Prepared in cooperation with the
New Jersey Department of Environmental Protection and the U.S. Army Corps of Engineers

Methodology for Estimation of Flood Magnitude and Frequency for New Jersey Streams

Scientific Investigations Report 2009–5167

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Cover. Photo on cover shows the April 2007 flood event at the U.S. Geological Survey streamflow-gaging station 01378500, Hackensack River at New Milford, New Jersey. (Photograph by Blaine T. White, U.S. Geological Survey)

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By Kara M. Watson and Robert D. Schopp

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

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Conversion Factors 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 mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

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

Abbreviations used in this report

DA, drainage area
DEM, digital elevation model
FEMA, Federal Emergency Management Agency
GIS, geographic information system
GLS, generalized least squares
GP, Glaciated Piedmont flood-frequency region
HUC14, Hydrologic Unit Code-14 digit
IACWD, Interagency Advisory Committee on Water Data
IN, Inner Coastal Plain flood-frequency region
MSE, mean-squared error
NHD, National Hydrography Dataset
NJDEP, New Jersey Department of Environmental Protection
NLCD, National Land Cover Data
OC, Outer Coastal Plain flood-frequency region
OLS, ordinary least squares
PopDen, population density
UP, Unglaciated Piedmont flood-frequency region
USACE, U.S. Army Corps of Engineers
USGS, U.S. Geological Survey
VR, Valley and Ridge, New England flood-frequency region

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Methodology for Estimation of Flood Magnitude and Frequency for New Jersey Streams

By Kara M. Watson and Robert D. Schopp

Abstract

Methodologies were developed for estimating flood magnitudes at the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for unregulated or slightly regulated streams in New Jersey. Regression equations that incorporate basin characteristics were developed to estimate flood magnitude and frequency for streams throughout the State by use of a generalized least squares regression analysis. Relations between flood-frequency estimates based on streamflow-gaging-station discharge and basin characteristics were determined by multiple regression analysis, and weighted by effective years of record. The State was divided into five hydrologically similar regions to refine the regression equations. The regression analysis indicated that flood discharge, as determined by the streamflow-gaging-station annual peak flows, is related to the drainage area, main channel slope, percentage of lake and wetland areas in the basin, population density, and the flood-frequency region, at the 95-percent confidence level. The standard errors of estimate for the various recurrence-interval floods ranged from 49 to 63.9 percent.

Annual-maximum peak flows observed at streamflow-gaging stations through water year[1] 2007 and basin characteristics determined using geographic information system techniques for 254 streamflow-gaging stations were used for the regression analysis. Drainage areas of the streamflow-gaging stations range from 0.18 to 779 mi^2. Peak-flow data and basin characteristics for 191 streamflow-gaging stations located in New Jersey were used, along with peak-flow data for stations located in adjoining States, including 25 stations in Pennsylvania, 17 stations in New York, 16 stations in Delaware, and 5 stations in Maryland. Streamflow records for selected stations outside of New Jersey were included in the present study because hydrologic, physiographic, and geologic boundaries commonly extend beyond political boundaries.

The StreamStats Web application was developed cooperatively by the U.S. Geological Survey and the Environmental Systems Research Institute, Inc., and was designed for national implementation. This web application has been recently implemented for use in New Jersey. This program used in conjunction with a geographic information system provides the computation of values for selected basin characteristics, estimates of flood magnitudes and frequencies, and statistics for stream locations in New Jersey chosen by the user, whether the site is gaged or ungaged.

Introduction

The size and number of urban and suburban areas in New Jersey are increasing. The U.S. Bureau of the Census reported in the 2000 Census that the population density of New Jersey was 1,134 persons per square mile (U.S. Census Bureau, 2008), making New Jersey the most densely populated State in the United States. In New Jersey, housing developments, office parks, and industrial complexes are rapidly replacing farms and woodlands, especially in the northern part of the State. Careful planning for future development is needed to ensure that land use does not adversely affect water resources of the State.

Increasing development and the subsequent reduction of open land have led to increased pressure to develop flood-prone areas. An attempt to manage this encroachment into flood-prone areas can be made through careful planning and zoning. Storm sewers, detention basins, and drainage structures can be designed for these areas at a relatively minimal expense if the information about flood characteristics is available.

Urbanization tends to increase the amount of impervious cover, which can increase surface-water runoff volume, as well as instantaneous peak streamflows. The amounts of curbs, gutters, and storm sewers that accompany urbanization have the potential to change the surface-water runoff patterns from a basin by increasing the rate of runoff. Reasonably accurate methods for estimating the magnitude and frequency of peak flows expected from streams draining undeveloped rural areas are available (Lumia, 1991; Stuckey and Reed, 2000); however, because of the rapid urbanization that is occurring in New Jersey, these methods may not be adequate for use in urban areas. Therefore, methods are needed for estimating the magnitude and frequency of floods in urban areas.

The U.S. Geological Survey (USGS), in cooperation with the New Jersey Department of Environmental Protection (NJDEP) and the U.S. Army Corps of Engineers (USACE), developed peak-flow regression equations to estimate flood

[1]Water year is the 12-month period from October 1 through September 30. It is designated by the calendar year in which it ends.

magnitudes at the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for streams in New Jersey with drainage areas greater than 0.4 mi^2.

Basin characteristics exhibiting significant correlation to log-Pearson type III peak flows were weighted according to their level of correlation. Values for those characteristics were then incorporated into regional regression equations that can be used to predict peak-flow magnitude and frequency for both gaged and ungaged locations. Because the State was divided into hydrologically similar regions, the equations presented in this report allow improved estimates to be made without the regional bias of some previously developed regression equations.

The purpose of this study was to develop a method for estimating peak-flow magnitudes for various recurrence intervals in basins with varying degrees of urban and suburban development. The method was developed with four constraints.

1. Input data (for example, stream-basin characteristics) can be readily obtained.
2. Sound and basic hydrologic principles are incorporated so the method can be used with confidence and understanding.
3. Minimal subjective judgment is needed in order to obtain consistent results with various users.
4. The format is simple and practical for ease of use.

Peak-flow data and basin characteristics from 254 continuous-record streamflow-gaging stations[2] and crest-stage partial-record station[3] with 10 or more years of record, continuing through the 2007 water year for most stations, were used to develop regional regression equations to estimate flood magnitudes at selected recurrence intervals (table 1). Peak-flow data for New Jersey can be accessed from the Web site *http://nwis.waterdata.usgs.gov/nj/nwis/peak*. Of the 254 streamflow-gaging stations, 191 are located in New Jersey; 25 are in Pennsylvania, 17 in New York, 16 in Delaware, and 5 in Maryland. Those stations outside New Jersey provided peak-flow data. The streamflow-gaging stations chosen are at open-channel sites on non-tidal portions of streams where peak flow is not substantially affected by upstream reservoir operations.

Purpose and Scope

This report presents techniques for estimating flood magnitudes and frequencies for rural and urban, unregulated or slightly regulated streams in New Jersey. The development of regional regression equations through the use of multiple-regression techniques is described, and the relation of physical characteristics of drainage basins to log-Pearson type III peak flows at gaged sites within each basin is presented. Peak flows and basin characteristics for 254 streamflow-gaging stations were used to develop the equations.

This report also presents information relative to the USGS web application StreamStats, which was implemented for use in New Jersey. This program, driven by a geographic information system (GIS), provides the computation of values for selected basin characteristics and estimates of peak-flow magnitudes and frequencies for stream locations in New Jersey chosen by the user, whether the site is gaged or ungaged.

Description of the Study Area

New Jersey, located in the North Atlantic slope adjacent to the Atlantic Ocean, includes parts of four physiographic provinces: (1) the Coastal Plain, (2) the Piedmont, (3) the New England (Highlands), and (4) the Valley and Ridge (Fenneman, 1938) (fig. 1). Inasmuch as the last glacial advance covered about one-half of northern New Jersey, the Piedmont, New England (Highlands), and Valley and Ridge Provinces can be further subdivided into glaciated and unglaciated areas, as noted in figure 1. Because of the nature of surface and near-surface geologic materials in these two areas, this subdivision represents differences great enough to affect streamflow. In addition, the Piedmont and Coastal Plain physiographic provinces are separated by the western limit of the Coastal Plain sediments, or the Fall Line.

The Fall Line is a low, eastward-facing, largely buried cliff extending more or less parallel to the Atlantic coastline from New Jersey to the Carolinas. The Fall Line is the western limit of the coastal sediments separating the hard Paleozoic metamorphic rocks of the Piedmont physiographic province to the west from softer, more gently dipping Mesozoic and Tertiary sedimentary rocks of the Coastal Plain to the east. This erosional scarp, in many ways, affects the behavior of streamflow due to the nature of the underlying geology. For example, whether a stream channel is steeply sloped with swift-moving waters or is more gently sloped with typically lower stream velocities is, to varying degrees, dependent on the underlying geology and streambed material.

