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Estimation of Flood Discharges at Selected Recurrence Intervals for Streams in New Hampshire

Scientific Investigations Report 2008–5206

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

Cover. Photograph of Suncook River at Main Street in the Village of Suncook, New Hampshire, during the Flood of May 2006.

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DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
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Conversion Factors, Datum, and Abbreviations

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Discharge	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]

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

°C=(°F–32)/1.8

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

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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

OTHER ABBREVIATIONS

NHDOT	New Hampshire Department of Transportation
GIS	Geographic Information System
NED	National Elevation Dataset
PRISM	Parameter-elevation Regression on Independent Slopes Model
USGS	U.S. Geological Survey
VIF	Variance Inflation Factor

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Estimation of Flood Discharges at Selected Recurrence Intervals for Streams in New Hampshire

By Scott A. Olson

Abstract

This report provides estimates of flood discharges at selected recurrence intervals for streamgages in and adjacent to New Hampshire and equations for estimating flood discharges at recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for ungaged, unregulated, rural streams in New Hampshire. The equations were developed using generalized least-squares regression. Flood-frequency and drainage-basin characteristics from 117 streamgages were used in developing the equations. The drainage-basin characteristics used as explanatory variables in the regression equations include drainage area, mean April precipitation, percentage of wetland area, and main channel slope. The average standard error of prediction for estimating the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood discharges with these equations are 30.0, 30.8, 32.0, 34.2, 36.0, 38.1, and 43.4 percent, respectively.

Flood discharges at selected recurrence intervals for selected streamgages were computed following the guidelines in Bulletin 17B of the U.S. Interagency Advisory Committee on Water Data. To determine the flood-discharge exceedence probabilities at streamgages in New Hampshire, a new generalized skew coefficient map covering the State was developed. The standard error of the data on new map is 0.298. To improve estimates of flood discharges at selected recurrence intervals for 20 streamgages with short-term records (10 to 15 years), record extension using the two-station comparison technique was applied. The two-station comparison method uses data from a streamgage with long-term record to adjust the frequency characteristics at a streamgage with a short-term record.

A technique for adjusting a flood-discharge frequency curve computed from a streamgage record with results from the regression equations is described in this report. Also, a technique is described for estimating flood discharge at a selected recurrence interval for an ungaged site upstream or downstream from a streamgage using a drainage-area adjustment.

The final regression equations and the flood-discharge frequency data used in this study will be available in StreamStats. StreamStats is a World Wide Web application providing automated regression-equation solutions for user-selected sites on streams.

Introduction

Flooding is the most costly natural hazard experienced in New Hampshire. Intense precipitation, a series of closely spaced major storms, springtime storms combined with snowmelt, tropical cyclones, and ice jams have all caused flooding in New Hampshire. Rarely do floods in New Hampshire have the same severity statewide. Since systematic monitoring of New Hampshire streams and their floods began in the early 1900s, floods with a recurrence interval greater than 50 years have occurred in parts of the State in 1927, 1936, 1938, 1943, 1953, 1959, 1973, 1987 (Hammond, 1991), 1996, 2005 (Olson, 2006), 2006 (Olson, 2007), and 2007 (Flynn, 2008).

In response to extensive damage caused by the closely spaced floods of 1927, 1936, and 1938, flood-control dams and reservoirs were built by the U.S. Army Corps of Engineers in the Merrimack and Connecticut River basins to decrease damages caused by flooding of major rivers. However, flooding continues to be a constant threat. In recent years (2005–07), another series of closely spaced, severe floods has occurred, resulting in the loss of life and property. These recent floods have been the greatest recorded at several streamgages on rivers and streams in southern New Hampshire (Olson, 2006 and 2007; Flynn, 2008).

The U.S. Geological Survey (USGS) and other agencies have been measuring and recording discharge at numerous streamgage sites throughout New Hampshire for the past 100 years. Continuous monitoring of discharge occurs at these streamgages. One purpose of the data collected from these streamgages is the characterization of the magnitudes and frequencies of flood discharges for rivers in the State. In 2008, there were 48 continuously operating streamgages in New Hampshire.

Estimates of the magnitude and frequency of flood discharges are needed to design safe and economical bridges, culverts, and other structures in or near streams; identify flood-hazard areas; and manage flood plains. Computation of flood-discharge magnitude and frequency estimates requires a statistical analysis of peak discharge data collected at streamgages. However, these estimates often are required for ungaged sites where no observed peak-discharge data are available. Investigations that provide methods for estimating flood-discharge frequency at ungaged sites in New Hampshire include Benson (1962), Potter (1957a, 1957b), LeBlanc (1978), and Dingman and Palaia (1999). Updated flood-discharge frequency estimates benefiting from additional years of peak-discharge data and enhanced statistical procedures can improve techniques for estimating flood-discharge frequency at ungaged sites. To address this, the USGS, in cooperation with the New Hampshire Department of Transportation (NHDOT), conducted this study to develop updated methods for estimating the flood discharges at selected recurrence intervals for unregulated and ungaged stream locations in New Hampshire.

Purpose and Scope

This report (1) provides estimates of flood discharges at recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years for streamgages in and adjacent to New Hampshire and (2) describes methods, including the use of equations developed from regression analyses, for estimating flood discharges at selected frequencies on ungaged, unregulated New Hampshire streams. In addition, this report (3) presents a method for estimating the standard error of prediction for each estimate made using the regression equations and (4) describes methods for transferring a flood-discharge estimate for a selected recurrence interval at a streamgage to a site upstream or downstream, based on drainage area.

Description of Study Area

New Hampshire (fig. 1) comprises a land area of 9,304 mi^2 in the northeastern United States, nearly one-seventh of the total land area of New England. The State is approximately 175 mi long from north to south and ranges from about 100 mi wide (east to west) at the southern end of the State to nearly 20 mi wide at its northern end. The southeast corner of the State borders the Atlantic Ocean for 18 mi.

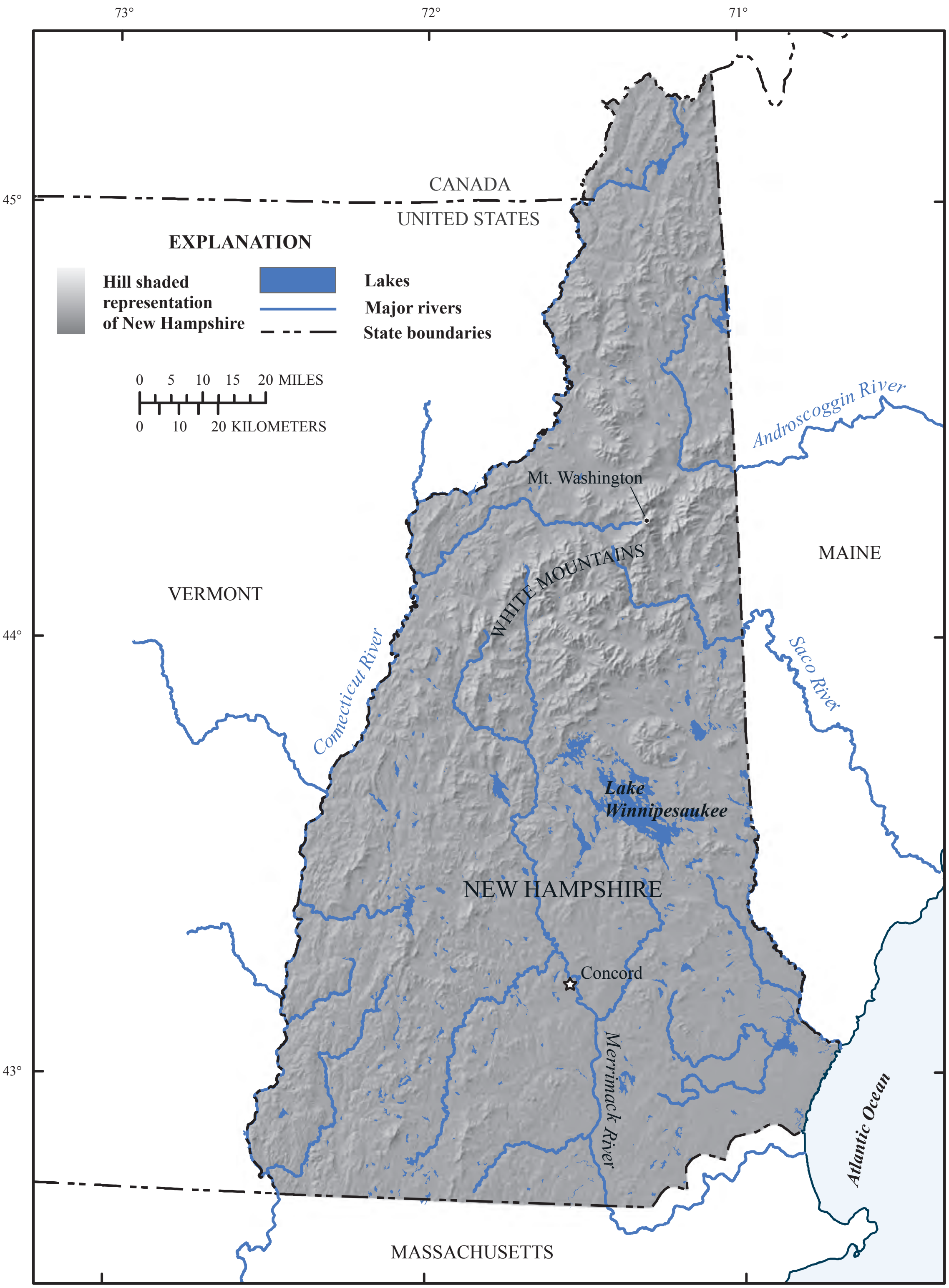
The terrain is hilly to mountainous with some flatlands along the coastline and along some river valleys. Land elevations range from sea level to about 500 ft in the southeastern part of the State from the Atlantic coastline inland, perpendicular to the coastline for 30 to 40 mi. Elevations are less than 500 ft in the valley floors of much of the Merrimack and Connecticut Rivers. Elevations in the remainder of the State generally range from 500 to 1,500 ft with many mountains having summits reaching elevations of 2,000 to 4,000 ft. The exception is the northernmost parts of the State where elevations typically exceed 1,500 ft. The White Mountains in the north-central part of New Hampshire have numerous summits that exceed 4,000 ft; Mount Washington reaches 6,288 ft. In the National Land Cover Data (Multi-Resolution Land Characteristics Consortium, 2003) database, land-cover classification in New Hampshire is approximately 78 percent forest, 8 percent developed land, 7 percent wetland, and 5 percent agricultural.

New Hampshire has about 40 rivers with a stream network totaling 41,800 mi (New Hampshire State Library, 2008). Four major rivers drain New Hampshire. The Connecticut River is the largest. The headwaters extend to the northernmost tip of the State and the river flows southerly making up most of the western border of New Hampshire. The headwaters of the Merrimack River are in the southern slopes of the White Mountains and the river flows southerly through central and southern New Hampshire. The Androscoggin and Saco Rivers drain eastern slopes of mountains in northern New Hampshire and flow southeasterly into Maine. New Hampshire has approximately 1,300 lakes or ponds that account for 277 total square miles (New Hampshire State Library, 2008). The largest lake is Lake Winnipesaukee, which covers an area of 71 mi^2, in the central part of the State.

Although the climate of New Hampshire is temperate and humid with four distinct seasons, it is renowned for its dramatic climatic extremes and rapid changes in weather. The mean annual air temperature ranges from about 41°F in the north to 45°F in the south. However, the historic range in temperature recorded in Concord, NH, is -37°F to 102°F.

Precipitation in the State is distributed fairly evenly throughout the year and averages about 43 in. annually. Areas with a high elevation may receive an additional 10 or more inches of precipitation annually. For example, the rain gage at 6,262 ft on Mount Washington receives an annual average of 102 in. of precipitation, whereas a rain gage located 18 mi north at an elevation of 930 ft receives an annual average of 40 in. (National Climatic Data Center, 2008).

Annual snowfall also varies across the State. Elevation has a strong effect on snowfall amounts. The coastal areas of New Hampshire receive about 50 in. of snowfall a year, and inland areas receive 60 to 70 in. (National Climatic Data Center, 2008). The average snowfall increases to more than 100 in. at higher elevations in the northern and western portions of the State; Mt. Washington receives more than 300 in. annually (Mount Washington Observatory, 2008).



Shaded relief: U.S. Geological Survey National Elevation Dataset, 2007, 1/3 arc-second resolution
Lakes/rivers: U.S. Geological Survey National Hydrography Dataset, 2007, 1:24,000
State Boundaries: U.S. Geological Survey Digital Line Graphs, 1990–94, 1:24,000

Figure 1. Location of major rivers and waterbodies in New Hampshire.

Flood Discharges at Selected Recurrence Intervals for Streamgages

To develop techniques for estimating flood-discharge magnitude and frequencies for ungaged stream locations, flood-discharge magnitude and frequency are first established at streamgages. The magnitude and frequency of floods at streamgages then can be statistically related to the physical and climatic characteristics of the contributing drainage basin upstream from the streamgage. The statistical relations that are established at the streamgages then can be used to estimate the magnitudes and frequencies of floods at an ungaged site using drainage-basin characteristics.

Peak Discharge Data Used in this Study

All available peak discharge data in New Hampshire and adjacent, physiographically similar areas in Maine, Massachusetts, and Vermont, and Quebec, Canada, collected by the USGS, the U.S. Forest Service, the New Hampshire Department of Environmental Services, and Environment Canada were considered for this study. These data include records from continuously recording streamgages and crest-stage streamgages (streamgages that record only the annual peak discharge), both current (2008) and discontinued.

Of the sites considered, 117 streamgages were selected for use in this study (fig. 2; table 1 in back of report). The selection criteria required the streamgage to have a minimum of 10 years of annual peak-discharge data that were free of trends and unaffected by regulation or urbanization. Regulation was assumed to have a negligible effect on peak discharges if the usable storage in the basin was less than 4.5 million cubic feet per square mile of drainage area (Benson, 1962). Peak-discharge data from sites that had greater than 4.5 million cubic feet of usable storage per square mile of drainage area were not used.

None of the streamgages included in this investigation have drainage basins considered to be urbanized. The maximum percentage of land area in a streamgage drainage basin classified as having high intensity developed land in the 2001 National Land Cover Data (Multi-Resolution Land Characteristics Consortium, 2003) is 2.8 percent; the average is 0.1 percent. The maximum percentage of land area in a streamgage drainage basin classified as having medium or high intensity developed land is 11 percent; the average is 0.9 percent.

The 117 streamgages selected are spatially well distributed in and adjacent to New Hampshire (fig. 2). However, a review of the sites reveals that the hundreds of small drainage basins in New Hampshire with drainage areas of less than 15 mi^2 are poorly represented. Only 12 small drainage basins in New Hampshire had sufficient discharge data for the study, and currently (2008) only one of the streamgages is active. Therefore, streamgages of small drainage basins in States adjacent to New Hampshire were included to compensate for this shortage.

To ensure that trends in the annual peak-discharge data did not exist, a two-sided Kendall Tau trend test (Helsel and Hirsch, 1992) was completed. The trend test was done with a program developed by the USGS called SWSTAT, a Computer Program for Interactive Computation of Surface-Water Statistics (A.M. Lumb, W.O. Thomas, Jr., and K.M. Flynn, U.S. Geological Survey, written commun., 1994). Streamgage records with less than 15 years of annual peak-discharge data were not tested for trends because trends over a period of record this short cannot be distinguished from serial correlation.

No substantial trends were found by the Kendall Tau test for the peak-discharge data used in this study. The Kendall Tau statistics indicated that an upward trend may exist for 21 of the 117 streamgages. However, for streamgages indicating a possible trend, the trend could be explained as the result of extreme climatic anomalies near the beginning or end of the peak-discharge record, such as the 2006 and 2007 floods (Olson, 2007; Flynn, 2008) or the drought of 1960–69 (Hammond, 1991). The evidence of trends did not exist or was statistically insignificant when extreme events, such as those, were eliminated from the Kendall Tau trend tests.

In recent years there has been much speculation regarding the impact of climatic changes on annual peak discharges (Milly and others, 2008). To evaluate if increased annual peak discharges have occurred in recent decades, flood-discharge frequency curves were computed for 14 active streamgages in and adjacent to New Hampshire having 60 years or more of unregulated annual peak discharge data. These flood-discharge frequency curves were compared to curves computed using only the most recent 20 years (1988–2007) of record. At 4 of the 14 streamgages, the flood-frequency curves (10- to 500-year recurrence interval) computed from the 1988–2007 data had greater discharges than the flood-frequency curves computed from the period of record; at 7 of the streamgages, frequency curves had smaller discharges; and at 2 streamgages, the frequency curves had little (less than 3 percent) to no change. Nearly identical results were found using the most recent 25 years of record (1983 to 2007). Table 2 displays the flood discharges for the 14 streamgages at the 100-year recurrence interval computed using the period of record for the streamgages and using the 1988 to 2007 period.

The results shown in table 2 indicate no definitive patterns in annual peak discharges that would suggest limiting the use of the entire period of record available for a streamgage. The annual peak-discharge data used in this study are therefore regarded as random, independent events that are homogeneous for a streamgage throughout the period of record.

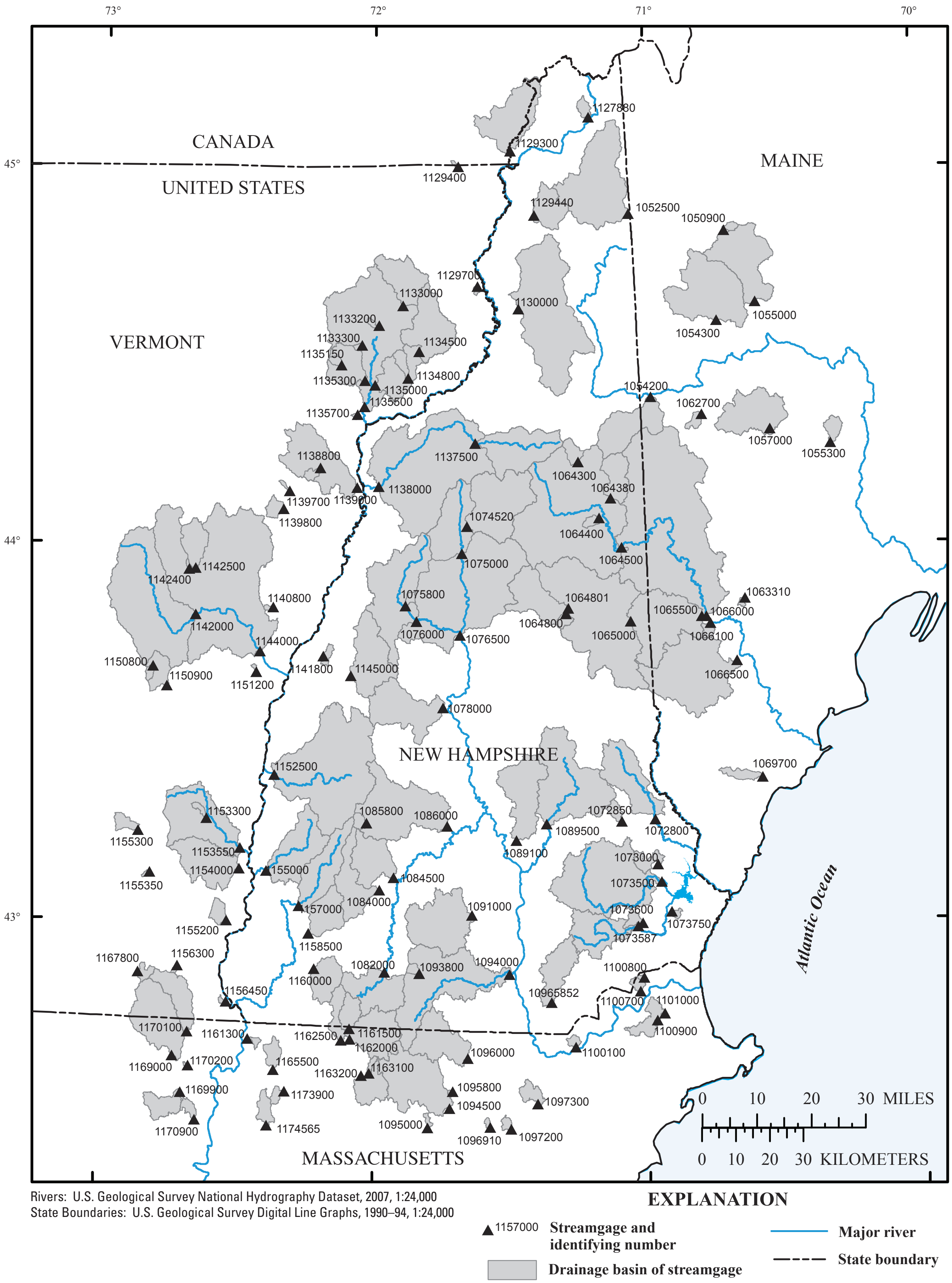


Figure 2. Locations of the 117 streamgages and upstream drainage basins used to develop regression equations for estimating the magnitude of flood flows for selected recurrence intervals in New Hampshire. (Leading 0 has been dropped from the streamgage station number)

Table 2. Differences between the 100-year flood discharge computed from the period of record and from the period 1988–2007 for selected streamgages in and adjacent to New Hampshire.

[Locations of streamgages are shown in figure 2. ft^3/s, cubic feet per second]

USGS streamgage station number	Station name	Years	Flood discharge at a 100-year recurrence interval (ft^3/s)	Change in the 100-year flood discharge computed from the period of record to the period 1988–2007
01052500	Diamond River near Wentworth Location, NH	1942–2007	10,400	Increase by 15 percent
		1988–2007	12,000	
01064500	Saco River near Conway, NH	1904–09, 1930–2007	52,800	Decrease by 26 percent
		1988–2007	38,900	
01073000	Oyster River near Durham, NH	1935–2007	1,200	Increase by 56 percent
		1988–2007	1,870	
01073500	Lamprey River near Newmarket, NH	1935–2007	9,270	Increase by 53 percent
		1988–2007	14,200	
01076500	Pemigewassett River at Plymouth, NH	1904–2007	57,700	Decrease by 29 percent
		1988–2007	40,800	
01078000	Smith River near Bristol, NH	1919–2007	5,740	Decrease by 8 percent
		1988–2007	5,290	
01094000	Souhegan River at Merrimack, NH	1910–76, 1982–2007	12,200	No change[1]
		1988–2007	12,100	
01134500	Moose River at Victory, VT	1947–2007	4,740	Decrease by 6 percent
		1988–2007	4,440	
01135500	Passumpsic River at Passumpsic, VT	1929–2007	17,000	No change[1]
		1988–2007	17,000	
01137500	Ammoonoosuc River at Bethlehem Junction, NH	1940–2007	12,200	Decrease by 11 percent
		1988–2007	10,800	
01139000	Wells River at Wells River, VT	1941–2007	5,170	Decrease by 5 percent
		1988–2007	4,900	
01142500	Ayers Brook at Randolph, VT	1940–2007	2,820	Increase by 29 percent
		1988–2007	3,640	
01144000	White River at West Hartford, VT	1916–2007	61,800	Decrease by 31 percent
		1988–2007	42,800	
01152500	Sugar River at West Claremont, NH	1929–2007	12,800	Decrease by 10 percent
		1988–2007	11,500	

[1]Less than 3-percent change in discharge is reported as no change.

