land, open water, agricultural land, and urban land.

Stream loads from agricultural sources are about 11 percent of agricultural inputs at North Walpole, and about 13 percent of agricultural inputs at Thompsonville. Total nitrogen inputs from agricultural sources are substantially larger than inputs from point-source discharges in both the northern and southern parts of the drainage basin. Agricultural sources account for about 17 percent of the stream nitrogen load along the Connecticut River at both North Walpole and Thompsonville.

Point sources are a minor source of the total nitrogen inputs and stream load in the sparsely developed drainage basin upstream from North Walpole. By contrast, municipal wastewater discharges account for about 28 percent of the total nitrogen load on the Connecticut River at Thompsonville. Most of the wastewater discharges enter the Connecticut River downstream from the North Walpole station, and these sources account for an estimated 36 percent of the total nitrogen load that enters the river between North Walpole and Thompsonville (table 10).

Forested land accounts for about two-thirds of the stream load of total nitrogen at the North Walpole station, but only about one-third of the stream load between North Walpole and Thompsonville (table 10). Comparison of nitrogen loads at these two stations shows the extent to which streamflow with low nitrogen concentrations from large forested areas in the northern part of the drainage basin dilutes the effects of large point discharges in the southern part of the drainage basin, resulting in average nutrient yield estimates for the Thompsonville drainage basin that are similar to yields of forested basins with less substantial urban effects.

A similar comparison between total phosphorus inputs and stream loads in the Connecticut River Basin has not been made because few data are available on the atmospheric deposition of total phosphorus and the magnitude of this source is not known; however, stream loads of total phosphorus have been apportioned to the various land uses in the Connecticut River Basin (table 11) using methods described previously in this report.

Total phosphorus loads at Thompsonville are about two times those at North Walpole. The major sources of total phosphorus in stream loads differ in the largely forested drainage area of the Connecticut River upstream from North Walpole and the drainage area of the Connecticut River between North Walpole and Thompsonville, which includes large urban areas. Nutrients from forested land account for more than 40 percent of the stream load at North Walpole, about 33 percent of the stream load at Thompsonville, and only about 25 percent of the load delivered between North Walpole and Thompsonville (table 11).

Agricultural land accounts for about 40 percent of the total phosphorus load at the North Walpole station, less that one-fourth of the load at the Thompsonville station, and about 8 percent of the total phosphorus load that enters the river between the North Walpole and Thompsonville stations (table 11). Municipal wastewater discharges are a minor source of the total phosphorus load at North Walpole but are the largest source of the stream load of phosphorus (37 percent) at Thompsonville. Municipal wastewater discharges account for about half of the total phosphorus load entering the Connecticut River between the North Walpole and Thompsonville stations.

Table 11. Estimated sources of total phosphorus loads in the Connecticut River Basin

[Land-use percentages shown in table 1. Estimated inputs from point sources shown in table 7. Stream loads apportioned to land uses and point sources as demonstrated in table 9. Numbers may not add to totals because of independent rounding. Annual loads are for water year 1994. DA, drainage area; lb/yr, pounds per year; mi^2, square mile]

Total phosphorus loads		
Source	**Estimated stream load (lb/yr)**	**Estimated stream load (percent)**
Connecticut River at North Walpole, N.H.: DA = 5,493 mi^2		
Forested land	286,000	43
Agricultural land	272,000	41
Point sources	98,000	15
Urban land (nonpoint sources)	14,300	2
Total (1994)	671,000	100
Connecticut River at Thompsonville, Conn. (including North Walpole drainage area): DA = 9,660 mi^2		
Forested land	492,000	33
Agricultural land	334,000	22
Point sources	548,000	37
Urban land (nonpoint sources)	116,000	8
Total (1994)	1,490,000	100
Connecticut River at Thompsonville, Conn. (minus North Walpole drainage area): DA = 4,167 mi^2		
Forested land	206,000	25
Agricultural land	61,900	8
Point sources	450,000	55
Urban land (nonpoint sources)	102,000	12
Total	819,000	100

NUTRIENT EXPORT FROM THE STUDY AREA

Changes In Nutrient Loads Over Time

Annual variations in nutrient loads are primarily determined by streamflow conditions, with higher loads in high-flow years and lower loads in low-flow years. The relation between nutrient loads and streamflow can be seen by comparing the annual mean discharges for the Connecticut River at Thompsonville (fig. 12) to total nitrogen loads (fig. 13) for the period 1973–95. For example, both annual mean discharges

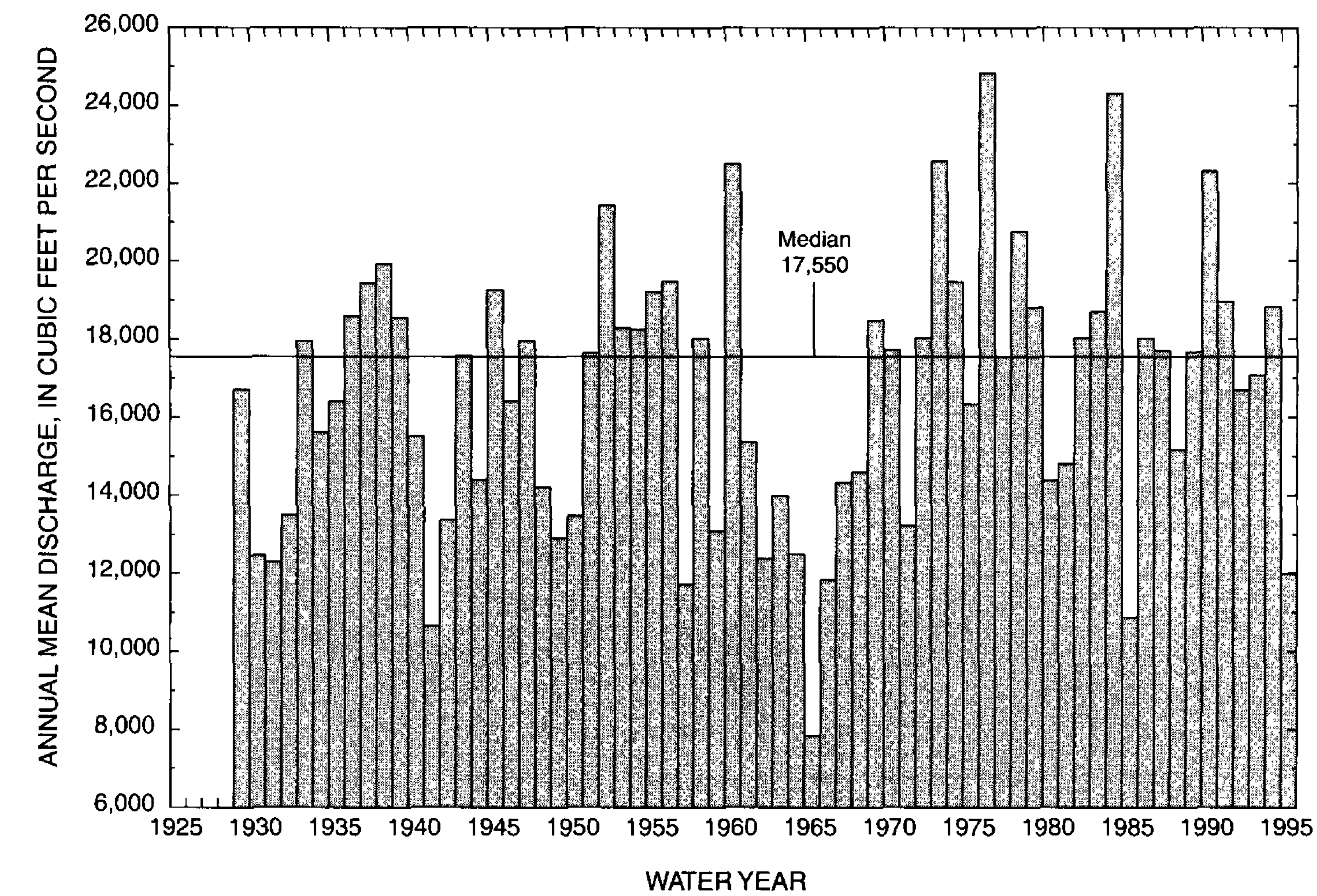


Figure 12. Annual mean discharges, Connecticut River at Thompsonville, Connecticut, water years 1929–95.

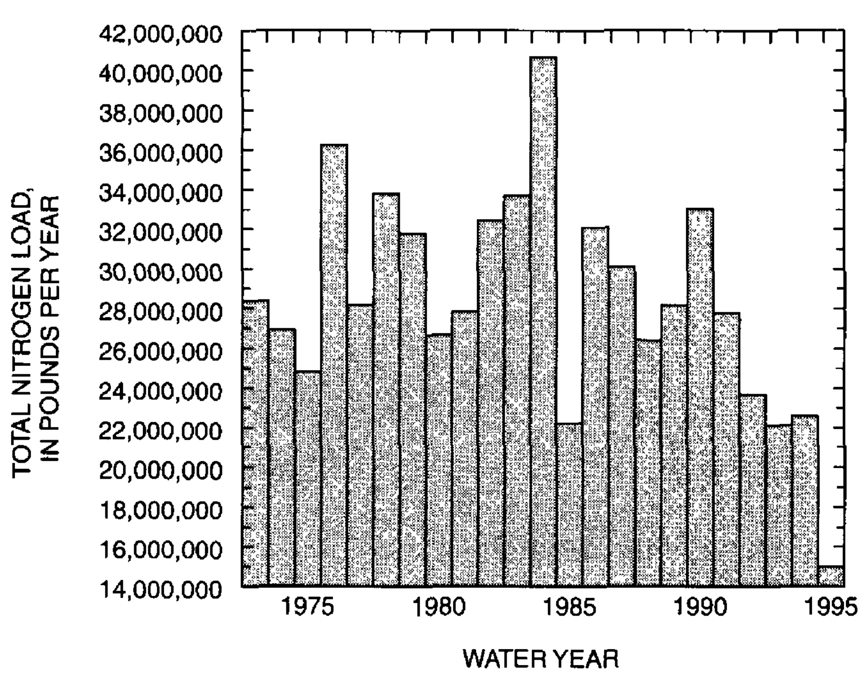


Figure 13. Total nitrogen loads, Connecticut River at Thompsonville, Connecticut, water years 1973–95

and total nitrogen loads were among the highest for the period of record in 1976 and 1984, and among the lowest for the period of record in 1985.

Trends in constituent concentration are important in interpreting variability in nutrient loads. If the stream discharge does not change substantially over the long term, then a trend in load is very closely related to the trend in concentration. A decreasing concentration trend indicates that for a typical year, constituent loads are lower now than in the past. Concentration trends determined in the ESTIMATOR program for total nitrogen and total phosphorus have been summarized for 16 stations with at least 5 years of nutrient data (table 12). All trends shown in table 12 are highly significant (p-value ≤ 0.01).

Total Nitrogen

Among the 16 stations for which trends have been summarized, results for 9 stations showed no trend in total nitrogen concentration during periods within water years 1972–95 (table 12). These nine stations, including stations on the Connecticut, Farmington, and Housatonic Rivers, monitor streamflow from more than three-quarters of the land in the study area. Stations with no trend in total nitrogen concentration also include some small, less developed drainage basins, such as Burlington Brook. Annual loads for Burlington Brook vary considerably over the period of record (fig. 14).