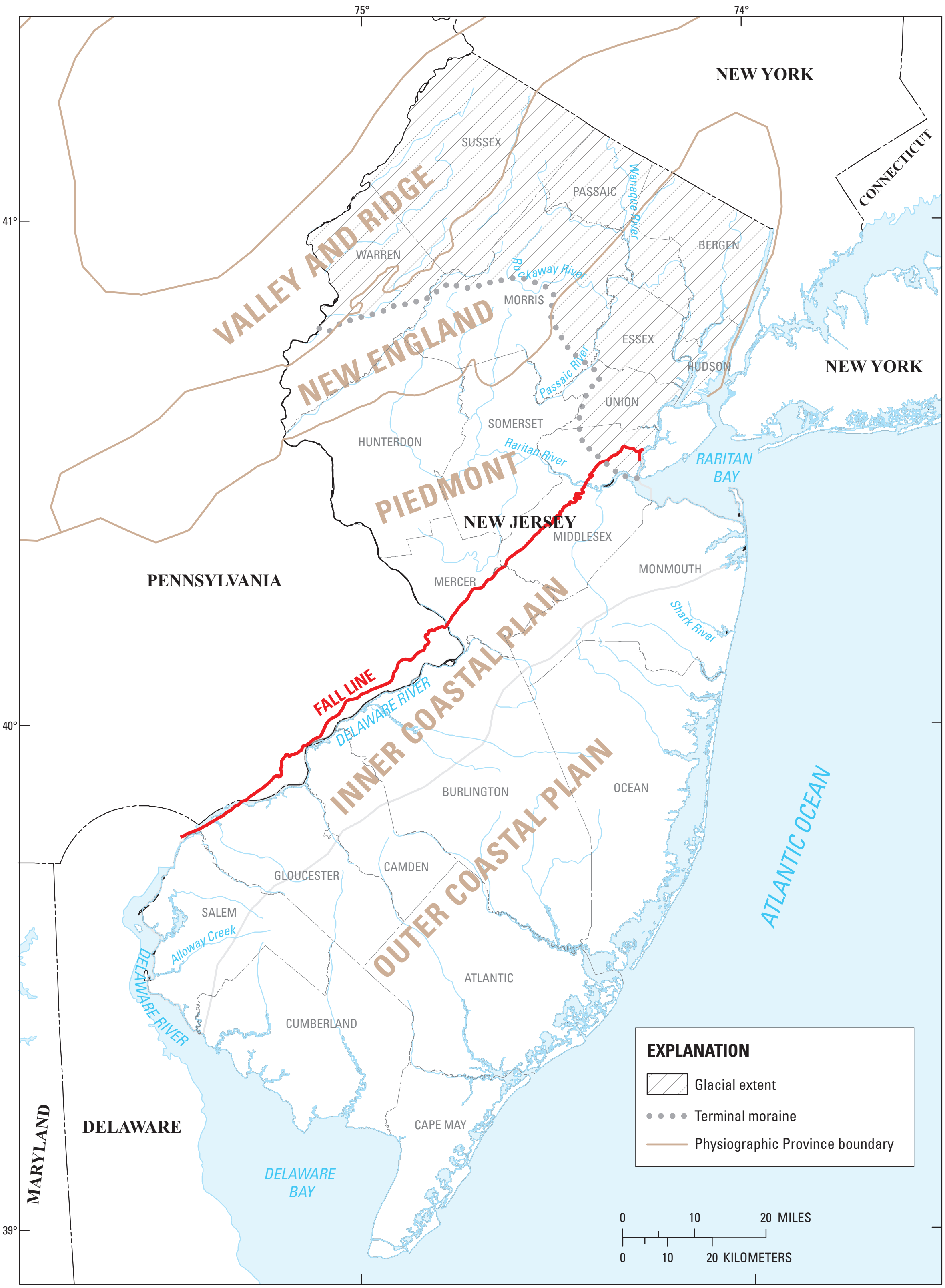
The Coastal Plain has been subdivided into an Inner and an Outer Coastal Plain. The division of the Coastal Plain roughly follows the topographic high of the underlying sediments. The Inner Coastal Plain extends from the Fall Line at the northern reach and the topographic high of the Coastal Plain to the southern reach. The extent of the Outer Coastal Plain covers the low-elevation region from the topographic high to the Atlantic Ocean.

Previous Investigations

The techniques presented in this report update techniques previously used for estimating flood magnitude and

[2]Continuous-record streamflow-gaging staion is a site on a stream or canal where observations of gage height or discharge are obtained, with sufficient frequency to define daily mean values and variations within a day.

[3]Partial-record station is a site where discrete measurements of one or more hydrologic parameters are obtained over a period of time without continuous data being recorded or computed. A common example is a crest-stage gage partial-record station, at which only peak stages and flows are recorded.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD 83

Figure 1. Study area and physiographic provinces in New Jersey and surrounding States.