Determination of the Magnitude and Frequency of Flood Discharges for Streamgages

The 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood discharges for the 117 streamgages (table 1 in back of report) were computed using the guidelines in Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982). Bulletin 17B recommends fitting the systematic annual peak-discharge data to a log-Pearson Type III probability distribution for estimating flood-discharge magnitude and frequency and provides procedures for weighting station skews, historical peaks, and the detection and treatment of outliers. Software developed by the USGS to analyze flood-discharge frequency, PEAKFQ, was used for these computations (W.O. Thomas, Jr., A.M. Lumb, K.M. Flynn, and W.H. Kirby, U.S. Geological Survey, written commun., 1997). Peak discharges affected by dam failure, ice-jam breach, or a similar event are not included in the frequency analyses.

Generalized Skew

Estimates of the magnitude and frequency of flood discharges are sensitive to skew—the measure of the lack of symmetry in the probability distribution of annual peak-flow data. Extreme flood events often affect skews computed from a streamgage peak-discharge record, and the impact of an extreme flood on skew is greater the shorter the length of streamgage record. To compensate for this effect, the skew used in estimating flood discharges for selected recurrence intervals at a streamgage is weighted with a generalized skew estimated by pooling the skews from nearby streamgages. The generalized skew can be taken from the generalized skew map in Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982). However, the map, prepared in 1976, is outdated and lacks the resolution desired for the study area. For these reasons, a new method for obtaining generalized skews for New Hampshire was developed.

Several methods for estimating skews for streamgages were tested, including a statewide average of skew, a data interpolation technique, and a multiple-regression analysis using skew and basin characteristics. Skews with the smallest error were obtained from a new generalized skew map developed using a geographical information system (GIS) tool, ArcGIS Spatial Analyst Kriging (Environmental Systems Research Institute, Inc., 2006). The procedure generates an estimated surface from a point dataset, which then can be converted to a contour map. The point dataset was comprised of computed skews from streamgages used in this study with 25 or more years of peak-discharge record.

Because a computed skew coefficient is a biased estimator of skew, a bias correction factor, C_b, was developed by Tasker and Stedinger (1986), where $C_b = 1+6/N$ and N is the number of years of streamgage peak-discharge record. All skew coefficients were adjusted using this bias correction factor prior to generating the contour map.

Each computed skew was located at the centroid of the respective basin and was given the same weight regardless of the number of years of record for the streamgage or the drainage area of the basin the skew was representing. The new generalized skew map for New Hampshire (fig. 3) has a standard error of estimate of 0.298, an improvement over the standard error of estimate (0.461) for the State from the National isoline skew map (U.S. Interagency Advisory Committee on Water Data, 1982).

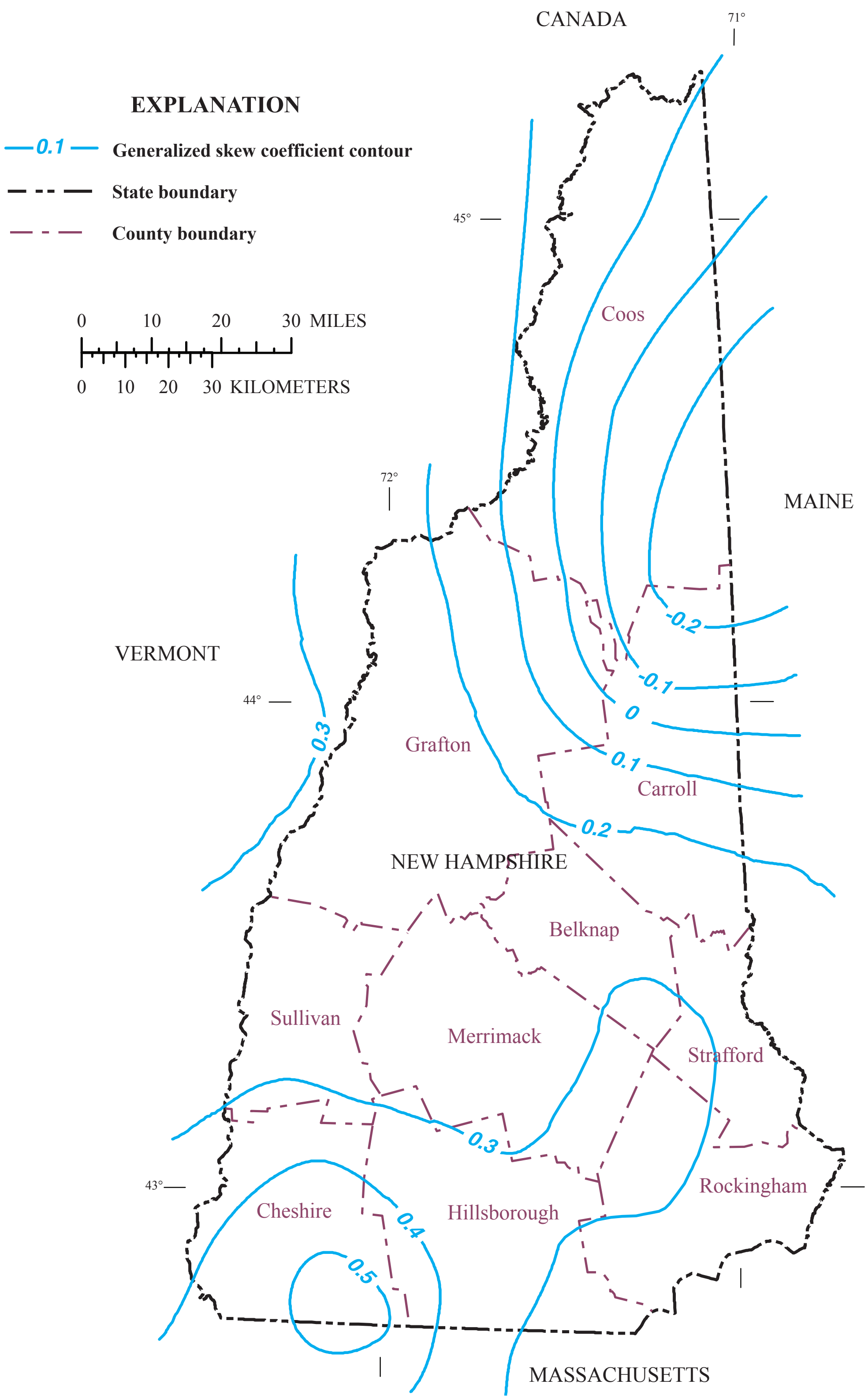
Record Extension

Record extension was used to improve the estimates of flood discharges at selected recurrence intervals for streamgages with relatively short peak-discharge records (10 to 15 years). The record-extension method used in this study was the two-station comparison method described in Guidelines for Determining Flood Flow Frequency (U.S. Interagency Advisory Committee on Water Data, 1982). The two-station comparison technique of record extension involves adjusting the logarithmic mean and standard deviation of a short-term streamgage record with flood-discharge statistics from a long-term streamgage record. Using this two-station comparison method, records were extended for 20 streamgages with short-term records.

For the application of the record-extension method, the streamgage with the long-term record had to be on an unregulated stream. In addition, the short- and long-term record streamgages had to have correlated peak-discharge data during their concurrent period of record. Of the 20 streamgages for which record extension was done, the minimum correlation coefficient determined using data from the long- and short-term record pairs was 0.631, which is within the guidelines for the two-station comparison technique documented in Guidelines for Determining Flood Flow Frequency (U.S. Interagency Advisory Committee on Water Data, 1982); the average was 0.817. The 20 streamgages for which this technique was used are listed in table 3, along with the long-term record streamgage and correlation coefficients.

Combined Records of Nearby Streamgages

Three discontinued streamgages included in this investigation were located a short distance upstream from new, active streamgages; the period of record of the older streamgages falls within 1929 to 1987. In each case, the location of the discontinued streamgage and the newer, active streamgage are considered to be proximate enough to have similar drainage-basin characteristics and represent a single streamgage. For this reason, table 1 (in back of report) contains 120 streamgages although 117 streamgages are used in the regression analysis. Before combining the peak-discharge record of the older, upstream streamgage and peak-discharge record of the newer, downstream streamgage, the peak discharges from the upstream streamgage were adjusted



County Boundaries: U.S. Geological Survey Digital Line Graphs, 1990–94, 1:24,000

Figure 3. Generalized skew coefficients of logarithms of annual peak discharge in New Hampshire.

Table 3. Streamgages for which record extension was applied, the associated long-term record streamgage, and correlation coefficients for streams in and adjacent to New Hampshire.

[Locations of streamgages are shown on figure 2]

Short-term record			Long-term record			
USGS streamgage station number	Station name	Years of record	USGS streamgage station number	Station name	Years of record	Correlation coefficient
01050900	Four Ponds Brook near Houghton, ME	11	01055000	Swift River near Roxbury, ME	78	0.789
01055300	Bog Brook near Buckfield, ME	11	01057000	Little Androscoggin River near South Paris, ME	86	0.799
01062700	Patte Brook near Bethel, ME	10	01064500	Saco River near Conway, NH	84	0.933
01064380	East Branch Saco River at Town Hall Road, near Lower Bartlett, NH	10	01064500	Saco River near Conway, NH	84	0.776
01064800	Cold Brook at South Tamworth, NH	10	01064500	Saco River near Conway, NH	84	0.777
01066100	Pease Brook near Cornish, ME	10	01066500	Little Ossipee River near South Limington, ME	43	0.736
01069700	Branch Brook near Kennebunk, ME	10	01073000	Oyster River near Durham, NH	73	0.703
01072800	Cocheco River near Rochester, NH	12	01073500	Lamprey River near Newmarket, NH	73	0.843
01073587	Exeter River at Haigh Road, near Brentwood, NH	11	01073500	Lamprey River near Newmarket, NH	73	0.939
01073750	Mill Brook near State Route 108, at Stratham, NH	11	01073000	Oyster River near Durham, NH	73	0.762
01095800	Easter Brook near North Leominster, MA	11	01094500	North Nashua River near Leominster, MA	72	0.859
01097200	Heath Hen Meadow Brook at Stow, MA	11	01097300	Nashoba Brook near Acton, MA	44	0.844
01100700	East Meadow River near Haverhill, MA	12	01073000	Oyster River near Durham, NH	73	0.939
01138800	Keenan Brook near Groton, VT	11	01139800	East Orange Branch at East Orange, VT	49	0.916
01155200	Sackets Brook near Putney, VT	11	01154000	Saxtons River at Saxtons River, VT	48	0.927
01155300	Flood Brook near Londonderry, VT	11	01154000	Saxtons River at Saxtons River, VT	48	0.631
01163100	Wilder Brook near Gardner, MA	11	01162000	Millers River near Winchendon, MA	90	0.818
01170200	Allen Brook near Shelburne Falls, MA	11	01162000	Millers River near Winchendon, MA	90	0.796
01170900	Mill River near South Deerfield, MA	12	01165500	Moss Brook at Wendell Depot, MA	66	0.743
01173900	Middle Branch Swift River at North New Salem, MA	11	01162500	Priest Brook near Winchendon, MA	90	0.810

by the drainage area ratio of the two sites. Discontinued streamgages for which peak discharge records were adjusted for drainage area and combined with the record from a newer, downstream streamgage are shown in table 4.

Magnitude and Frequency of Flood Discharges for Streamgages

The magnitudes of flood discharges at selected recurrence intervals for streamgages used in this study are shown in table 5 (in back of report). The flood discharge at a given recurrence interval, in years, represents the flood-discharge frequency curve of each streamgage used in this investigation. Flood-discharge frequency curves, determined using log-Pearson Type III analysis, are shown in figure 4.

Maximum Recorded Floods and Envelope Curves

The maximum recorded flood discharges (table 5 in back of report) plotted against drainage area for each streamgage in this study are displayed in figure 5. Flood discharges affected by dam failure, ice-jam breach, or a similar event are not included. An envelope curve encompassing the maximum recorded floods is included in the figure, along with a line developed using generalized least-squares regression analysis showing the relation between drainage area and the 100-year discharge for each streamgage. A regional envelope developed by Crippen and Bue (1977) is also shown. Figure 5 can be used to evaluate the reasonableness of flood estimates made using techniques described in this report.

Characteristics of Streamgage Drainage Basins

In flood-frequency regression analysis, the variations in the magnitude of flood discharges at a selected recurrence interval for streamgages used in the study are related to variations in basin characteristics. The flood discharges are the dependent variables, and the basin characteristics are the independent or explanatory variables. For this study, 110 basin characteristics were determined for each streamgage, including physical properties such as drainage area, channel slope, elevation, forest cover, lake area, and soil permeability; and climatic characteristics such as precipitation and temperature.

Boundaries for the drainage basins of the streamgages were obtained from the Watershed Boundary Dataset (Natural Resources Conservation Service, 2001) or were digitized manually on 1:24,000 digital raster graphs (U.S. Geological Survey, 2001) when the basin boundary was not defined by the Watershed Boundary Dataset. Additional dimensional properties of the drainage basins and waterways were computed with the ArcHydro software (Environmental Systems Research Institute, Inc., 2008) using a digital elevation dataset derived from the National Elevation Dataset (NED) (U.S. Geological Survey, 2007a). Prior to being used for basin delineation, the NED was hydrologically corrected (U.S. Geological Survey, 2004, and P.A. Steeves and A.H. Rea, U.S. Geological Survey, written commun., 2007) using the National Hydrography Dataset (U.S. Geological Survey, 2007b) and the Watershed Boundary Dataset (National Resources Conservation Service, 2001).

Table 4. Discontinued streamgages, associated active downstream streamgage, and drainage area ratio for selected streams in and adjacent to New Hampshire.

[mi^2, square miles]

Discontinued streamgage				Active downstream streamgage				
USGS streamgage station number	Station name	Drainage area (mi^2)	Period of record	USGS streamgage station number	Station name	Drainage area (mi^2)	Period of record	Drainage area ratio
01074500	East Branch Pemigewassett River near Lincoln, NH	106	1929–52, 1960, 1968–70	01074520	East Branch Pemigewasset River at Lincoln, NH	115	1993–2007	1.085
01089000	Soucook River near Concord, NH	77.7	1952–87	01089100	Soucook River, at Pembroke Road, near Concord, NH	82.7	1989–2007	1.064
01153500	Williams River at Brockways Mills, VT	102	1941–84	01153550	Williams River near Rockingham, VT	112	1987–2007	1.098

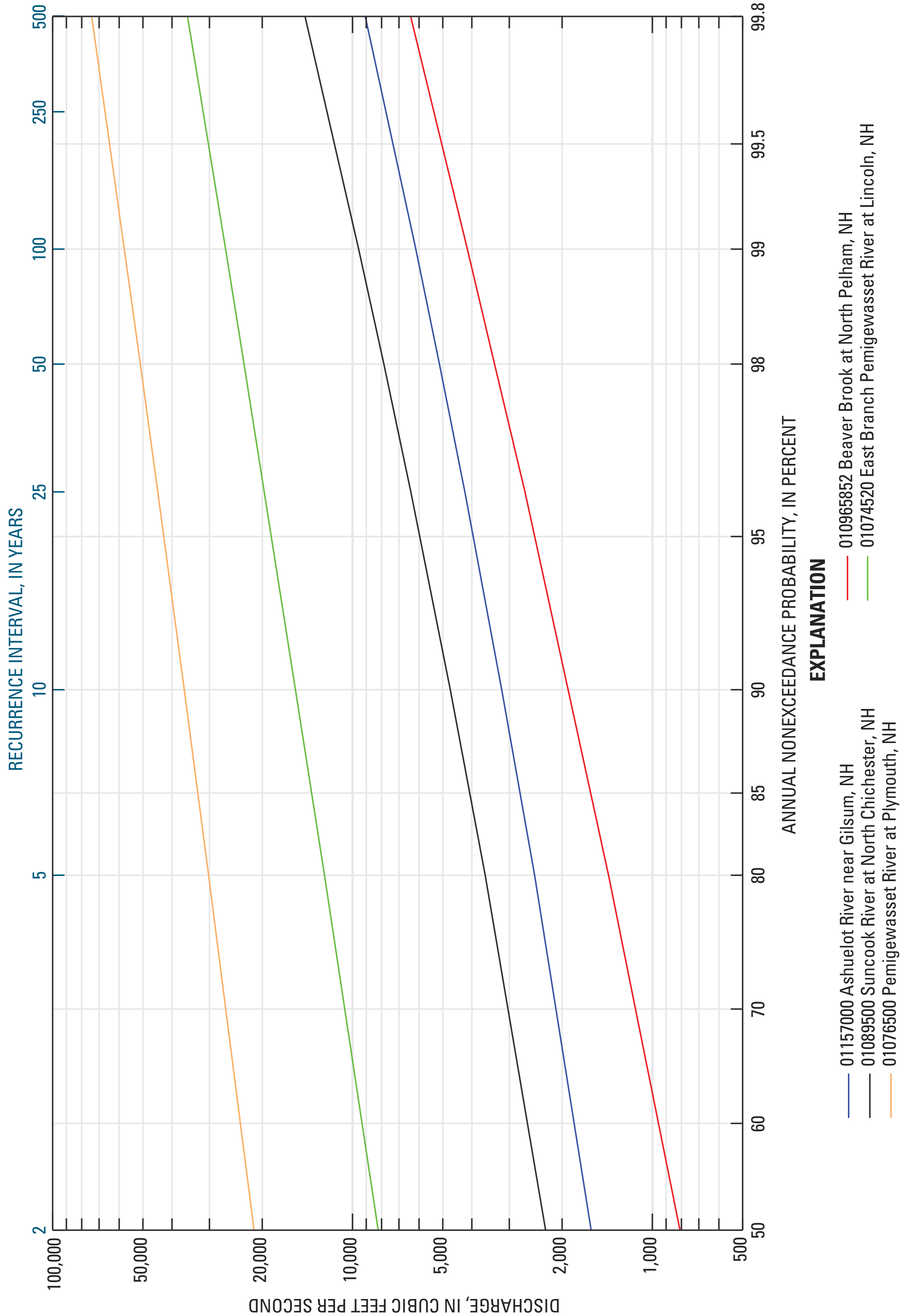


Figure 4. Flood-discharge frequency curves for selected streamgages in New Hampshire.

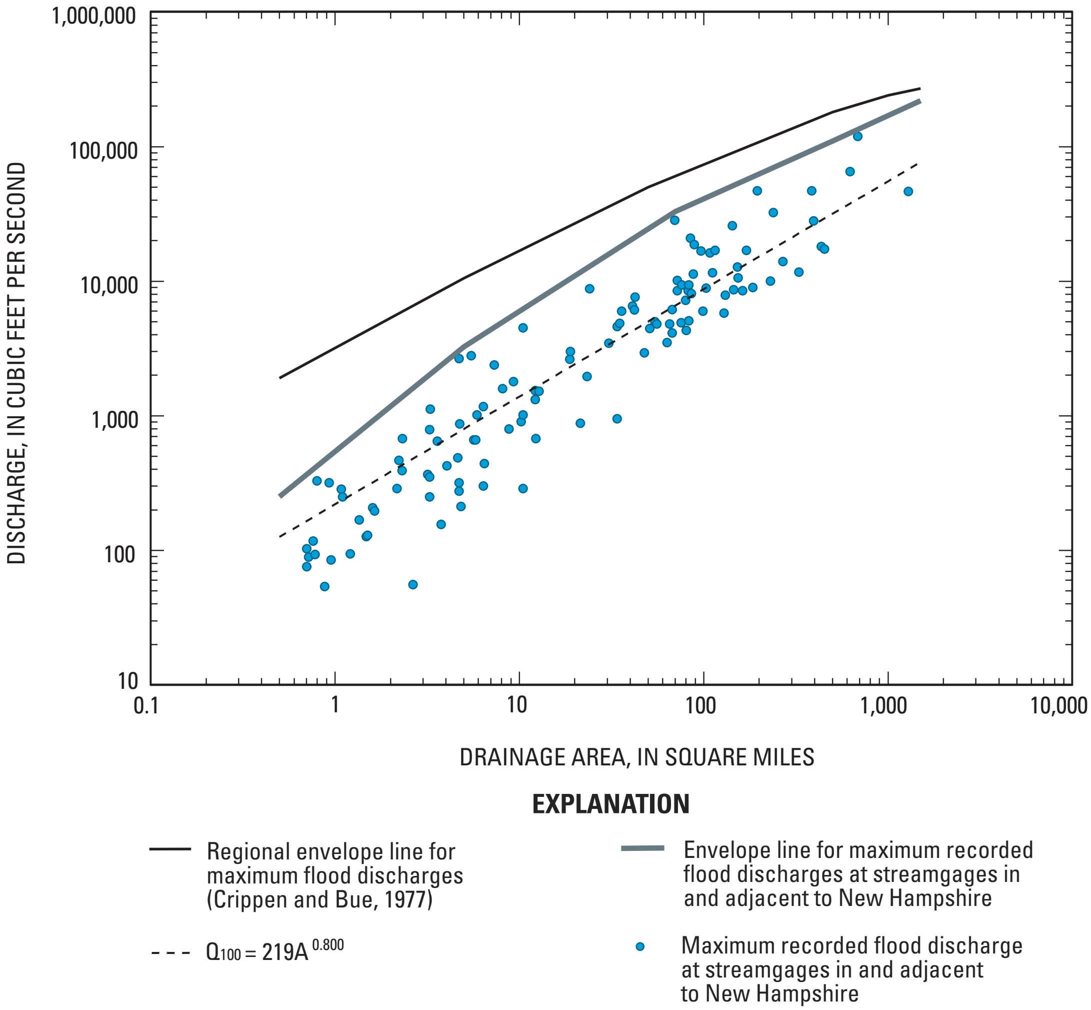


Figure 5. Maximum recorded flood discharges at streamgages in New Hampshire in and adjacent to New Hampshire in relation to drainage area, with envelope lines and a regression line relating the 100-year discharge (Q_{100}) to drainage area.