Table 12. Trends in concentrations of total nitrogen and total phosphorus in selected drainage basins, Connecticut, Housatonic, and Thames River Basins study area

[All trends shown have a significance level of 0.01 or less. **Category:** F, forested; A, agricultural; U, urban]

Station name	Category	Period of record		Significant trends in concentration (average percent change per year)	
		Total nitrogen	Total phosphorus	Total nitrogen	Total phosphorus
Shetucket River at South Windham, Conn.	F	1974–95	1974–95	no trend	down (-6)
Quinebaug River at Quinebaug, Conn.	F	1981–95	1981–95	down (-5)	down (-14)
Quinebaug River at Jewett City, Conn.	F	1972–95	1972–95	down (-1)	down (-5)
Connecticut River at North Walpole, N.H.	F	1981–91	1981–94	down (-5)	no trend
Connecticut River at Thompsonville, Conn.	F	1973–95	1970–95	no trend	down (-4)
Stony Brook near West Suffield, Conn.	A	1982–91	1982–91	down (-4)	down (-8)
Still River at Riverton, Conn.	F	1974–91	1974–91	no trend	down (-4)
Burlington Brook near Burlington, Conn.	A	1973–95	1973–95	no trend	no trend
Farmington River at Unionville, Conn.	F	1984–95	1984–95	down (-10)	down (-8)
Farmington River at Tariffville, Conn.	F	1972–95	1972–95	no trend	down (-3)
Salmon River near East Hampton, Conn.	F	1973–95	1972–95	no trend	no trend
Quinnipiac River at Wallingford, Conn.	U	1972–95	1972–95	no trend	down (-3)
Housatonic River at Stevenson, Conn.	A	1973–95	1972–95	no trend	down (-3)
Naugatuck River at Beacon Falls, Conn.	U	1975–95	1975–95	down (-1)	down (-2)
Saugatuck River near Redding, Conn.	U	1973–95	1972–95	no trend	no trend
Norwalk River at Winnipauk, Conn.	U	1981–95	1981–95	down (-4)	down (-5)

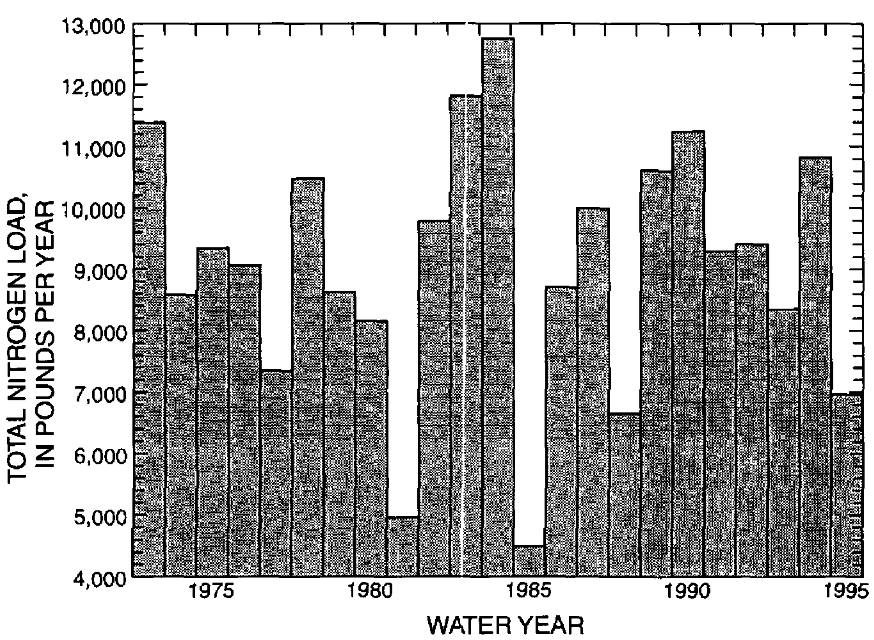


Figure 14. Total nitrogen loads, Burlington Brook near Burlington, Connecticut, water years 1973–95.

Trend results for seven stations, including the Naugatuck and Norwalk Rivers, showed decreasing concentrations of total nitrogen within the same period (table 12). Annual loads for the Naugatuck and Norwalk Rivers, although variable, are generally lower toward the end of the period of record (figs. 15 and 16). Some of the stations with decreasing total nitrogen concentrations receive point discharges, and improvements in the quality of treated wastewater may be a causative factor in the decrease in concentrations detected in these drainage basins. Other factors that may have affected the reported trends include changes in streamflow, changes in the atmospheric deposition of nitrogen, changes in agricultural practices, and previously noted changes in laboratory methods for sample analysis. The decrease in nitrogen concentrations for the largely forested Farmington River at Unionville is the largest percentage decrease, and data for this station would require further examination to explain the reasons for a result that appears unusual in comparison to similar drainage basins.

Total Phosphorus

Among the 16 stations for which trends have been reported, records for 4 stations showed no change in total phosphorus concentrations during periods within water years 1970-95. Records for 12 stations showed decreasing concentrations of total phosphorus (table 12). Annual phosphorus loads for the Connecticut River at Thompsonville and the Quinnipiac River at Wallingford have decreased substantially during this period (figs. 17 and 18).

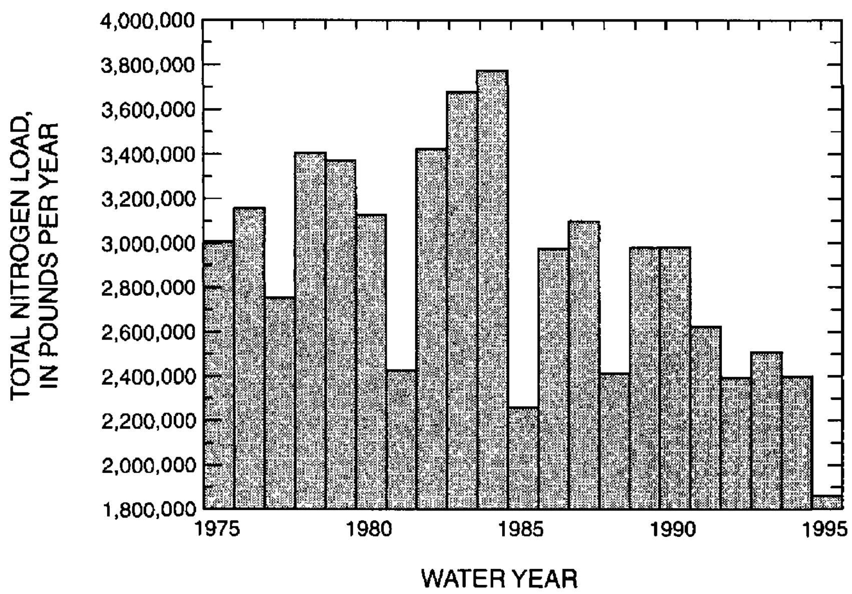


Figure 15. Total nitrogen loads, Naugatuck River at Beacon Falls, Connecticut, water years 1975–95.

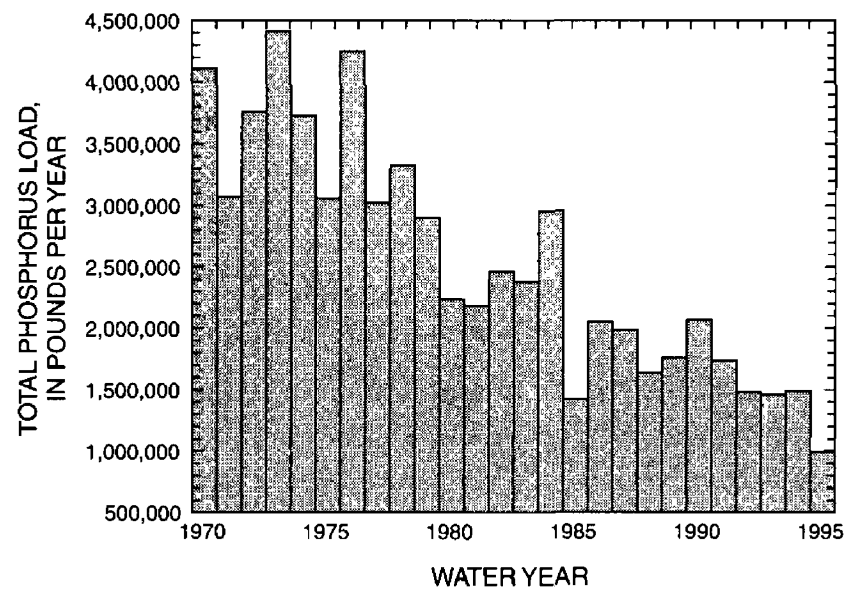


Figure 17. Total phosphorus loads, Connecticut River at Thompsonville, Connecticut, water years 1970–95.

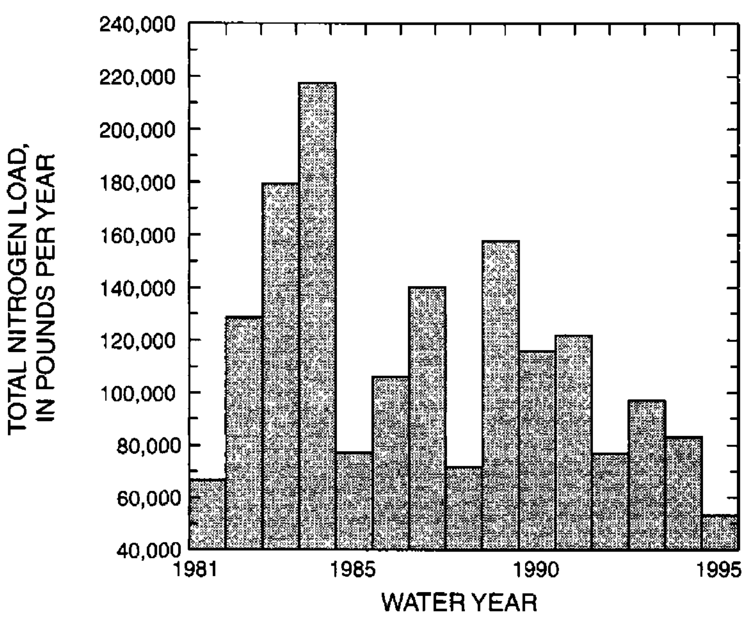


Figure 16. Total nitrogen loads, Norwalk River at Winnipauk, Connecticut, water years 1981–95.