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
1	01368000	Wallkill River near Unionville, NY	VR	1938–2000[2]	51	62
2	01368500	Rutgers Creek at Gardnerville, NY	VR	1944–2005[2]	41	--
3	01369000	Pochuck Creek near Pine Island, NY	VR	1938–84[2]	41	--
4	01369500	Quaker Creek at Florida, NY	VR	1938–84[2]	43	--
5	01370000	Wallkill River at Pellets Island, NY	VR	1920–93[2]	55	--
6	01370500	Wallkill River near Phillipsburg, NY	VR	1936–93[2]	29	--
7	01371000	Shawangunk Kill at Pine Bush, NY	VR	1925–92[2]	32	--
8	01373690	Woodbury Creek near Highland Mills, NY	VR	1966–84[2]	13	--
9	01374130	Canopus Creek at Oscawana Corners, NY	VR	1975–86	12	--
10	01374250	Peekskill Hollow Creek at Tompkins Corners, NY	VR	1975–2005	31	--
11	01377475	Musquapsink Brook near Westwood, NJ	GP	1977–99	22	--
12	01377490	Musquapsink Brook at Westwood, NJ	GP	1977–99	22	--
13	01377500	Pascack Brook at Westwood, NJ	GP	1934–2007	73	--
14	01378350	Tenakill Brook at Cresskill, NJ	GP	1964–78	14	--
15	01378385	Tenakill Brook at Closter, NJ	GP	1965–2007	42	--
16	01378590	Metzler Brook at Englewood, NJ	GP	1964–2007	43	--
17	01378615	Wolf Creek at Ridgefield, NJ	GP	1976–99	23	--
18	01378690	Passaic River near Bernardsville, NJ	VR	1968–2007	40	--
19	01379000	Passaic River near Millington, NJ	VR	1918–2007	89	--
20	01379500	Passaic River near Chatham, NJ	VR	1937–2007	70	--
21	01379700	Rockaway River at Berkshire Valley, NJ	VR	1936–2000[2]	13	--
22	01379773	Green Pond Brook at Picatinny Arsenal, NJ	VR	1982–2007	25	--
23	01379790	Green Pond Brook at Wharton, NJ	VR	1983–2006	24	--
24	01380500	Rockaway River above Reservoir, at Boonton, NJ	VR	1937–2006	69	--
25	01381400	Whippany River near Morristown, NJ	VR	1996–2007	12	--
26	01381500	Whippany River at Morristown, NJ	VR	1921–2007	86	--
27	01381800	Whippany River near Pine Brook, NJ	VR	1997–2007	11	--
28	01381900	Passaic River at Pine Brook, NJ	VR	1966–2007	39	--
29	01383500	Wanaque River at Awosting, NJ	VR	1918–2007	89	--
30	01384000	Wanaque River at Monks, NJ	VR	1933–85	52	--
31	01384500	Ringwood Creek near Wanaque, NJ	VR	1943–2007	64	--
32	01385000	Cupsaw Brook near Wanaque, NJ	VR	1935–58	24	--
33	01386000	West Brook near Wanaque, NJ	VR	1936–2007[2]	49	72
34	01386500	Blue Mine Brook near Wanaque, NJ	VR	1935–58	23	--
35	01387250	Ramapo River at Sloatsburg, NY	VR	1955–2000[2]	11	--
36	01387300	Stony Brook at Sloatsburg, NY	VR	1960–69	10	--
37	01387350	Nakoma Brook at Sloatsburg, NY	VR	1960–78	19	--
38	01387400	Ramapo River at Ramapo, NY	VR	1936–2005[2]	26	--
39	01387410	Torne Brook at Ramapo, NY	VR	1960–2002	43	--
40	01387420	Ramapo River at Suffern, NY	VR	1936–2003[2]	25	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
41	01387450	Mahwah River near Suffern, NY	GP	1959–2007	47	--
42	01387500	Ramapo River near Mahwah, NJ	VR	1911–2007	96	103
43	01387880	Pond Brook at Oakland, NJ	VR	1972–2007	35	--
44	01388000	Ramapo River at Pompton Lakes, NJ	VR	1921–2006	85	--
45	01388500	Pompton River at Pompton Plains, NJ	VR	1940–2007	67	103
46	01389030	Preakness Brook near Preakness, NJ	GP	1979–2007	29	--
47	01389500	Passaic River at Little Falls, NJ	VR	1898–2007	109	197
48	01389534	Peckman River at Ozone Avenue, at Verona, NJ	GP	1978–2007	29	61
49	01389765	Molly Ann Brook at North Haledon, NJ	GP	1978–2007	29	62
50	01389900	Fleischer Brook at Market Street, at Elmwood Park, NJ	GP	1968–2007	39	--
51	01390450	Saddle River at Upper Saddle River, NJ	GP	1965–2007	42	--
52	01390500	Saddle River at Ridgewood, NJ	GP	1954–2007	53	62
53	01390810	Hohokus Brook at Allendale, NJ	GP	1968–2007	39	--
54	01390900	Ramsey Brook at Allendale, NJ	GP	1974–2007	33	--
55	01391000	Hohokus Brook at Ho-Ho-Kus, NJ	GP	1953–2007	54	--
56	01391485	Sprout Brook at Rochelle Park, NJ	GP	1965–78	13	--
57	01391500	Saddle River at Lodi, NJ	GP	1966–2007	42	--
58	01392000	Weasel Brook at Clifton, NJ	GP	1969–99	30	61
59	01392170	Third River at Bloomfield, NJ	GP	1988–2007	19	--
60	01392210	Third River at Passaic, NJ	GP	1978–99	21	24
61	01392500	Second River at Belleville, NJ	GP	1937–99	59	--
62	01393450	Elizabeth River at Ursino Lake, at Elizabeth, NJ	GP	1952–2007	55	--
63	01394000	West Branch Rahway River at Millburn, NJ	GP	1985–2007	22	90
64	01394500	Rahway River near Springfield, NJ	GP	1937–2007	67	--
65	01395000	Rahway River at Rahway, NJ	GP	1921–2007	86	--
66	01396000	Robinsons Branch at Rahway, NJ	GP	1942–2007	66	69
67	01396500	South Branch Raritan River near High Bridge, NJ	VR	1919–2007	90	111
68	01396582	Spruce Run at Main Street, at Glen Gardner, NJ	VR	1979–2007	26	--
69	01396660	Mulhockaway Creek at Van Syckel, NJ	UP	1977–2007	30	--
70	01397000	South Branch Raritan River at Stanton, NJ	UP	1915–2007	92	--
71	01397500	Walnut Brook near Flemington, NJ	UP	1936–2007	71	--
72	01398000	Neshanic River at Reaville, NJ	UP	1930–2007	77	--
73	01398045	Back Brook tributary near Ringoes, NJ	UP	1978–2007	29	--
74	01398107	Holland Brook at Readington, NJ	UP	1981–2007	26	--
75	01398500	North Branch Raritan River near Far Hills, NJ	VR	1921–2007	86	88
76	01399190	Lamington (Black) River at Succasunna, NJ	VR	1988–2000	12	--
77	01399200	Lamington (Black) River near Ironia, NJ	VR	1986–2000	14	--
78	01399500	Lamington (Black) River near Pottersville, NJ	VR	1921–2007	86	--
79	01399510	Upper Cold Brook near Pottersville, NJ	VR	1974–99	25	--
80	01399525	Axle Brook near Pottersville, NJ	UP	1978–2007	29	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
81	01399670	South Branch Rockaway Creek at Whitehouse Station, NJ	UP	1977–2007	30	--
82	01399700	Rockaway Creek at Whitehouse, NJ	UP	1980–99	19	--
83	01399830	North Branch Raritan River at North Branch, NJ	UP	1979–2007	28	111
84	01400000	North Branch Raritan River near Raritan, NJ	UP	1922–2007	85	111
85	01400300	Peters Brook near Raritan, NJ	UP	1980–99	19	111
86	01400350	Macs Brook at Somerville, NJ	UP	1981–95	14	--
87	01400500	Raritan River at Manville, NJ	UP	1911–2007	96	111
88	01400630	Millstone River Southfield Road, near Grovers Mill, NJ	IN	1976–2000	24	--
89	01400730	Millstone River at Plainsboro, NJ	IN	1964–2000	36	--
90	01400775	Bear Brook at Route 535, near Locust Corner, NJ	IN	1976–2000	24	--
91	01400795	Bear Brook at Route 571, near Grovers Mill, NJ	IN	1986–2000	15	--
92	01400822	Little Bear Brook at Penns Neck, NJ	IN	1976–95	19	--
93	01400850	Woodsville Brook at Woodsville, NJ	UP	1961–80	19	--
94	01400900	Stony Brook at Glenmoore, NJ	UP	1959–99	40	--
95	01400930	Baldwins Creek at Pennington, NJ	UP	1959–2007	48	--
96	01400947	Stony Brook at Pennington, NJ	UP	1965–78	13	--
97	01400950	Hart Brook near Pennington, NJ	UP	1967–2007	39	--
98	01400960	Honey Branch near Mount Rose, NJ	UP	1968–78	10	--
99	01400970	Honey Branch near Rosedale, NJ	UP	1968–78	10	--
100	01401000	Stony Brook at Princeton, NJ	UP	1953–2007	54	--
101	01401160	Duck Pond Run near Princeton Junction, NJ	IN	1979–2000	21	--
102	01401200	Duck Pond Run at Clarksville, NJ	UP	1966–85	19	--
103	01401301	Millstone River at Carnegie Lake, at Princeton, NJ	UP	1933–2007[2]	50	84
104	01401520	Beden Brook near Hopewell, NJ	UP	1966–85	19	--
105	01401595	Rock Brook near Blawenburg, NJ	UP	1967–2007	40	--
106	01401600	Beden Brook near Rocky Hill, NJ	UP	1966–2007	40	--
107	01401650	Pike Run at Belle Mead, NJ	UP	1979–2007	28	197
108	01401870	Six Mile Run near Middlebush, NJ	UP	1967–2007	40	--
109	01402000	Millstone River at Blackwells Mills, NJ	UP	1920–2007	87	--
110	01402600	Royce Brook tributary near Belle Mead, NJ	UP	1978–2005	29	195
111	01403060	Raritan River below Calco Dam, at Bound Brook, NJ	UP	1933–2007	76	306
112	01403150	West Branch Middle Brook near Martinsville, NJ	UP	1979–2007	28	--
113	01403395	Blue Brook at Seeley Pond Dam, near Berkeley Heights, NJ	UP	1979–2007	28	110
114	01403400	Green Brook at Seeley Mills, NJ	UP	1968–2007	39	110
115	01403500	Green Brook at Plainfield, NJ	UP	1935–2007	72	--
116	01403535	East Branch Stony Brook at Best Lake, at Watchung, NJ	UP	1979–2007	28	110
117	01403540	Stony Brook at Watchung, NJ	UP	1974–2007	33	110
118	01403600	Green Brook at Rock Avenue, at Plainfield, NJ	UP	1972–2007[2]	25	110
119	01403900	Bound Brook at Middlesex, NJ	UP	1973–2007	34	--
120	01405030	Lawrence Brook at Weston Mills, NJ	UP	1989–2007	19	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
121	01405300	Matchaponix Brook at Spotswood, NJ	IN	1956–67	11	--
122	01405400	Manalapan Brook at Spotswood, NJ	IN	1956–2007	51	--
123	01405500	South River at Old Bridge NJ	IN	1940–88	49	--
124	01407000	Matawan Creek at Matawan, NJ	IN	1933–55	22	--
125	01407290	Big Brook near Marlboro, NJ	IN	1980–2007	28	--
126	01407500	Swimming River near Red Bank, NJ	IN	1922–2007	85	87
127	01407705	Shark River near Neptune City, NJ	OC	1966–2007	41	--
128	01407760	Jumping Brook near Neptune City, NJ	OC	1966–2007	41	--
129	01407830	Manasquan River near Georgia, NJ	OC	1968–95	27	--
130	01408000	Manasquan River at Squankum, NJ	OC	1931–2007	76	--
131	01408015	Mingamahone Brook at Farmingdale, NJ	OC	1968–2007	39	--
132	01408029	Manasquan River near Allenwood, NJ	OC	1969–2007	39	--
133	01408120	North Branch Metedeconk River near Lakewood, NJ	OC	1972–2007	35	--
134	01408500	Toms River near Toms River, NJ	OC	1928–2007	79	--
135	01409000	Cedar Creek at Lanoka Harbor, NJ	OC	1968–2007	39	--
136	01409095	Oyster Creek near Brookville, NJ	OC	1965–85	20	26
137	01409280	Westecunk Creek at Stafford Forge, NJ	OC	1985–2007	22	--
138	01409375	Mullica River near Atco, NJ	OC	1985–99	14	25
139	01409400	Mullica River near Batsto, NJ	OC	1957–2007	50	--
140	01409403	Wildcat Branch at Chesilhurst, NJ	OC	1974–87	13	--
141	01409500	Batsto River at Batsto, NJ	OC	1927–2005	78	--
142	01409810	West Branch Wading River near Jenkins, NJ	OC	1975–2007[2]	25	--
143	01410000	Oswego River at Harrisville, NJ	OC	1930–2007	77	--
144	01410150	East Branch Bass River near New Gretna, NJ	OC	1977–2007	30	--
145	01410810	Fourmile Branch at New Brooklyn, NJ	OC	1972–91	19	--
146	01411000	Great Egg Harbor River at Folsom, NJ	OC	1925–2007	82	--
147	01411120	Deep Run at US Route 40, at Buena, NJ	OC	1997–2007	11	--
148	01411122	Little Deep Run at NJ Route 54, at Landisville, NJ	OC	1997–2007	11	--
149	01411300	Tuckahoe River at Head of River, NJ	OC	1970–2007	37	--
150	01411456	Little Ease Run near Clayton, NJ	OC	1988–2007	20	--
151	01411500	Maurice River at Norma, NJ	OC	1932–2007	75	140
152	01412000	Menantico Creek near Millville, NJ	OC	1951–95	44	--
153	01412500	West Branch Cohansey River at Seeley, NJ	OC	1953–2007	54	--
154	01412800	Cohansey River at Seeley, NJ	OC	1985–2007	22	--
155	01440000	Flat Brook near Flatbrookville, NJ	VR	1923–2007	84	--
156	01443280	East Branch Paulins Kill near Lafayette, NJ	VR	1993–2007	15	--
157	01443500	Paulins Kill at Blairstown, NJ	VR	1923–2007	84	--
158	01445000	Pequest River at Huntsville, NJ	VR	1945–2007	63	--
159	01445430	Pequest River at Townsbury, NJ	VR	1977–93	16	--
160	01445490	Furnace Brook at Oxford, NJ	VR	1965–78	13	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
161	01445500	Pequest River at Pequest, NJ	VR	1951–2007	56	--
162	01446000	Beaver Brook near Belvidere, NJ	VR	1929–2007	78	--
163	01446564	Lapahannock Creek at Ridge Road, at Roxburg, NJ	VR	1995–2006	12	--
164	01446600	Martins Creek near East Bangor, PA	VR	1961–86	26	--
165	01451500	Little Lehigh Creek near Allentown, PA	VR	1935–2005[2]	60	--
166	01452500	Monocacy Creek at Bethlehem, PA	VR	1945–2005	57	--
167	01455200	Pohatcong Creek at New Village, NJ	VR	1962–2000	38	--
168	01456000	Musconetcong River near Hackettstown, NJ	VR	1925–2000	75	--
169	01457000	Musconetcong River near Bloomsbury, NJ	VR	1918–2007	89	--
170	01459010	Delaware River tributary at Byram, NJ	UP	1945–2007[2]	14	63
171	01459500	Tohickon Creek near Pipersville, PA	UP	1936–2005[2]	40	--
172	01462197	Moores Creek tributary at Valley Road, near Lambertville, NJ	UP	1995–2007	13	--
173	01463620	Assunpink Creek near Clarksville, NJ	IN	1982–2007	25	--
174	01463812	Shabakunk Creek trib at Texas Avenue, near Lawrenceville, NJ	UP	1995–2007	13	--
175	01464000	Assunpink Creek at Trenton, NJ	UP	1924–2007[2]	42	125
176	01464400	Crosswicks Creek at New Egypt, NJ	OC	1968–94	26	--
177	01464405	Stony Ford Brook at New Egypt, NJ	OC	1978–2007[2]	14	--
178	01464500	Crosswicks Creek at Extonville, NJ	IN	1940–2007	67	69
179	01464515	Doctors Creek at Allentown, NJ	IN	1968–95	27	--
180	01464520	Doctors Creek at Groveville, NJ	IN	1967–79	12	--
181	01464524	Crosswicks Creek trib 3 at US Route 206, near Bordentown, NJ	IN	1995–2007	13	--
182	01464525	Thorton Creek at Bordentown, NJ	IN	1995–2007	13	--
183	01464530	Blacks Creek at Mansfield Square, NJ	IN	1977–95	18	--
184	01464533	Crafts Creek at NJ Route 68, at Georgetown, NJ	IN	1995–2007	13	--
185	01464538	Crafts Creek at Columbus, NJ	IN	1977–2007	30	--
186	01464582	Assiscunk Creek near Columbus, NJ	IN	1978–95	17	--
187	01465000	Neshaminy Creek at Rushland, PA	UP	1885–1934[2]	32	--
188	01465500	Neshaminy Creek near Langhorne, PA	UP	1933–2005	71	--
189	01465785	Walton Run at Philadelphia, PA	UP	1965–78	14	--
190	01465790	Byberry Creek at Chalfont Road, Philadelphia, PA	UP	1966–78	13	--
191	01465798	Poquessing Creek at Grant Avenue, at Philadelphia, PA	UP	1966–2005	40	--
192	01465850	South Branch Rancocas Creek at Vincentown, NJ	IN	1965–2007	42	68
193	01465880	Southwest Branch Rancocas Creek at Medford, NJ	IN	1990–2007	17	--
194	01466000	Middle Branch Mt Misery Brook in Byrne State Forest, NJ	OC	1953–78	25	--
195	01466500	McDonalds Branch in Byrne State Forest, NJ	OC	1953–2007	54	--
196	01467000	North Branch Rancocas Creek at Pemberton, NJ	IN	1921–2007	86	--
197	01467042	Pennypack Creek at Pine Road, at Philadelphia, PA	UP	1965–81	17	--
198	01467048	Pennypack Creek at Lower Rhawn St. Brg., Philadelphia, PA	UP	1966–2005	40	--
199	01467057	Pompeston Creek at Cinnaminson, NJ	IN	1974–88	14	--
200	01467069	North Branch Pennsauken Creek near Moorestown, NJ	IN	1974–88	14	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
201	01467081	South Branch Pennsauken Creek at Cherry Hill, NJ	IN	1968–2007	39	--
202	01467086	Tacony Creek at County Line, Philadelphia, PA	UP	1966–86	21	--
203	01467087	Frankford Creek at Castor Avenue, Philadelphia, PA	UP	1982–2005	24	--
204	01467130	Cooper River at Kirkwood, NJ	IN	1964–2004[2]	17	64
205	01467150	Cooper River at Haddonfield, NJ	IN	1963–2007	44	67
206	01467160	North Branch Cooper River near Marlton, NJ	IN	1978–2004	26	64
207	01467305	Newton Creek at Collingswood, NJ	IN	1964–2007	43	--
208	01467317	South Branch Newton Creek at Haddon Heights, NJ	IN	1963–2007	44	--
209	01467330	South Branch Big Timber Creek at Blackwood, NJ	IN	1963–84	21	--
210	01467351	North Branch Big Timber Creek, Laurel Road, Laurel Springs, NJ	IN	1974–88	14	--
211	01472198	Perkiomen Creek at East Greenville, PA	VR	1982–2005	24	--
212	01472199	West Branch Perkiomen Creek at Hillegass, PA	VR	1982–2005	24	--
213	01472500	Perkiomen Creek near Frederick, PA	UP	1885–1913	29	--
214	01473000	Perkiomen Creek at Graterford, PA	UP	1915–2005	91	--
215	01473120	Skippack Creek near Collegeville, PA	UP	1966–94	29	--
216	01475000	Mantua Creek at Pitman, NJ	IN	1948–2007	59	124
217	01475017	Bees Branch at Hurffville, NJ	IN	1997–2007	11	--
218	01475019	Mantua Creek at Salina, NJ	IN	1974–88	14	--
219	01475033	Plank Run at Glassboro, NJ	IN	1997–2007	11	--
220	01475300	Darby Creek at Waterloo Mills, near Devon, PA	UP	1972–99	26	--
221	01475510	Darby Creek near Darby, PA	UP	1964–90	27	--
222	01475530	Cobbs Creek at US Highway No 1, at Philadelphia, PA	UP	1965–2005[2]	18	--
223	01475550	Cobbs Creek at Darby, PA	UP	1964–90	27	--
224	01475850	Crum Creek near Newtown Square, PA	UP	1977–2005	29	--
225	01476500	Ridley Creek at Moylan, PA	UP	1932–85[2]	31	--
226	01477000	Chester Creek near Chester, PA	UP	1932–2005	74	--
227	01477102	Miery Run near Ewan, NJ	IN	1997–2007	11	--
228	01477110	Raccoon Creek at Mullica Hill, NJ	IN	1980–99	19	118
229	01477120	Raccoon Creek near Swedesboro, NJ	IN	1966–2007	41	--
230	01477480	Oldmans Creek near Harrisonville, NJ	IN	1974–95	21	--
231	01477500	Oldmans Creek near Woodstown, NJ	IN	1932–1967[2]	10	84
232	01477800	Shellpot Creek at Wilmington, DE	UP	1945–2004	59	--
233	01478000	Christina River at Coochs Bridge, DE	UP	1943–2003	61	--
234	01478040	Christina River near Bear, DE	UP	1979–91	12	--
235	01482310	Doll Run at Red Lion, DE	IN	1966–75	10	--
236	01482500	Salem River at Woodstown, NJ	IN	1946–2007	61	124
237	01483000	Alloway Creek at Alloway, NJ	IN	1952–72	20	--
238	01483200	Blackbird Creek at Blackbird, DE	IN	1952–2004	52	--
239	01483290	Paw Paw Branch tributary near Clayton, DE	IN	1966–75	10	--
240	01483400	Sawmill Branch tributary near Blackbird, DE	IN	1966–75	10	--