With appropriate GIS datasets, other basin characteristics also were delineated with the ArcHydro software. The National Hydrography Dataset, the 2001 National Land Cover Data (Multi-Resolution Land Characteristics Consortium, 2003), the State soil geographic (STATSGO) database (U.S. Geological Survey, 1995), and the National Wetlands Inventory (U.S. Fish and Wildlife Service, 2007) were the source GIS datasets for land-surface properties. The sources for climatic data were PRISM (Parameter-elevation Regressions on Independent Slopes Model) (PRISM Group, Oregon State University, 2006a–c) and Climatesource (Daly and others, 2000). The PRISM climatic data were resampled to a 180-ft-cell resolution. The source for runoff data was Randall (1996), and the source for population data was the U.S. Census Bureau (2006). The physiographic divisions were from Fenneman and Johnson (1946). Maps showing the 24-hr rainfall with 2- and 100-year recurrence intervals (U.S. Department of Commerce, 1961) were delineated manually for use in a GIS. A complete list of basin characteristics determined for potential use as explanatory variables in the regression analysis is presented in table 6 (in back of report).

Regression Equations for Estimation of Flood Discharges at Selected Recurrence Intervals for Ungaged Stream Sites

Multiple-regression techniques, employing generalized least-squares regression (Stedinger and Tasker, 1985), were used to define relations between the flood-discharges determined for the streamgages at the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals (dependent variables) and the basin characteristics (independent variables) of those streamgages. The use of generalized least-squares regression allows for weighting of streamgage data to compensate for the differences in record length and the cross-correlation of concurrent records among streamgages. Furthermore, Stedinger and Tasker (1985) showed that generalized least-squares regression equations are more accurate and provide better estimates of model error than ordinary least-squares regression equations, when working with flood frequency.

The regression results provide equations for estimating the values of dependent variables from one or more independent variables. The regression equations take the general form

$$Y_T = b_o + b_1X_1 + b_2X_2 + \ldots + b_jX_j\ , \qquad (1)$$

where

Y_T is the magnitude of the flood discharge having a recurrence interval of T years,

b_o to b_j are coefficients developed from the regression analysis, and

X_1 to X_j are the basin characteristics.

When transformation to the explanatory and response variable are logarithmic, equation 1 can be manipulated to take the form

$$Y_T = 10^{bo} X_1^{\ b1} X_2^{\ b2} \ldots X_j^{bj}\ . \qquad (2)$$

The limitations, sensitivity, and accuracy of the regression equations are reported following the final regression equations. In addition, techniques are discussed for determining the accuracy, equivalent years of record, and confidence intervals for each individual estimate from the regression equations. Methods of weighting regression equation estimates with streamgage data when the regression equations are used for a site near or at a streamgage also are discussed.

Regression Analysis and Final Regression Equations

More than 100 basin characteristics were determined for each streamgage and used in the regression analysis. Mathematical transformations were applied to each basin characteristic and flood discharge statistic to obtain the most linear relations. The transformations used were logarithms, square roots, squares, and raising the values to the -0.125 power. Correlation data and stepwise linear regression (SAS Institute, Inc., 1990) were used to evaluate which basin characteristics, transformed or untransformed, were the most significant explanatory variables.

Next, generalized least-squares regression techniques were used to determine the final significant basin characteristics and to compute the final regression equations. The generalized least-squares regression analysis was done using GLSNET, a hydrologic regression and streamflow-network analysis program that uses the generalized least-squares regression procedure (G.D. Tasker, K.M. Flynn, A.M. Lumb, W.O. Thomas, Jr., U.S. Geological Survey, written commun., 1995). The basin characteristics used in the development of the final regression equations are listed in table 7 (in back of report), by streamgage. Logarithmic base-10 transformations were made on all final variables in the equations except for the percentage of the basin covered by wetlands. The final regression equations (equations 3–9) for estimating flood discharges on ungaged, unregulated streams in rural drainage basins in New Hampshire are as follows:

$$Q_2 = 2.60A^{0.958}P^{1.50}10^{-0.0245(W)}S^{0.205}\ , \qquad (3)$$

$$Q_5 = 3.23A^{0.929}P^{1.73}10^{-0.0245(W)}S^{0.211}\ , \qquad (4)$$

$$Q_{10} = 3.88A^{0.912}P^{1.83}10^{-0.0247(W)}S^{0.211}\ , \qquad (5)$$

$$Q_{25} = 4.99A^{0.892}P^{1.90}10^{-0.0250(W)}S^{0.207}\ , \qquad (6)$$

$$Q_{50} = 5.96A^{0.879}P^{1.94}10^{-0.0252(W)}S^{0.203}, \quad (7)$$

$$Q_{100} = 7.13A^{0.867}P^{1.98}10^{-0.0254(W)}S^{0.198}, \text{ and} \quad (8)$$

$$Q_{500} = 10.6A^{0.841}P^{2.03}10^{-0.0259(W)}S^{0.183}, \quad (9)$$

where

- Q_T is the estimated flood discharge, in cubic feet per second, at a T-year recurrence interval;
- A is the drainage area of the basin, in square miles, computed using the ArcHydro software (Environmental Systems Research Institute, Inc., 2008) (boundaries were from the Watershed Boundary Dataset (Natural Resources Conservation Service, 2001) or digitized manually when a basin boundary was not defined by this GIS coverage);
- P is the basinwide mean of the average April precipitation, in inches, determined with the PRISM 1971–2000 April precipitation dataset (PRISM Group, Oregon State University, 2006c) resampled with bilinear interpolation to a 180-ft-cell resolution;
- W is the percentage of the basin with land cover categorized as wetland from the National Land Cover Data (Multi-Resolution Land Characteristics Consortium, 2003) using a GIS. Waterbody areas from the National Hydrography Dataset (U.S. Geological Survey, 2007b), which include lakes, ponds, and swamps, were used in areas north of the New Hampshire-Quebec border where the National Land Cover Data does not extend; and
- S is the slope of the main channel, in feet per mile, determined between points 10- and 85-percent up the main channel from the selected stream site extended to the drainage divide using the ArcHydro software (Environmental Systems Research Institute, Inc., 2008) and elevation datasets derived from the National Elevation Dataset (U.S. Geological Survey, 2007a).

The procedure for estimating the flood discharge at a selected recurrence interval for an ungaged stream site using the regression equations is described in appendix 3.

Attempts were made to group streamgages with similar geographic, peak-discharge, or drainage-basin characteristics into subregions to reduce the standard error of the regression equations. This grouping would have resulted in a set of regression equations for each subregion. To evaluate whether subregions should be generated, residuals, the difference between the flood discharges estimated from the frequency analysis and the flood discharges predicted from the regression equations, were determined for each streamgage and for each regression equation. These residuals were plotted spatially at the streamgage location and plotted in relation to drainage-basin characteristics. Residuals of the 10- and 100-year regression equations in relation to drainage-basin characteristics are shown as examples in figures 6A and 6B. No apparent trends or patterns were observed in these plots. Thus, the streamgages were not grouped into subregions, and the equations presented in this report are intended for statewide use.

The residual plots shown in figures 6A and 6B also were used as a diagnostic tool for the regression equations. The random scatter of the points above and below the zero reference line provides verification that the model is satisfactorily meeting the assumptions of multiple-linear-regression techniques. Other diagnostics tools included the evaluation of Cook's D and the variance inflation factor (VIF) (Helsel and Hirsch, 1992). Cook's D is a value that is computed for each observation—the data used for developing the regression equations. It is a measure of the influence of each observation on the regression equations and can be used to assist in the identification of outliers. The magnitude of Cook's D flagged some observations as potential outliers; however, it was concluded that the potential outliers were sound data and there was no justification for excluding them from the regression analysis.

The VIF is a diagnostic tool that may be used to evaluate collinearity of explanatory variables. There are no formal criteria for VIF, although some authors suggest that a VIF exceeding 10 may be cause for concern (Freund and Littell, 2000), indicating that explanatory variables may be correlated. The greatest VIF computed for a variable used in the final regression equations was 3.9.

Limitations and Sensitivity

It is important to note that basin characteristics used to develop equations 3–9 were determined with the ArcHydro (Environmental Systems Research Institute, Inc., 2008) software using datasets described in the section entitled "Regression Analysis and Results." Determining the basin characteristics for use in the regression equations with alternate data sources or using different computational methods than those of the ArcHydro software may produce statistics that are different than those reported here, and may introduce bias and yield discharge estimates that have unknown error.

The regression equations are applicable only to sites on ungaged, unregulated streams in rural New Hampshire basins. Use of the equations is appropriate to sites with drainage-basin characteristics that are within the range of drainage-basin characteristics used in the development of the equations. The ranges of drainage-basin characteristics used in the analysis are shown in table 8. If independent variables used in the regression equations are outside of these ranges, the results of the equations are considered extrapolations,

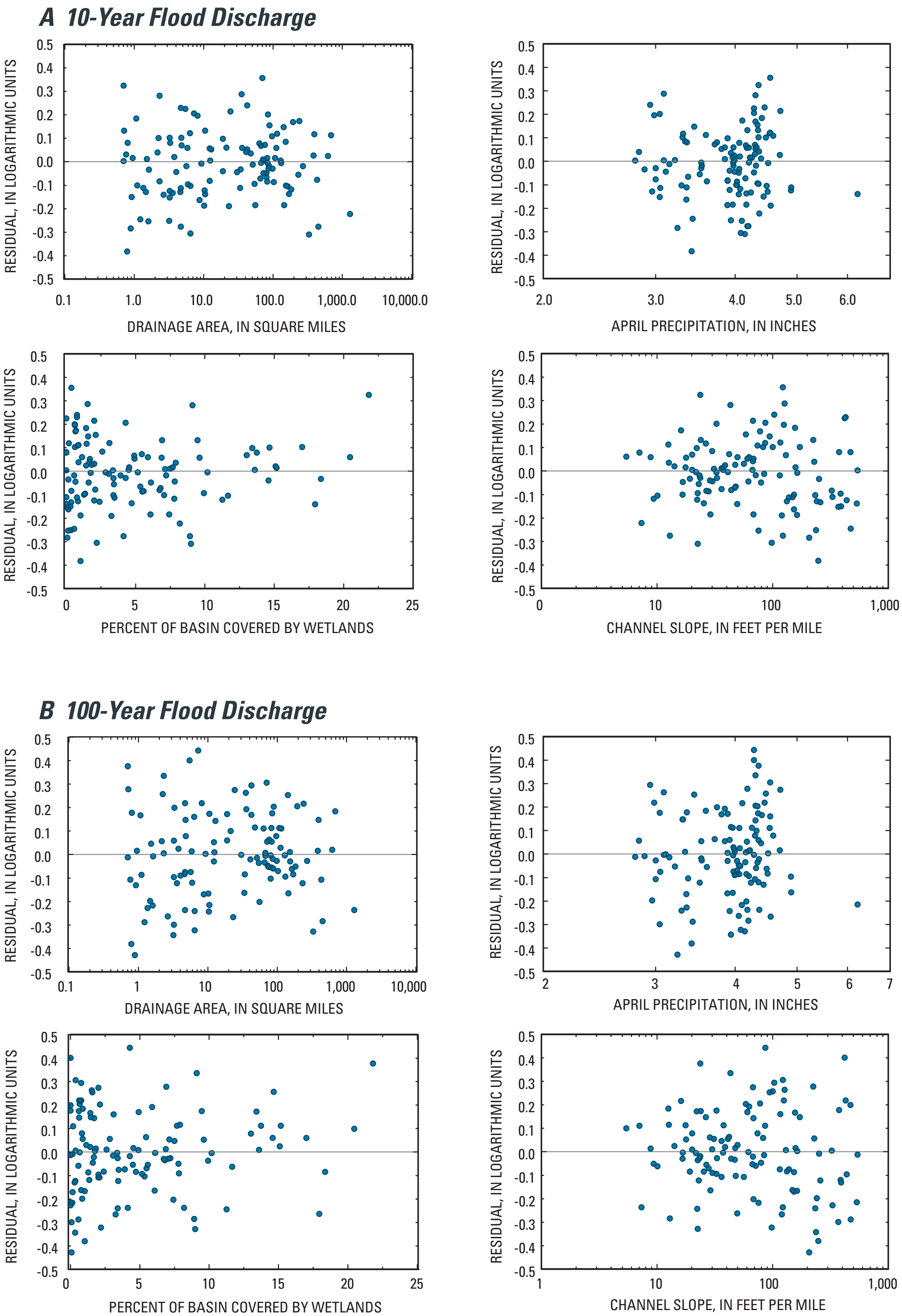


Figure 6. Residuals of the regression equation for estimating the magnitude of *(A)* a 10-year flood discharge, and *(B)* a 100-year flood discharge in relation to basin characteristics for selected streamgages in and adjacent to New Hampshire.

Table 8. Ranges of explanatory variables used in the development of the regression equations for estimating flood discharges at selected recurrence intervals for ungaged, unregulated streams in New Hampshire.

Explanatory variable	Minimum	Maximum	Mean
Drainage area, in square miles	0.70	1,290	83.6
Basinwide mean of average April precipitation, in inches	2.79	6.23	3.94
Percent of the basin covered by wetlands	0.0	21.8	4.86
Main channel slope, in feet per mile	5.43	543	114

and the accuracy of the predictions is unknown. For sites that have drainage-basin characteristics outside the acceptable ranges, a simplified equation that uses drainage area as the only explanatory variable is provided in the section entitled "Drainage-Area-Only Regression Equations." For sites that are considered urban, Moglen and Shivers (2006) describe techniques for transforming rural flood-discharge-frequency estimates to estimates for urban watersheds.

The sensitivity of each regression equation to changes in the magnitude of the independent variables was tested to evaluate the amount of error that can be introduced if basin characteristics are incorrectly computed. The sensitivity analysis was conducted by adjusting a basin characteristic by plus or minus 10 percent while holding the other basin characteristics constant at their respective mean magnitudes. The results of the sensitivity analysis listed in table 9 indicate that the regression equations are most sensitive to changes in drainage area and the average April precipitation. However, a 10-percent change in the April precipitation value accounts for a much greater percentage of its range (table 8) than does a 10-percent change in drainage area.

Accuracy of the Regression Equations

There are several measures of the accuracy of a regression equation. The adjusted coefficient of determination, or adjusted R^2, indicates the proportion of variability observed in the data that is accounted for by the regression model (SAS Institute, Inc., 2000). The closer the adjusted coefficient of determination is to 1, the better the regression explains the variation in the response variables. The adjusted coefficient of determination for each regression equation is presented in table 10.

Table 9. Results of sensitivity analysis presented as percent change in computed flood discharge as a result of a 10-percent change of the input basin characteristic.

Percent change in basin characteristic	Percent change in computed flood discharge by the regression equation for estimating floods having a recurrence interval of:						
	2-years	5-years	10-years	25-years	50-years	100-years	500-years
Drainage area							
+10	9.6	9.3	9.1	8.9	8.7	8.6	8.3
-10	-9.6	-9.3	-9.2	-9.0	-8.8	-8.7	-8.5
Basinwide mean of average April precipitation							
+10	15.4	18.0	19.0	20.0	20.4	20.7	21.4
-10	-14.6	-16.7	-17.5	-18.2	-18.5	-18.8	-19.3
Percentage of basin covered by wetlands							
+10	-2.7	-2.7	-2.7	-2.8	-2.8	-2.8	-2.9
-10	2.8	2.8	2.8	2.8	2.9	2.9	2.9
Main channel slope							
+10	1.8	2.0	2.0	2.0	2.0	1.9	1.8
-10	-2.1	-2.2	-2.2	-2.2	-2.1	-2.1	-1.9

Table 10. Measures of accuracy of the regression equations for estimating flood discharges at selected recurrence intervals for ungaged, unregulated streams in rural drainage basins in New Hampshire.

[R^2, coefficient of determination]

Flood frequency with recurrence interval of:	Adjusted R^2	Standard error of regression		Average standard error of prediction		Average equivalent years of record
		in log units	in percent	in log units	in percent	
2 years	0.97	0.132	-26.2 to 35.5	0.128	-25.5 to 34.3	3.2
5 years	0.97	0.139	-27.4 to 37.7	0.132	-26.2 to 35.5	4.7
10 years	0.96	0.147	-28.7 to 40.3	0.137	-27.1 to 37.1	6.2
25 years	0.95	0.159	-30.7 to 44.2	0.145	-28.4 to 39.6	8.0
50 years	0.94	0.170	-32.4 to 47.9	0.153	-29.7 to 42.2	9.0
100 years	0.94	0.181	-34.1 to 51.7	0.162	-31.1 to 45.2	9.8
500 years	0.91	0.210	-38.3 to 62.2	0.183	-34.4 to 52.4	11.0

One of the most common measures of accuracy is the standard error of regression (table 10). This is a measure of how much the regression results deviate from the observed data. It is computed from the variance of the regression results with 5 degrees of freedom (Ott, 1988).

Another measure of accuracy is the average standard error of prediction (table 10). This has a model error component—the error resulting from the model—and a sampling error component—the error that results from development of model parameters from samples of the population. Thus, the average standard error of prediction is a measure of the expected accuracy of a regression model applied at an ungaged location with basin characteristics similar to those used to develop the regression equation. This measure of accuracy is needed because regression equations typically are used for ungaged locations. About two-thirds of the estimates made using a regression equation for ungaged locations will have errors less than the average standard error of prediction for that equation.

A fourth accuracy metric shown in table 10 is the average equivalent years of record. This is defined as the number of years of data collection at a stream location that would be required to achieve flood-discharge frequency results with accuracy equal to that of the regression equations.

Accuracy Analysis of Individual Estimates from the Regression Equations

Because the standard error of regression, the average standard error of prediction, and the average equivalent years of record (table 10) are computed using all the streamgage data, they are approximations of the regression equation's overall accuracy for ungaged sites. Techniques for computing the accuracy of individual regression equation estimates for ungaged sites are available and are discussed in this section. The measures of accuracy for an individual estimate include standard error of prediction, equivalent years of record, and prediction intervals.

Standard Error of Prediction

Hodge and Tasker (1995) describe the mathematical formulation for computing the standard error of prediction, SE_{pred}, of a flood-discharge frequency estimate as

$$SE_{pred} = [\gamma^2 + x_i(X^{tr}\Lambda^{-1}X)^{-1}x_i^{tr}]^{1/2} , \tag{10}$$

where

SE_{pred} is the standard error of prediction;
γ^2 is the model error variance (table 11);
x_i is a row vector containing 1, $log_{10}(A)$, $log_{10}(P)$, W, and $log_{10}(S)$ for the study site i;
tr is the matrix algebra symbol for transposing a matrix; and
$(X^{tr}\Lambda^{-1}X)^{-1}$ is the $(p \times p)$ matrix with X being a $(n \times p)$ matrix that has rows of logarithmically transformed basin characteristics augmented by a 1 and Λ being the $(n \times n)$ covariance matrix used for weighting sample data in the generalized least-squares regression; n is the number of streamgages used in the regression analysis, and p is the number of basin characteristics plus 1; the $(X^{tr}\Lambda^{-1}X)^{-1}$ matrices for selected recurrence intervals are shown in table 11.

Table 11. Model error variance and the $(X^{tr}\Lambda^{-1}X)^{-1}$ matrices for the regression equations.

[Numbers in matrices are in scientific notation]

Flood-frequency characteristic	Model error variance, γ^2	$(X^{tr}\Lambda^{-1}X)^{-1}$ matrix					
			Intercept	Drainage area	April precipitation	Percent wetland	Channel slope
Flood discharge with a 2-year recurrence interval	0.0153	Intercept	0.29131E-01	-0.24237E-02	-0.23530E-01	-0.29390E-03	-0.55764E-02
		Drainage area	-0.24237E-02	0.61481E-03	-0.61196E-03	0.51072E-04	0.91224E-03
		April precipitation	-0.23530E-01	-0.61196E-03	0.47946E-01	-0.19204E-03	-0.17764E-02
		Percent wetland	-0.29390E-03	0.51072E-04	-0.19204E-03	0.15059E-04	0.14686E-03
		Channel slope	-0.55764E-02	0.91224E-03	-0.17764E-02	0.14686E-03	0.26378E-02
Flood discharge with a 5-year recurrence interval	0.0160	Intercept	0.33144E-01	-0.27925E-02	-0.27017E-01	-0.33090E-03	-0.61190E-02
		Drainage area	-0.27925E-02	0.71282E-03	-0.71391E-03	0.58038E-04	0.10377E-02
		April precipitation	-0.27017E-01	-0.71391E-03	0.55423E-01	-0.21153E-03	-0.22804E-02
		Percent wetland	-0.33090E-03	0.58038E-04	-0.21153E-03	0.16780E-04	0.16337E-03
		Channel slope	-0.61190E-02	0.10377E-02	-0.22804E-02	0.16337E-03	0.29618E-02
Flood discharge with a 10-year recurrence interval	0.0171	Intercept	0.38041E-01	-0.32220E-02	-0.31238E-01	-0.37706E-03	-0.68710E-02
		Drainage area	-0.32220E-02	0.82466E-03	-0.83869E-03	0.66422E-04	0.11942E-02
		April precipitation	-0.31238E-01	-0.83869E-03	0.64408E-01	-0.23771E-03	-0.28151E-02
		Percent wetland	-0.37706E-03	0.66422E-04	-0.23771E-03	0.18999E-04	0.18498E-03
		Channel slope	-0.68710E-02	0.11942E-02	-0.28151E-02	0.18498E-03	0.33809E-02
Flood discharge with a 25-year recurrence interval	0.0192	Intercept	0.45989E-01	-0.39111E-02	-0.37992E-01	-0.45400E-03	-0.81537E-02
		Drainage area	-0.39111E-02	0.10022E-02	-0.10366E-02	0.80152E-04	0.14491E-02
		April precipitation	-0.37992E-01	-0.10366E-02	0.78706E-01	-0.28148E-03	-0.36210E-02
		Percent wetland	-0.45400E-03	0.80152E-04	-0.28148E-03	0.22721E-04	0.22133E-03
		Channel slope	-0.81537E-02	0.14491E-02	-0.36210E-02	0.22133E-03	0.40725E-02
Flood discharge with a 50-year recurrence interval	0.0212	Intercept	0.52917E-01	-0.45085E-02	-0.43828E-01	-0.52217E-03	-0.93013E-02
		Drainage area	-0.45085E-02	0.11551E-02	-0.12062E-02	0.92210E-04	0.16714E-02
		April precipitation	-0.43828E-01	-0.12062E-02	0.91015E-01	-0.32027E-03	-0.42923E-02
		Percent wetland	-0.52217E-03	0.92210E-04	-0.32027E-03	0.26028E-04	0.25364E-03
		Channel slope	-0.93013E-02	0.16714E-02	-0.42923E-02	0.25364E-03	0.46798E-02
Flood discharge with a 100-year recurrence interval	0.0235	Intercept	0.60575E-01	-0.51667E-02	-0.50248E-01	-0.59817E-03	-0.10587E-01
		Drainage area	-0.51667E-02	0.13231E-02	-0.13914E-02	0.10560E-03	0.19168E-02
		April precipitation	-0.50248E-01	-0.13914E-02	0.10452E-00	-0.36357E-03	-0.50145E-02
		Percent wetland	-0.59817E-03	0.10560E-03	-0.36357E-03	0.29723E-04	0.28972E-03
		Channel slope	-0.10587E-01	0.19168E-02	-0.50145E-02	0.28972E-03	0.53530E-02
Flood discharge with a 500-year recurrence interval	0.0301	Intercept	0.80866E-01	-0.69046E-02	-0.67187E-01	-0.80128E-03	-0.14036E-01
		Drainage area	-0.69046E-02	0.17649E-02	-0.18749E-02	0.14126E-03	0.25660E-02
		April precipitation	-0.67187E-01	-0.18749E-02	0.14008E-00	-0.47958E-03	-0.68759E-02
		Percent wetland	-0.80128E-03	0.14126E-03	-0.47958E-03	0.39623E-04	0.38630E-03
		Channel slope	-0.14036E-01	0.25660E-02	-0.68759E-02	0.38630E-03	0.71400E-02

The standard error of prediction of an estimate can be converted to positive and negative percent errors with the following formulas:

$$S_{pos} = 100\left(10^{SE_{pred}} - 1\right), \text{ and} \tag{11}$$

$$S_{neg} = 100\left(10^{-SE_{pred}} - 1\right), \tag{12}$$

where

S_{pos} is the positive percent error of prediction,
SE_{pred} is the standard error of prediction in logarithmic units, and
S_{neg} is the negative percent error of prediction.