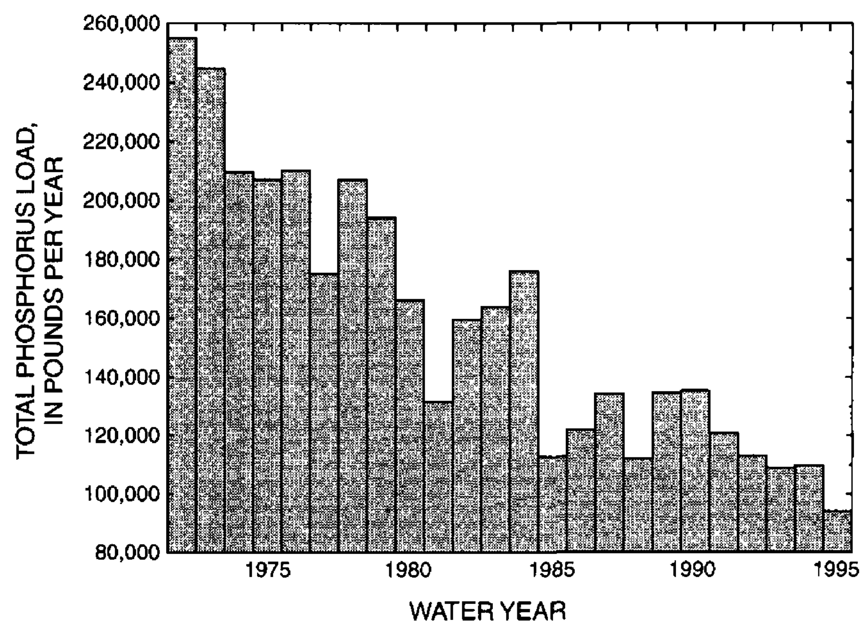


Figure 18. Total phosphorus loads, Quinnipiac River at Wallingford, Connecticut, water years 1972–95.

Stations with decreasing phosphorus concentrations monitor streamflow from about 85 percent of the land in the study area.

Eleven of the 12 streams with decreasing phosphorus concentrations are affected by municipal point-source discharges. The observed decreases may have been caused, in part, by decreases in the phosphorus content of detergents and by improvements in wastewater treatment (Litke, 1999). Despite the substantial decreases in total phosphorus concentrations, total phosphorus yields in basins where wastewater flows are large relative to streamflow are still an order of magnitude larger than the yields in forested basins (fig. 8*B*).

Historically, the relative range in total phosphorus loads for large drainage basins is greater than the range for total nitrogen loads. In large drainage basins with a record of 20 years or more, maximum total nitrogen loads are two to three times larger than minimum total nitrogen loads, whereas maximum total phosphorus loads are three to six times larger than minimum total phosphorus loads. This wide range in phosphorus loads probably reflects the downward trend in total phosphorus concentrations in streams over a 20-year period (Trench, 1996; Zimmerman, 1997).

Total Nutrient Export in the 1980's and 1990's

Nutrient loads exported from the study area have varied considerably from year to year during the period of record covered by this report, depending on flow conditions and nutrient concentration trends. This

Table 13. Export of total nitrogen from major drainage basins for selected water years, Connecticut, Housatonic, and Thames River Basins study area

[Numbers may not add to totals because of independent rounding]

Drainage basin	Drainage area (square miles)	Annual total nitrogen load (pounds)					
		1984	1985	1991	1992	1993	1994
Shetucket	408	1,730,000	840,000	1,120,000	1,020,000	1,080,000	1,100,000
Quinebaug	713	3,810,000	1,720,000	2,380,000	2,160,000	2,280,000	2,190,000
Connecticut	9,660	40,700,000	22,200,000	27,800,000	23,700,000	22,100,000	22,600,000
Farmington	577	3,280,000	1,400,000	2,470,000	2,320,000	2,390,000	2,440,000
Salmon	100	515,000	192,000	246,000	195,000	228,000	192,000
Quinnipiac	115	1,580,000	858,000	1,280,000	1,210,000	1,220,000	1,280,000
Housatonic	1,544	8,230,000	2,700,000	4,940,000	4,010,000	4,570,000	4,660,000
Naugatuck	260	3,780,000	2,260,000	2,630,000	2,400,000	2,510,000	2,400,000
Total	13,377	63,600,000	32,200,000	43,100,000	37,000,000	36,400,000	36,900,000

Table 14. Export of total phosphorus from major drainage basins for selected water years, Connecticut, Housatonic, and Thames River Basins study area

[Numbers may not add to totals because of independent rounding]

Drainage basin	Drainage area (square miles)	Annual total phosphorus load (pounds)					
		1984	1985	1991	1992	1993	1994
Shetucket	408	92,000	48,100	49,000	44,300	43,700	45,200
Quinebaug	713	291,000	140,000	126,000	110,000	94,700	85,900
Connecticut	9,660	2,960,000	1,420,000	1,740,000	1,480,000	1,460,000	1,490,000
Farmington	577	346,000	186,000	204,000	188,000	185,000	176,000
Salmon	100	27,300	7,070	8,890	6,710	8,330	6,910
Quinnipiac	115	176,000	113,000	121,000	113,000	109,000	110,000
Housatonic	1,544	429,000	116,000	202,000	155,000	189,000	185,000
Naugatuck	260	411,000	271,000	291,000	266,000	300,000	276,000
Total	13,377	4,730,000	2,300,000	2,740,000	2,360,000	2,390,000	2,380,000

variability may affect the magnitude of the effect of nutrient loads on environmentally sensitive water bodies. Annual mean flows at most of the 25 stations during water years 1984 and 1985 were among the highest flows and lowest flows, respectively, during the period 1970–95 (fig. 12), and these 2 years are used to approximate maximum and minimum loads. Annual mean flows during 1991, 1992, and 1993 were generally near median-flow conditions at most stations (fig. 12), and these years represent typical streamflow conditions for the 1990's. Annual mean flows during 1994 were slightly to moderately above the median flow at many locations. Annual mean flows during 1995 were well below median at most locations.

Export of total nitrogen from the major drainage basins, as measured at monitoring stations that are variable distances upstream from the mouth of each river (fig. 3), has ranged from 36,400,000 to 43,100,000 lb during 1991 to 1994 (table 13). Export of total phosphorus has ranged from 2,360,000 to 2,740,000 lb (table 14). All annual load estimates for total nitrogen and total phosphorus for the 25 drainage basins discussed in this report are tabulated at the back of this report (table 15).

Export of total nitrogen from the major monitored drainage basins has ranged from about 32,000,000 to 64,000,000 lb/yr during the 1980's and 1990's, and in the 1990's has typically been about 37,000,000 lb/yr (table 13). The nitrogen load on the Connecticut River, measured at the Thompsonville station, generally represents a little less than two-thirds of this total load. Total nitrogen export for 1984 (high-flow year) is about twice the export of 1985 (low-flow year) and is 70 to 75 percent larger than near-median flow years in the early 1990's.

Export of total phosphorus from major monitored basins has ranged from about 2.3 to 4.7 million pounds per year from the mid-1980's to the mid-1990's, and during the 1990's has typically been about 2.4 million pounds per year (table 14). The phosphorus load on the Connecticut River, measured at the Thompsonville station, represents a little more than three-fifths of this total load. Total phosphorus export for 1984 (high-flow year) is about twice the export of 1985 (low-flow year), and also is about twice the export of near-median flow years in the early 1990's. During some years in the 1970's, export of total phosphorus substantially exceeded the 1984 value of 4.7 million pounds per year; however, these historical maximum loads do not represent currently expectable maximum conditions because of the observed downward trends in phosphorus concentrations on many streams.

The 25 drainage basins discussed in this report (table 3) represent about 86 percent of the study area. The load from these basins, however, probably represents considerably less than 86 percent of the total nutrient load exported from the study area. The monitored area includes essentially all the undeveloped land in the study area, and nutrient yields from undeveloped forested areas are low. Also, many point discharges in highly urban coastal areas of Connecticut are either in unmonitored basins or discharge directly to Long Island Sound and thus are not accounted for in the estimates of point discharge for this study.

SUMMARY AND CONCLUSIONS

Sources and loads of total nitrogen and total phosphorus in streams were evaluated for the Connecticut, Housatonic, and Thames River Basins study unit as part of the USGS National Water-Quality Assessment Program. The study area encompasses 15,758 mi^2 and extends from northern New Hampshire and Vermont to coastal Connecticut.

Annual stream nutrient loads and basin yields for forested, agricultural, and urban drainage basins were estimated using data from 25 U.S. Geological Survey water-quality monitoring stations in and near New England. Nutrient yields for forested drainage basins, along with information on point-source loads and literature estimates of nonpoint yields from urban land, were used to estimate nutrient yields for agricultural land.

Nutrient Sources and Transport

Stream loads of total nitrogen and total phosphorus are closely related to land-use practices and waste discharges in the Connecticut, Housatonic, and Thames River Basins study area. Nutrient loads increase with increasing intensity of land use and with increasing population densities. Major sources of nutrients include atmospheric deposition, agricultural fertilizer and manure, urban nonpoint runoff, and municipal wastewater discharges.

Annual atmospheric deposition of total nitrogen in forested areas substantially exceeds total nitrogen yields from forested land. It appears that substantial amounts of atmospheric nitrogen are retained and stored in less developed areas. Data on atmospheric deposition of phosphorus are sparse, but available data suggest that atmospheric deposition of phosphorus is less than the stream load of phosphorus in forested areas. Atmospheric deposition of nutrients is strongly episodic. Consequently, nutrients derived from atmospheric deposition could constitute a substantial percentage of stream nutrient loads under some seasonal and weather conditions and a negligible percentage at other times.

Estimated yields of total nitrogen in undeveloped forested drainage basins are generally less than about 2,000 lb/mi^2/yr, and yields of total phosphorus are generally less than about 100 lb/mi^2/yr. Data for these basins are limited, and additional years of monitoring are needed to confirm these estimates. Nutrient yields are somewhat higher in forested drainage basins that have larger percentages of developed land or that receive point-source discharges, with total nitrogen yields generally less than 4,000 lb/mi^2/yr and total phosphorus yields generally less than 400 lb/mi^2/yr. Runoff with low nutrient concentrations from forested land constitutes most of the stream discharge and dilutes wastewater effluents in large (300 mi^2 or greater) forested drainage basins, resulting in basin nutrient yields that are considerably lower than those of small and medium-sized (less than 300 mi^2) urban basins that receive point discharges.

Nonpoint agricultural sources, including fertilizer and manure, constitute substantial nutrient inputs in some drainage basins, but they do not always result in high stream nutrient loads. Average basin yields of total nitrogen for three agricultural drainage basins were generally less than 4,000 lb/mi^2/yr, similar to forested basins, and total phosphorus yields were generally less than 300 lb/mi^2/yr. Yields estimated specifically for agricultural land within two agricultural drainage basins ranged from 2,500 to 6,500 lb/mi^2/yr for total nitrogen and 150 to 260 lb/mi^2/yr for total phosphorus. Total nitrogen yields for the small, agricultural Broad Brook Basin exceeded 10,000 lb/mi^2/yr, similar to nitrogen yields in urban basins that receive point discharges. Conditions in the Broad Brook Basin may not be representative of typical agricultural basins in the study area. Additional information on nutrient yields from agricultural land is needed to characterize typical yields.

Wastewater discharges in urban areas are important sources of total nitrogen and total phosphorus because these effluents discharge directly to streams with no overland transport mitigation. Municipal wastewater discharges are major sources of stream nutrient loads in urban areas of Massachusetts and Connecticut. The importance of point discharges is particularly evident in small drainage basins where wastewater constitutes a substantial percentage of streamflow. Point-source discharges are the most important sources of nutrient loads in four highly urban basins—the Pequabuck, Hockanum, Quinnipiac, and Naugatuck River Basins in Connecticut—even though 46 to 67 percent of the land in these drainage basins is undeveloped. These findings emphasize the importance of point discharges in urban coastal areas as sources of nutrients to Long Island Sound.