Table 1. Streamflow-gaging stations in New Jersey and surrounding States for which streamflow statistics were computed.—Continued

[ID, identifier; USGS, U.S. Geological Survey; GP, Glaciated portion of Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated portion of Piedmont flood-frequency region; VR, Valley and Ridge and New England (Highlands) flood-frequency region; Ne, the effective number of years of gaged peak-flow record ; Hst. period, years specified for historic data adjustment]

Map ID	USGS station number	Name	Flood-frequency region	Peak-flow record[1]	N_e	Hst. period
241	01483500	Leipsic River near Cheswold, DE	IN	1943–75	33	--
242	01483700	St. Jones River at Dover, DE	IN	1958–2004	47	--
243	01483720	Puncheon Branch at Dover, DE	IN	1966–75	10	--
244	01484000	Murderkill River near Felton, DE	IN	1932–99[2]	31	--
245	01484002	Murderkill River tributary near Felton, DE	IN	1966–75	10	--
246	01484050	Pratt Branch near Felton, DE	IN	1966–75	10	--
247	01488500	Marshyhope Creek near Adamsville, DE	IN	1943–2005[2]	59	--
248	01489000	Faulkner Branch at Federalsburg, MD	IN	1950–91	42	--
249	01490600	Meredith Branch near Sandtown, DE	IN	1966–75	10	--
250	01490800	Oldtown Branch at Goldsboro, MD	IN	1967–76	10	--
251	01491000	Choptank River near Greensboro, MD	IN	1948–2005	58	--
252	01491010	Sangston Prong near Whiteleysburg, DE	IN	1966–75	10	--
253	01491050	Spring Branch near Greensboro, MD	IN	1967–76	10	--
254	01495000	Big Elk Creek at Elk Mills, MD	UP	1884–2004[2]	73	--

[1] Peak-flow record is given in water years, the 12-month period from October 1 through September 30, with the water year designated by the calendar year in which it ends.

[2] Years given for the peak-flow record may have gaps as a result of a gage being discontinued for a number of years due to loss of funding.

frequency. Thomas (1964) presented a peak-flow magnitude and frequency estimating procedure based on the flood-index method outlined by Dalrymple (1960). Later analyses by the same method resulted in the estimating procedure presented by Tice (1968). McCall and Lendo (1970) used a multiple-regression method to develop yet another estimating technique. Stankowski (1972) related population density in New Jersey to the percentage of drainage areas occupied by manmade impervious surface cover in order to simplify the estimation of manmade impervious surface cover under future or past conditions. Stankowski (1974) developed a set of equations based on regression techniques that were intended for use throughout the State. Drainage area, percentage of lakes and wetland (storage), channel slope, and percentage of manmade impervious surface cover are basin characteristics input to these regression equations. These equations, presented in NJDEP Special Report 38 (Stankowski, 1974), are the most recent equations for estimating flood magnitude in New Jersey prior to the present study.

Methods of Study

The publication "Guidelines for Determining Flood Flow Frequency, Bulletin 17B" (Interagency Advisory Committee on Water Data, 1982), first published as "A Uniform Technique for Determining Flood Flow Frequencies, Bulletin 15" (Water Resources Council, 1967), provides recommendations for the computation of peak-flow frequency estimates, which are based on measurements of peak-flow data at unregulated streamflow-gaging stations.

An estimation of flood magnitude and frequency for a specific location can be developed by analyzing the annual peak flows at a streamflow-gaging station. Typically, these estimates are reported in terms of exceedance probability, or they may be presented in terms of recurrence intervals, for example the 100-year flood. Exceedance probability is defined as the probability of exceeding a specified flow within a 1-year period and is usually expressed as a fraction less than 1.0. It can also be expressed as a percentage less than 100, the reciprocal of recurrence interval. Recurrence interval is the average interval of time, in years, within which annual maximum flood peaks were greater than a particular value. For example, a peak streamflow at the 100-year recurrence interval would be expected to be exceeded, on average, once every 100 years. However, the 100-year flood may occur more frequently and, indeed, may occur more than once in a single year. The designation "100-year flood" does not mean that peak flow will occur only once every 100 years; it is a probability of occurrence, not a certainty. The 100-year flood means a recurrence interval of 100 years has an annual exceedance probability of 0.01 (1 percent), hence the definition that there is a 1 percent chance the peak flow will be exceeded in any given year.

Different procedures are used to estimate flood magnitude and frequency at streamflow-gaging stations and at ungaged sites along a stream. Estimates for streamflow-gaging stations were made using log-Pearson type III statistics. The general procedure used to determine flood-frequency estimates for ungaged sites follows 10 steps. Details of each step are discussed farther on in the report.

1. A group of continuous-record streamflow-gaging stations and crest-stage gages with 10 or more years of annual peak-flow data, located on unregulated or slightly flow-regulated non-tidal streams within New Jersey and surrounding States, is selected.

2. The initial log-Pearson type III flood-frequency estimates are computed (for each of the previously selected stations) by weighting the respective station skew with generalized-skew values taken from "Guidelines For Determining Flood Flow Frequency" (Bulletin 17B) by the Interagency Advisory Committee on Water Data (1982). The log-Pearson type III estimates of flow at specific frequencies for the streamflow-gaging stations in New Jersey are computed by inputting annual maximum flood-peak flows measured at streamflow-gaging stations to the USGS computer program PeakFQ. The PeakFQ program and associated documentation can be downloaded from the Web at *http://water.usgs.gov/software/PeakFQ/*.

3. A trend analysis is conducted to identify streamflow-gaging stations with streamflow records that would require additional review and to determine whether the station should be included in the analysis or if the period of record for the station needed to be adjusted because of hydraulic modification in the drainage basin, such as channel modification or an addition of an upstream reservoir.

4. The initial station-skew coefficients are analyzed to determine new generalized-skew values for the regions. Skew analysis was run on a subset of 119 streamflow-gaging stations from the flood-frequency study.