The two formulas above apply not only to the standard error of prediction, but also to the standard error of regression by substituting the appropriate error term in logarithmic units. The probability that the true value of flood discharge at a given frequency is between the positive- and negative-percent standard error of prediction is approximately 68 percent. For example, there is a 68-percent chance that the true 10-year discharge at a site ranges from -27.1 to +37.1 percent of the estimated 10-year discharge.

Equivalent Years of Record

The equivalent years of record (Hardison, 1971) shown in table 10 is another measure of accuracy of the regression equations that can be computed for individual estimates. It can be interpreted as the number of years of data collection at an ungaged site that would be required to achieve flood-discharge frequency results with accuracy equal to that of the regression equations. It is computed with the formula

$$E = \frac{s^2\left[1 + k_T g + 0.5 k_T{}^2\left(1 + 0.75 g^2\right)\right]}{SE_{pred}{}^2}, \tag{13}$$

where

E is the equivalent years of record;
s is the standard deviation of annual events estimated from a regression of the standard deviation and drainage area in square miles, A, at gages used in the regression analysis ($s = e^{-(1.31 + 0.134 log(A))}$);
k_T is the log-Pearson type III frequency factor for the T-year event;
g is the skew used in the computation of the frequency curve (assumed to be zero when computing equivalent years of record for an estimate at an ungaged site); and
SE_{pred} is the standard error of prediction.

Prediction Intervals

Prediction intervals indicate the uncertainty in the result of the equations. For example, one can be 90-percent confident that the true value of a flood-discharge estimate lies within the 90-percent prediction interval. Prediction intervals for selected percentages can be computed as follows:

Let

$$V = 10^{\left(t_{\alpha/2,n-p} SE_{pred}\right)}, \tag{14}$$

then

$$(1/V)Q_{pred} < Q_{true} < (V)Q_{pred}, \tag{15}$$

where

$t_{\alpha/2,n-p}$ is the critical value from a Students-*t* distribution at alpha level α ($\alpha = 0.10$ for a 90-percent confidence interval of a prediction) with $n-p$ degrees of freedom; $n = 117$, the number of stations used in the regression analysis and $p = 5$, the number of basin characteristics in the regression equation, plus 1;
SE_{pred} is the standard error of prediction of a flood's discharge frequency estimate;
Q_{pred} is the computed discharge at a selected frequency from the regression equation; and
Q_{true} is the true value of discharge at a selected frequency.

Use of Regression Equations at or Near Streamgages

An estimate of flood discharge at a selected recurrence interval made at a streamgage can be adjusted by combining regression equation results with the frequency curve computed from the streamgage record. This technique may be particularly useful when a streamgage has a limited number of years available for frequency analysis. The procedure recommended in Bulletin 17B of the U.S. Interagency Advisory Committee on Water Data (1982) is to compute a weighted average of flood discharge using the regression equation estimate and the result of a log-Pearson type III analysis of the streamgage record using the following equation:

$$log_{10} Q_{T,w} = \frac{(N) log_{10} Q_{T,s} + (E) log_{10} Q_{T,r(g)}}{N + E}, \tag{16}$$

where

$Q_{T,w}$ is the weighted flood discharge for the T-year recurrence interval,

$Q_{T,s}$ is the flood-discharge for the T-year recurrence interval computed from the streamgage record,

$Q_{T,r(g)}$ is the flood-discharge estimate for the T-year recurrence interval from the regression equation at the streamgage,

N is the number of years of streamgage record used to compute $Q_{T,s}$, and

E is the equivalent years of record for $Q_{T,r(g)}$.

Magnitude and frequency of flood discharges for ungaged sites that are not at, but are relatively near, a streamgage and are on the same unregulated stream can be calculated by combined use of the regression equations and the nearby streamgage data. It is assumed for the procedure that drainage area and flood discharge are linearly related in logarithmic coordinates. The procedure should not be applied to sites that have a drainage area less than 50 percent, or greater than 150 percent, of the drainage area of the streamgage. The method requires that estimates from the regression equations be determined at both the gaged and ungaged locations. The logarithmic slope, m, between the regression estimate for the streamgage and the regression estimate for the ungaged location of interest is computed as follows:

$$m = \frac{log_{10}\left(Q_{T,r(u)} / Q_{T,r(g)}\right)}{log_{10}\left(A_u / A_g\right)}, \quad (17)$$

where

$Q_{T,r(u)}$ is the flood-discharge estimate at the T-year recurrence interval generated using the regression equation for the ungaged site,

$Q_{T,r(g)}$ is the flood-discharge estimate at the T-year recurrence interval generated using the regression equation for the streamgage,

A_u is the drainage area of the ungaged site, and

A_g is the drainage area at the streamgage.

The next step is to determine the slope, c, of a line in logarithmic coordinates that goes through the weighted estimate of flood discharge at the T-year recurrence interval, $Q_{T,w}$, determined using equation 16 and intersects the line having slope equal to m at a point where full weight will be given to the regression equation. This slope can be computed as follows:

$$c = m + \frac{log_{10}\left(Q_{T,r(g)} / Q_{T,w}\right)}{log_{10}(a)}, \quad (18)$$

where

a is the percentage of the drainage area, in decimal units, where full weight is given to the regression equation results. Typically $a = 0.5$ for $A_u < A_g$ and $a = 1.5$ for $A_u > A_g$.

The value of a determines where the lines having slope m and c intersect. At this intersection, full weight is given to the regression equation. Modification of the magnitude of a will change how far upstream or downstream from the streamgage, in terms of percent of drainage area, an estimate can extend before full weight is given to the regression equations. In the definition of a above, the drainage area limits are 50 to 150 percent of the streamgage drainage area, matching the rule of thumb often applied to these adjustments (Wandle, 1983). Because of the log-linear relation of drainage area to discharge, the user may consider applying $a = 0.667$ when $A_u < A_g$ and limiting the weighting of a streamgage estimate to 66.7 percent of the drainage area. The reason for this is using drainage area limits of 66.7 to 150 percent will result in drainage areas that are symmetrical in difference from the streamgage drainage area in logarithmic units. Using 50 to 150 percent of the streamgage drainage area will not result in a symmetrical change about the streamgage drainage area in logarithmic units.

The final step is to compute the weighted flood-frequency estimate for the ungaged site, $Q_{T,u}$, using

$$Q_{T,u} = Q_{T,w}\left[\frac{A_u}{A_g}\right]^c. \quad (19)$$

As with any technique used to compute a weighted flood-discharge estimate, unexpected results could occur if there is a substantial difference between the discharges being weighted. If the difference is substantial, c could become negative, indicating discharge and drainage area are inversely related. This procedure is not valid if c is negative.

Drainage-Area-Only Regression Equations

Some ungaged sites may have basin characteristics outside the acceptable ranges required by the full regression equations (equations 3–9). The acceptable ranges of the basin characteristics are described in the section titled "Limitations and Sensitivity." Because of this, a set of simplified regression equations that incorporate drainage area as the only independent variable was developed. Generalized least-squares regression techniques were used to compute the coefficients in the equations. The simplified regression equations (equations 20–26) for estimating flood discharges on ungaged, unregulated streams in rural drainage basins in New Hampshire are as follows:

$$Q_2 = 43.5A^{0.885}, \quad (20)$$

$$Q_5 = 75.5A^{0.858}, \quad (21)$$

$$Q_{10} = 102A^{0.842}, \quad (22)$$

$$Q_{25} = 143A^{0.824}, \quad (23)$$

$$Q_{50} = 179A^{0.811}, \quad (24)$$

$$Q_{100} = 219A^{0.800}, \text{ and} \quad (25)$$

$$Q_{500} = 331A^{0.777}, \quad (26)$$

where

Q_T is the estimated flood discharge, in cubic feet per second, at the T-year recurrence interval; and

A is the drainage area of the basin, in square miles.

The same 117 streamgages used to develop the previously presented regression equations were used to develop the simplified equations; hence, the equations would be applicable to sites with drainage areas from 0.70 to 1,290 mi^2. Having only one explanatory variable, the simplified regression equations are less accurate than the full regression equations presented in this report. The standard error of regression and the average standard error of prediction of the simplified equations are presented in table 12.

Although the accuracy of the drainage-area-only regression equations is relatively poor, these simplified equations are valuable. The exponent in each of the drainage-area-only regression equations is the slope of the average linear logarithmic relation between drainage area and flood discharge for a selected recurrence interval. Hence, the exponent can be used in an alternate method for adjusting flood-frequency data from a streamgage to locations upstream and downstream. This use of the method should be limited to sites within 50- to 150-percent of the streamgage drainage area (Wandle, 1983). Using this approach, one would use equation 19 with the exponent from the simplified regression equation at a selected recurrence interval substituted for c.

Table 12. Measures of accuracy of the drainage-area-only regression equations used for estimating flood discharges at selected recurrence intervals for ungaged, unregulated streams in rural drainage basins in New Hampshire.

Flood frequency with recurrence interval of:	Standard error of regression		Average standard error of prediction		Average equivalent years of record
	in log units	in percent	in log units	in percent	
2 years	0.231	-41.3 to 70.2	0.228	-40.8 to 69.0	1.0
5 years	0.238	-42.2 to 73.0	0.233	-41.5 to 71.0	1.5
10 years	0.243	-42.9 to 75.0	0.237	-42.1 to 72.6	2.1
25 years	0.251	-43.9 to 78.2	0.241	-42.6 to 74.2	2.9
50 years	0.258	-44.8 to 81.1	0.245	-43.1 to 75.8	3.5
100 years	0.265	-45.7 to 84.1	0.250	-43.8 to 77.8	4.1
500 years	0.283	-47.9 to 91.9	0.262	-45.3 to 82.8	5.4

New Hampshire StreamStats

StreamStats, a World Wide Web application (http://water.usgs.gov/osw/streamstats/), allows users to obtain discharge statistics, drainage-basin characteristics, and other information for user-selected sites on streams. StreamStats users choose stream sites of interest from an interactive map. If a user selects the location of a USGS streamgage, the user will get previously published information for the site from a database. If a user selects an ungaged site, a GIS program will determine the boundary of the drainage basin upstream from the site and measure the basin characteristics required by the regression equations to estimate discharge statistics for the site. The application then solves the equations. The results are presented in a table along with a map showing the basin outline. Historically, determining the basin characteristics and solving the regression equations for an ungaged site could take an experienced person hours. StreamStats reduces the effort to only a few minutes.

Furthermore, the application ensures that the basin characteristics input to the regression equations are determined using the same data and methodologies as the basin characteristics used to develop the equations. This avoids bias that could be introduced by improperly estimating basin characteristics.

New Hampshire StreamStats will become available online immediately following the publication of this report. The web application will provide flood-discharge frequency data for streamgages used in this study and compute flood-discharge frequency estimates for ungaged locations using the final regression equations (equations 3–9).

Summary

This report, prepared by the U.S. Geological Survey in cooperation with the New Hampshire Department of Transportation, documents the development of regression equations for estimating flood-discharge magnitudes for rural, unregulated New Hampshire streams at recurrence intervals of 2, 5, 10, 25, 50, 100, and 500 years. Regression techniques were used to determine relations between the flood discharge magnitudes and selected basin characteristics at 117 streamgages in and adjacent to New Hampshire.

The flood discharge magnitudes at selected recurrence intervals for the 117 streamgages were determined following guidelines in Bulletin 17B of the U.S. Interagency Advisory Committee on Water Data. Record-extension techniques were applied to improve the estimates of flood discharges for selected recurrence intervals at 20 streamgages with short-term records (10–15 years). A generalized skew coefficient map, having a standard error of 0.298, was developed for the frequency analysis.

A total of 110 basin characteristics for each streamgage was determined using a Geographic Information System. Using correlation data, stepwise linear regression techniques, and generalized least-squares regression techniques, the 110 basin characteristics were narrowed down to the four variables that best explained the magnitude and variability of flood discharges: drainage area, mean April precipitation, percentage of basin in wetlands, and slope of the main channel. The final regression equations were developed using generalized least-squares regression techniques. The average standard error of prediction for estimating the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence interval flood discharges with these equations are 30.0, 30.8, 32.0, 34.2, 36.0, 38.1, and 43.4 percent, respectively.

The regression equations developed from these relations can be used as a method for estimating flood discharges at selected recurrence intervals for ungaged, unregulated, rural streams. This report also presents methods for adjusting a flood-discharge frequency curve computed from a streamgage record with results from the regression equations. In addition, a technique is described for estimating flood discharge at a selected recurrence interval for an ungaged site upstream or downstream from a streamgage using a drainage-area adjustment.

The equations and flood-discharge frequency data used in this study will be available in StreamStats, a World Wide Web application (http://water.usgs.gov/osw/streamstats/) providing statistics, drainage-basin characteristics, and other information for user-selected sites on streams.

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Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01050900	Four Ponds Brook near Houghton, ME	Lat 44°49'55", long 70°42'10", Franklin County, at culvert on State Route 17, 1.1 mi upstream of mouth at Bemis Stream, and 1.2 mi downstream of Long Pond outlet.	1964–74
01052500	Diamond River near Wentworth Location, NH	Lat 44°52'40", long 71°03'25", Coos County, on left bank, 0.8 mi downstream of the confluence of the Swift Diamond River and Dead Diamond River, 0.8 mi upstream of mouth, 1.3 mi north of Wentworth Location, and 7.7 northeast of Errol.	1942–2007
01054200	Wild River at Gilead, ME	Lat 44°23'25", long 70°58'53", Oxford County, on right bank 200 ft upstream of U.S. Route 2 highway bridge, 2,000 ft upstream of mouth, and 0.4 mi west of Gilead.	1960, 1965–2007
01054300	Ellis River at South Andover, ME	Lat 44°35'37", long 70°44'01", Oxford County, on left bank 100 ft upstream of covered bridge at South Andover.	1964–82, 2001–2007
01055000	Swift River near Roxbury, ME	Lat 44°38'34", long 70°35'20", Oxford County, on left bank 0.2 mi downstream of Philbrick Brook, 2.1 mi downstream of Roxbury, and 7.2 mi upstream of mouth.	1930–2007
01055300	Bog Brook near Buckfield, ME	Lat 44°15'57", long 70°19'00", Oxford County, at culvert on State Route 117, 0.2 mi upstream of mouth at Nezinscot River, and 3.0 mi southeast of State Routes 117 and 140 intersection in Buckfield.	1964–74
01057000	Little Androscoggin River near South Paris, ME	Lat 44°17'08", long 70°32'16", Oxford County, on island 50 ft upstream of Snow Falls, 5.9 mi north of the intersection of State Routes 26 and 117 in South Paris, and 6 mi upstream of South Paris.	1914–23, 1932–2007
01062700	Patte Brook near Bethel, ME	Lat 44°20'41", long 70°47'34", Oxford County, at culvert on Old West Bethel Road 0.3 mi upstream of confluence with Crooked River, and 0.6 mi northwest of Old West Bethel Road and State Route 5 intersection.	1965–74
01063310	Stony Brook at East Sebago, ME	Lat 43°51'20", long 70°38'25", Cumberland County, on left bank at upstream side of culvert under State Route 11/114, 0.1 mi upstream of the confluence with Northwest River, and 0.6 mi upstream of mouth of Northwest River at Sebago Lake.	1996–2007
01064300	Ellis River near Jackson, NH	Lat 44°13'08", long 71°14'59", Carroll County, in White Mountain National Forest, on right bank, 0.2 mi downstream of small right-bank tributary, 0.4 mi upstream of small left-bank tributary, 1.3 mi upstream of bridge on NH 16, and 6.1 mi northwest of the intersection of State Routes 16A and 16B in Jackson.	1964–2004
01064380	East Branch Saco River at Town Hall Road, near Lower Bartlett, NH	Lat 44°07'18", long 71°07'50", Carroll County, at bridge on Town Hall Road, 725 ft downstream of Gardiner Brook confluence, 1.6 mi northeast of the intersection of State Routes 16 and 16A at Lower Bartlett, 2.5 mi west of the intersection of State Route 16 and U.S. Route 302 at Glen, and 3.0 mi upstream of mouth at Saco River.	1967–76
01064400	Lucy Brook near North Conway, NH	Lat 44°04'13", long 71°10'24", Carroll County, on left bank, 0.6 mi west of Dianas Bath Road and River Road intersection, 1.8 mi west of Hurricane Mountain Road and U.S. Route 302 intersection at Intervale, 1.6 mi upstream of mouth at Saco River, and 2.3 mi northwest of River Road and U.S. Route 302 intersection at North Conway.	1965–92
01064500	Saco River near Conway, NH	Lat 43°59'27", long 71°05'29", Carroll County, on left bank, at Odell Falls, 0.4 mi upstream of U.S. Route 302, 1.5 mi northeast of the intersection of State Routes 16 and 113 in Conway, 1.8 mi downstream of the Swift River confluence.	1904–09, 1930–2007

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01064800	Cold Brook at South Tamworth, NH	Lat 43°48'57", long 71°17'50", Carroll County, on right bank 100 ft upstream of Bemis Mountain Road bridge, 0.7 mi south of Bemis Mountain Road and State Route 25 intersection at South Tamworth, 0.9 mi upstream of mouth at Bearcamp River.	1964–73
01064801	Bearcamp River at South Tamworth, NH	Lat 43°49'48", long 71°17'18", Carroll County, on right bank, 0.7 mi upstream of Sanger Brook confluence, 0.8 mi east of Bemis Mountain Road and State Route 25 intersection at South Tamworth, and 1.0 mi downstream of Cold Brook confluence.	1993–2007
01065000	Ossipee River at Effingham Falls, NH	Lat 43°47'42", long 71°03'35", Carroll County, on left bank, 0.2 mi upstream from State Route 153, 0.2 mi west of the intersection of State Routes 25 and 153 at Effingham Falls, and 0.2 mi downstream of Ossipee Lake outlet.	1943–90, 1998–2007
01065500	Ossipee River at Cornish, ME	Lat 43°48'26", long 70°47'55", Oxford County, on left bank 100 ft downstream of Bridge Street bridge in Cornish, and 1.3 mi upstream of mouth.	1917–96
01066000	Saco River at Cornish, ME	Lat 43°48'35", long 70°46'53", Cumberland County, on left bank 300 ft upstream of State Route 117 highway bridge at Cornish and 0.4 mi downstream of Ossipee River confluence.	1917–2007
01066100	Pease Brook near Cornish, ME	Lat 43°47'19", long 70°46'00", York County, at culvert on State Route 25, 0.3 mi upstream of mouth at Saco River, and 0.7 mi northwest of the intersection of State Routes 117 and 25 in Limington.	1965–74, 1997
01066500	Little Ossipee River near South Limington, ME	Lat 43°41'22", long 70°40'15", York County, on right bank 25 ft upstream of Sand Pond Road bridge, 2.0 mi southeast of South Limington, and 5.8 mi upstream of mouth.	1936, 1941–82, 1997, 2007
01069700	Branch Brook near Kennebunk, ME	Lat 43°22'44", long 70°34'59", York County, at culvert on State Route 9A, 1.8 mi west of the intersection of State Routes 9A and 99 in Kennebunk.	1965–74, 1996
01072800	Cocheco River near Rochester, NH	Lat 43°16'06", long 70°58'27", Strafford County, on right bank, directly behind Rochester Country Club, 0.5 mi southeast of Main Street and Church Street intersection in Gonic, 2.5 mi south of Rochester City Hall, and 4.0 mi upstream of mouth of Isinglass River.	1996–2007
01072850	Mohawk Brook near Center Strafford, NH	Lat 43°15'47", long 71°05'50", Strafford County, on left bank, 0.5 mi downstream of State Route 202A bridge, and 1.5 mi east of the intersection of State Routes 202A and 126 in Center Strafford.	1965–77, 2006
01073000	Oyster River near Durham, NH	Lat 43°08'55", long 70°57'56", Strafford County, on left bank, 200 ft upstream of Old Concord Road, 0.6 mi east of the intersection of State Route 155 and U.S. Route 4, and 7 mi upstream from mouth on Little Bay.	1935–2007
01073500	Lamprey River near Newmarket, NH	Lat 43°06'09", long 70°57'11", Strafford County, on right bank, 200 ft upstream of Packers Falls and Packers Falls Road, 1.8 mi northwest of Newmarket Town Hall, 2.6 mi southwest of the intersection of State Routes 108 and 155A in Durham, and 4.6 mi upstream from mouth on Great Bay.	1935–2007
01073587	Exeter River at Haigh Road, near Brentwood, NH	Lat 42°59'04", long 71°02'20", Rockingham County, on right bank, 10 ft downstream of Haigh Road bridge, 0.4 mi south of State Route 111A and Haigh Road intersection, and 0.8 mi upstream of the Little River confluence.	1997–2007
01073600	Dudley Brook near Exeter, NH	Lat 42°59'35", long 71°01'20", Rockingham County, on right bank, upstream side of breached dam, 100 ft upstream from State Route 111A, 2.2 mi upstream of mouth at Little River, 2.8 mi east of the intersection of State Routes 111A and 125, Middle Road (State Route 111A) and State Route 125 in Brentwood.	1963–85, 2006, 2007