As wastewater flows increase in proportion to streamflow, basin yields of total nitrogen and total phosphorus increase. The largest total nitrogen and total phosphorus yields were found in the Pequabuck, Hockanum, Quinnipiac, and Naugatuck River Basins, where wastewater discharges constitute from 9 to 19 percent of the annual mean streamflow in a median flow year. Basin yields of total nitrogen generally ranged from 8,000 to 14,000 lb/mi^2/yr, and basin yields of total phosphorus generally ranged from 1,000 to 1,400 lb/mi^2/yr.

Nutrient yields from two urban drainage basin with no point sources were substantially different, probably reflecting the different type and intensity of urban land use in each basin, but were much smaller than yields in drainage basins that receive point discharges. Information for urban basins without point sources is very limited, and additional monitoring is needed to quantify nonpoint nutrient yields from different intensities of urban land use.

Although yields are moderately low in large, primarily forested drainage basins, rivers draining these large basins transport most of the nutrient load. The Connecticut River, measured at the Thompsonville station, transports about two-thirds of the total nitrogen exported from the major monitored drainage basins and about three-fifths of the total phosphorus.

The major sources of nutrients differ between the northern and southern parts of the study area. Forested land accounts for about two-thirds of the stream load of total nitrogen estimated for the Connecticut River at North Walpole, N.H. Point sources are a minor source of nutrients at the North Walpole station. By contrast, municipal wastewater discharges are the dominant source of nutrients downstream from North Walpole and are estimated to contribute about 36 percent of the total nitrogen and about half of the total phosphorus that enters the river between North Walpole and Thompsonville.

Export of total nitrogen from the major monitored drainage basins has ranged from about 32,000,000 to 64,000,000 lb/yr from the mid-1980's to the mid-1990's, and has typically been about 37,000,000 lb/yr during the 1990's. Export of total phosphorus from major monitored basins has ranged from about 2,300,000 to 4,700,000 lb/yr from the mid-1980's to the mid-1990's, and has typically been about 2,400,000 lb/yr during the 1990's. At some monitoring stations, export of total phosphorus during some years in the 1970's substantially exceeded maximum values for the 1980's and 1990's (figs. 17 and 18); however, these historical maximum loads do not represent currently expected maximum conditions because of the observed downward trends in phosphorus concentrations on many streams.

Export of nutrients was estimated for nontidal locations. The load of nitrogen or phosphorus at the farthest downstream nontidal location on a stream is likely to differ from the load that actually enters Long Island Sound, because of additional nutrient inputs along tidally affected reaches and estuarine processes that affect transport of nitrogen and phosphorus.

Areas for Further Investigation

The importance of atmospheric deposition in supplying nutrients to streams in forested areas can be further elucidated by long-term monitoring of stream nutrient concentrations, investigation of nutrient cycling processes in forest soils, and use of isotope hydrology to determine sources of nutrients in streams, soils, and ground water. Rates of atmospheric deposition of nutrients need to be related to regional as well as local sources and to the effects of prevailing storm tracks that cross the study area. Deposition quantities are episodic, and additional understanding is needed of how atmospheric deposition affects stream nutrient loads on a seasonal or storm-event basis.

Improved methods for estimating amounts of agricultural manure and fertilizer applied to small drainage basins are needed to evaluate the importance of these nutrient sources in different basins. Yield estimates for agricultural drainage basins have a large range and considerable uncertainty. Water-quality monitoring in agricultural basins with varied agricultural activities and intensity of use would provide needed information on the nutrient yields from different types of agricultural land.

Investigation of the nonpoint sources of nutrients in urban areas is needed to define the most important sources affecting stream loads, and to identify appropriate management targets. Additional information is needed on atmospheric deposition of nutrients in urban areas and on the proportion of the nonpoint nutrient load supplied to urban streams by atmospheric deposition during different streamflow conditions. Further study also is needed to determine the relative proportions of nutrients delivered to urban streams by surface runoff and ground-water discharge. Limited information from an urban area of the Hockanum River Basin in Connecticut indicates that ground-water contributions of nutrients can be substantial. Additional information for specific locations and conditions, including nutrient transport during storms, is necessary to characterize the expected range of urban nonpoint contributions to streams, and to quantify the contributions of different urban land uses.

Improved estimation of municipal wastewater nutrient loads, including information from effluent monitoring, is needed for urban drainage basins. Compilation of current data on nutrient contributions from industrial discharges and CSOs also is needed for some drainage basins. Additionally, information on instream attenuation of point-source loads is needed in order to evaluate the extent to which these loads diminish with distance from the source.

Evaluation of loads for the component constituents of nitrogen and phosphorus is needed. For example, a large proportion of the nitrogen load in urban basins may be in the form of nitrate in basins receiving discharges from advanced wastewater-treatment plants. By contrast, the proportion of ammonia may be substantial in basins receiving discharges from secondary wastewater-treatment plants. Information on proportions of nitrogen and phosphorus constituents may help to identify the major sources supplying nutrients in different land-use settings.

Investigation of seasonal variations in nutrient loads, and use of nutrient data from synoptic studies done at high-flow and low-flow conditions, can help to identify periods when large quantities of nutrients are transported. Seasonal variations in nutrient loads are expected to be less in urban basins than in forested basins because of the relatively constant nutrient supply from point sources. Low-flow loads can be used to define nonpoint-source contributions from ground water in forested, agricultural, and urban drainage basins. Stream monitoring during high flows can be used to determine the importance of flood events in nutrient transport.

Estimation of annual stream nutrient loads provides an integrated look at processes taking place throughout a drainage basin over a complete seasonal cycle. Opportunities are available for further research into nutrient transport processes and nutrient load variability at different temporal and areal scales.

SELECTED REFERENCES

Alexander, R.B., and Smith, R.A., 1990, County-level estimates of nitrogen and phosphorus fertilizer use in the United States, 1945 to 1985: U.S. Geological Survey Open-File Report 90-130, 12 p.

Anderson, J.R., Hardy, E.E., Roasch, J.T., and Witmer, R.E., 1976, A land use and land cover classification system for use with remote sensor data: U.S. Geological Survey Professional Paper 964, 28 p.

Battaglin, W.A., and Goolsby, D.A., 1995, Spatial data in geographic information system format on agricultural chemical use, land use, and cropping practices in the United States: U.S. Geological Survey Water-Resources Investigations Report 94-4176, 87 p.

Canter, L.W., and Knox, R.C., 1985, Septic tank system effects on ground water quality: Chelsea, Mich., Lewis Publishers, Inc., 336 p.

Chen, Hsiu-Min, Nikolaidis, N.P., and Miller, D.R., 1994, Estimation of nitrogen, sulfur, and phosphorus deposition to the Long Island Sound; a technical report on the Long Island Sound Atmospheric Deposition projects: Storrs, Conn., University of Connecticut, 137 p.

Cohn, T.A., 1988, Adjusted maximum likelihood estimation of the moments of lognormal populations from Type I censored samples: U.S. Geological Survey Open-File Report 88-350, 34 p.

Cohn, T.A., DeLong, L.L., Gilroy, E.J., Hirsch, R.M., and Wells, D.K., 1989, Estimating constituent loads: Water Resources Research, v. 25, no. 5, p. 937–942.

Cohn, T.A., Caulder, D.L., Gilroy, E.J., Zynjuk, L.D., and Summers, R.M., 1992a, The validity of a simple statistical model for estimating fluvial constituent loads; an empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, no. 9, p. 2353–2363.

Cohn, T.A., Gilroy, E.J., and Baier, W.G., 1992b, Estimating fluvial transport of trace constituents using a regression model with data subject to censoring: Proceedings of the Joint Statistical Meeting, Boston, Mass., August 9–13, 1992, p. 142–151.

Connecticut Department of Environmental Protection, 1994, 1994 Water quality report to Congress, prepared pursuant to Clean Water Act Section 305(b): Hartford, Conn., Bureau of Water Management, 97 p.

Davies, B.S., 3rd, Bohr, J.R., Morrison, Jonathan, Kiesman, S.S., and Loos, D.A., 1996, Water resources data, Connecticut, Water Year 1995: U.S. Geological Survey Water-Data Report CT-95-1, 367 p.

Driver, N.E., 1989, Variables that affect urban storm-runoff quality and quantity, *in* Ragone, Stephen, (ed.), Regional characterization of water quality: IAHS Publication No. 182, p. 231–238.

Driver, N.E., and Tasker, G.D., 1990, Techniques for estimation of storm-runoff loads, volumes, and selected constituent concentrations in urban watersheds in the United States: U.S. Geological Survey Water-Supply Paper 2363, 44 p.

Ebbert, J.C., and Wagner, R.J., 1987, Contributions of rainfall to constituent loads in storm runoff from urban catchments: Water Resources Bulletin, v. 23, no. 5, p. 867–871.

Farrow, D.R.G., Arnold, F.D., Lombardi, M.L., Main, M.B., and Eichelberger, P.D., 1986, The National coastal pollutant discharge inventory; estimates for Long Island Sound: Rockville, Md., National Oceanic and Atmospheric Administration, 40 p. and Selected Appendixes.

Fenneman, N.M., 1938, Physiography of the eastern United States: New York, McGraw-Hill Book Co., 714 p.

Frick, E.A., Stell, S.M., and Buell, G.R., 1993, National water-quality assessment program—A preliminary evaluation of 1990 nutrient loads for the Apalachicola-Chattahoochee-Flint River Basin: Athens, Ga., Proceedings of the 1993 Georgia Water Resources Conference, April 20–21, 1993, 5 p.

Frink, C.R., 1991, Estimating nutrient exports to estuaries: Journal of Environmental Quality, v. 20, no. 4, p. 717–724.

Gilliom, R.J., Alley, W.M., and Gurtz, M.E., 1995, Design of the National Water-Quality Assessment Program—Occurrence and distribution of water-quality conditions: U.S. Geological Survey Circular 1112, 33 p.

Gilroy, E.J., Hirsch, R.M., and Cohn, T.A., 1990, Mean square error of regression-based constituent transport estimates: Water Resources Research, v. 26, no. 9, p. 2069–2077.

Grady, S.J., 1994, Effects of land use on quality of water in stratified-drift aquifers in Connecticut: U.S. Geological Survey Water-Supply Paper 2381, Chap. B, 56 p.

Grady, S.J., and Mullaney, J.R., 1998, Natural and human factors affecting shallow water quality in surficial aquifers in the Connecticut, Housatonic, and Thames River Basins: U.S. Geological Survey Water-Resources Investigations Report 98-4042, 81 p.

Healy, D.F., and Kulp, K.P., 1995, Water-quality characteristics of selected public recreational lakes and ponds in Connecticut: U.S. Geological Survey Water-Resources Investigations Report 95-4098, 277 p.