5. The flood-frequency estimates for the streamflow-gaging stations are re-computed by weighting the station skew with the new generalized-skew values, using the PeakFQ computer program.

6. Values for physical basin characteristics are computed to quantify their relation to annual peak streamflow for the drainage basin associated with each streamflow-gaging station.

7. Regression analysis is used to develop equations for use in estimating flood frequencies and magnitudes at ungaged sites in the State or regions.

8. Flood-frequency estimates and basin characteristics are analyzed to determine whether relations are homogenous throughout the State or if the State should be divided into multiple regions.

9. The accuracy of the regression equations developed is assessed for estimating flood magnitudes and frequencies for ungaged sites.

Use of these steps results in the selection of peak-flow data and basin characteristics from 254 continuous-record streamflow-gaging stations and crest-stage gages in New Jersey and surrounding States for use in the flood-frequency analysis. The State was divided into five regions for this flood-frequency analysis.

Peak-Flow Data

The streamflow data forming the basis of the current study are the records of annual maximum flood-peak flows measured for a group of USGS streamflow-gaging stations and crest-stage gages located throughout New Jersey, plus records for selected sites in the adjoining States of New York, Pennsylvania, Delaware, and Maryland (fig. 2; table 2). Peak-flow data from surrounding states were used because political and civil boundaries ignore physiographic, geologic, and drainage-basin characteristics. The peak-flow data from surrounding States were included to better define the relations between drainage-basin characteristics and annual peak streamflow, with the expected result of more accurate regional regression equations. The drainage areas of the streamflow-gaging stations range from 0.18 to 779 mi^2. The distribution of streamflow-gaging stations used in this study relative to drainage-area size is shown in figure 3.

A number of revisions have been made to the original 1967 publication, Bulletin 15 (Water Resources Council, 1967), reflecting advances in the understanding of flood-flow frequency determination and associated techniques; Bulletin 17B is the most current publication. Among other guidelines, Bulletin 17B outlines methods and weighting techniques for the inclusion of historical annual streamflow peaks that may have been inferred from newspaper accounts, personal interviews, anecdotal evidence, or indirect measurements of discharge from past floods. Annual peak water levels considered to be reasonable on the basis of information from nearby streamflow-gaging stations have been included in the annual peak-flow records for New Jersey and weighted accordingly. In many instances, this type of information can dramatically extend the period of record[4] used for analysis. For each station in table 1, professional judgment was used to determine whether to include the information in the computation of regional regression equations. The historical adjustment of confirmed records of annual peak streamflows can have a substantial effect on the final predicted flood-flow frequencies for a location.

Table 2. Number of streamflow-gaging stations with records included in the regression analysis of New Jersey streams, by flood-frequency region and State.

[NJ, New Jersey; PA, Pennsylvania; NY, New York; DE, Delaware; MD, Maryland]

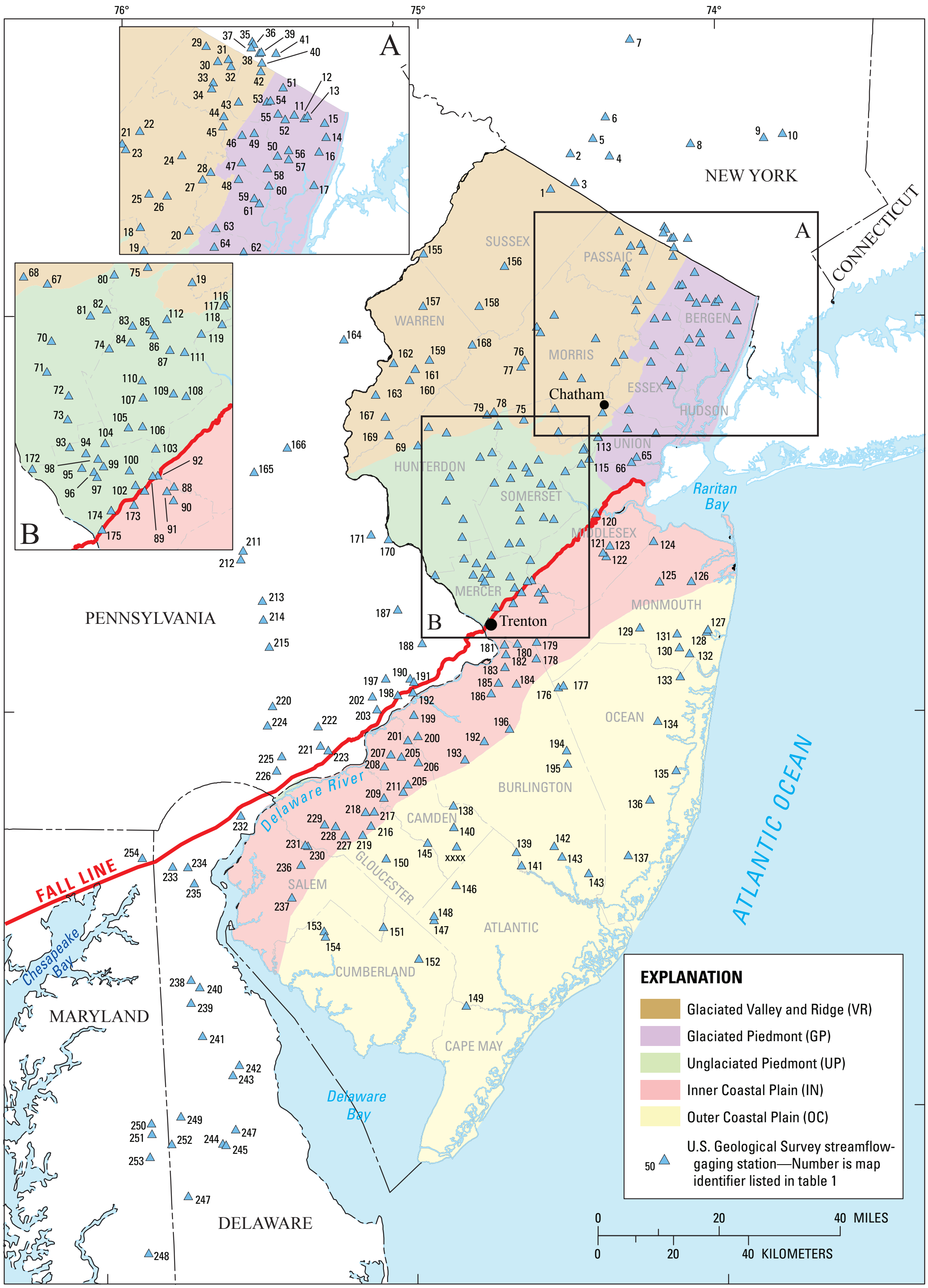
Flood-frequency region	State					Total
	NJ	PA	NY	DE	MD	
Glaciated Piedmont	27	0	1	0	0	28
Inner Coastal Plain	46	0	0	13	4	63
Outer Coastal Plain	32	0	0	0	0	32
Unglaciated Piedmont	45	20	0	3	1	69
Valley and Ridge	41	5	16	0	0	62
All	**191**	**25**	**17**	**16**	**5**	**254**

Trend Analysis

In New Jersey, unlike many more rural States, there are few watersheds that have not undergone some type of anthropogenic change. Changes such as development from woodlands and open farmland to suburban housing and shopping centers; greater industrial development; the accompanying infrastructure of roads, bridges, and water-control structures such as retention and detention basins; and the straightening and channelization of streams have occurred. In other areas, drainage basins have evolved from undeveloped woodlands to nearly clear-cut farmland, then allowed to revert to mostly forested basins. All of these changes in land use can affect peak streamflow and flood frequency. Add to this climate change in the form of global warming or the natural cyclical patterns in precipitation, or the combination of these influences, and a complex scenario emerges for developing regional regression equations for estimating flood-flow frequency.

Bulletin 17B presents guidelines for making assumptions about data, including climate trends and watershed changes. To better understand the possible effects of these changes on flood peaks, an analysis of trends was conducted for 191 streamflow-gaging stations in an attempt to identify significant trends or discontinuities. All 191 stations are located in New Jersey and New York and were considered for inclusion in the flood-frequency study, although some were not used. Streamflow-gaging stations located in Delaware, Maryland, and Pennsylvania were not included in the trend study because these stations were used in a flood-frequency analysis for Delaware/Maryland and Pennsylvania (Ries and Dillow, 2006; Roland and Stuckey, 2008). The trend analysis was conducted to identify streamflow-gaging stations that would require additional review of the annual streamflow record and to determine whether the station should be included in the study or whether the period of record to be used should be adjusted. As discussed below, four stations with significant trends were found to have discontinuities in peak flows around the time of channel modifications; the period of record used in the analysis was adjusted accordingly.

[4]The time period for which records have been published for the Station.



Base from U.S. Geological Survey digital line graph files, 1:24,000,
Universal Transverse Mercator projection, Zone 18, NAD 83

Figure 2. Location of flood-frequency regions and streamflow-gaging stations in New Jersey and surrounding States for which flood-frequency estimates were computed.

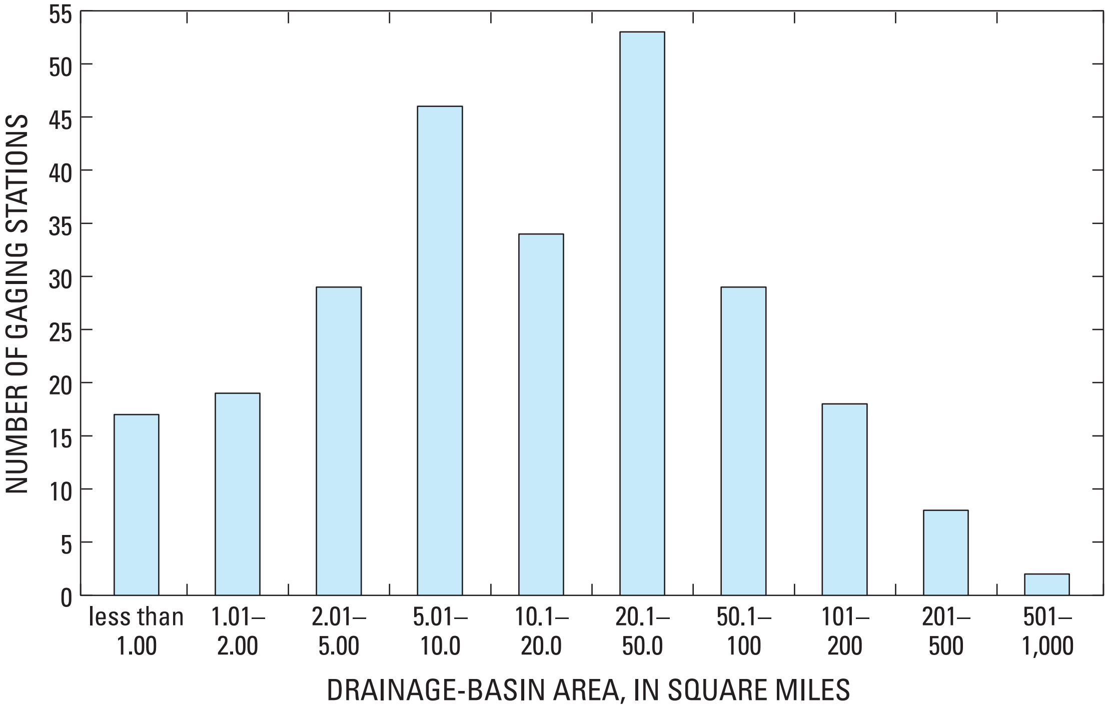


Figure 3. Distribution of streamflow-gaging stations used for the flood-frequency analysis, by drainage-basin area.