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01073750	Mill Brook near State Route 108, at Stratham, NH	Lat 43°01'24", long 70°55'04", Rockingham County, at downstream most culvert of the Stratham traffic circle, 100 ft northeast of junction of State Route 108 and unnamed road, 1,000 ft north of the junction of State Routes 33 and 108, and 1.5 mi upstream of mouth at Squamscott River.	1973–79, 2003–04, 2006–07
[1]01074500	East Branch Pemigewasset River near Lincoln, NH	Lat 44°03'41", long 71°37'00", Grafton County, on right bank, 0.3 mi upstream of Clear Brook confluence, 0.3 mi east of Clearbrook Road and State Route 112 intersection, and 1.1 mi downstream of Hancock Branch confluence.	1929–52, 1960, 1968–70
01074520	East Branch Pemigewasset River at Lincoln, NH	Lat 44°02'51", long 71°39'37", Grafton County, on right bank, at old crib dam, locally known as "the old hole," 800 ft upstream of bridge, 0.4 mi downstream of Pollard Brook confluence, 0.8 mi east of the intersection of Connector Road and State Route 112 in Lincoln, and 1.8 mi above mouth.	1993–2007
01075000	Pemigewasset River at Woodstock, NH	Lat 43°58'34", long 71°40'48", Grafton County, on right bank, 300 ft upstream of southernmost State Route 175 bridge over Pemigewasset River, 300 ft east of North Station Road and State Route 175 intersection in Woodstock, and 0.7 mi upstream of Eastman Brook confluence.	1940–80, 1985–2007
01075800	Stevens Brook near Wentworth, NH	Lat 43°50'10", long 71°53'09", Grafton County, on left bank, 150 ft upstream of Bufflo Road bridge, 0.3 mi upstream of mouth, 1.7 mi northwest of Sand Hill Road and State Route 25 intersection in West Rumney.	1964–98, 2006
01076000	Baker River near Rumney, NH	Lat 43°47'44", long 71°50'45", Grafton County, on right bank, 200 ft upstream of a small right bank tributary, 0.3 mi upstream of Halls Brook confluence, and 1.7 mi southeast of Sand Hill Road and State Route 25 intersection in West Rumney.	1928–77, 1982, 1985–93, 1995–2007
01076500	Pemigewasset River at Plymouth, NH	Lat 43°45'33", long 71°41'10", Grafton County, on right bank, 150 ft downstream of State Route 175A bridge in Plymouth, 0.1 mi northeast of Plymouth Town Hall, 0.3 mi downstream of Baker River confluence, and 0.8 mi south of the intersection of State Route 3A and U.S. Route 3.	1904–2007
01078000	Smith River near Bristol, NH	Lat 43°33'59", long 71°44'54", Merrimack County, on right bank, 0.4 mi north of Borough Road and Axtell Road intersection, 0.6 mi upstream of Borough Road bridge, 1.5 mi upstream of the mouth, and 1.7 mi southwest of the intersection of State Routes 3A and 104 in Bristol.	1919–2007
01082000	Contoocook River at Peterborough, NH	Lat 42°51'45", long 71°57'35", Hillsborough County, on left bank, 0.2 mi downstream of a mill dam, 0.3 mi northwest of Powersbridge Road and Old Sharon Road intersection in Noone, 0.6 mi southwest of the intersection of Grove Street, U.S. Route 202, and State Route 101 in Peterborough, and 1.2 mi upstream of Nubanusit Brook confluence.	1946–77, 1980, 1982–2007
01084000	North Branch River near Antrim, NH	Lat 43°04'54", long 71°58'44", Hillsborough County, on right bank, 0.1 mi upstream of Old North Branch Road bridge, 0.5 mi northeast of the intersection of State Routes 9 and 31, 4.0 mi northwest of the intersection of State Route 31 and U.S. Route 202 in Antrim, and 5.2 mi upstream of Beards Brook confluence.	1925–70
01084500	Beards Brook near Hillsborough, NH	Lat 43°06'51", long 71°55'36", Hillsborough County, on right bank, 300 ft upstream from West Main Street bridge, 560 ft upstream of mouth at North Branch, 0.5 mi west of West Main Street and U.S. Route 202 intersection, and 1.6 mi west of the intersection of State Route 149, School Street, Henniker Street, and West Main Street intersections in Hillsborough.	1946–76, 2006–07
01085800	West Branch Warner River near Bradford, NH	Lat 43°15'33", long 72°01'35", Merrimack County, on left bank, 75 ft downstream of a small right-bank tributary, 200 ft upstream of Fairground Road bridge, 750 ft east of the intersection of Fairground Road and West Road, 3.5 mi west of Main Street and State Route 103 intersection in Bradford.	1963–2004, 2006

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01086000	Warner River at Davisville, NH	Lat 43°15'03", long 71°43'58", Merrimack County, on left bank, 60 ft downstream of State Route 127 bridge at Davisville, 0.9 mi east of Interstate 89 and State Route 103 interchange, 2.2 mi northwest of the intersection of State Routes 103 and 127 in Contoocook, and 2.3 mi upstream of mouth at Contoocook River.	1940–78, 1999–2007
[2]01089000	Soucook River near Concord, NH	Lat 43°14'19", long 71°27'45", Merrimack County, on left bank, 500 ft upstream of State Route 9 bridge, 0.8 mi upstream of Cemetery Brook confluence, 0.4 mi northeast of the intersection of State Routes 9 and 106.	1952–87
01089100	Soucook River at Pembroke Road, near Concord, NH	Lat 43°12'49", long 71°28'51", Merrimack County, on left bank, 100 ft upstream of Pembroke Road bridge, 550 ft upstream of Frenchs Brook confluence, and 770 ft east of the intersection of Pembroke Road and State Route 106.	1989–2007
01089500	Suncook River at North Chichester, NH	Lat 43°15'24", long 71°22'12", Merrimack County, on left bank, 100 ft downstream from Depot Road bridge, 0.1 mi east of the intersection of Depot Road, Main Street, and State Route 28 at North Chichester, 0.4 mi upstream of Sanders Brook confluence, and 3.1 mi upstream of Little Suncook River confluence.	1919–20, 1922–27, 1929–77, 2006–07
01091000	South Branch Piscataquog River near Goffstown, NH	Lat 43°00'53", long 71°38'31", Hillsborough County, on right bank, 20 ft upstream of Parker Road bridge, 50 ft north of the intersection of Parker Road and State Route 13, 1.7 mi upstream of mouth at Piscataquog River, 2.1 mi west of the intersection of State Routes 13 and 114, and Elm Street in Goffstown.	1941–78, 2006–07
01093800	Stony Brook Tributary near Temple, NH	Lat 42°51'36", long 71°50'00", Hillsborough County, on left bank, 450 ft downstream of Putnam Road bridge, 0.3 mi northwest of Putnam Road and Webster Highway intersection, 1.6 mi northeast of the intersection of Webster Highway and State Routes 101 and 45, and 5.2 mi upstream of mouth at Stony Brook.	1964–2004
01094000	Souhegan River at Merrimack, NH	Lat 42°51'27", long 71°30'24", Hillsborough County, on left bank, at head of Wildcat Falls, 0.6 mi upstream of south bound bridge on Everett Turnpike, 0.9 mi southwest of Baboosic Lake Road and U.S. Route 3 intersection in Merrimack, and 1.3 mi upstream from mouth at Merrimack River.	1910–76, 1980, 1982–2007
01094500	North Nashua River near Leominster, MA	Lat 42°30'06", long 71°43'23", Worcester County, on right bank 1.3 mi upstream of Wekepeke Brook confluence, 2.5 mi southeast of Leominster, and 6.1 mi upstream of confluence with Nashua River.	1936–2007
01095000	Rocky Brook near Sterling, MA	Lat 42°26'57", long 71°48'10", Worcester County, on right bank 150 ft downstream of Beaman Road bridge, 0.7 mi upstream of mouth, and 2.2 mi west of Sterling.	1947–67
01095800	Easter Brook near North Leominster, MA	Lat 42°32'46", long 71°42'45", Worcester County, at culvert on Lancaster Avenue, and 1.5 mi east of North Leominster.	1964–74
01096000	Squannacook River near West Groton, MA	Lat 42°38'03", long 71°39'30", Middlesex County, on left bank 0.7 mi downstream of Trout Brook confluence, and 2.7 mi northwest of West Groton.	1950–2007
010965852	Beaver Brook at North Pelham, NH	Lat 42°46'58", long 71°21'15", Rockingham County, on right bank, 10 ft downstream from State Route 128 bridge at the Windham-Pelham town line, 0.7 mi north of State Route 128 and Castle Hill Road intersection at North Pelham, and 1.3 mi south of the intersection of State Routes 128 and 111 at West Windham.	1987–2007
01096910	Boulder Brook at East Bolton, MA	Lat 42°27'04", long 71°34'39", Worcester County, on right bank 900 ft downstream from Interstate 495, 0.9 mi west of East Bolton, and 1.3 mi upstream of mouth.	1972–83

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01097200	Heath Hen Meadow Brook at Stow, MA	Lat 42°26'44", long 71°30'02", Middlesex County, at culvert on West Acton Road, 0.7 mi northeast of Stow.	1964–74
01097300	Nashoba Brook near Acton, MA	Lat 42°30'45", long 71°24'17", Middlesex County, on right bank 500 ft downstream of dam at North Acton, 2.2 mi northeast of Acton, and 5 mi upstream of mouth. Prior to January 8, 1997, lat 42°30'39", long 71°24'25", on right bank 1,500 ft downstream of dam at North Acton.	1964–2007
01100100	Richardson Brook near Lowell, MA	Lat 42°39'48", long 71°16'02", Middlesex County, at culvert on Methuen Street, and 2.0 mi northeast of Lowell.	1963–83
01100700	East Meadow River near Haverhill, MA	Lat 42°48'41", long 71°01'59", Essex County, on left bank 10 ft downstream of culvert on State Route 110, and 3.5 mi northeast of Haverhill.	1963–74
01100800	Cobbler Brook near Merrimack, MA	Lat 42°50'55", long 71°01'10", Essex County, at culvert on Highland Street, 1.3 mi northwest of Merrimack.	1963–83
01100900	Parker River Tributary near Georgetown, MA	Lat 42°44'03", long 70°58'22", Essex County, at culvert on North Street, 1.2 mi northeast of Georgetown.	1964–74
01101000	Parker River at Byfield, MA	Lat 42°45'10", long 70°56'46", Essex County, on left bank 1,400 ft downstream of dam, 0.5 mi south of Byfield, 0.7 mi upstream of Wheeler Brook confluence, and 5.5 mi southwest of Newburyport.	1946–2007
01127880	Big Brook near Pittsburg, NH	Lat 45°08'06", long 71°12'23", Coos County, on left bank, 10 ft downstream of culvert on U.S. Route 3, 0.3 mi upstream of mouth, 8.2 mi south of the U.S. Route 3 border crossing at the U.S. and Canada Border, and 10.7 mi northeast of U.S. Route 3 and State Route 145 intersection in Pittsburg.	1964–84
01129300	Halls Stream near East Hereford, Quebec	Lat 45°02'41", long 71°29'54", Compton County, on right bank, opposite Alain's farm, 2.3 mi south of East Hereford, Quebec, Canada, 2.5 mi north of Post Office in Beecher Falls, 3.7 mi upstream of mouth, and 5.2 mi west of U.S. Route 3 and State Highway 145 intersection in Pittsburg.	1943, 1963–86, 1988–94
01129400	Black Brook at Averill, VT	Lat 45°00'14", long 71°41'34", Essex County, at culvert on State Highway 114, at Averill-Canaan town line, 0.6 mi south of the U.S.-Canada Border Monument #530, 1.1 mi northeast of Averill, 1.3 mi upstream of mouth on Leach Creek, and 3.3 mi west of Wallace Pond.	1964–78
01129440	Mohawk River near Colebrook, NH	Lat 44°52'28", long 71°24'38", Coos County, on right bank, upstream of Bungy Road bridge, south of the intersection of State Highway 26 and Bungy Road, 0.8 mi upstream of Read Brook confluence, 1.7 mi downstream of Roaring Brook confluence, and 5 mi east of Colebrook.	1987–2004
01129700	Paul Stream Tributary near Brunswick, VT	Lat 44°41'06", long 71°37'18", Essex County, at culvert on Maidstone Lake Road, 400 ft upstream of mouth at Paul Stream, 1.7 mi west of Mason, NH, 1.9 mi northeast of Maidstone Lake outlet, 3.5 mi south of Brunswick Springs, and 4.6 mi south of North Stratford, NH.	1966–78, 1999–2006
01130000	Upper Ammonoosuc River near Groveton, NH	Lat 44°37'30", long 71°28'10", Coos County, on left bank, 75 ft upstream of Emerson Road bridge, 0.2 mi downstream of Nash Stream confluence, and 2.8 mi northeast of Groveton.	1941–80, 1983–2004
01133000	East Branch Passumpsic River near East Haven, VT	Lat 44°38'02", long 71°53'53", Caledonia County, on right bank, in Town of Burke, downstream of Watkins Road, 0.5 mi upstream of Flower Brook confluence, 0.9 mi south of Hartwellville, 4.2 mi east of Post Office in West Burke, and 8.4 mi upstream of mouth.	1940–45, 1949–79, 1998–2007
01133200	Quimby Brook near Lyndonville, VT	Lat 44°34'52", long 71°59'11", Caledonia County, at culvert on Sutton Road, 0.1 mi north of Sutton Road and U.S. Route 5 intersection, 2.0 mi west of Post Office in East Burke, and 3.3 mi north of Lyndon Town Hall in Lyndonville.	1964–74, 1999–2000, 2002–07

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01133300	Cold Hill Brook near Lyndon, VT	Lat 44°31'45", long 72°02'57", Caledonia County, at culvert on Brown Brady Road that runs along Cold Hill Brook, 100 ft east of Brown Bradley Road and Penton Chester Road intersection, 0.3 mi upstream of confluence with South Wheelock Branch, 2.1 mi northwest of Interstate 91 and U.S. Route 5 intersection in Lyndon.	1964–78
01134500	Moose River at Victory, VT	Lat 44°30'42", long 71°50'16", Essex County, on right bank, 0.5 mi northeast of Victory, 0.8 mi downstream of Cold Brook confluence, 1.1 mi upstream of Stanley Brook confluence, and 5.0 mi southwest of Burke Road and River Road intersection in Gallup Mills.	1947–2007
01134800	Kirby Brook at Concord, VT	Lat 44°26'30", long 71°52'44", Essex County, at culvert on U.S. Route 2, 600 ft southwest of Kirby Road and U.S. Route 2 intersection, 700 ft upstream of mouth, 1.1 mi northeast of High Street and U.S. Route 2 intersection in Concord.	1964–74, 1999–2007
01135000	Moose River at St. Johnsbury, VT	Lat 44°25'22", long 72°00'02", Caledonia County, on left bank, 750 ft downstream of U.S. Route 2 bridge, 0.5 mi upstream from mouth, and 1.1 mi east of Town Hall in St. Johnsbury.	1929–83
01135150	Pope Brook near N. Danville, VT	Lat 44°28'34", long 72°07'30", Caledonia County, on left bank, 200 ft upstream of Morrill Flat Road, 0.3 mi north of Pope Cemetery, 1.1 mi upstream of North Brook confluence, and 1.7 mi northwest of North Danville.	1991–2007
01135300	Sleepers River near St. Johnsbury, VT	Lat 44°26'07", long 72°02'20", Caledonia County, on left bank, just upstream of Emerson Falls, 0.6 mi upstream of U.S. Route 2 bridge, 1.5 mi northwest of Post Office in St. Johnsbury, and 2.7 mi above mouth.	1991–2007
01135500	Passumpsic River at Passumpsic, VT	Lat 44°21'56", long 72°02'23", Caledonia County, on right bank, 0.7 mi upstream of Water Andric, 1.1 mi downstream of dam, bridge, and village of Passumpsic, 3.8 mi south of Town Hall in St. Johnsbury, 4.0 mi upstream from mouth, and 4.8 mi north of Post Office in Barnet.	1929–2007
01135700	Joes Brook Tributary near East Barnet, VT	Lat 44°20'39", long 72°03'53", Caledonia County, at culvert on Joes Brook Road, just southeast of Warden Pond Road and Joes Brook Road intersection, 100 ft upstream of mouth, 1.8 mi northwest of East Barnet, 2.9 mi southwest of Passumpsic, and 3.4 mi north of Post Office in Barnet.	1964–74, 1999, 2001–07
01137500	Ammonoosuc River at Bethlehem Junction, NH	Lat 44°16'07", long 71°37'51", Grafton County, on left bank, 0.2 mi upstream of Pierce Bridge and Bethlehem Junction, 0.8 mi upstream of unnamed tributary, 3.0 mi east of U.S. Route 302 and State Route 142 intersection in Bethlehem, and 3.4 mi downstream of Little River confluence.	1940–2007
01138000	Ammonoosuc River near Bath, NH	Lat 44°09'14", long 71°59'10", Grafton County, on left bank, 0.4 mi downstream of Wild Ammonoosuc River, 1.4 mi southwest of Bath, 2.5 mi east of U.S. Route 302 and State Route 135 intersection in Woodsville, and 3.1 mi upstream of mouth.	1936–80
01138800	Keenan Brook at Groton, VT	Lat 44°12'08", long 72°12'03", Caledonia County, at downstream culvert on Topsham Road, 0.6 mi south of U.S. Route 302 and Topsham Road intersection in Groton, 1.1 mi upstream of mouth on Wells River, and 3.0 mi west of South Ryegate, VT.	1964–74
01139000	Wells River at Wells River, VT	Lat 44°09'01", long 72°03'56", Orange County, on right bank, 0.8 mi west of village of Wells River, 1.3 mi southeast of Interstate 91 and U.S. Route 302 intersection in Four Corners, and 1.5 mi upstream from mouth.	1941–2007
01139700	Waits River Tributary near West Topsham, VT	Lat 44°08'29", long 72°18'52", Orange County, at culvert on U.S. Route 302, 800 ft upstream of mouth at Waits River, 0.3 mi east of U.S. Route 302 and State Route 25 intersection, and 2.0 mi north of West Topsham.	1964–74, 1999–2000, 2002–06

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01139800	East Orange Branch at East Orange, VT	Lat 44°05'34", long 72°20'10", Orange County, on left bank, 0.3 mi east of East Orange Road and Fish Pond Road intersection in East Orange, 1.7 mi upstream of mouth, 2.0 mi southwest of West Topsham, and 5.0 mi southwest of Orange.	1959–2007
01140800	West Branch Ompompanoosuc River Tributary at South Strafford, VT	Lat 43°49'56", long 72°22'20", Orange County, at culvert on Prestonville Road, 500 ft north of Prestonville Road intersection with State Route 132, 0.4 mi southwest of Tunbridge Road and State Route 132 intersection in South Strafford, 0.6 mi upstream of mouth at West Branch Ompompanoosuc River, and 5.3 mi northeast of State Routes 14 and 132 intersection in Sharon.	1964–77
01141800	Mink Brook near Etna, NH	Lat 43°42'08", long 72°11'l5", Grafton County, on left bank, 0.1 mi west of Three Mile Road and Ruddsboro Road intersection, 1.6 mi northeast of Etna Road and King Road intersection in Etna, 4.8 mi northwest of City Hall in Enfield, and 5.1 mi east of Post Office in Hanover.	1963–98, 2006
01142000	White River near Bethel, VT	Lat 43°48'41", long 72°39'24", Windsor County, on right bank, 0.3 mi upstream of Locust Creek confluence, 0.3 mi northwest of the State Routes 12 and 107 intersection, and 1.8 mi southwest of State Routes 12 and 107 intersection in Bethel.	1932–55
01142400	Third Branch White River Tributary at Randolph, VT	Lat 43°55'54", long 72°40'54", Orange County, at culvert on State Route 12A, 0.3 mi upstream of mouth, 0.8 mi west of junction of State Highways 12 and 12A in Randolph, and 0.8 mi northwest of Town Hall in Randolph.	1964–74, 1998–2007
01142500	Ayers Brook at Randolph, VT	Lat 43°56'04", long 72°39'30", Orange County, on right bank, 135 ft upstream of bridge on State Highway 12, 0.4 mi upstream of Adams Brook confluence, 0.7 mi upstream of mouth, and 0.9 mi northeast of Town Hall in Randolph.	1940–2007
01144000	White River at West Hartford, VT	Lat 43°42'51", long 72°25'07", Windsor County, on left bank, 700 ft upstream of Quechee-West Hartford Road bridge at West Hartford, 0.2 mi south of the State Route 14 and Tigertown Road intersection in West Hartford, 5.1 mi south of State Routes 14 and 132 intersection in Sharon, 5.5 mi west of Post Office in Norwich, and 7.4 mi upstream from mouth.	1916–2007
01145000	Mascoma River at West Canaan, NH	Lat 43°39'04", long 72°05'07", Grafton County, on right bank, 45 ft downstream from abandoned railroad bridge, 0.6 mi east of U.S. Route 4 and South Road intersection in West Canaan, 1.4 mi downstream of Indian River confluence, and 3.0 mi east of City Hall in Enfield.	1938, 1940–78, 1985–2006
01150800	Kent Brook near Killington, VT	Lat 43°40'24", long 72°48'33", Rutland County, at culvert on State Highway 100, 0.4 mi north of junction of State Route 100 and U.S. Route 4, 1.6 mi upstream of mouth, and 2.0 mi northwest of River Road and U.S. Route 4 intersection in Killington.	1964–74, 1999–2007
01150900	Ottauquechee River near West Bridgewater, VT	Lat 43°37'20", long 72°45'34", Rutland County, on right bank, 50 ft upstream of Mission Chapel Road bridge, 1.6 mi north of State Route 100 and U.S. Route 4 intersection in West Bridgewater, and 2.6 mi south of River Road and U.S. Route 4 intersection in Sherburne Center.	1985–2007
01151200	Ottauquechee River Tributary near Quechee, VT	Lat 43°39'37", long 72°25'55", Windsor County, at culvert on West Hartford-Quechee Road, 0.2 mi upstream of mouth, 1.2 mi northwest of Quechee Main Street, Deweys Mills Road and Waterman Hill Road intersection in Quechee, and 2.8 mi northeast of Happy Valley Road and U.S. Route 4 intersection in Taftsville.	1964–74, 1999–2004, 2007
01152500	Sugar River at West Claremont, NH	Lat 43°23'15", long 72°21'45", Sullivan County, on right bank, 0.2 mi downstream of Redwater Brook confluence, 0.7 mi southeast of Clay Hill Road and Paddy Hollow Road intersection in West Claremont, 1.6 mi northwest of City Hall in Claremont, and 2.4 mi upstream of mouth.	1929–2007