Healy, D.F., Pizzuto, E.J., and Hoffman, G.F., 1994, Water quality data for selected rivers and harbors in Connecticut, 1973–1985: Connecticut Department of Environmental Protection, Connecticut Water Resources Bulletin no. 44, 293 p.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water (3d ed.): U.S. Geological Survey Water-Supply Paper 2254, 264 p.

Hirsch, R.M., Alley, W.M., and Wilber, W.G., 1988, Concepts for a National Water-Quality Assessment Program: U.S. Geological Survey Circular 1021, 42 p.

HydroQual, Inc., 1996, Water quality modeling analysis of hypoxia in Long Island Sound using LIS 3.0; Management Committee, Long Island Sound Estuary Study and New England Interstate Water Pollution Control Commission; Mahwah, N.J., variously paged.

Jaworski, N.A., Groffman, P.M., Keller, A.A., and Prager, J.C., 1992, A watershed nitrogen and phosphorus balance—the upper Potomac River Basin: Estuaries, v. 15, no. 1, p. 83–95.

Knox, C.E., and Nordenson, T.J., 1955, Average annual runoff and precipitation in the New England–New York area: U.S. Geological Survey Hydrologic Investigations Atlas 7, scale 1:1,000,000.

Litke, D.W., 1999, Review of phosphorus control measures in the United States and their effects on water quality: U.S. Geological Survey Water-Resources Investigations Report 99-4007, 38 p.

McCarty, P.L., 1970, Chemistry of nitrogen and phosphorus in water: Committee Report of the Water Quality Division Committee on Nutrients in Water, Journal of the American Water Works Association, Feb. 1970, p. 127–140.

Medalie, Laura, 1996, Wastewater collection and return flow in New England, 1990: U.S. Geological Survey Water-Resources Investigations Report 95-4144, 79 p.

Mitchell, W.B., Guptill, S.C., Anderson, K.E., Fegeas, R.G., and Hallam, C.A., 1977, GIRAS—A geographic information and analysis system for handling land use and land cover data: U.S. Geological Survey Professional Paper 1059, 16 p.

Mullaney, J.R., and Grady, S.J., 1997, Hydrogeology and water quality of a surficial aquifer underlying an urban area, Manchester, Connecticut: U.S. Geological Survey Water-Resources Investigations Report 97-4195, 40 p.

Murdoch, P.S., and Stoddard, J.L., 1992, The role of nitrate in the acidification of streams in the Catskill Mountains of New York: Water Resources Research, v. 28, no. 10, p. 2707–2720.

National Atmospheric Deposition Program/National Trends Network, 1996, NADP/NTN wet deposition in the United States, 1995: Natural Resources Ecology Laboratory, Colorado State University, Fort Collins, Colo.

National Oceanic and Atmospheric Administration (NOAA), 1997, NOAA's Estuarine Eutrophication Survey; Volume 2: Mid-Atlantic Region: Silver Spring, Md., Office of Ocean Resources Conservation and Assessment, 51 p.

New Hampshire Department of Environmental Services, 1996, State of New Hampshire 1996 Section 305(b) Water Quality Report: Concord, N.H., NHDES-WD-96-8.

Norvell, W.A., Frink, C.R., and Hill, D.E., 1979, Phosphorus in Connecticut lakes predicted by land use: Proceedings of the National Academy of Science, USA, v. 76, no. 11, p. 5426–5429.

Novotny, Vladimir, and Chesters, Gordon, 1981, Handbook of nonpoint pollution; sources and management: New York, Van Nostrand Reinhold Company, 555 p.

Price, C.V., and Schaefer, F.L., 1995, Estimated loads of selected constituents from permitted and nonpermitted sources at selected surface-water-quality stations in the Musconetcong, Rockaway, and Whippany River Basins, New Jersey, 1985-90: U.S. Geological Survey Water-Resources Investigations Report 95-4040, 28 p.

Puckett, L.J., 1995, Identifying the major sources of nutrient water pollution: Environmental Science & Technology, v. 29, no. 9, p. 408–414.

Puckett, L.J., and Triska, F.J., eds., 1996, U.S. Geological Survey nitrogen-cycling workshop, Denver, Colorado, October 30–November 2, 1995: U.S. Geological Survey Open-File Report 96-477, 88 p.

Smith, R.A., Alexander, R.B., and Lanfear, K.J., 1993, Stream water quality in the conterminous United States—Status and trends of selected indicators during the 1980's, *in* U.S. Geological Survey, National Water Summary 1990–91—Hydrologic events and stream water quality: U.S. Geological Survey Water-Supply Paper 2400, p. 111–140.

Trench, E.C.T., 1996, Trends in surface-water quality in Connecticut, 1969–88: U.S. Geological Survey Water-Resources Investigations Report 96-4161, 176 p.

U.S. Bureau of the Census, 1991, Census of population and housing, 1990: PUBLIC LAW (P.L.) 94-171 Data (Connecticut, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont) [machine-readable data files], prepared by the Bureau of the Census, Washington, D.C.

U.S. Department of Commerce, 1994, 1992 Census of Agriculture; Volume 1, Geographic Area Series; Part 7, Connecticut, State and County data: Washington, D.C., Economics and Statistics Administration and Bureau of the Census, 218 p. plus appendixes.

U.S. Environmental Protection Agency, 1994, The Long Island Sound Study; Summary of the Comprehensive Conservation and Management Plan: Stamford, Conn., 66 p.

U.S. Geological Survey, 1999, The quality of our Nation's waters—Nutrients and pesticides: U. S. Geological Survey Circular 1225, 82 p.

Yang, Xiusheng, Miller, D.R., Xu, Xiaohong, Yang, L.H., Chen, Hsiu-Min, and Nikolaidis, N.P., 1996, Spatial and temporal variations of atmospheric deposition in interior and coastal Connecticut: Atmospheric Environment, v. 30, no. 22, p. 3801–3810.

Zimmerman, M.J., 1997, Trends in nitrogen and phosphorus concentrations in southern New England streams, 1974–92: National Water Quality Assessment, U.S. Geological Survey Fact Sheet 001-97.

Zimmerman, M.J., Grady, S.J., Trench, E.C.T., Flanagan, S.M., and Nielsen, M.G., 1996, Water-quality assessment of the Connecticut, Housatonic, and Thames River Basins study unit—Analysis of available data on nutrients, suspended sediments, and pesticides, 1972–92: U.S. Geological Survey Water-Resources Investigations Report 95-4203, 162 p.

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area

[The 95-percent confidence interval for an annual load equals the load plus or minus the indicated number. **Drainage basin category:** F, forested; A, agricultural; U, urban; lb/yr, pounds per year; lb/mi²/yr, pounds per square mile per year; mi², square mile; --, no data]

Station identification number (table 3)	Drainage area (mi²)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval		Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01122610	408	F	1974	1,180,000	2,890	149,000	12.6	138,000	338	18,200	13.1
01122610	408	F	1975	1,180,000	2,900	122,000	10.3	129,000	316	15,100	11.7
01122610	408	F	1976	1,360,000	3,340	131,000	9.6	133,000	326	16,000	12.1
01122610	408	F	1977	1,030,000	2,520	85,700	8.4	91,700	225	9,860	10.8
01122610	408	F	1978	1,540,000	3,780	131,000	8.5	126,000	308	14,500	11.6
01122610	408	F	1979	1,380,000	3,390	126,000	9.1	101,000	248	11,900	11.8
01122610	408	F	1980	1,140,000	2,790	81,400	7.1	81,800	200	7,600	9.3
01122610	408	F	1981	799,000	1,960	55,000	6.9	54,500	134	4,670	8.6
01122610	408	F	1982	1,510,000	3,690	136,000	9.1	91,400	224	10,600	11.6
01122610	408	F	1983	1,470,000	3,610	132,000	8.9	81,300	199	8,800	10.8
01122610	408	F	1984	1,730,000	4,230	157,000	9.1	92,000	226	10,400	11.3
01122610	408	F	1985	840,000	2,060	52,800	6.3	48,100	118	3,560	7.4
01122610	408	F	1986	1,180,000	2,890	80,900	6.9	60,100	147	4,900	8.2
01122610	408	F	1987	1,300,000	3,170	110,000	8.5	60,300	148	6,360	10.5
01122610	408	F	1988	892,000	2,190	54,800	6.2	42,800	105	3,360	7.9
01122610	408	F	1989	1,340,000	3,290	101,000	7.5	62,200	153	6,600	10.6
01122610	408	F	1990	1,340,000	3,280	100,000	7.5	59,300	145	6,360	10.7
01122610	408	F	1991	1,120,000	2,740	80,200	7.2	49,000	120	4,950	10.1
01122610	408	F	1992	1,020,000	2,490	75,800	7.5	44,300	109	4,390	9.9
01122610	408	F	1993	1,080,000	2,640	113,000	10.5	43,700	107	5,650	12.9
01122610	408	F	1994	1,100,000	2,710	124,000	11.2	45,200	111	5,700	12.6
01122610	408	F	1995	750,000	1,840	89,500	11.9	31,500	77	3,710	11.8
01124000	155	F	1981	361,000	2,330	65,900	18.3	57,300	370	11,000	19.2
01124000	155	F	1982	687,000	4,430	122,000	17.8	83,500	539	13,700	16.4
01124000	155	F	1983	649,000	4,180	106,000	16.3	74,000	477	10,400	14.1
01124000	155	F	1984	799,000	5,150	137,000	17.2	80,900	522	12,000	14.8
01124000	155	F	1985	276,000	1,780	30,900	11.2	44,900	290	5,410	12.1
01124000	155	F	1986	507,000	3,270	62,800	12.4	57,500	371	6,940	12.1
01124000	155	F	1987	521,000	3,360	86,300	16.6	47,600	307	6,480	13.6
01124000	155	F	1988	344,000	2,220	40,400	11.7	37,500	242	4,640	12.4