There are a number of possible reasons for trends in streamflow data:

1. increased development and the resultant increase in impervious cover;
2. hydraulic modifications as a result of the construction of reservoirs, rerouting of stormwater, or stream modifications;
3. changes to forest cover within a basin; and
4. changes in precipitation cycles as a result of both short-term (drought of the 1960s or periods of heavy rain such as the 1970s) and long-term climate changes (global warming).

An increase in impervious cover would be expected to increase peak discharge, especially for the low-recurrence-interval floods such as the 2- and 5-year floods. For high-recurrence-interval floods, such as the 100-year flood, the effect may be less significant because, with increasing precipitation, even soils in forested areas tend to become saturated and act similarly to impervious surfaces. One factor that may reduce the effect of an increase in impervious cover in New Jersey is that stormwater detention basins have been required to be included in most new developments since about 1980.

A number of water-supply reservoir systems, at locations such as the Rockaway, Wanaque, Hackensack, Pequannock, and Delaware Rivers, have been developed in New Jersey and New York over the past 100 years, and gaging stations immediately downstream from these systems were not included in the development of the regional regression equations because those stations could be subject to flow regulation. Flood-frequency estimates developed for the Federal Emergency Management Agency (FEMA) flood-insurance studies may be available for these gaging-station locations (Federal Emergency Management Agency, 1985, 1995, 2007).

Forest cover is a basin characteristic that was initially considered in the development of the flood-flow frequency regression equations but was not one of the final basin characteristics used. In general, as forest cover decreases it is expected that flood-peak flow will increase, and the opposite would occur with an increase in forest cover. Although this is what one would expect, streamflow-gaging station 01440000, Flat Brook near Flatbrookville, NJ, which is in a predominantly forested area and is considered an index station (close to natural conditions) in New Jersey for both streamflow and water quality, had a significant positive trend in annual peak flow (that is, annual peak flows increased over the station’s period of record). Because forest land has probably increased over the last 100 years, and agriculture declined when much of the watershed was purchased for inclusion in the Delaware Water Gap National Recreation Area in the late 1960s, a possible explanation would be a climate shift that increased precipitation (Lins, 2005).

In much of New Jersey, forests were clear cut for timber or for agricultural use in the late 1800s. From the early 1900s to the present, much of this land has been reforested, has remained in agriculture, or has been urbanized. For example, the watershed upstream from streamflow-gaging station 01403060, Raritan River below Calco Dam at Bound Brook, NJ, which has a drainage area of 779 mi^2, had approximately 13 percent forest cover (Vermeule, 1894) in 1894, and in 2002 forest cover was determined to be 30 percent of the basin, even with the presence of development throughout the basin.

Climate change as a result of global warming or some other factor can affect the amount of precipitation. The effect of global warming on precipitation in New Jersey is not clear. Cyclical patterns of precipitation may last 1 or 2 months, 30 years, 500 years, or tens of thousands of years. A streamflow study by Lins (2005) indicates a shift to a wet period beginning in 1940 and an abrupt shift to increasing precipitation in the northeastern United States about 1970.

Initially, plots of the annual peak flows were visually examined for monotonic trends, step trends, or some combination. Both monotonic trends and step trends were noted for some stations, warranting further analysis. SWSTAT was run to perform a Kendall's tau test (Helsel and Hirsch, 2002) for the 191 streamflow-gaging stations. The SWSTAT program and accompanying documentation can be downloaded from *http://water.usgs.gov/software/SWSTAT/*.

The Kendall's tau test is a nonparametric test that can be used to indicate the likelihood of an upward or downward trend over time. A nonparametric test is one that does not require a known or assumed probability distribution for the variables in question. The Kendall's tau test is rank-based and does not depend specifically on the magnitudes of the data values. This test is effective for identifying monotonic trends in streamflow because extreme values and skewness in the data have little effect on the outcome.

Within the Kendall's tau test, the data are first ranked. Then the rank of each peak flow is compared to the rank of peaks following it in the time series. If the second value is consistently higher than the previous value, tau is positive. If the second value is consistently lower than the previous value, tau is negative. An equal number of positive and negative values indicates that a trend does not exist. Therefore, tau is a measure of the correlation between the series and time.

A trend is considered to be significant if the probability, p (p-value is the probability that a true null hypothesis of no trend is falsely rejected), is less than or equal to 0.05 (the 95-percent confidence interval). The slope of the trend line, then, gives some measure of the magnitude of the trend.

Although the Kendall's tau test is relatively insensitive to the presence of individual outliers, a sequence of extreme occurrences near the beginning or end of the period of record could have an effect on the outcome of the test. Therefore, the record must be examined for multi-year sequences that are wetter or drier than normal at both ends of the period. The existence of a trend can be determined by the results of the Kendall's tau test. If tau is positive, there is an upward trend; if tau is negative, there is a downward trend; and if tau is zero, no trend exists. Likewise, a small p-value indicates a rare event, and a large slope value indicates a trend of greater magnitude than that of a small slope.

The results of the trend analysis for New Jersey and New York streamflow-gaging-station annual peak-flow data show that, at a significance level of 95 percent, 35 stations have significant trends. Of these, 31 have positive trends, and 4 have negative trends. Each of the annual peak-flow series was plotted, and the results were studied. Four of the identified stations—01391500 Saddle River at Lodi, NJ; 01392500, Second River at Belleville, NJ; 01393450, Elizabeth River at Ursino Lake, at Elizabeth, NJ; and 01445500, Pequest River at Pequest, NJ—showed significant discontinuities in years when substantial changes in channel geometry are believed to have occurred in the basins. Data from these four stations were reanalyzed with an adjusted period of record using only those peaks following the discontinuity before the stations were included in the flood-frequency study.

The remaining 31 stations that showed significant trends were reviewed, but no obvious hydraulic modification in the basin could be identified that would justify adjusting the period of record or removing the stations from the analysis. It was noted that 22 of the 31 stations showed a jump in peak flows around 1970. This abrupt increase in peak flows is consistent with the findings of Lins (2005) for portions of the United States, including the Mid-Atlantic Region. This jump may be indicative of a climate change. The remaining nine stations had generally short records or were located in the southern part of the State. It was decided by the authors that in the absence of a specific reason, such as a channel modification or an upstream reservoir, for not including a gaging station or for adjusting the record used in the analysis, the full record of the station would be used in the analysis even if there was a significant trend. To attribute a cause and effect to each trend was beyond the scope of this study. In addition, some of the stations with significant trends were those that experienced what the authors considered to be very little change in basin characteristics over the period of record.

Generalized Skew Coefficients

The methodology used in this study to compute streamflow for various recurrence intervals, as specified in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982), includes a weighting of the station skew coefficient with the generalized skew coefficient. A national map with isolines of generalized skew values was published in the Bulletin 17B guidelines. Since that publication, other studies have shown that the generalized skew values for New Jersey were overestimated by Bulletin 17B (for example, U.S. Army Corps of Engineers, 1983). Consequently, the generalized skew values for New Jersey were recomputed as part of the current study in an effort to improve streamflow estimates.

Bulletin 17B provides several guidelines for computing generalized skew, including the following:

- Any streamflow-gaging stations used for the study must have at least 25 years of systematic record, data routinely collected over a number of years;

- At least 40 stations, or all stations within a 100-mile radius of the study area, are used in the analysis;
- For each station used in the analysis, the station skew is plotted at the centroid of the station basin and contoured to determine whether any topographic or geographic trends are apparent;
- A prediction equation, developed through linear-regression techniques, is developed to relate the computed skew coefficients to watershed and climatic variables;
- The arithmetic mean of the station skews at a minimum of 20 stations in an area of homogeneous hydrology is computed; and
- The results from the method that provides the most accurate estimate of the skew coefficient, based on minimization of the mean-square error of computed skews, is used for the final computation.

For the current study, the State was partitioned into two regions, Coastal Plain and non-Coastal Plain, on the basis of differences in geology, topography, and typical hydrologic response to storms (fig. 4). The Fall Line provides the division between the two regions. From the data set of 254 streamflow-gaging stations analyzed for the peak-flow frequency study, 119 stations had 25 or more years of record and were used for the skew study. A list of the 119 streamflow-gaging stations used and the results of the skew study are presented in Appendix 1.

The centroid of the drainage basin for each streamflow-gaging station was determined and plotted with the station skew value. Isolines were created using the value of the station skew at each of the station centroids. The isolines were examined for patterns, but no discernible patterns were evident. The mean and variance of the station skew were computed for each of the regions, and those results were used for the generalized skew and variance values.

The generalized skew is the average unbiased station skew from all stations with 25 or more years of record within each region. A bias-correction equation based on record length (years) is presented by Tasker and Stedinger (1986) as:

$$\hat{g}_i = \left[1 + \left(\frac{6}{N_i}\right)\right] * G_i \,, \qquad (1)$$

where

$\hat{g}_i$ is the unbiased station skew,
N_i is the number of years of record for the streamflow-gaging station, and
G_i is the station skew coefficient.

This correction factor takes the number of years of record for the station into account and creates an unbiased skew value for the station. The average of the unbiased station skews for the Coastal Plain and non-Coastal Plain regions is then computed, producing the generalized skew for each region. To determine the mean-square error (*MSE*) of the generalized skew, the difference between the unbiased station skew and the generalized skew for each station was computed, and the differences were averaged. The Bulletin 17B map skew *MSE* was compared with that of the generalized skew to determine the method that provides the most accurate estimate of the skew coefficient, based on minimization of the mean-square error of computed skews. The generalized skew *MSE* for both regions was lower; therefore, it was determined the generalized skew would be used for the final computation.