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01153300	Middle Branch Williams River Tributary at Chester, VT	Lat 43°16'13", long 72°36'32", Windsor County, at culvert on Lover Lane Road, 0.2 mi north of Lover Lane Road and State Route 11 intersection, 0.8 mi northeast of intersection of State Routes 11 and 35 in Chester, and 1.5 mi upstream of mouth.	1964–78, 1999–2004, 2007
[3]01153500	Williams River at Brockways Mills, VT	Lat 43°12'31", long 72°31'05", Windham County, on left bank, 25 ft upstream of road bridge at Brockways Mills, 1.0 mi downstream of Stream Brook confluence, 2.2 mi upstream of Station 01153550, “Williams River near Rockingham,” 3.9 mi downstream of Hall Brook confluence, and 4.4 mi upstream from mouth.	1941–84
01153550	Williams River near Rockingham, VT	Lat 43°11'30", long 72°29'08", Windham County, on left bank, 50 ft downstream of Parker Hill Road bridge, 0.2 mi downstream of Divoll Brook confluence, 0.3 mi northeast of Rockingham, 2.2 mi upstream from mouth, 2.2 mi downstream of Station 01153500, “Williams River at Brockways Mills.”	1987–2007
01154000	Saxtons River at Saxtons River, VT	Lat 43°08'15", long 72°29'19", Windham County, on right bank, 130 ft upstream of Hall Bridge Road bridge, 1.1 mi east of Saxtons River, 1.3 mi upstream of Bundy Brook confluence, and 3.9 mi upstream of mouth.	1941–82, 2002–07
01155000	Cold River at Drewsville, NH	Lat 43°07'54", long 72°23'27", Cheshire County, on left bank, 50 ft upstream of State Route 123 bridge at Drewsville, 0.9 mi upstream of Great Brook confluence, 1.9 mi southwest of Alstead, and 3.2 mi upstream from mouth.	1941–78, 2006
01155200	Sacketts Brook near Putney, VT	Lat 42°59'57", long 72°31'59", Windham County, on left bank, 50 ft upstream of Westminster West Road bridge, 1.8 mi north of Westminster West Road and U.S. Route 5 intersection in Putney, and 7.5 mi southeast of the intersection of State Routes 30 and 35 in Townshend.	1964–74
01155300	Flood Brook near Londonderry, VT	Lat 43°14'11", long 72°51'23", Windham County, on left bank, 20 ft downstream of State Route 11 bridge, 0.9 mi upstream of Burnt Meadow Brook confluence, 2.5 mi west of State Highway 11 and 100 intersection in Londonderry, and 3.6 mi northwest of Main Street and State Route 100 intersection in South Londonderry.	1964–74
01155350	Tributary to West River Tributary near Jamaica, VT	Lat 43°07'33", long 72°48'46", Windham County, at culvert on State Route 100, 800 ft north of Stratton Gate Road and State Route 100 intersection, 0.5 mi upstream of mouth, 1.9 mi west of Ball Mountain Dam, 2.0 mi southeast of State Routes 30 and 100 intersection in Rawsonville, and 2.5 mi northwest of Depot Street and State Route 30/100 intersection in Jamaica.	1964–78, 1999–2007
01156300	Whetstone Brook Tributary near Marlboro, VT	Lat 42°52'42", long 72°42'32", Windham County, at culvert on State Route 9, 600 ft southwest of Sunset Lake Road and State Route 9 intersection, 800 ft upstream of mouth, 0.5 mi southeast of mouth of Hidden Lake, and 1.5 mi northeast of Marlboro.	1963, 1965–74, 1999–2002, 2004–07
01156450	Connecticut River Tributary near Vernon, VT	Lat 42°47'01", long 72°31'57", Windham County, at downstream culvert on Tyler Hill Road, 0.3 mi west of Tyler Hill Road and State Route 142 intersection, 0.6 mi upstream of mouth, 1.3 mi northwest of Vernon Dam, and 1.8 mi northwest of West Road and State Route 142 intersection in Vernon.	1964–74, 1999–2001, 2003–07
01157000	Ashuelot River near Gilsum, NH	Lat 43°02'21", long 72°16'14", Cheshire County, on right bank, 50 ft downstream of White Brook confluence, 60 ft upstream of stone-arch bridge on Surry Road, 200 ft west of Surry Road and State Route 10 intersection, and 0.8 mi southwest of Post Office in Gilsum.	1923–80, 2006

Table 1. Descriptions of streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; lat, latitude; long, longitude; mi, mile; ft, feet]

USGS streamgage station number	Station name	Station location	Period of record (water years)
01158500	Otter Brook near Keene, NH	Lat 42°57'55", long 72°14'05", Cheshire County, on left bank, 10 ft downstream from unnamed road bridge, 0.2 mi south of unnamed road and State Route 9 intersection, 1.3 mi north of Otter Brook Flood Control Dam, 1.4 mi east of the intersection of State Routes 9 and 10, 1.5 mi upstream of station 01158600, Otter Brook below Otter Brook Dam, near Keene, and 3.8 mi upstream of confluence with Minnewawa Brook to form The Branch.	1924–57
01160000	South Branch Ashuelot River at Webb, near Marlborough, NH	Lat 42°52'19", long 72°12'51", Cheshire County, on right bank, 15 ft downstream of bridge (destroyed) at Webb, 400 ft upstream of State Route 12 bridge, and 2.3 mi south of Town Hall in Marlborough.	1921–78
01161300	Millers Brook at Northfield, MA	Lat 42°41'07", long 72°27'11", Franklin County, at culvert on Beers Plain Road, 0.8 mi south of Northfield.	1964, 1966–83
01161500	Tarbell Brook near Winchendon, MA	Lat 42°42'45", long 72°05'09", Worcester County, on left bank 0.1 mi downstream of Spud Brook confluence, 0.3 mi downstream of Massachusetts-New Hampshire State line, and 2.8 mi northwest of Winchendon.	1917–82
01162000	Millers River near Winchendon, MA	Lat 42°41'03", long 72°05'02", Worcester County, on right bank 10 ft downstream of Nolan Bridge, 0.3 mi downstream of Tarbell Brook confluence, and 2.0 mi west of Winchendon.	1918–2007
01162500	Priest Brook near Winchendon, MA	Lat 42°40'57", long 72°06'56", Worcester County, on right bank 100 ft downstream of bridge, 3.0 mi upstream of mouth, and 3.5 mi west of Winchendon.	1917, 1918–2007
01163100	Wilder Brook near Gardner, MA	Lat 42°35'42", long 72°00'53", Worcester County, at culvert on Clark Street, and 1.5 mi northwest of Gardner.	1964–74
01163200	Otter River at Otter River, MA	Lat 42°35'18", long 72°02'29", Worcester County, on right bank at upstream side of Turner Street bridge, 0.2 mi upstream of Bailey Brook confluence, 0.8 mi southeast of Otter River, and 2.0 mi northwest of Gardner.	1965–2007
01165500	Moss Brook at Wendell Depot, MA	Lat 42°36'10", long 72°21'36", Franklin County, on left bank 0.2 mi upstream of mouth, 0.2 mi north of Wendell Depot, and 2.5 mi west of Orange.	1917–82
01167800	Beaver Brook at Wilmington, VT	Lat 42°51'38", long 72°51'06", Windham County, on right bank 20 ft downstream of bridge on State Route 9, 0.1 mi east of the eastern intersection of State Routes 9 and 100, 1.2 mi southeast of the intersection of State Routes 9 and 100 intersection in Wilmington, and 1.6 mi upstream of mouth.	1963–77
01169000	North River at Shattuckville, MA	Lat 42°38'18", long 72°43'32", Franklin County, on right bank in Shattuckville, 1.2 mi south of Griswoldville, and 1.3 mi upstream of mouth.	1940–2007
01169900	South River near Conway, MA	Lat 42°32'31", long 72°41'39", Franklin County, on left bank at upstream side of Reeds Bridge just off Bardwell Road, 2.2 mi north of Conway, and 2.6 mi upstream of mouth.	1967–2007
01170100	Green River near Colrain, MA	Lat 42°42'12", long 72°40'16", Franklin County, on right bank 0.5 mi upstream of bridge on West Leyden Road and 2.5 mi northeast of Colrain.	1968–2007
01170200	Allen Brook near Shelburne Falls, MA	Lat 42°36'46", long 72°40'02", Franklin County, at culvert on Peckville Road, and 3.5 mi east of Shelburne Falls.	1964–74
01170900	Mill River near South Deerfield, MA	Lat 42°28'09", long 72°38'31", Franklin County, at culvert on North Street, and 2.0 mi southwest of South Deerfield.	1963–74
01173900	Middle Branch Swift River at North New Salem, MA	Lat 42°32'45", long 72°19'10", Franklin County, at culvert on Elm Street at North New Salem.	1964–74
01174565	West Branch Swift River near Shutesbury, MA	Lat 42°27'18", long 72°22'56", Franklin County, on left bank 800 ft downstream of State Route 202, and 1.4 mi east of Shutesbury.	1984–85, 1996–2007

[1]Record combined with record from streamgage 01074520, East Branch Pemigewasset River at Lincoln, NH, for frequency analysis.

[2]Record combined with record from streamgage 01089100, Soucook River at Pembroke Road, near Concord, NH, for frequency analysis.

[3]Record combined with record from streamgage 01153550, Williams River near Rockingham, VT, for frequency analysis.

Table 5. Flood discharges at selected recurrence intervals for streamgages on selected streams in and adjacent to New Hampshire.

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; mi², square miles; ft³/s, cubic feet per second]

USGS streamgage station number	Station name	Drainage area (mi²)	Flood discharge at given recurrence intervals (ft³/s)							Maximum recorded flood	
			2-year	5-year	10-year	25-year	50-year	100-year	500-year	Discharge (ft³/s)	Date
01050900	Four Ponds Brook near Houghton, ME	3.26	95.4	159	205	268	317	369	495	349	7-30-1969
01052500	Diamond River near Wentworth Location, NH	153	4,950	6,450	7,420	8,630	9,520	10,400	12,500	12,800	3-31-1998
01054200	Wild River at Gilead, ME	69.9	9,110	14,600	18,200	22,600	25,700	28,800	35,400	28,300	10-24-1959
01054300	Ellis River at South Andover, ME	131	4,280	5,970	7,010	8,220	9,070	9,860	11,600	7,830	12-18-2003
01055000	Swift River near Roxbury, ME	96.8	6,260	9,890	12,400	15,600	18,000	20,400	26,000	16,800	10-24-1959
01055300	Bog Brook near Buckfield, ME	10.5	189	262	308	364	404	443	530	289	2-11-1970
01057000	Little Androscoggin River near South Paris, ME	76.5	2,200	3,400	4,260	5,400	6,290	7,210	9,480	9,340	4-1-1987
01062700	Patte Brook near Bethel, ME	5.67	241	388	493	630	735	841	1,100	664	7-1-1973
01063310	Stony Brook at East Sebago, ME	1.51	44.6	85.8	121	176	223	277	432	130	9-17-1999
01064300	Ellis River near Jackson, NH	10.5	1,260	2,030	2,570	3,250	3,770	4,290	5,490	4,500	11-3-1966
01064380	East Branch Saco River at Town Hall Road, near Lower Bartlett, NH	33.9	1,950	3,010	3,750	4,700	5,430	6,160	7,920	4,610	4-25-1968
01064400	Lucy Brook near North Conway, NH	4.69	576	1,050	1,420	1,920	2,320	2,730	3,750	2,660	8-11-1990
01064500	Saco River near Conway, NH	385	17,200	26,300	32,500	40,600	46,700	52,800	67,400	47,200	3-27-1953
01064800	Cold Brook at South Tamworth, NH	5.46	464	1,020	1,570	2,510	3,430	4,580	8,310	2,800	7-4-1973
01064801	Bearcamp River at South Tamworth, NH	67.4	3,600	5,070	6,050	7,300	8,240	9,180	11,400	6,150	6-14-1998
01065000	Ossipee River at Effingham Falls, NH	329	3,550	4,900	5,870	7,160	8,170	9,240	11,900	11,700	3-28-1953
01065500	Ossipee River at Cornish, ME	452	4,450	6,350	7,710	9,520	10,900	12,400	16,200	17,200	3-21-1936
01066000	Saco River at Cornish, ME	1,290	13,500	19,000	22,700	27,500	31,100	34,800	43,600	46,600	3-21-1936
01066100	Pease Brook near Cornish, ME	4.63	180	324	447	636	802	992	1,540	486	4-23-1969
01066500	Little Ossipee River near South Limington, ME	163	2,040	3,220	4,150	5,510	6,660	7,920	11,400	8,530	3-19-1936
01069700	Branch Brook near Kennebunk, ME	10.5	321	558	755	1,050	1,310	1,610	2,450	1,020	10-22-1996
01072800	Cocheco River near Rochester, NH	79.9	1,640	2,650	3,460	4,660	5,680	6,820	10,000	7,240	4-16-2007
01072850	Mohawk Brook near Center Strafford, NH	7.30	293	686	1,100	1,870	2,670	3,700	7,360	2,370	5-14-2006
01073000	Oyster River near Durham, NH	12.2	305	488	632	839	1,010	1,200	1,730	1,320	4-16-2007
01073500	Lamprey River near Newmarket, NH	185	2,200	3,550	4,650	6,280	7,690	9,270	13,700	8,970	5-16-2006

Table 5. Flood discharges at selected recurrence intervals for streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; mi², square miles; ft³/s, cubic feet per second]

USGS streamgage station number	Station name	Drainage area (mi²)	Flood discharge at given recurrence intervals (ft³/s)							Maximum recorded flood	
			2-year	5-year	10-year	25-year	50-year	100-year	500-year	Discharge (ft³/s)	Date
01073587	Exeter River at Haigh Road, near Brentwood, NH	63.5	882	1,420	1,840	2,450	2,960	3,530	5,060	3,520	5-15-2006
01073600	Dudley Brook near Exeter, NH	5.79	168	257	325	422	502	590	825	660	5-14-2006
01073750	Mill Brook near State Route 108, at Stratham, NH	2.31	114	214	302	440	564	706	1,130	390	4-2-1973
01074520	East Branch Pemigewasset River at Lincoln, NH	115	8,210	12,400	15,500	19,700	23,000	26,500	35,500	16,900	4-14-2002
01075000	Pemigewasset River at Woodstock, NH	195	11,800	19,000	24,500	32,200	38,400	45,100	62,400	47,000	10-24-1959
01075800	Stevens Brook near Wentworth, NH	3.29	206	395	570	857	1,130	1,460	2,490	1,120	6-30-1973
01076000	Baker River near Rumney, NH	143	5,180	8,650	11,600	16,000	20,000	24,500	37,900	25,900	11-3-1927
01076500	Pemigewasset River at Plymouth, NH	623	21,300	30,200	36,400	44,600	51,000	57,700	74,100	65,400	3-19-1936
01078000	Smith River near Bristol, NH	86.1	1,760	2,620	3,260	4,170	4,920	5,740	7,910	8,100	3-19-1936
01082000	Contoocook River at Peterborough, NH	67.4	1,300	1,920	2,390	3,050	3,600	4,190	5,770	4,110	4-16-2007
01084000	North Branch River near Antrim, NH	54.2	910	1,460	1,920	2,610	3,230	3,930	6,010	5,000	3-19-1936
01084500	Beards Brook near Hillsborough, NH	55.4	1,210	1,750	2,150	2,710	3,160	3,640	4,920	4,800	10-9-2005
01085800	West Branch Warner River near Bradford, NH	5.88	354	582	752	987	1,180	1,380	1,890	1,010	5-14-2006
01086000	Warner River at Davisville, NH	145	2,210	3,380	4,260	5,490	6,500	7,580	10,400	8,640	5-15-2006
01089100	Soucook River at Pembroke Road, near Concord, NH	82.7	1,360	2,130	2,730	3,570	4,280	5,040	7,110	5,110	5-14-2006
01089500	Suncook River at North Chichester, NH	154	2,270	3,610	4,720	6,390	7,860	9,540	14,400	10,600	4-17-2007
01091000	South Branch Piscataquog River near Goffstown, NH	103	2,070	3,230	4,110	5,340	6,340	7,410	10,200	8,880	4-17-2007
01093800	Stony Brook Tributary near Temple, NH	3.60	188	308	407	556	685	831	1,250	648	10-21-1996
01094000	Souhegan River at Merrimack, NH	171	3,200	4,950	6,350	8,430	10,200	12,200	17,900	16,900	3-19-1936
01094500	North Nashua River near Leominster, MA	108	2,480	4,200	5,660	7,920	9,920	12,200	19,100	16,300	3-18-1936
01095000	Rocky Brook near Sterling, MA	2.23	59.4	120	181	287	393	527	987	470	7-20-1959
01095800	Easter Brook near North Leominster, MA	0.95	52.3	89.4	120	167	208	254	389	85.0	3-18-1968
01096000	Squannacook River near West Groton, MA	65.6	1,440	2,370	3,090	4,130	4,990	5,930	8,460	4,820	4-16-2007
010965852	Beaver Brook at North Pelham, NH	47.6	809	1,400	1,910	2,680	3,360	4,140	6,400	2,940	5-15-2006
01096910	Boulder Brook at East Bolton, MA	1.60	44.7	78.5	108	155	197	246	397	208	1-25-1979

Table 5. Flood discharges at selected recurrence intervals for streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; mi², square miles; ft³/s, cubic feet per second]

USGS streamgage station number	Station name	Drainage area (mi²)	Flood discharge at given recurrence intervals (ft³/s)							Maximum recorded flood	
			2-year	5-year	10-year	25-year	50-year	100-year	500-year	Discharge (ft³/s)	Date
01097200	Heath Hen Meadow Brook at Stow, MA	3.76	59.1	98.9	131	179	219	265	392	156	3-18-1968
01097300	Nashoba Brook near Acton, MA	12.3	198	326	425	566	683	811	1,150	679	1-26-1979
01100100	Richardson Brook near Lowell, MA	4.04	111	166	208	268	318	373	525	424	1-25-1979
01100700	East Meadow River near Haverhill, MA	4.81	109	185	246	337	415	502	743	211	3-19-1968
01100800	Cobbler Brook near Merrimack, MA	0.76	57.9	80.9	97.2	119	136	154	199	117	3-18-1968
01100900	Parker River Tributary near Georgetown, MA	0.70	18.2	34.6	49.1	72.4	93.6	119	194	76.0	3-18-1968
01101000	Parker River at Byfield, MA	21.4	218	357	472	646	797	969	1,460	883	10-22-1996
01127880	Big Brook near Pittsburg, NH	6.47	264	341	389	446	487	527	616	441	5-3-1967
01129300	Halls Stream near East Hereford, Quebec	84.8	3,330	4,560	5,460	6,680	7,650	8,690	11,400	21,000	6-1943
01129400	Black Brook at Averill, VT	0.88	30.8	40.8	47.7	56.5	63.2	70.1	86.9	54.0	12-21-1973
01129440	Mohawk River near Colebrook, NH	35.2	2,140	3,160	3,880	4,840	5,580	6,340	8,230	4,880	3-31-1998
01129700	Paul Stream Tributary near Brunswick, VT	1.48	50.8	74.3	91.4	115	133	153	203	126	6-12-2002
01130000	Upper Ammonoosuc River near Groveton, NH	230	4,910	6,660	7,770	9,110	10,100	11,000	13,100	[1]24,100	5-20-1969
01133000	East Branch Passumpsic River near East Haven, VT	51.3	1,370	1,970	2,410	3,030	3,540	4,080	5,500	4,450	6-30-1973
01133200	Quimby Brook near Lyndonville, VT	2.16	80.6	131	172	232	285	344	512	290	6-12-2002
01133300	Cold Hill Brook near Lyndon, VT	1.64	55.9	93.4	124	171	211	257	387	195	6-30-1973
01134500	Moose River at Victory, VT	75.2	2,090	2,760	3,220	3,810	4,270	4,740	5,880	4,940	7-1-1973
01134800	Kirby Brook at Concord, VT	8.13	394	628	814	1,090	1,320	1,580	2,320	1,600	6-30-1973
01135000	Moose River at St. Johnsbury, VT	129	2,660	3,790	4,600	5,690	6,550	7,440	9,700	5,820	5-5-1972
01135150	Pope Brook near North Danville, VT	3.27	152	190	214	245	267	290	342	249	7-15-1997
01135300	Sleepers River near St. Johnsbury, VT	42.5	1,870	2,930	3,780	5,030	6,110	7,310	10,700	7,570	8-12-1998
01135500	Passumpsic River at Passumpsic, VT	434	7,630	10,100	11,700	13,800	15,400	17,000	20,800	18,200	7-1-1973
01135700	Joes Brook Tributary near East Barnet, VT	0.70	34.0	53.8	69.6	92.8	112	134	195	103	12-17-2000
01137500	Ammonoosuc River at Bethlehem Junction, NH	88.2	4,400	6,320	7,660	9,440	10,800	12,200	15,800	11,300	11-12-1995
01138000	Ammonoosuc River near Bath, NH	396	10,700	15,800	19,600	24,800	29,100	33,600	45,600	27,900	3-18-1936

Table 5. Flood discharges at selected recurrence intervals for streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; mi², square miles; ft³/s, cubic feet per second]

USGS streamgage station number	Station name	Drainage area (mi²)	Flood discharge at given recurrence intervals (ft³/s)							Maximum recorded flood	
			2-year	5-year	10-year	25-year	50-year	100-year	500-year	Discharge (ft³/s)	Date
01138800	Keenan Brook at Groton, VT	4.72	96.9	165	220	302	372	451	672	275	6-30-1973
01139000	Wells River at Wells River, VT	98.8	1,720	2,500	3,080	3,870	4,500	5,170	6,900	5,970	6-30-1973
01139700	Waits River Tributary near West Topsham, VT	1.21	44.2	69.7	88.9	116	138	162	224	94.0	12-21-1973
01139800	East Orange Branch at East Orange, VT	8.79	255	397	507	661	789	927	1,300	800	7-23-1990
01140800	West Branch Ompompanoosuc River Tributary at South Strafford, VT	1.35	78.8	105	123	148	168	189	242	168	6-30-1973
01141800	Mink Brook near Etna, NH	4.76	221	385	521	724	900	1,100	1,660	870	5-14-2006
01142000	White River near Bethel, VT	239	10,100	15,400	19,600	25,700	30,900	36,800	53,000	32,200	9-21-1938
01142400	Third Branch White River Tributary at Randolph, VT	0.80	47.9	86.3	122	183	241	313	550	327	6-27-1998
01142500	Ayers Brook at Randolph, VT	30.5	737	1,130	1,450	1,920	2,340	2,820	4,180	3,480	6-27-1998
01144000	White River at West Hartford, VT	687	17,700	26,100	32,900	43,100	51,900	61,800	90,500	120,000	11-4-1927
01145000	Mascoma River at West Canaan, NH	80.4	1,630	2,340	2,810	3,430	3,900	4,370	5,510	4,310	9-1938
01150800	Kent Brook near Killington, VT	3.25	212	368	500	701	878	1,080	1,660	792	4-14-2002
01150900	Ottauquechee River near West Bridgewater, VT	23.3	990	1,350	1,610	1,950	2,230	2,510	3,230	1,960	10-22-1995
01151200	Ottauquechee River Tributary near Quechee, VT	0.78	17.1	27.8	36.7	50.4	62.5	76.3	117	93.0	6-30-1973
01152500	Sugar River at West Claremont, NH	270	4,720	6,650	8,020	9,860	11,300	12,800	16,700	14,000	3-19-1936
01153300	Middle Branch Williams River Tributary at Chester, VT	3.19	140	198	239	294	338	384	499	367	8-10-1976
01153550	Williams River near Rockingham, VT	112	4,930	7,180	8,760	10,800	12,400	14,100	18,200	11,500	3-31-1987
01154000	Saxtons River at Saxtons River, VT	72.1	2,690	4,070	5,100	6,540	7,720	8,970	12,300	8,460	8-10-1976
01155000	Cold River at Drewsville, NH	83.3	1,990	3,150	4,080	5,470	6,680	8,040	11,900	[2]21,800	10-9-2005
01155200	Sacketts Brook near Putney, VT	10.2	321	527	691	933	1,140	1,370	2,000	903	6-30-1973
01155300	Flood Brook near Londonderry, VT	9.28	561	918	1,210	1,630	2,000	2,400	3,540	1,800	6-30-1973
01155350	Tributary to West River Tributary at State Route 30 near Jamaica, VT	0.93	57.4	99.4	135	191	242	300	473	320	6-30-1973
01156300	Whetstone Brook Tributary near Marlboro, VT	1.08	112	191	255	350	431	521	770	284	10-8-2005
01156450	Connecticut River Tributary near Vernon, VT	1.10	52.2	86.3	115	161	201	249	391	250	10-8-2005
01157000	Ashuelot River near Gilsum, NH	71.9	1,600	2,470	3,180	4,220	5,130	6,150	9,070	10,200	10-9-2005