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interv		Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01124000	155	F	1989	492,000	3,170	69,200	14.1	42,400	273	5,720	13.5
01124000	155	F	1990	490,000	3,160	70,900	14.5	35,500	229	4,800	13.5
01124000	155	F	1991	356,000	2,290	43,500	12.2	25,600	165	3,180	12.4
01124000	155	F	1992	345,000	2,230	44,000	12.8	22,500	145	3,000	13.3
01124000	155	F	1993	325,000	2,100	56,200	17.3	15,500	100	2,370	15.3
01124000	155	F	1994	345,000	2,230	67,400	19.5	14,000	90	2,620	18.7
01124000	155	F	1995	177,000	1,140	37,000	20.9	7,750	50	1,710	22.1
01127000	713	F	1972	3,540,000	4,970	434,000	12.3	363,000	509	55,200	15.2
01127000	713	F	1973	3,810,000	5,350	413,000	10.8	375,000	527	50,100	13.3
01127000	713	F	1974	3,080,000	4,320	290,000	9.4	291,000	408	33,600	11.5
01127000	713	F	1975	2,930,000	4,110	233,000	7.9	286,000	401	29,000	10.1
01127000	713	F	1976	3,480,000	4,880	269,000	7.7	334,000	469	33,400	10.0
01127000	713	F	1977	2,460,000	3,440	179,000	7.3	235,000	330	22,300	9.5
01127000	713	F	1978	3,730,000	5,230	279,000	7.5	351,000	492	35,000	10.0
01127000	713	F	1979	3,470,000	4,870	284,000	8.2	307,000	431	31,600	10.3
01127000	713	F	1980	2,660,000	3,720	185,000	6.9	245,000	344	23,300	9.5
01127000	713	F	1981	1,870,000	2,630	132,000	7.0	165,000	231	15,800	9.6
01127000	713	F	1982	3,480,000	4,890	284,000	8.2	297,000	416	34,000	11.5
01127000	713	F	1983	3,400,000	4,760	299,000	8.8	260,000	364	30,400	11.7
01127000	713	F	1984	3,810,000	5,340	330,000	8.7	291,000	408	34,900	12.0
01127000	713	F	1985	1,720,000	2,410	115,000	6.7	140,000	197	13,200	9.4
01127000	713	F	1986	2,550,000	3,580	171,000	6.7	185,000	260	17,200	9.3
01127000	713	F	1987	2,840,000	3,980	237,000	8.4	178,000	250	19,800	11.1
01127000	713	F	1988	1,990,000	2,790	129,000	6.5	128,000	180	11,400	8.9
01127000	713	F	1989	2,720,000	3,820	187,000	6.9	178,000	249	18,300	10.3
01127000	713	F	1990	2,880,000	4,040	216,000	7.5	167,000	234	18,000	10.8
01127000	713	F	1991	2,380,000	3,340	178,000	7.5	126,000	176	13,600	10.8
01127000	713	F	1992	2,160,000	3,020	168,000	7.8	110,000	154	12,100	11.0
01127000	713	F	1993	2,280,000	3,190	233,000	10.2	94,700	133	13,000	13.7
01127000	713	F	1994	2,190,000	3,070	241,000	11.0	85,900	120	12,700	14.8
01127000	713	F	1995	1,540,000	2,170	187,000	12.1	54,900	77	9,040	16.5

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval (lb/yr)	95-percent confidence interval (percent)	Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval (lb/yr)	95-percent confidence interval (percent)
01135300	42.9	A	1993	59,200	1,380	32,500	54.9	2,740	64	4,440	162
01135300	42.9	A	1994	64,000	1,490	30,100	47.1	3,390	79	5,500	162
01135300	42.9	A	1995	34,900	814	17,100	49.0	1,420	33	2,350	166
01137500	87.6	F	1993	113,000	1,290	15,400	13.7	2,350	27	1,330	56.5
01137500	87.6	F	1994	127,000	1,450	14,600	11.5	2,730	31	1,580	57.7
01137500	87.6	F	1995	87,600	1,000	6,810	7.8	1,820	21	809	44.6
01144000	690	F	1993	929,000	1,350	550,000	59.2	58,600	85	82,000	140
01144000	690	F	1994	1,090,000	1,570	755,000	69.5	72,500	105	97,600	135
01144000	690	F	1995	592,000	858	229,000	38.6	22,800	33	24,100	105
01154500	5493	F	1981	13,900,000	2,540	4,590,000	32.9	876,000	160	635,000	72.5
01154500	5493	F	1982	18,000,000	3,280	6,440,000	35.7	1,290,000	235	1,250,000	96.6
01154500	5493	F	1983	18,200,000	3,310	4,850,000	26.7	1,000,000	183	692,000	68.9
01154500	5493	F	1984	24,000,000	4,370	8,140,000	33.9	1,660,000	302	1,680,000	101
01154500	5493	F	1985	11,800,000	2,150	3,000,000	25.3	419,000	76	175,000	41.7
01154500	5493	F	1986	17,900,000	3,270	4,790,000	26.7	975,000	177	757,000	77.7
01154500	5493	F	1987	15,300,000	2,790	4,540,000	29.6	894,000	163	869,000	97.2
01154500	5493	F	1988	13,200,000	2,410	3,200,000	24.2	621,000	113	349,000	56.2
01154500	5493	F	1989	13,000,000	2,370	3,250,000	25.0	661,000	120	426,000	64.5
01154500	5493	F	1990	15,700,000	2,850	3,910,000	24.9	874,000	159	540,000	61.7
01154500	5493	F	1991	11,300,000	2,060	2,820,000	25.0	653,000	119	406,000	62.1
01154500	5493	F	1992	8,460,000	1,540	2,360,000	27.8	499,000	91	324,000	65.0
01154500	5493	F	1993	7,470,000	1,360	3,020,000	40.4	586,000	107	499,000	85.3
01154500	5493	F	1994	7,110,000	1,290	3,640,000	51.1	671,000	122	650,000	96.9
01170100	41.4	F	1993	57,900	1,400	7,370	12.7	3,000	72	3,570	119
01170100	41.4	F	1994	51,800	1,250	4,480	8.7	2,590	63	2,520	97.1
01170100	41.4	F	1995	32,100	774	2,670	8.3	1,240	30	910	73.2
01184000	9660	F	1970	--	--	--	--	4,110,000	426	656,000	15.9
01184000	9660	F	1971	--	--	--	--	3,070,000	318	477,000	15.5
01184000	9660	F	1972	--	--	--	--	3,760,000	389	575,000	15.3

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval		Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01184000	9660	F	1973	28,400,000	2,940	2,680,000	9.5	4,410,000	457	656,000	14.9
01184000	9660	F	1974	26,900,000	2,790	2,300,000	8.5	3,730,000	386	522,000	14.0
01184000	9660	F	1975	24,800,000	2,570	1,910,000	7.7	3,060,000	317	379,000	12.4
01184000	9660	F	1976	36,200,000	3,750	2,960,000	8.2	4,250,000	440	588,000	13.8
01184000	9660	F	1977	28,200,000	2,920	2,220,000	7.9	3,020,000	313	403,000	13.3
01184000	9660	F	1978	33,800,000	3,500	2,630,000	7.8	3,330,000	345	414,000	12.4
01184000	9660	F	1979	31,800,000	3,290	2,680,000	8.4	2,900,000	300	418,000	14.4
01184000	9660	F	1980	26,700,000	2,760	2,040,000	7.6	2,240,000	231	244,000	10.9
01184000	9660	F	1981	27,800,000	2,880	2,190,000	7.8	2,180,000	226	248,000	11.3
01184000	9660	F	1982	32,400,000	3,360	2,600,000	8.0	2,470,000	255	292,000	11.9
01184000	9660	F	1983	33,700,000	3,490	2,810,000	8.3	2,380,000	246	290,000	12.2
01184000	9660	F	1984	40,700,000	4,210	3,590,000	8.8	2,960,000	306	473,000	16.0
01184000	9660	F	1985	22,200,000	2,300	1,720,000	7.7	1,420,000	147	148,000	10.4
01184000	9660	F	1986	32,100,000	3,320	2,420,000	7.5	2,050,000	212	228,000	11.1
01184000	9660	F	1987	30,100,000	3,120	2,380,000	7.9	1,990,000	206	282,000	14.2
01184000	9660	F	1988	26,400,000	2,730	1,870,000	7.1	1,640,000	169	181,000	11.0
01184000	9660	F	1989	28,200,000	2,920	2,100,000	7.4	1,760,000	182	215,000	12.2
01184000	9660	F	1990	33,000,000	3,420	2,590,000	7.8	2,070,000	214	274,000	13.2
01184000	9660	F	1991	27,800,000	2,880	2,170,000	7.8	1,740,000	180	224,000	12.9
01184000	9660	F	1992	23,700,000	2,450	1,900,000	8.0	1,480,000	153	187,000	12.6
01184000	9660	F	1993	22,100,000	2,290	2,080,000	9.4	1,460,000	151	223,000	15.3
01184000	9660	F	1994	22,600,000	2,340	2,320,000	10.3	1,490,000	154	219,000	14.7
01184000	9660	F	1995	15,000,000	1,550	1,690,000	11.2	992,000	103	141,000	14.2
01184100	10.4	A	1982	53,000	5,090	8,370	15.8	6,310	606	2,740	43.4
01184100	10.4	A	1983	55,800	5,360	7,970	14.3	4,480	431	1,190	26.6
01184100	10.4	A	1984	64,300	6,180	9,000	14.0	5,510	530	1,740	31.6
01184100	10.4	A	1985	20,500	1,970	1,900	9.3	1,230	119	209	17.0
01184100	10.4	A	1986	39,200	3,760	5,130	13.1	2,670	257	651	24.4
01184100	10.4	A	1987	42,800	4,120	5,670	13.2	2,540	245	561	22.0
01184100	10.4	A	1988	30,300	2,910	3,300	10.9	1,510	145	256	17.0

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi²)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval (lb/yr)	95-percent confidence interval (percent)	Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval (lb/yr)	95-percent confidence interval (percent)
01184100	10.4	A	1989	44,500	4,280	6,460	14.5	3,440	331	1,020	29.7
01184100	10.4	A	1990	42,400	4,080	5,940	14.0	2,760	266	839	30.3
01184100	10.4	A	1991	34,500	3,310	5,250	15.2	2,150	207	693	32.2
01184490	15.5	A	1993	216,000	13,900	26,200	12.2	11,700	758	5,350	45.6
01184490	15.5	A	1994	228,000	14,700	14,400	6.3	8,960	578	2,650	29.6
01184490	15.5	A	1995	167,000	10,800	11,900	7.1	6,190	399	1,550	25.1
01186800	86.2	F	1974	213,000	2,470	36,800	17.3	22,300	258	5,260	23.6
01186800	86.2	F	1975	255,000	2,960	35,300	13.8	26,600	309	5,010	18.8
01186800	86.2	F	1976	279,000	3,230	32,300	11.6	28,700	333	4,510	15.7
01186800	86.2	F	1977	263,000	3,050	26,800	10.2	27,400	318	3,660	13.4
01186800	86.2	F	1978	320,000	3,720	31,400	9.8	31,400	365	4,060	12.9
01186800	86.2	F	1979	285,000	3,310	28,000	9.8	28,000	324	3,430	12.3
01186800	86.2	F	1980	266,000	3,090	25,800	9.7	26,400	306	3,270	12.4
01186800	86.2	F	1981	186,000	2,160	18,900	10.1	19,500	226	2,530	13.0
01186800	86.2	F	1982	297,000	3,450	30,500	10.3	27,200	316	3,610	13.3
01186800	86.2	F	1983	303,000	3,510	33,700	11.1	25,800	299	3,590	13.9
01186800	86.2	F	1984	336,000	3,900	38,000	11.3	27,200	315	3,830	14.1
01186800	86.2	F	1985	207,000	2,400	18,500	8.9	19,100	221	2,360	12.3
01186800	86.2	F	1986	293,000	3,400	28,400	9.7	22,800	264	2,950	12.9
01186800	86.2	F	1987	272,000	3,150	27,100	10.0	19,600	228	2,490	12.7
01186800	86.2	F	1988	209,000	2,420	19,100	9.2	15,600	181	1,980	12.6
01186800	86.2	F	1989	250,000	2,900	26,700	10.7	16,300	189	2,350	14.4
01186800	86.2	F	1990	250,000	2,900	31,100	12.4	15,000	174	2,550	17.0
01186800	86.2	F	1991	210,000	2,430	31,200	14.9	11,900	138	2,430	20.5
01188000	4.1	A	1973	11,400	2,780	2,660	23.3	786	192	316	40.2
01188000	4.1	A	1974	8,590	2,090	1,730	20.2	515	126	219	42.5
01188000	4.1	A	1975	9,350	2,280	1,660	17.8	583	142	246	42.1
01188000	4.1	A	1976	9,060	2,210	1,450	16.0	504	123	177	35.1
01188000	4.1	A	1977	7,340	1,790	1,120	15.2	386	94	115	29.8
01188000	4.1	A	1978	10,500	2,560	1,670	15.9	564	138	188	33.4