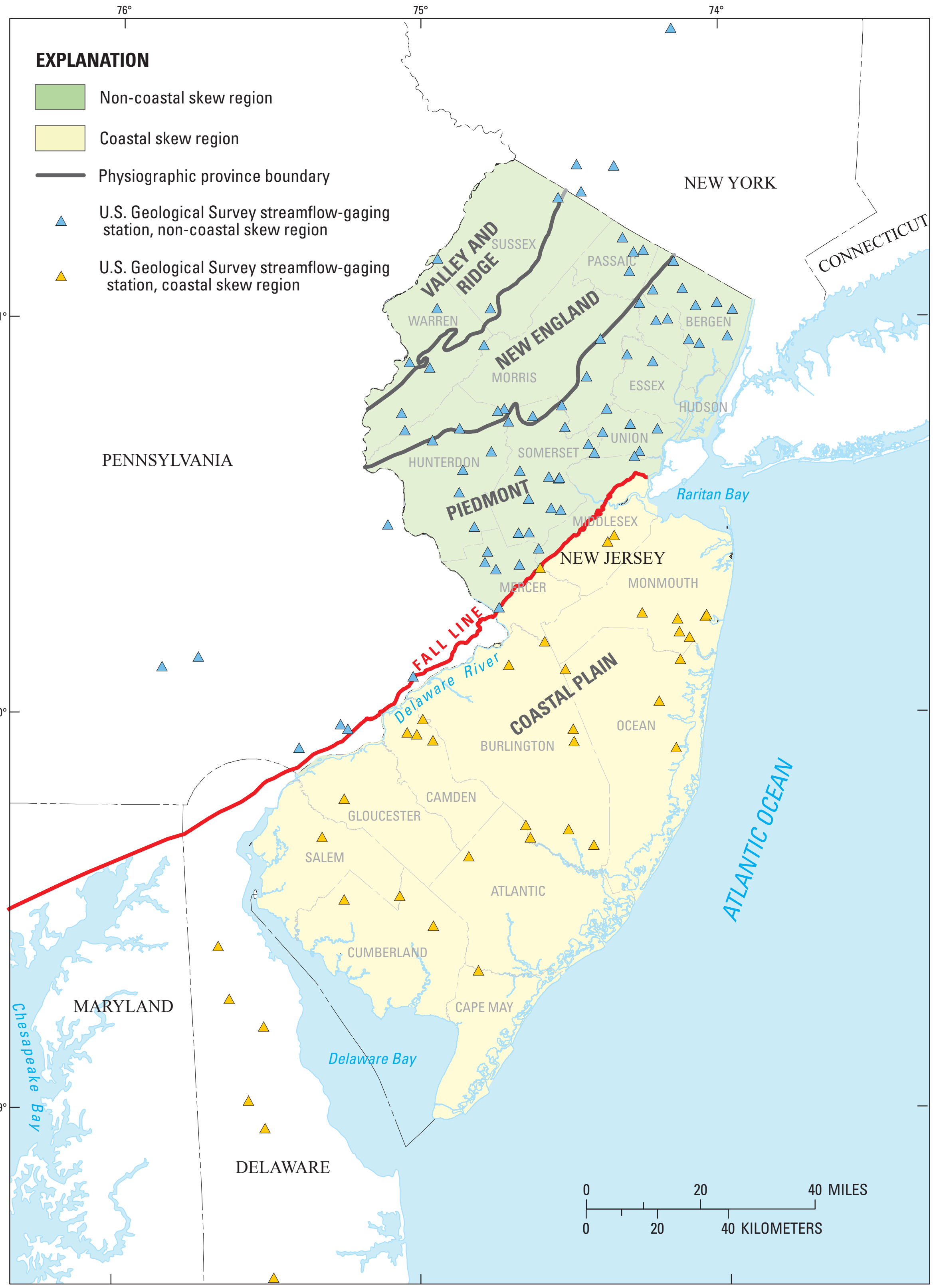
Published estimates of generalized skew from Bulletin 17B maps for the entire State are approximately 0.7, using a total of 38 streamflow-gaging stations from New Jersey. In the current study, for non-Coastal Plain stations, the generalized skew was computed to be 0.41 with a standard error of 0.53, using data from a total of 75 streamflow-gaging stations—66 from New Jersey, 4 from New York, and 5 from Pennsylvania. These results agree well with those of past studies where generalized skew values from 0.3 to 0.4 were determined, depending on data used, using the same methods (U.S. Army Corps of Engineers, 1983; Lumia, 2000). For streamflow-gaging stations located in the Coastal Plain, the generalized skew was computed to be 0.156 with a standard error of 0.65, using data from 44 streamflow-gaging stations—38 from New Jersey and 6 from Delaware. The results for the Coastal Plain region agree well with those of past studies from neighboring States, such as Delaware, where a generalized skew value for the Coastal Plain of 0.204 was determined, depending on the data used, using the same methods (Ries and Dillow, 2006). Therefore, these estimates of generalized skew were used in the current study in the computation of flood frequencies at gaged sites, effectively separating streamflow-gaging stations into those that fall within the Coastal Plain physiographic province and those that do not.

The station and generalized skew coefficients can be combined to form a more accurate estimate of skew for a given streamflow-gaging station. The weighted skew can be computed using the following equation as presented in Bulletin 17B:

$$G_W = \frac{MSE_{\widehat{G}}(G) + MSE_G(\widehat{G})}{MSE_{\widehat{G}} + MSE_G} \,, \qquad (2)$$

where

G_W is the streamflow-gaging station's weighted skew coefficient,
G is the streamflow-gaging station's skew coefficient,
$\hat{G}$ is the streamflow-gaging station's unbiased generalized skew coefficient,
$MSE_{\hat{G}}$ is the mean-square error of the unbiased generalized skew coefficient, and
MSE_G is the mean-square error of the streamflow-gaging station's skew coefficient.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD 83

Figure 4. Streamflow-gaging stations in New Jersey and surrounding States with 25 or more years of record used for the skew study.

Basin Characteristics Used in Regression Equation Development

Several basin characteristics were examined to quantify their relation to annual peak streamflow, using ordinary least squares (OLS) regression. The basin characteristics were derived using GIS techniques to ensure consistency and reproducibility. Basin characteristics evaluated for each streamflow-gaging station considered for use in the regression analysis are listed in table 3. The GIS-computed values for drainage-basin areas agree closely with previously published values for drainage areas. The values for drainage areas presented in this report are from the GIS computations. The ranges of values for basin characteristics used to develop the equations are provided in table 4. The original set of variables regressed against flood-magnitude and -frequency data included—

1. basin drainage area, in square miles;
2. percentage of forest cover, from the GIS data set NJDEP 2002 Landuse/Landcover by Watershed Management Area (WMA) (New Jersey Department of Environmental Protection, 2007);
3. percentage of urban development, from the GIS data set NJDEP 2002 Landuse/Landcover by Watershed Management Area (WMA);
4. percentage of lakes/wetlands/reservoirs, commonly defined as storage, from the GIS data set NJDEP 2002 Landuse/Landcover by Watershed Management Area (WMA). Storage values used in the current study may be significantly higher than those used in Special Report 38 (Stankowski, 1974). Land-use coverages have improved since Special Report 38 was published, thereby adding more detailed coverage of the wetland areas;
5. channel slope by the 10–85 method—that is, the difference in elevation of points 10 and 85 percent of the distance along the main channel, from the gage to the basin divide, divided by the distance between the two points, in feet per mile;
6. main channel length, to basin divide, in miles;
7. basin shape index, computed as the ratio of the square of the main channel stream length (in square miles) to the drainage area (in square miles), a dimensionless ratio of basin length to basin width; and
8. statewide population density from each of the decadal censuses (Workforce New Jersey Public Information Network, 2000) from 1930 to 1990, and the ratios among these population densities.

From the initial OLS regression analysis, those basin characteristics that were found to relate to annual peak streamflows with statistical significance at the 95-percent confidence interval were

- drainage area,
- the 10–85 basin stream slope,
- 1990 Census population density, and
- percentage of storage.

Each of these variables is described in the following section, “Explanatory Variable Selection Methods.” These are the variables that were used in the determination of the final regression equations using the Generalized Least Squares (GLS) method. The multiple linear-regression iterations were performed using the statistical software package Generalized Least Squares-Network Analysis (GLSNet). The GLSNet program and accompanying documentation can be downloaded from *http://water.usgs.gov/software/GLSNet/*.

Explanatory Variable Selection Methods

The methods discussed in the following sections describe the work required, and data sets used, to determine the basin-characteristic values for the peak-flow frequency study. Drainage-basin boundaries are needed before any other basin characteristic can be calculated. For each streamflow-gaging station, coordinates of the site location and a 10-meter-resolution Digital Elevation Model (DEM) coverage from the National Elevation Data set (U.S. Geological Survey, 1999b) for New Jersey were used to create the drainage-basin boundary. The DEM is a digital cartographic/geographic data set of elevations derived from contour lines and aerial photography using USGS 7.5-minute topographic quadrangle maps. All elevation data presented in this report are referenced to the North American Vertical Datum of 1988 (NAVD 88). The 10-meter DEM uses the same source as the historical elevation data, which are manually derived from 7.5-minute quadrangle maps, but the 10-meter DEM also contains updated point data that provide refined elevation values. The vertical accuracy of the 10-meter DEM is considered to be +/- 7 to 15 meters.

The DEM can be inaccurate in geographically flat areas, such as the coastal areas of New Jersey. To improve the DEM used for this study, a process was performed to conform the stream boundaries from the National Hydrography Data set (NHD) (U.S. Geological Survey, 1999a) and the Hydrologic Unit Code-14 (HUC14) (New Jersey Department of Environmental Protection and New Jersey Geological Survey, 2000) to the DEM. This process was conducted using the ArcHydro Tools (Environmental Systems Research Institute, Inc., 2007) developed by Peter Steeves (2002). The result is a conditioned DEM, which was used for drainage-basin delineation.