Table 5. Flood discharges at selected recurrence intervals for streamgages on selected streams in and adjacent to New Hampshire.—Continued

[All streamgages are shown in figure 2; USGS, U.S. Geological Survey; mi², square miles; ft³/s, cubic feet per second]

USGS streamgage station number	Station name	Drainage area (mi²)	Flood discharge at given recurrence intervals (ft³/s)							Maximum recorded flood	
			2-year	5-year	10-year	25-year	50-year	100-year	500-year	Discharge (ft³/s)	Date
01158500	Otter Brook near Keene, NH	42.2	1,150	2,010	2,770	3,980	5,090	6,410	10,500	6,130	9-21-1938
01160000	South Branch Ashuelot River at Webb, near Marlborough, NH	35.9	958	1,690	2,350	3,430	4,460	5,710	9,700	5,960	9-21-1938
01161300	Millers Brook at Northfield, MA	2.32	111	196	274	403	525	673	1,150	680	9-26-1975
01161500	Tarbell Brook near Winchendon, MA	18.8	248	408	552	787	1,010	1,280	2,130	2,630	9-21-1938
01162000	Millers River near Winchendon, MA	82.3	1,030	1,640	2,160	3,000	3,770	4,680	7,510	8,500	9-22-1938
01162500	Priest Brook near Winchendon, MA	18.9	347	570	763	1,070	1,340	1,670	2,650	3,000	9-21-1938
01163100	Wilder Brook near Gardner, MA	2.65	46.2	61.7	72.5	86.8	97.8	109	138	56.0	3-23-1972, 3-17-1973
01163200	Otter River at Otter River, MA	34.0	456	636	764	937	1,070	1,220	1,580	948	3-7-1979
01165500	Moss Brook at Wendell Depot, MA	12.2	258	431	575	796	991	1,220	1,870	1,540	3-19-1936
01167800	Beaver Brook at Wilmington, VT	6.36	436	745	1,010	1,410	1,770	2,180	3,400	1,170	8-10-1976
01169000	North River at Shattuckville, MA	89.0	4,850	7,840	10,200	13,700	16,700	20,000	29,200	18,800	10-9-2005
01169900	South River near Conway, MA	24.2	1,940	3,210	4,300	5,990	7,510	9,280	14,600	8,770	10-9-2005
01170100	Green River near Colrain, MA	41.2	2,510	3,470	4,150	5,060	5,770	6,520	8,400	6,540	10-9-2005
01170200	Allen Brook near Shelburne Falls, MA	0.72	33.3	72.8	112	181	248	333	616	89.0	6-18-1976
01170900	Mill River near South Deerfield, MA	6.41	156	247	318	419	504	597	849	300	4-3-1970
01173900	Middle Branch Swift River at North New Salem, MA	4.72	114	189	253	352	442	546	861	320	12-21-1973
01174565	West Branch Swift River near Shutesbury, MA	12.8	557	1,020	1,430	2,080	2,680	3,380	5,530	1,520	10-9-2005

[1] Peak discharge affected by dam failure.

[2] Peak discharge affected by failure of embankment temporarily impounding flood waters.

Table 6. Basin characteristics determined for use in regression analysis.

[PRISM, parameter-elevation regressions on independent slopes model; USGS, U.S. Geological Survey; °F, degrees Fahrenheit; %, percent; /, divided by; ×, multiplied by; --, none]

Characteristic description	Units	Source	Minimum	Mean	Maximum
Drainage area	Square miles	National Elevation Dataset[1]	0.70	83.7	1,290
Maximum elevation	Feet	National Elevation Dataset[1]	149	2,419	6,286
Minimum elevation	Feet	National Elevation Dataset[1]	24	636	2,059
Relief (maximum minus minimum elevation)	Feet	National Elevation Dataset[1]	81	1,783	6,026
Mean elevation	Feet	National Elevation Dataset[1]	94.8	1,220	3,360
Mean basin slope	Percent	National Elevation Dataset[1]	3.38	13.9	38.2
Percentage of basin having a slope greater than 30 percent	Percent	National Elevation Dataset[1]	0	8.83	65.1
Percentage of basin facing north having a slope greater than 30 percent	Percent	National Elevation Dataset[1]	0	2.29	16.8
Mean annual precipitation	Inches	PRISM[2]	39.7	48.0	74.3
Mean January precipitation	Inches	PRISM[2]	2.87	3.87	6.34
Mean February precipitation	Inches	PRISM[2]	2.10	3.00	4.78
Mean March precipitation	Inches	PRISM[2]	2.72	3.88	6.65
Mean April precipitation	Inches	PRISM[2]	2.79	3.94	6.23
Mean May precipitation	Inches	PRISM[2]	3.25	4.10	5.89
Mean June precipitation	Inches	PRISM[2]	3.52	4.22	6.33
Mean July precipitation	Inches	PRISM[2]	3.38	4.20	5.93
Mean August precipitation	Inches	PRISM[2]	3.40	4.36	6.20
Mean September precipitation	Inches	PRISM[2]	3.26	3.99	6.15
Mean October precipitation	Inches	PRISM[2]	3.50	4.24	6.38
Mean November precipitation	Inches	PRISM[2]	3.39	4.39	7.31
Mean December precipitation	Inches	PRISM[2]	2.91	3.83	6.16
Mean fall (October through November) precipitation	Inches	PRISM[2]	6.89	8.58	13.69
Mean winter (December through February) precipitation	Inches	PRISM[2]	7.88	10.70	17.28
Mean spring (March through May) precipitation	Inches	PRISM[2]	8.98	11.92	18.76
Mean maximum annual temperature	°F	PRISM[3]	7.0	12.1	15.1
Mean maximum December temperature	°F	PRISM[3]	-4.4	0.1	3.8
Mean maximum January temperature	°F	PRISM[3]	-9.4	-2.1	1.6
Mean maximum February temperature	°F	PRISM[3]	-5.3	-0.7	2.8
Mean maximum March temperature	°F	PRISM[3]	-1.2	4.2	7.5
Mean maximum April temperature	°F	PRISM[3]	5.2	11.1	14.1
Mean maximum May temperature	°F	PRISM[3]	12.7	18.5	20.7
Mean minimum annual temperature	°F	PRISM[4]	-3.7	0.1	3.9
Mean minimum December temperature	°F	PRISM[4]	-15.0	-10.0	-5.6
Mean minimum January temperature	°F	PRISM[4]	-19.1	-13.4	-8.3
Mean minimum February temperature	°F	PRISM[4]	-19.2	-12.7	-7.6

Table 6. Basin characteristics determined for use in regression analysis.—Continued

[PRISM, parameter-elevation regressions on independent slopes model; USGS, U.S. Geological Survey; °F, degrees Fahrenheit; %, percent; /, divided by; ×, multiplied by; --, none]

Characteristic description	Units	Source	Minimum	Mean	Maximum
Mean minimum March temperature	°F	PRISM[4]	-12.7	-7.2	-3.0
Mean minimum April temperature	°F	PRISM[4]	-4.9	-1.0	2.3
Mean minimum May temperature	°F	PRISM[4]	2.0	4.9	7.7
Percentage of basin that is wetland	Percent	National Wetlands Inventory[5]	0	5.68	20.6
Percentage of basin that is lacustrine or palustrine wetland	Percent	National Wetlands Inventory[5]	0	5.65	20.6
Percentage of basin that is lacustrine wetland	Percent	National Wetlands Inventory[5]	0	0.89	17.8
Percentage of basin that is palustrine wetland	Percent	National Wetlands Inventory[5]	0	4.75	19.0
Percentage of basin that is riverine wetland	Percent	National Wetlands Inventory[5]	0	0.04	0.35
Percentage of basin covered by forest	Percent	National Land Cover Data[6]	40.7	80.8	99.5
Percentage of basin covered by shrubland	Percent	National Land Cover Data[6]	0	1.54	8.62
Percentage of basin covered by water	Percent	National Land Cover Data[6]	0	0.97	15.8
Percentage of basin covered by wetlands	Percent	National Land Cover Data[6]	0	4.86	21.8
Percentage of basin covered by developed land	Percent	National Land Cover Data[6]	0	6.20	35.4
Percentage of basin covered by barren land	Percent	National Land Cover Data[6]	0	0.32	10.5
Percentage of basin covered by agricultural land	Percent	National Land Cover Data[6]	0	6.25	25.7
Percentage of basin with imperviousness greater than 0%	Percent	National Land Cover Data[6]	0	5.98	33.5
Percentage of basin with imperviousness greater than or equal to 20%	Percent	National Land Cover Data[6]	0	2.58	23.9
Percentage of basin with imperviousness greater than or equal to 40%	Percent	National Land Cover Data[6]	0	1.43	16.5
Percentage of basin with imperviousness greater than or equal to 60%	Percent	National Land Cover Data[6]	0	0.52	8.02
Percentage of basin with imperviousness greater than or equal to 80%	Percent	National Land Cover Data[6]	0	0.14	3.15
Average imperviousness	Percent	National Land Cover Data[6]	0	1.40	12.5
Percentage of basin with tree canopy greater than or equal to 20%	Percent	National Land Cover Data[6]	55.6	87.0	99.9
Percentage of basin with tree canopy greater than or equal to 40%	Percent	National Land Cover Data[6]	52.5	85.0	99.9
Percentage of basin with tree canopy greater than or equal to 60%	Percent	National Land Cover Data[6]	47.7	81.0	99.5
Percentage of basin with tree canopy greater than or equal to 80%	Percent	National Land Cover Data[6]	31.6	69.1	96.6
Average tree canopy percentage	Percent	National Land Cover Data[6]	43.5	74.5	93.1
Northing of basin centroid	Feet	National Elevation Dataset[1]	-14,476	384,493	969,502
Easting of basin centroid	Feet	National Elevation Dataset[1]	654,632	951,250	
Percentage of basin covered by lakes and ponds	Percent	National Hydrography Dataset[7]	0	1.22	18.2
Percentage of basin covered by swamps	Percent	National Hydrography Dataset[7]	0	1.41	11.1
Percentage of basin covered by lakes, ponds, and swamps	Percent	National Hydrography Dataset[7]	0	2.63	18.2
Mean permeability of soils	Inches per hour	State Soil Geographic (STATSGO) Database[8]	1.2	4.0	14.1
Mean liquid limit of soils	Percent	State Soil Geographic (STATSGO) Database[8]	14.7	21.4	28.6
Mean available water content	Inches per inch	State Soil Geographic (STATSGO) Database[8]	0.1	0.1	0.2
Mean quality of soil drainage	--	State Soil Geographic (STATSGO) Database[8]	2.6	3.4	4.4

Table 6. Basin characteristics determined for use in regression analysis.—Continued

[PRISM, parameter-elevation regressions on independent slopes model; USGS, U.S. Geological Survey; °F, degrees Fahrenheit; %, percent; /, divided by; ×, multiplied by; --, none]

Characteristic description	Units	Source	Minimum	Mean	Maximum
Mean of hydrologic grouping of soils	--	State Soil Geographic (STATSGO) Database[8]	2.0	2.8	3.5
Percentage of basin with hydric soils	Percent	State Soil Geographic (STATSGO) Database[8]	0	0.1	0.4
Percentage of the basin above 500 feet	Percent	National Elevation Dataset[1]	0	82.1	100
Percentage of the basin above 750 feet	Percent	National Elevation Dataset[1]	0	72.9	100
Percentage of the basin above 1,000 feet	Percent	National Elevation Dataset[1]	0	60.4	100
Percentage of the basin above 1,200 feet	Percent	National Elevation Dataset[1]	0	47.0	100
Percentage of the basin above 1,400 feet	Percent	National Elevation Dataset[1]	0	36.1	100
Population in basin	Persons	2000 Census[9]	0	5,161	88,426
Population density in basin	Persons per square mile	2000 Census[9]	0	104	912
Number of housing units in basin	Units	2000 Census[9]	3	2,563	35,894
Housing unit density in basin	Units per square mile	2000 Census[9]	0.58	42.9	334
Longest flow path length	Miles	National Elevation Dataset[1]	1.47	16.4	96.1
Maximum elevation change along longest flow path	Feet	National Elevation Dataset[1]	76	1,526	5,628
Channel slope of longest flow path	Feet per mile	National Elevation Dataset[1]	12.8	158	691
Outlet elevation	Feet	National Elevation Dataset[1]	25	636	2,049
Elevation at upstream end of longest flow path	Feet	National Elevation Dataset[1]	143	2,162	6,273
Elevation 10% of the distance up the longest flow path	Feet	National Elevation Dataset[1]	38	681	2,135
Elevation 85% of the distance up the longest flow path	Feet	National Elevation Dataset[1]	97	1,337	4,337
Channel slope between points 10- and 85-percent up longest flow path	Feet per mile	National Elevation Dataset[1]	5.43	114	543
Basin perimeter	Miles	National Elevation Dataset[1]	3.71	39.8	223
Relative relief (relief/basin perimeter)	--	National Elevation Dataset[1]	9.5	73.8	321
Compactness ratio[10]	--	National Elevation Dataset[1]	1.18	1.57	2.13
Basin length[11]	Miles	National Elevation Dataset[1]	1.00	11.0	44.6
Sinuosity (longest flow path length/basin length)	--	National Elevation Dataset[1]	1.07	1.41	2.55
Basin width (drainage area/basin length)	Miles	National Elevation Dataset[1]	0.39	4.28	29.1
Shape factor (basin length/basin width)	--	National Elevation Dataset[1]	0.98	2.99	6.74
Elongation ratio[12]	--	National Elevation Dataset[1]	0.43	0.70	1.14
Rotundity ratio[13]	--	National Elevation Dataset[1]	1.11	1.91	2.93
Slope ratio (channel slope/basin slope)	--	National Elevation Dataset[1]	0.04	0.20	0.55
Total length of streams	Miles	National Hydrography Dataset[7]	0.33	158	2,258

Table 6. Basin characteristics determined for use in regression analysis.—Continued

[PRISM, parameter-elevation regressions on independent slopes model; USGS, U.S. Geological Survey; °F, degrees Fahrenheit; %, percent; /, divided by; ×, multiplied by; --, none]

Characteristic description	Units	Source	Minimum	Mean	Maximum
Stream density	Miles per square mile	National Elevation Dataset[1] and National Hydrography Dataset[7]	0.37	2.01	4.46
Constant of channel maintenance (drainage area/total length of streams)	Miles	National Elevation Dataset[1] and National Hydrography Dataset[7]	0.22	0.56	2.67
Ruggedness number (relative relief × total length of stream/drainage area)	--	National Elevation Dataset[1] and National Hydrography Dataset[7]	202	3,460	14,600
Basinwide mean of the 2-year, 24-hour rainfall	Inches	Weather Bureau Technical Paper No. 40[14]	2.36	2.82	3.59
Basinwide mean of the 100-year, 24-hour rainfall	Inches	Weather Bureau Technical Paper No. 40[14]	4.91	6.11	7.16
Basinwide mean of mean annual runoff	Inches	Mean annual runoff, precipitation, and evapotranspiration in the glaciated northeastern United States, 1951–80[15]	18.4	25.4	39.5
Basinwide mean of the mean annual snowfall	Inches	Climatesource[16]	51.3	92.2	218
Percentage of basin in the Seaboard Lowland section of the New England Physiographic Province	Percent	Physiographic divisions of the conterminous United States[17]	0	12.0	100
Percentage of basin in the White Mountain section of the New England Physiographic Province	Percent	Physiographic divisions of the conterminous United States[17]	0	22.0	100
Percentage of basin in the New England Upland section of the New England Physiographic Province	Percent	Physiographic divisions of the conterminous United States[17]	0	58.3	100

[1]U.S. Geological Survey (2007a).

[2]PRISM Group, Oregon State University (2006c).

[3]PRISM Group, Oregon State University (2006a).

[4]PRISM Group, Oregon State University (2006b).

[5]U.S. Fish and Wildlife Service (2007).

[6]Multi-Resolution Land Characteristics Consortium (2003).

[7]U.S. Geological Survey (2007b).

[8]U.S. Geological Survey (1995).

[9]U.S. Census Bureau (2006).

[10]Ratio of basin perimeter to the perimeter of a circle have an area equal to the drainage area of the basin.

[11]Length of a line areally centered through the basin from the endpoint of the basin's longest flow path.

[12]Ratio of the diameter of a circle have an area equal to the drainage area of the basin to the basin length.

[13]Ratio of basin width to the diameter of a circle have an area equal to the drainage area of the basin.

[14]U.S. Department of Commerce (1961).

[15]Randall (1996).

[16]Daly and others (2000).

[17]Fenneman and Johnson (1946).

Table 7. Basin characteristics of selected streamgages in and adjacent to New Hampshire and vicinity used in the development of the final regression equations.

[USGS, U.S. Geological Survey; all station locations are shown on figure 2; mi², square miles]

USGS streamgage station number	Station name	Drainage area (mi²)	Basinwide mean of April precipitation (inches)	Percent of basin covered by wetlands	Main channel slope (feet per mile)
01050900	Four Ponds Brook near Houghton, ME	3.26	4.35	17.0	83.1
01052500	Diamond River near Wentworth Location, NH	153	3.34	2.58	29.9
01054200	Wild River at Gilead, ME	69.9	4.54	0.397	123
01054300	Ellis River at South Andover, ME	131	4.20	5.15	32.7
01055000	Swift River near Roxbury, ME	96.8	4.59	0.827	74.0
01055300	Bog Brook near Buckfield, ME	10.5	3.92	11.2	22.2
01057000	Little Androscoggin River near South Paris, ME	76.5	3.71	5.47	42.1
01062700	Patte Brook near Bethel, ME	5.67	3.97	3.90	116
01063310	Stony Brook at East Sebago, ME	1.51	4.39	7.52	36.2
01064300	Ellis River near Jackson, NH	10.5	6.23	0	533
01064380	East Branch Saco River at Town Hall Road, near Lower Bartlett, NH	33.9	4.90	0.782	148
01064400	Lucy Brook near North Conway, NH	4.69	4.45	0.768	428
01064500	Saco River near Conway, NH	385	4.70	1.83	47.3
01064800	Cold Brook at South Tamworth, NH	5.46	4.28	0	421
01064801	Bearcamp River at South Tamworth, NH	67.4	4.16	4.89	131
01065000	Ossipee River at Effingham Falls, NH	329	4.14	8.99	22.5
01065500	Ossipee River at Cornish, ME	452	4.20	8.92	12.9
01066000	Saco River at Cornish, ME	1,290	4.36	8.18	7.33
01066100	Pease Brook near Cornish, ME	4.63	4.50	2.41	133
01066500	Little Ossipee River near South Limington, ME	163	4.48	11.6	10.1
01069700	Branch Brook near Kennebunk, ME	10.5	4.34	9.48	24.0
01072800	Cocheco River near Rochester, NH	79.9	4.28	6.12	16.7
01072850	Mohawk Brook near Center Strafford, NH	7.30	4.29	4.28	86.6
01073000	Oyster River near Durham, NH	12.2	4.18	9.60	17.9
01073500	Lamprey River near Newmarket, NH	185	4.07	7.79	9.36
01073587	Exeter River at Haigh Road, near Brentwood, NH	63.5	4.06	13.7	7.09
01073600	Dudley Brook near Exeter, NH	5.79	4.20	6.88	8.80
01073750	Mill Brook near State Route 108, at Stratham, NH	2.31	4.30	9.09	43.2
01074520	East Branch Pemigewasset River at Lincoln, NH	115	4.53	0.206	86.1
01075000	Pemigewasset River at Woodstock, NH	195	4.31	0.664	78.2
01075800	Stevens Brook near Wentworth, NH	3.29	3.75	0	472
01076000	Baker River near Rumney, NH	143	3.45	1.58	94.5
01076500	Pemigewasset River at Plymouth, NH	623	3.99	1.43	38.9
01078000	Smith River near Bristol, NH	86.1	3.54	4.30	23.6
01082000	Contoocook River at Peterborough, NH	67.4	3.97	10.2	21.8
01084000	North Branch River near Antrim, NH	54.2	4.34	9.92	22.5
01084500	Beards Brook near Hillsborough, NH	55.4	4.16	7.43	68.6
01085800	West Branch Warner River near Bradford, NH	5.88	4.35	1.38	388
01086000	Warner River at Davisville, NH	145	3.96	6.08	29.0
01089100	Soucook River at Pembroke Road, near Concord, NH	82.7	3.61	5.58	26.7

Table 7. Basin characteristics of selected streamgages in and adjacent to New Hampshire and vicinity used in the development of the final regression equations.—Continued

[USGS, U.S. Geological Survey; all station locations are shown on figure 2; mi², square miles]