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval		Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01188000	4.1	A	1979	8,620	2,100	1,750	20.3	505	123	281	55.6
01188000	4.1	A	1980	8,150	1,990	1,640	20.1	470	115	268	57.1
01188000	4.1	A	1981	4,960	1,210	937	18.9	239	58	105	44.0
01188000	4.1	A	1982	9,780	2,390	1,930	19.7	581	142	393	67.6
01188000	4.1	A	1983	11,800	2,880	2,830	23.9	704	172	456	64.8
01188000	4.1	A	1984	12,800	3,110	2,740	21.5	713	174	375	52.6
01188000	4.1	A	1985	4,480	1,090	737	16.4	183	45	56	30.5
01188000	4.1	A	1986	8,700	2,120	1,550	17.8	365	89	124	33.9
01188000	4.1	A	1987	9,990	2,440	1,920	19.2	447	109	181	40.6
01188000	4.1	A	1988	6,640	1,620	1,080	16.3	235	57	65	27.7
01188000	4.1	A	1989	10,600	2,590	2,080	19.6	496	121	208	41.9
01188000	4.1	A	1990	11,200	2,740	2,120	18.9	474	116	201	42.4
01188000	4.1	A	1991	9,290	2,270	1,840	19.8	380	93	158	41.7
01188000	4.1	A	1992	9,400	2,290	2,020	21.5	408	100	205	50.1
01188000	4.1	A	1993	8,350	2,040	2,030	24.3	327	80	141	43.0
01188000	4.1	A	1994	10,800	2,640	2,930	27.1	444	108	193	43.5
01188000	4.1	A	1995	6,960	1,700	2,020	29.0	239	58	99	41.4
01188090	378	F	1984	1,750,000	4,640	615,000	35.1	128,000	339	84,900	66.3
01188090	378	F	1985	429,000	1,130	69,100	16.1	24,300	64	5,590	23.0
01188090	378	F	1986	830,000	2,200	119,000	14.3	43,100	114	8,920	20.7
01188090	378	F	1987	923,000	2,440	248,000	26.9	63,600	168	40,500	63.7
01188090	378	F	1988	465,000	1,230	58,600	12.6	24,000	63	4,190	17.5
01188090	378	F	1989	684,000	1,810	116,000	17.0	39,100	104	10,000	25.6
01188090	378	F	1990	768,000	2,030	133,000	17.3	44,200	117	12,000	27.2
01188090	378	F	1991	552,000	1,460	79,100	14.3	30,500	81	6,340	20.8
01188090	378	F	1992	466,000	1,230	67,900	14.6	27,400	73	6,540	23.8
01188090	378	F	1993	524,000	1,390	118,000	22.4	35,400	94	12,400	34.9
01188090	378	F	1994	411,000	1,090	77,100	18.8	24,900	66	6,380	25.6
01188090	378	F	1995	246,000	651	56,900	23.1	15,500	41	4,790	31.0

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi²)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval		Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01189000	45.8	U	1993	868,000	18,900	188,000	21.7	72,800	1,590	6,350	8.7
01189000	45.8	U	1994	637,000	13,900	58,000	9.1	72,600	1,580	6,240	8.6
01189000	45.8	U	1995	602,000	13,100	69,000	11.5	72,300	1,580	6,700	9.3
01189995	577	F	1972	2,830,000	4,910	327,000	11.6	420,000	728	53,900	12.8
01189995	577	F	1973	2,950,000	5,110	294,000	10.0	417,000	722	46,000	11.0
01189995	577	F	1974	2,400,000	4,150	206,000	8.6	344,000	596	32,700	9.5
01189995	577	F	1975	2,550,000	4,430	192,000	7.5	360,000	624	31,400	8.7
01189995	577	F	1976	2,950,000	5,110	209,000	7.1	391,000	677	32,200	8.2
01189995	577	F	1977	2,190,000	3,800	142,000	6.5	309,000	535	23,400	7.6
01189995	577	F	1978	3,200,000	5,540	219,000	6.9	396,000	687	32,700	8.2
01189995	577	F	1979	2,770,000	4,800	193,000	7.0	346,000	600	28,400	8.2
01189995	577	F	1980	2,510,000	4,350	176,000	7.0	316,000	548	26,700	8.4
01189995	577	F	1981	1,610,000	2,790	112,000	7.0	232,000	402	21,300	9.2
01189995	577	F	1982	2,580,000	4,470	182,000	7.1	306,000	531	27,400	9.0
01189995	577	F	1983	3,030,000	5,250	264,000	8.7	334,000	579	33,800	10.1
01189995	577	F	1984	3,280,000	5,680	279,000	8.5	346,000	599	36,000	10.4
01189995	577	F	1985	1,400,000	2,420	97,700	7.0	186,000	322	16,600	8.9
01189995	577	F	1986	2,450,000	4,240	161,000	6.6	248,000	429	19,800	8.0
01189995	577	F	1987	2,540,000	4,410	184,000	7.2	251,000	435	21,400	8.5
01189995	577	F	1988	1,900,000	3,290	117,000	6.1	192,000	332	14,400	7.5
01189995	577	F	1989	2,460,000	4,260	161,000	6.6	228,000	396	18,200	8.0
01189995	577	F	1990	2,810,000	4,880	197,000	7.0	240,000	415	20,700	8.7
01189995	577	F	1991	2,470,000	4,280	172,000	7.0	204,000	354	17,200	8.4
01189995	577	F	1992	2,320,000	4,020	170,000	7.3	188,000	326	17,100	9.1
01189995	577	F	1993	2,390,000	4,150	218,000	9.1	185,000	321	20,100	10.8
01189995	577	F	1994	2,440,000	4,230	237,000	9.7	176,000	305	20,600	11.7
01189995	577	F	1995	1,850,000	3,210	206,000	11.1	138,000	239	18,600	13.5
01192500	73.4	U	1992	886,000	12,100	74,600	8.4	94,900	1,290	8,920	9.4
01192500	73.4	U	1993	843,000	11,500	49,600	5.9	85,400	1,160	5,410	6.3
01192500	73.4	U	1994	844,000	11,500	50,000	5.9	84,800	1,160	5,450	6.4
01192500	73.4	U	1995	717,000	9,770	51,000	7.1	69,700	950	5,970	8.6

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi²)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval		Load (lb/yr)	Yield (lb/mi²/yr)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01193500	100	F	1972	--	--	--	--	16,700	167	7,370	44.1
01193500	100	F	1973	325,000	3,250	72,400	22.3	20,500	205	9,980	48.6
01193500	100	F	1974	229,000	2,290	42,000	18.4	11,600	116	5,040	43.3
01193500	100	F	1975	227,000	2,270	33,600	14.8	10,400	104	3,310	31.8
01193500	100	F	1976	297,000	2,970	49,400	16.6	14,700	147	6,400	43.7
01193500	100	F	1977	240,000	2,400	39,800	16.6	11,200	112	4,680	41.9
01193500	100	F	1978	356,000	3,560	65,300	18.3	18,500	185	10,800	58.0
01193500	100	F	1979	440,000	4,400	106,000	24.1	25,200	252	18,700	74.1
01193500	100	F	1980	287,000	2,870	45,400	15.9	12,600	126	6,210	49.3
01193500	100	F	1981	186,000	1,860	26,800	14.4	6,680	67	2,550	38.2
01193500	100	F	1982	447,000	4,470	109,000	24.3	31,900	319	39,900	125
01193500	100	F	1983	422,000	4,220	75,500	17.9	18,400	184	8,730	47.5
01193500	100	F	1984	515,000	5,150	103,000	20.0	27,300	273	17,500	64.1
01193500	100	F	1985	192,000	1,920	22,600	11.8	7,070	71	2,970	42.0
01193500	100	F	1986	249,000	2,490	33,000	13.3	8,040	80	2,700	33.6
01193500	100	F	1987	352,000	3,520	68,200	19.3	15,000	150	8,610	57.4
01193500	100	F	1988	187,000	1,870	22,800	12.2	5,620	56	1,600	28.5
01193500	100	F	1989	341,000	3,410	47,600	14.0	14,600	146	5,380	36.9
01193500	100	F	1990	316,000	3,160	43,700	13.8	12,100	121	4,320	35.6
01193500	100	F	1991	246,000	2,460	33,300	13.5	8,890	89	3,090	34.8
01193500	100	F	1992	195,000	1,950	26,500	13.6	6,710	67	2,400	35.7
01193500	100	F	1993	228,000	2,280	40,500	17.8	8,330	83	3,350	40.3
01193500	100	F	1994	192,000	1,920	35,500	18.5	6,910	69	2,790	40.3
01193500	100	F	1995	121,000	1,210	23,100	19.0	3,650	37	1,440	39.5
01196500	115	U	1972	1,500,000	13,100	127,000	8.4	255,000	2,220	24,600	9.7
01196500	115	U	1973	1,510,000	13,100	113,000	7.5	245,000	2,130	20,700	8.5
01196500	115	U	1974	1,280,000	11,100	80,000	6.3	210,000	1,820	15,200	7.2
01196500	115	U	1975	1,310,000	11,400	70,300	5.4	207,000	1,800	13,200	6.4
01196500	115	U	1976	1,410,000	12,200	73,000	5.2	210,000	1,830	12,800	6.1
01196500	115	U	1977	1,130,000	9,840	51,800	4.6	175,000	1,520	9,880	5.6

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval		Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01196500	115	U	1978	1,510,000	13,100	76,100	5.0	207,000	1,800	12,700	6.1
01196500	115	U	1979	1,460,000	12,700	83,200	5.7	194,000	1,690	12,800	6.6
01196500	115	U	1980	1,210,000	10,600	56,900	4.7	166,000	1,440	9,630	5.8
01196500	115	U	1981	901,000	7,840	44,200	4.9	132,000	1,140	8,490	6.5
01196500	115	U	1982	1,250,000	10,900	69,100	5.5	160,000	1,390	10,600	6.7
01196500	115	U	1983	1,380,000	12,000	92,700	6.7	164,000	1,430	12,600	7.7
01196500	115	U	1984	1,580,000	13,800	96,600	6.1	176,000	1,530	13,100	7.4
01196500	115	U	1985	858,000	7,460	40,100	4.7	113,000	981	6,830	6.1
01196500	115	U	1986	1,040,000	9,040	47,200	4.5	122,000	1,060	6,960	5.7
01196500	115	U	1987	1,260,000	10,900	70,600	5.6	134,000	1,170	8,880	6.6
01196500	115	U	1988	1,000,000	8,720	42,600	4.3	112,000	975	6,060	5.4
01196500	115	U	1989	1,340,000	11,700	67,700	5.1	134,000	1,170	8,350	6.2
01196500	115	U	1990	1,430,000	12,400	74,300	5.2	135,000	1,180	8,710	6.4
01196500	115	U	1991	1,280,000	11,100	64,200	5.0	121,000	1,050	7,530	6.2
01196500	115	U	1992	1,210,000	10,500	64,000	5.3	113,000	984	7,550	6.7
01196500	115	U	1993	1,220,000	10,600	76,800	6.3	109,000	948	8,470	7.8
01196500	115	U	1994	1,280,000	11,100	93,300	7.3	110,000	954	9,890	9.0
01196500	115	U	1995	1,080,000	9,380	87,300	8.1	94,100	819	9,640	10.2
01199900	194	A	1992	404,000	2,080	54,900	13.6	13,500	69	5,830	43.3
01199900	194	A	1993	572,000	2,950	59,100	10.3	25,800	133	14,300	55.6
01199900	194	A	1994	640,000	3,300	60,700	9.5	27,600	142	11,900	43.1
01199900	194	A	1995	450,000	2,320	49,300	11.0	13,900	72	6,100	43.9
01205500	1544	A	1972	--	--	--	--	398,000	258	71,100	17.9
01205500	1544	A	1973	5,710,000	3,700	781,000	13.7	440,000	285	73,100	16.6
01205500	1544	A	1974	4,900,000	3,170	584,000	11.9	358,000	232	55,300	15.4
01205500	1544	A	1975	5,580,000	3,620	561,000	10.0	377,000	244	50,400	13.4
01205500	1544	A	1976	6,670,000	4,320	614,000	9.2	443,000	287	56,000	12.6
01205500	1544	A	1977	5,430,000	3,520	509,000	9.4	344,000	223	48,200	14.0
01205500	1544	A	1978	6,710,000	4,350	578,000	8.6	415,000	269	53,800	13.0
01205500	1544	A	1979	6,260,000	4,060	655,000	10.5	383,000	248	65,500	17.1

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield (lb/mi^2/yr)	95-percent confidence interval		Load (lb/yr)	Yield (lb/mi^2/yr)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01205500	1544	A	1980	5,100,000	3,310	470,000	9.2	289,000	187	44,000	15.2
01205500	1544	A	1981	3,200,000	2,070	285,000	8.9	166,000	107	24,000	14.5
01205500	1544	A	1982	5,630,000	3,650	486,000	8.6	287,000	186	38,600	13.4
01205500	1544	A	1983	6,540,000	4,240	671,000	10.3	336,000	218	53,200	15.8
01205500	1544	A	1984	8,230,000	5,330	980,000	11.9	429,000	278	84,900	19.8
01205500	1544	A	1985	2,700,000	1,750	213,000	7.9	116,000	75	13,800	11.9
01205500	1544	A	1986	5,340,000	3,460	449,000	8.4	244,000	158	32,400	13.3
01205500	1544	A	1987	5,540,000	3,590	524,000	9.5	255,000	165	39,800	15.6
01205500	1544	A	1988	4,320,000	2,800	314,000	7.3	181,000	117	19,800	11.0
01205500	1544	A	1989	5,400,000	3,500	440,000	8.1	226,000	147	28,400	12.6
01205500	1544	A	1990	6,390,000	4,140	529,000	8.3	269,000	174	34,400	12.8
01205500	1544	A	1991	4,940,000	3,200	406,000	8.2	202,000	131	25,300	12.5
01205500	1544	A	1992	4,010,000	2,600	343,000	8.6	155,000	101	20,100	13.0
01205500	1544	A	1993	4,570,000	2,960	521,000	11.4	189,000	123	32,700	17.3
01205500	1544	A	1994	4,660,000	3,020	571,000	12.2	185,000	120	33,500	18.1
01205500	1544	A	1995	2,920,000	1,890	405,000	13.9	112,000	73	22,700	20.2
01208500	260	U	1975	3,010,000	11,600	321,000	10.7	395,000	1,520	62,000	15.7
01208500	260	U	1976	3,160,000	12,100	291,000	9.2	398,000	1,530	53,800	13.5
01208500	260	U	1977	2,750,000	10,600	216,000	7.9	350,000	1,350	40,000	11.4
01208500	260	U	1978	3,410,000	13,100	262,000	7.7	409,000	1,570	46,300	11.3
01208500	260	U	1979	3,370,000	13,000	271,000	8.0	407,000	1,570	48,000	11.8
01208500	260	U	1980	3,130,000	12,000	219,000	7.0	368,000	1,420	37,600	10.2
01208500	260	U	1981	2,430,000	9,330	174,000	7.2	307,000	1,180	33,000	10.7
01208500	260	U	1982	3,420,000	13,200	251,000	7.3	382,000	1,470	41,400	10.8
01208500	260	U	1983	3,680,000	14,100	331,000	9.0	418,000	1,610	53,500	12.8
01208500	260	U	1984	3,780,000	14,500	311,000	8.2	411,000	1,580	49,000	11.9
01208500	260	U	1985	2,260,000	8,690	155,000	6.9	271,000	1,040	27,700	10.2
01208500	260	U	1986	2,970,000	11,400	202,000	6.8	322,000	1,240	31,700	9.8
01208500	260	U	1987	3,100,000	11,900	240,000	7.7	346,000	1,330	39,000	11.3
01208500	260	U	1988	2,410,000	9,290	150,000	6.2	270,000	1,040	24,400	9.0

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen				Total phosphorus			
				Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval		Load (lb/yr)	Yield ($lb/mi^2/yr$)	95-percent confidence interval	
						(lb/yr)	(percent)			(lb/yr)	(percent)
01208500	260	U	1989	2,980,000	11,500	211,000	7.1	327,000	1,260	33,500	10.2
01208500	260	U	1990	2,980,000	11,500	215,000	7.2	326,000	1,250	34,900	10.7
01208500	260	U	1991	2,630,000	10,100	183,000	7.0	291,000	1,120	29,200	10.1
01208500	260	U	1992	2,400,000	9,220	180,000	7.5	266,000	1,020	29,300	11.0
01208500	260	U	1993	2,510,000	9,650	246,000	9.8	300,000	1,160	42,500	14.1
01208500	260	U	1994	2,400,000	9,230	249,000	10.4	276,000	1,060	41,200	14.9
01208500	260	U	1995	1,860,000	7,170	221,000	11.8	231,000	890	39,500	17.1
01208873	10.6	U	1993	47,200	4,450	12,700	26.8	833	79	934	112
01208873	10.6	U	1994	73,800	6,960	10,500	14.3	3,560	336	3,510	98.8
01208873	10.6	U	1995	40,300	3,810	6,530	16.2	797	75	507	63.6
01208990	21	U	1972	--	--	--	--	2,880	137	1,030	36.0
01208990	21	U	1973	44,400	2,120	9,600	21.6	2,650	126	694	26.2
01208990	21	U	1974	33,700	1,610	6,470	19.2	1,850	88	500	27.0
01208990	21	U	1975	41,800	1,990	7,470	17.9	2,590	123	955	36.9
01208990	21	U	1976	50,900	2,420	7,740	15.2	2,780	133	639	22.9
01208990	21	U	1977	35,500	1,690	5,680	16.0	1,760	84	428	24.3
01208990	21	U	1978	60,400	2,880	9,670	16.0	3,290	157	843	25.6
01208990	21	U	1979	58,300	2,770	10,300	17.7	3,000	143	847	28.2
01208990	21	U	1980	48,500	2,310	9,720	20.0	2,640	126	1,080	40.9
01208990	21	U	1981	23,400	1,120	3,350	14.3	976	47	207	21.2
01208990	21	U	1982	47,600	2,270	6,900	14.5	2,340	111	650	27.8
01208990	21	U	1983	65,500	3,120	13,200	20.1	3,310	158	1,050	31.6
01208990	21	U	1984	88,100	4,200	19,200	21.8	5,360	255	2,230	41.7
01208990	21	U	1985	24,100	1,150	3,000	12.5	1,030	49	225	21.9
01208990	21	U	1986	37,500	1,780	5,130	13.7	1,520	73	314	20.6
01208990	21	U	1987	51,200	2,440	9,080	17.7	2,390	114	711	29.8
01208990	21	U	1988	29,300	1,400	3,490	11.9	1,100	53	179	16.2
01208990	21	U	1989	48,800	2,320	7,780	16.0	2,490	118	658	26.5
01208990	21	U	1990	46,300	2,210	6,500	14.0	2,200	105	499	22.7
01208990	21	U	1991	38,800	1,850	5,610	14.5	1,760	84	403	22.9

Table 15. Annual loads, yields, and confidence intervals for total nitrogen and total phosphorus for 25 drainage basins in the Connecticut, Housatonic, and Thames River Basins study area—*Continued*

Station identification number (table 3)	Drainage area (mi^2)	Drainage basin category	Water year	Total nitrogen Load (lb/yr)	Total nitrogen Yield ($lb/mi^2/yr$)	Total nitrogen 95-percent confidence interval (lb/yr)	Total nitrogen 95-percent confidence interval (percent)	Total phosphorus Load (lb/yr)	Total phosphorus Yield ($lb/mi^2/yr$)	Total phosphorus 95-percent confidence interval (lb/yr)	Total phosphorus 95-percent confidence interval (percent)
01208990	21	U	1992	29,200	1,390	3,950	13.5	1,320	63	276	20.9
01208990	21	U	1993	29,900	1,420	5,250	17.6	1,290	61	330	25.7
01208990	21	U	1994	29,800	1,420	5,520	18.5	1,400	67	366	26.1
01208990	21	U	1995	16,600	791	3,330	20.1	645	31	176	27.3
01209710	33	U	1981	66,700	2,020	12,300	18.4	4,160	126	893	21.5
01209710	33	U	1982	128,000	3,890	20,100	15.7	9,430	286	2,320	24.6
01209710	33	U	1983	179,000	5,430	32,200	18.0	12,400	375	3,420	27.7
01209710	33	U	1984	217,000	6,590	35,300	16.2	17,300	525	5,230	30.2
01209710	33	U	1985	77,100	2,340	7,930	10.3	5,060	153	966	19.1
01209710	33	U	1986	106,000	3,210	12,400	11.7	5,970	181	1,000	16.7
01209710	33	U	1987	140,000	4,250	22,100	15.8	8,220	249	2,080	25.3
01209710	33	U	1988	71,600	2,170	7,920	11.1	3,430	104	447	13.0
01209710	33	U	1989	158,000	4,780	26,200	16.6	12,100	367	3,530	29.1
01209710	33	U	1990	116,000	3,510	13,100	11.3	7,160	217	1,280	17.9
01209710	33	U	1991	122,000	3,690	14,800	12.2	7,250	220	1,480	20.4
01209710	33	U	1992	76,800	2,330	7,500	9.8	4,950	150	899	18.1
01209710	33	U	1993	97,100	2,940	12,300	12.7	5,080	154	986	19.4
01209710	33	U	1994	83,200	2,520	10,800	12.9	4,900	148	873	17.8
01209710	33	U	1995	53,300	1,610	7,810	14.7	2,540	77	449	17.7

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