USGS streamgage station number	Station name	Drainage area (mi²)	Basinwide mean of April precipitation (inches)	Percent of basin covered by wetlands	Main channel slope (feet per mile)
01089500	Suncook River at North Chichester, NH	154	4.03	7.05	16.6
01091000	South Branch Piscataquog River near Goffstown, NH	103	4.03	5.48	28.0
01093800	Stony Brook Tributary near Temple, NH	3.60	4.23	0.363	258
01094000	Souhegan River at Merrimack, NH	171	4.17	4.73	25.5
01094500	North Nashua River near Leominster, MA	108	4.25	7.68	37.7
01095000	Rocky Brook near Sterling, MA	2.23	4.47	14.6	101
01095800	Easter Brook near North Leominster, MA	0.95	4.22	4.53	158
01096000	Squannacook River near West Groton, MA	65.6	4.15	6.80	47.0
010965852	Beaver Brook at North Pelham, NH	47.6	3.94	7.89	12.6
01096910	Boulder Brook at East Bolton, MA	1.60	4.10	0.128	75.2
01097200	Heath Hen Meadow Brook at Stow, MA	3.76	4.06	15.1	14.2
01097300	Nashoba Brook near Acton, MA	12.3	3.99	13.6	20.2
01100100	Richardson Brook near Lowell, MA	4.04	4.00	7.81	30.2
01100700	East Meadow River near Haverhill, MA	4.81	4.30	13.0	20.1
01100800	Cobbler Brook near Merrimack, MA	0.76	4.29	2.03	56.7
01100900	Parker River Tributary near Georgetown, MA	0.70	4.35	21.8	23.8
01101000	Parker River at Byfield, MA	21.4	4.32	20.5	5.43
01127880	Big Brook near Pittsburg, NH	6.47	3.30	3.39	234
01129300	Halls Stream near East Hereford, Quebec	84.8	3.04	0.615	32.6
01129400	Black Brook at Averill, VT	0.88	3.25	0.066	207
01129440	Mohawk River near Colebrook, NH	35.2	3.09	1.56	127
01129700	Paul Stream Tributary near Brunswick, VT	1.48	2.97	0.844	240
01130000	Upper Ammonoosuc River near Groveton, NH	230	3.52	3.44	23.0
01133000	East Branch Passumpsic River near East Haven, VT	51.3	3.15	3.05	84.7
01133200	Quimby Brook near Lyndonville, VT	2.16	2.83	0.873	229
01133300	Cold Hill Brook near Lyndon, VT	1.64	2.88	0.177	252
01134500	Moose River at Victory, VT	75.2	3.22	4.50	66.7
01134800	Kirby Brook at Concord, VT	8.13	2.98	0.636	125
01135000	Moose River at St. Johnsbury, VT	129	3.09	3.38	37.3
01135150	Pope Brook near North Danville, VT	3.27	3.05	0.062	369
01135300	Sleepers River near St. Johnsbury, VT	42.5	2.94	0.776	104
01135500	Passumpsic River at Passumpsic, VT	434	3.00	2.08	36.2
01135700	Joes Brook Tributary near East Barnet, VT	0.70	2.79	0	543
01137500	Ammonoosuc River at Bethlehem Junction, NH	88.2	4.31	0.574	71.5
01138000	Ammonoosuc River near Bath, NH	396	3.32	1.45	26.4
01138800	Keenan Brook at Groton, VT	4.72	3.05	3.49	138
01139000	Wells River at Wells River, VT	98.8	3.00	3.39	32.9
01139700	Waits River Tributary near West Topsham, VT	1.21	3.43	0.578	475
01139800	East Orange Branch at East Orange, VT	8.79	3.35	0.163	153
01140800	West Branch Ompompanoosuc River Tributary at South Strafford, VT	1.35	3.36	0	330

Table 7. Basin characteristics of selected streamgages in and adjacent to New Hampshire and vicinity used in the development of the final regression equations.—Continued

[USGS, U.S. Geological Survey; all station locations are shown on figure 2; mi², square miles]

USGS streamgage station number	Station name	Drainage area (mi²)	Basinwide mean of April precipitation (inches)	Percent of basin covered by wetlands	Main channel slope (feet per mile)
01141800	Mink Brook near Etna, NH	4.76	3.31	0.622	172
01142000	White River near Bethel, VT	239	4.11	0.701	16.2
01142400	Third Branch White River Tributary at Randolph, VT	0.80	3.36	0	376
01142500	Ayers Brook at Randolph, VT	30.5	3.11	0.653	61.5
01144000	White River at West Hartford, VT	687	3.60	0.874	12.5
01145000	Mascoma River at West Canaan, NH	80.4	3.37	5.35	47.8
01150800	Kent Brook near Killington, VT	3.25	4.89	2.03	438
01150900	Ottauquechee River near West Bridgewater, VT	23.3	4.54	3.27	121
01151200	Ottauquechee River Tributary near Quechee, VT	0.78	3.42	1.04	249
01152500	Sugar River at West Claremont, NH	270	3.54	7.21	23.3
01153300	Middle Branch Williams River Tributary at Chester, VT	3.19	3.94	0.319	237
01153550	Williams River near Rockingham, VT	112	3.98	1.13	49.6
01154000	Saxtons River at Saxtons River, VT	72.1	4.05	1.60	79.1
01155000	Cold River at Drewsville, NH	83.3	3.54	2.83	41.1
01155200	Sacketts Brook near Putney, VT	10.2	3.89	1.03	163
01155300	Flood Brook near Londonderry, VT	9.28	4.51	1.77	164
01155350	Tributary to West River Tributary near Jamaica, VT	0.93	4.43	0.282	390
01156300	Whetstone Brook Tributary near Marlboro, VT	1.08	4.40	1.43	156
01156450	Connecticut River Tributary near Vernon, VT	1.10	4.01	1.29	153
01157000	Ashuelot River near Gilsum, NH	71.9	3.85	7.12	31.0
01158500	Otter Brook near Keene, NH	42.2	3.81	4.92	60.8
01160000	South Branch Ashuelot River at Webb, near Marlborough, NH	35.9	3.85	5.90	62.6
01161300	Millers Brook at Northfield, MA	2.32	3.89	0.376	324
01161500	Tarbell Brook near Winchendon, MA	18.8	3.92	14.6	28.6
01162000	Millers River near Winchendon, MA	82.3	3.97	15.2	17.7
01162500	Priest Brook near Winchendon, MA	18.9	3.89	13.4	22.0
01163100	Wilder Brook near Gardner, MA	2.65	4.05	17.9	49.3
01163200	Otter River at Otter River, MA	34.0	4.06	18.4	19.2
01165500	Moss Brook at Wendell Depot, MA	12.2	3.89	6.73	43.8
01167800	Beaver Brook at Wilmington, VT	6.36	4.54	3.12	117
01169000	North River at Shattuckville, MA	89.0	4.34	2.13	58.8
01169900	South River near Conway, MA	24.2	4.71	2.02	67.6
01170100	Green River near Colrain, MA	41.2	4.36	1.69	67.6
01170200	Allen Brook near Shelburne Falls, MA	0.72	4.18	6.92	224
01170900	Mill River near South Deerfield, MA	6.41	4.08	2.21	98.1
01173900	Middle Branch Swift River at North New Salem, MA	4.72	4.18	4.12	123
01174565	West Branch Swift River near Shutesbury, MA	12.8	4.30	1.70	68.2

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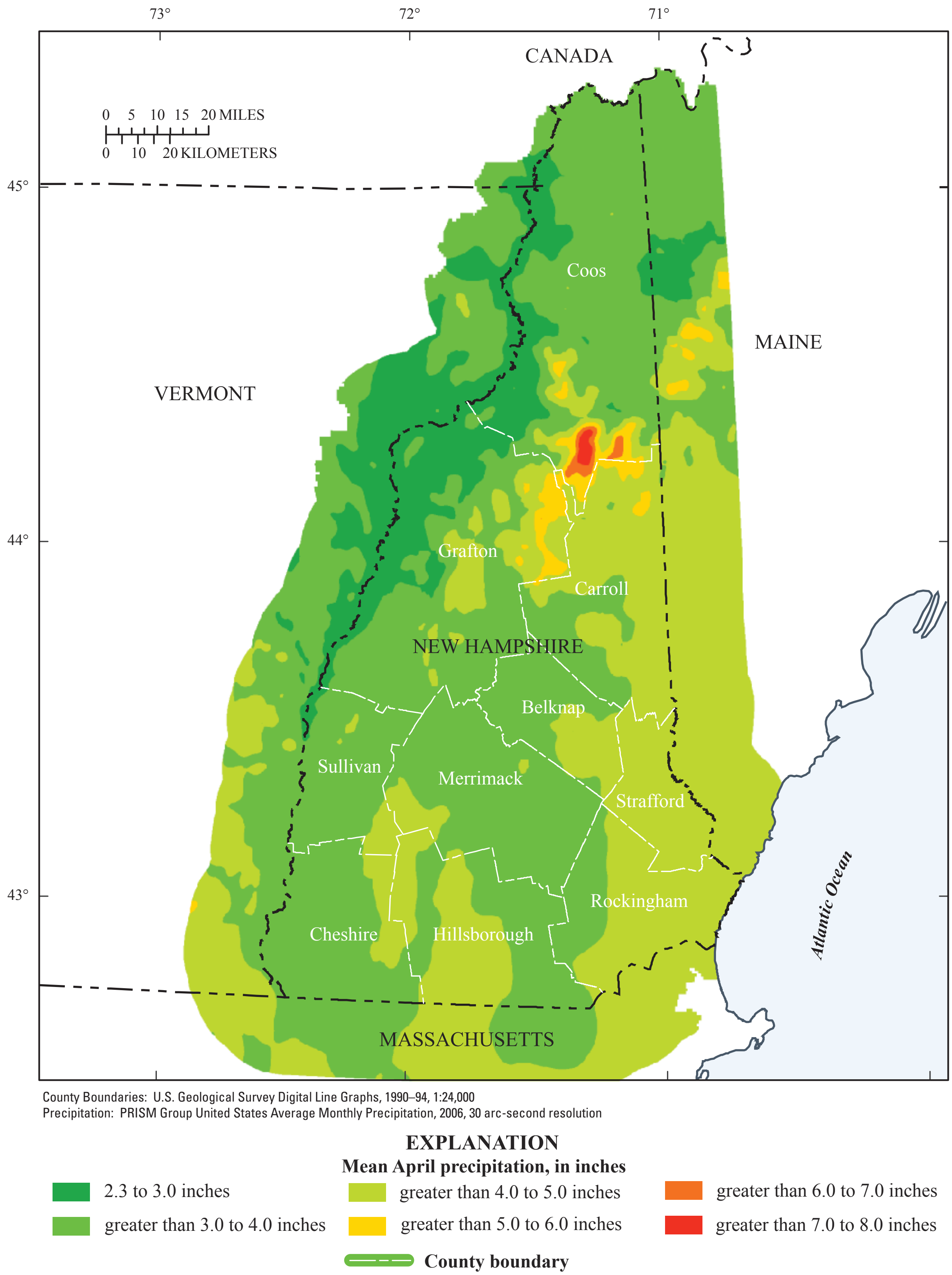
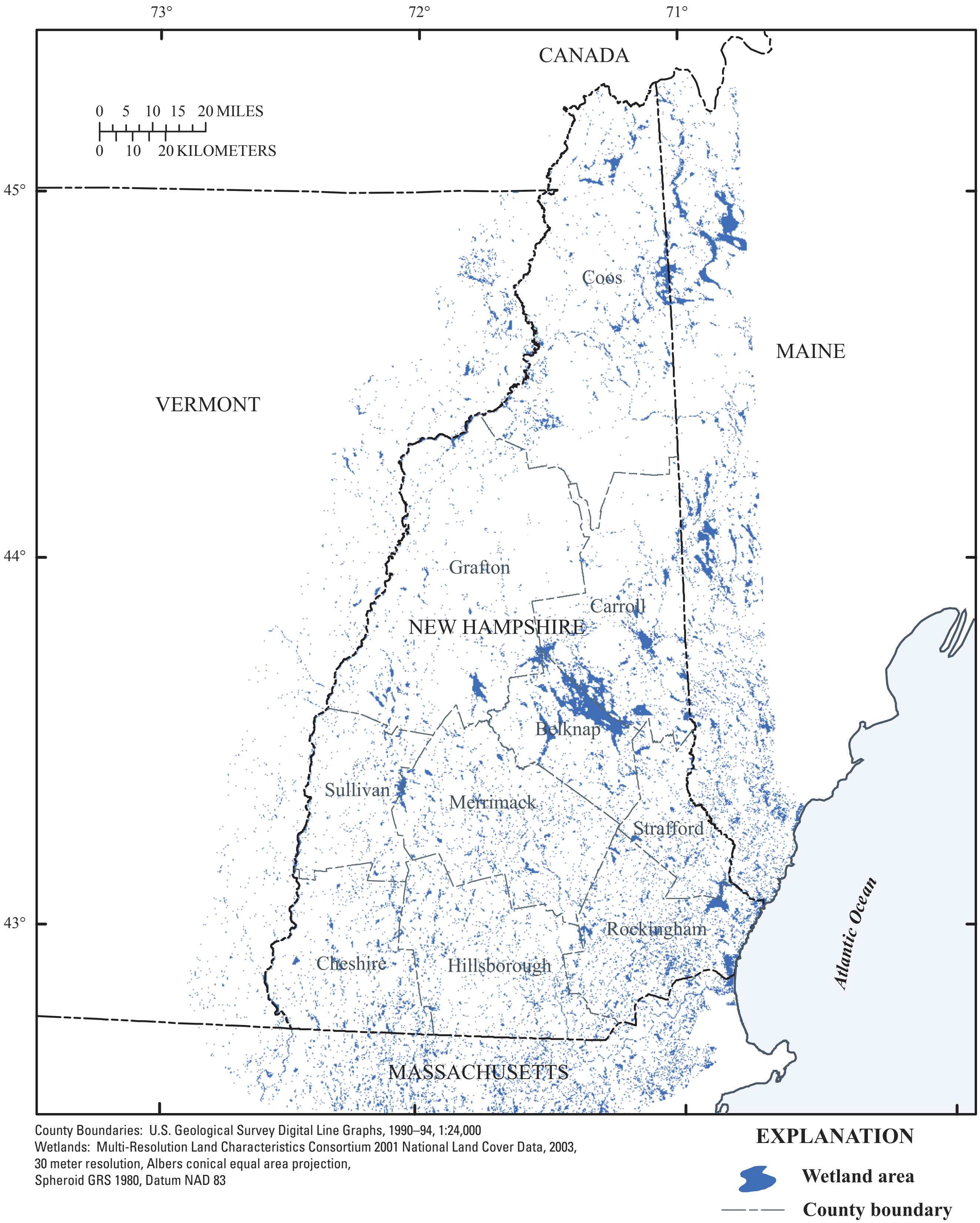
Appendixes 1–3



Appendix 1. Mean April precipitation. (PRISM Group, Oregon State University, http://www.prismclimate.org, map created April 8, 2008)



Appendix 2. Wetland areas. (Multi-Resolution Land Characteristics Consortium, 2003)

Appendix 3. Example Application

The general procedure for estimating the magnitude of a flood discharge at a selected recurrence interval using the methods described in the report is illustrated in the following example. The example does not apply to any specific location as the basin characteristics were selected randomly. The purpose of the example is to illustrate the methods described in the report.

An estimate of the 100-year flood discharge (Q_{100}) is needed for a rural, ungaged stream in New Hampshire. The drainage area, basinwide mean of the average April precipitation, areal percent of wetlands in the basin, and main channel slope are determined to be 22.0 mi², 4.05 in., 3.27 percent, and 62.6 ft/mi, respectively, using the same basin-characteristics data sources described in this report. To determine the magnitude of the 100-year flood discharge in cubic feet per second, equation 8 would be solved:

$$Q_{100} = 7.13A^{0.867}P^{1.98}10^{-0.0254(W)}S^{0.198}, \quad (8)$$

$$Q_{100} = 7.13(22.0)^{0.867}(4.05)^{1.98}10^{-0.0254(3.27)}(62.6)^{0.198}, \text{ and}$$

$$Q_{100,r(g)} = Q_{100} = 3{,}110 \text{ ft}^3/\text{s}.$$

The standard error of prediction for this estimate would be computed using equation 10. The row vector, x_i, in equation 10 is based on the basin characteristics and is as follows:

$$x_i = [1 \; log_{10}(22.0) \; log_{10}(4.05) \; 3.27 \; log_{10}(62.6)] \text{ or}$$

$$x_i = [1 \; 1.34 \; 0.607 \; 3.27 \; 1.80].$$

The model error variance, γ^2, obtained from table 11 is 0.0235. The $(X^{tr}\Lambda^{-1}X)^{-1}$ matrix is

$$(X^{tr}\Lambda^{-1}X)^{-1} = \begin{bmatrix} 0.060575 & -0.0051667 & -0.050248 & -0.00059817 & -0.010587 \\ -0.0051667 & 0.0013231 & -0.0013914 & 0.00010560 & 0.0019168 \\ -0.050248 & -0.0013914 & 0.10452 & -0.00036357 & -0.0050145 \\ -0.00059817 & 0.00010560 & -0.00036357 & 0.000029723 & 0.00028972 \\ -0.010587 & 0.0019168 & -0.0050145 & 0.00028972 & 0.0053530 \end{bmatrix}$$

Inserting x_i, γ^2, and $(X^t\Lambda^{-1}X)^{-1}$ into equation 10, the standard error of prediction is

$$SE_{pred} = [\gamma^2 + x_i(X^{tr}\Lambda^{-1}X)^{-1}x_i^{tr}]^{1/2}, \quad (10)$$

$$SE_{pred} = [0.0235 + 0.00117]^{1/2} \text{ or}$$

$$SE_{pred} = 0.157.$$

The standard error of prediction for the estimate in percent is then computed using equations 11 and 12

$$S_{pos} = 100(10^{SEpred}-1), \text{ and} \quad (11)$$

$$S_{neg} = 100(10^{-SEpred}-1), \quad (12)$$

or

$$S_{pos} = 100(10^{0.157}-1), \text{ and}$$

$$S_{neg} = 100(10^{-0.157}-1) = -30.3.$$

Thus, S_{pos} = 43.5 percent and S_{neg} = -30.3 percent.

The equivalent years of record for this estimate is computed using equation 13. Because the drainage area, A, used for this estimate is 22.0 mi², the standard deviation of annual events as defined for equation 13 is

$$s = e^{-(1.31 + 0.134\, log(22.0))} \text{ or}$$

$$s = 0.225.$$

The log-Pearson type III frequency factor, k_T, is 2.326 obtained from Bulletin 17B (U.S. Interagency Advisory Committee on Water Data, 1982), with the skew, g, equal to zero since this is an estimate at an ungaged site. Equation 13 is solved as follows:

$$E = \frac{s^2\left[1 + k_T g + 0.5k_T{}^2\left(1 + 0.75g^2\right)\right]}{SE_{pred}{}^2}, \quad (13)$$

$$E = \frac{(0.225)^2\left[1 + 0.5(2.326)^2\right]}{(0.157)^2} \text{ or}$$

$$E = 7.6 \text{ years.}$$

The prediction interval for this estimate can be computed using equations 14 and 15. For example, if the 90-percent confidence interval were required, the critical value from a Student's-t distribution for the appropriate confidence interval would be found using any standard statistics textbook. The value for $t_{0.05,112}$ is 1.66, and the standard error of prediction was found earlier to be 0.157. Equation 14 is solved as follows:

$$V = 10^{\left(t_{\alpha/2,n-p} SE_{pred}\right)}, \quad (14)$$

$V = 10^{(1.66*0.157)}$, and

$V = 1.82$.

Therefore, the 90-percent prediction interval is

$$(1/V)Q_{pred} < Q_{true} < (V)Q_{pred}, \quad (15)$$

$(1/1.82)3{,}110 < Q_{true} < (1.82)3{,}110$ or

1,710 $ft^3/s < Q_{true} <$ 5,660 ft^3/s.

If the regression equation estimate of the 100-year discharge shown above was made for a streamgage location having 10 years of record, a weighted average, $Q_{100,w}$, of the regression estimate and the 100-year discharge estimate from a frequency analysis of the 10 years of record can be computed. If the 100-year discharge determined from the streamgage data, $Q_{100,s}$, is 3,700 ft^3/s, then the weighted average can be computed using equation 16.

$$log_{10} Q_{T,w} = \frac{(N) log_{10} Q_{T,s} + (E) log_{10} Q_{T,r(g)}}{N + E}, \quad (16)$$

$$log_{10} Q_{100,w} = \frac{(10)(log_{10} 3{,}700) + (7.6)(log_{10} 3{,}100)}{10 + 7.6}, \text{ and}$$

$Q_{100,w} =$ 3,430 ft^3/s.

If a flood discharge estimate is required at an ungaged site near a streamgage, a weighted estimate, $Q_{100,u}$, of the regression equation result and the flood discharge for the streamgage can be made using equations 17, 18, and 19. Continuing with the same example data, assume that a 100-year discharge estimate is required at a location downstream from a streamgage with a drainage area of 30 mi^2. At this ungaged site, assume that the mean annual April precipitation is 4.00 in., the percent of wetlands is 3.40 percent, and the main channel slope is 59.0 ft per mile. Using the regression equation for estimating a 100-year discharge,

$$Q_{100} = 7.13 A^{0.867} P^{1.98} 10^{-0.0254(W)} S^{0.198}, \quad (8)$$

$Q_{100} = 7.13(30.0)^{0.867}(4.00)^{1.98}10^{-0.0254(3.40)}(59.0)^{0.198}$, and

$Q_{100,r(u)} = Q_{100} =$ 3,890 ft^3/s.

With the data obtained, the slope of the regression line, m, between streamgage and the ungaged site can be determined from equation 17.

$$m = \frac{log_{10}\left(Q_{T,r(u)} / Q_{T,r(g)}\right)}{log_{10}\left(A_u / A_g\right)}, \quad (17)$$

$$m = \frac{log_{10}(3{,}890 / 3{,}110)}{log_{10}(30.0 / 22.0)}, \text{ and}$$

$m = 0.722$.

Then the slope of the line that passes through the best estimate for the streamgage and intersects the regression line with slope m at a point with a drainage area of 150 percent of the streamgage drainage area is determined from equation 18.

$$c = m + \frac{log_{10}\left(Q_{T,r(g)} / Q_{T,w}\right)}{log_{10}(a)}, \quad (18)$$

$$c = 0.722 + \frac{log_{10}(3{,}110 / 3{,}430)}{log_{10}(1.5)}, \text{ and}$$

$c = 0.480$.

This slope (0.480) is then used to adjust the estimate of the 100-year discharge for the streamgage, $Q_{100,w} =$ 3,430 ft^3/s in this example, to obtain the estimate for the ungaged site with a drainage area of 30 mi^2 using equation 19.

$$Q_{T,u} = Q_{T,w}\left[\frac{A_u}{A_g}\right]^c, \quad (19)$$

$$Q_{100,u} = 3{,}430\left[\frac{30.0}{22.0}\right]^{0.480}, \text{ and}$$

$Q_{100,u} =$ 3,980 ft^3/s.

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