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01368000	140	18.8	312	15.6	46.4	5.68	28.2
01368500	59.1	4.37	138	26.2	56.4	6.96	20.3
01369000	97.9	13.4	335	28.0	54.3	11.5	33.5
01369500	9.70	6.82	380	42.1	50.6	4.33	6.5
01370000	381	12.5	255	21.5	48.0	5.04	43.8
01370500	415	11.6	308	19.7	47.4	5.91	49.5
01371000	103	2.36	180	19.3	69.9	12.4	35.7
01373690	11.2	3.96	436	104	74.6	2.54	5.3
01374130	8.30	3.99	105	103	94.6	7.79	8.0
01374250	14.9	7.29	134	75.8	89.0	3.85	7.6
01377475	2.18	3.94	1,850	86.2	16.7	4.75	3.2
01377490	6.67	5.89	2,840	25.7	9.97	8.24	7.4
01377500	27.8	4.68	3,410	33.5	10.2	10.3	17.0
01378350	3.09	.74	3,770	176	4.61	2.47	2.8
01378385	8.65	3.73	2,840	87.8	12.0	3.62	5.6
01378590	1.57	3.88	7,310	31.6	3.46	4.55	2.7
01378615	1.75	8.08	12,600	92.0	4.78	6.83	3.5
01378690	8.80	5.43	413	50.2	49.3	4.82	6.5
01379000	54.2	30.1	608	7.15	26.9	3.64	14.0
01379500	98.8	25.5	878	2.56	24.4	9.02	29.8
01379700	24.4	12.4	364	33.4	66.2	11.9	17.0
01379773	7.70	30	107	48.5	57.7	5.92	6.8
01379790	13.1	25.4	111	43.7	55.8	8.97	10.8
01380500	117	14.7	829	12.9	53.1	11.4	36.5
01381400	13.9	9.25	539	86.2	53.3	4.10	7.6
01381500	29.7	6.93	1450	44.6	40.7	5.47	12.7
01381800	68.7	15.4	1490	15.9	26.8	7.17	22.2
01381900	350	18.7	1170	17.5	33.8	6.69	48.4
01383500	28.4	17.9	504	44.4	61.1	3.74	10.3
01384000	42.1	15.8	403	38.1	68.0	6.41	16.4
01384500	16.9	8.11	103	56.1	87.1	7.52	11.3
01385000	4.23	13.6	523	85.4	71.0	3.74	4.0
01386000	11.8	11.3	376	161	69.8	2.89	5.8
01386500	1.01	14.5	237	268	85.2	5.70	2.4
01387250	60.3	5.89	396	17.2	76.4	6.39	19.6
01387300	18.4	7.22	72	75.3	91.2	6.17	10.7
01387350	5.25	8.14	183	99.5	86.8	3.21	4.1
01387400	87.0	6.18	317	16.4	80.2	5.87	22.6
01387410	2.68	5.98	41	220	97.1	4.90	3.6
01387420	93.2	5.78	308	17.1	80.7	6.53	24.7

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01387450	12.4	3.08	645	117	54.1	5.79	8.5
01387500	121	5.29	537	16.8	71.6	5.77	26.4
01387880	7.12	9.59	1,330	25.2	21.2	7.14	7.1
01388000	160	7. 00	649	12.3	66.2	9.29	38.5
01388500	355	11.9	552	12.2	67.0	4.68	40.7
01389030	3.06	7.50	1,270	70.5	55.3	3.11	3.1
01389500	763	15.9	919	11.9	48.1	5.49	64.7
01389534	4.39	3.23	3,590	67.8	21.8	4.23	4.3
01389765	4.01	6.30	1,740	76.7	27.9	4.08	4.0
01389900	1.27	1.95	6,350	17.6	7.22	3.96	2.2
01390450	10.9	1.00	2,150	65.7	8.89	2.91	5.6
01390500	21.7	3.92	1,750	38.0	14.3	6.64	12.0
01390810	9.08	9.34	1,650	26.2	18.2	3.72	5.8
01390900	2.64	8.23	1,980	52.3	12.5	11.7	5.6
01391000	16.4	8.83	2,080	26.9	14.6	5.45	9.5
01391485	5.62	5.92	2,060	9.37	6.08	9.55	7.3
01391500	56.4	5.71	2,530	20.9	11.7	7.13	20.0
01392000	4.05	3.55	5,680	51.2	8.03	2.99	3.5
01392170	7.73	2.18	5,130	34.5	9.52	9.68	8.7
01392210	11.9	1.76	6,090	22.2	7.30	14.0	12.9
01392500	11.4	.62	9,250	43.0	6.22	4.44	7.1
01393450	16.7	2.59	13,500	19.9	3.74	4.87	9.0
01394000	7.13	5.69	1,820	33.5	41.7	8.09	7.6
01394500	24.9	2.73	3,980	34.1	18.8	5.32	11.5
01395000	41.7	3.92	4,010	19.2	15.3	11.3	21.7
01396000	21.2	11.6	3490	11.0	7.58	3.98	9.2
01396500	66.3	14.9	565	14.2	41.3	11.2	27.2
01396582	12.3	11.1	288	62.4	47.7	8.19	10.0
01396660	11.7	12.4	178	106	48.0	2.75	5.7
01397000	150	12.8	431	18.3	39.9	10.3	39.3
01397500	2.23	16.9	184	155	45.4	3.76	2.9
01398000	25.5	11.6	297	30.0	22.7	4.00	10.1
01398045	1.97	13.4	118	119	27.1	2.71	2.3
01398107	9.02	3.95	279	31.6	33.7	5.68	7.2
01398500	26.5	7.56	411	65.5	48.6	6.18	12.8
01399190	7.39	14.5	975	66.8	42.4	4.17	5.5
01399200	10.9	17.3	1,120	34.3	34.4	4.52	7.0
01399500	32.2	17.0	570	18.4	41.7	11.4	19.1
01399510	2.20	7.14	209	184	40.6	2.47	2.3
01399525	1.22	.86	83	138	49.7	4.24	2.3

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi^2, square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi^2)	Storage (percent)	1990 population density (persons per mi^2)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01399670	12.2	8.02	312	56.3	41.8	6.35	8.8
01399700	37.0	6.38	228	50.8	44.1	6.85	15.9
01399830	173	8.52	356	23.3	42.6	7.07	35.0
01400000	188	8.49	378	22.0	41.2	7.44	37.4
01400300	4.20	7.53	1,230	37.8	18.0	4.04	4.1
01400350	.77	9.08	658	111	17.7	4.87	1.9
01400500	492	11.1	439	11.6	35.1	8.86	66.0
01400630	40.9	28.4	588	5.31	16.6	8.60	18.8
01400730	65.7	27.1	695	5.72	13.1	7.53	22.2
01400775	6.58	25.6	1,240	6.16	7.38	4.72	5.6
01400795	9.25	23.9	1,020	7.33	6.53	5.70	7.3
01400822	1.84	20.2	660	19.0	7.44	1.06	1.4
01400850	1.73	9.21	164	52.9	44.5	4.21	2.7
01400900	16.9	18.8	142	43.3	42.0	3.95	8.2
01400930	1.98	5.81	179	115	24.6	2.15	2.1
01400947	26.6	15.7	222	31.5	36.8	5.27	11.8
01400950	.49	9.03	165	35.2	20.1	3.49	1.3
01400960	1.20	21.3	317	61.0	33.2	3.76	2.1
01400970	3.84	12.9	330	27.6	36.3	3.58	3.7
01401000	44.4	14.7	356	21.6	35.6	9.47	20.5
01401160	1.83	27.5	1,430	11.4	10.3	3.20	2.4
01401200	3.82	32.0	959	13.3	10.1	5.40	4.5
01401301	162	23.3	658	4.89	18.6	4.32	26.5
01401520	6.60	12.4	442	87.7	41.3	3.62	4.9
01401595	9.16	15.6	210	65.9	50.3	6.01	7.4
01401600	27.0	13.8	276	28.7	39.0	5.40	12.1
01401650	5.29	16.2	433	88.8	36.3	5.02	5.2
01401870	10.8	15.0	1,760	29.5	18.0	3.03	5.7
01402000	260	20.7	624	4.73	22.5	6.40	40.8
01402600	.99	3.20	1,980	10.8	11.5	5.99	2.4
01403060	779	14.6	523	11.0	30.2	6.06	68.7
01403150	1.89	22.3	765	70.2	22.6	3.14	2.4
01403395	3.60	4.65	1,120	22.7	63.5	6.85	5.0
01403400	6.24	3.53	1,140	22.3	51.6	4.08	5.0
01403500	8.88	3.36	2,120	27.2	44.3	10.5	9.6
01403535	1.52	.97	745	101	28.7	2.70	2.0
01403540	5.49	7.57	822	79.0	30.8	1.99	3.3
01403600	18.6	5.63	2,530	26.4	33.2	7.37	11.7
01403900	48.5	11.7	3,330	21.0	15.5	5.02	15.6
01405030	44.7	19.4	1,450	6.09	18.3	5.63	15.4

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01405300	43.9	26.5	1,250	5.96	15.2	6.85	17.3
01405400	40.5	26.8	470	6.27	22.1	12.4	22.4
01405500	95.1	27.5	982	6.56	18.9	6.28	24.4
01407000	6.05	15.0	1,540	27.4	21.1	3.30	4.5
01407290	6.41	20.6	810	24.7	15.7	3.53	4.8
01407500	49.7	21.8	469	13.6	17.6	2.72	11.6
01407705	9.95	37.2	414	15.4	29.7	6.01	7.7
01407760	6.48	14.7	1,390	21.1	18.3	5.85	6.2
01407830	10.7	22.7	871	14.4	18.9	2.35	5.0
01408000	44.0	30.6	732	7.75	17.5	6.37	16.7
01408015	6.18	46.3	190	8.79	23.0	5.13	5.6
01408029	63.6	37.5	551	7.11	19.0	6.04	19.6
01408120	34.6	31.2	1,250	6.76	22.2	11.7	20.1
01408500	124	24.6	361	4.82	46.8	6.86	29.2
01409000	53.1	19.5	108	7.57	71.9	7.11	19.4
01409095	7.78	19.5	15	20.1	75.6	4.23	5.7
01409280	15.8	19.3	28	11.8	80.1	2.99	7.0
01409375	3.20	13.3	1,310	12.8	33.7	6.46	4.5
01409400	46.9	35.0	267	1.79	47.0	11.01	22.7
01409403	1.03	5.51	782	34.6	36.8	2.24	1.5
01409500	67.9	31.4	100	4.30	53.7	6.48	21.0
01409810	83.9	37.2	25	4.68	60.5	6.41	23.2
01410000	68.8	19.9	23	5.84	78.4	6.91	21.8
01410150	8.15	15.1	19	11.6	81.9	4.65	6.2
01410810	7.46	21.4	1,050	9.84	20.7	6.04	6.7
01411000	57.0	25.6	810	4.21	34.3	8.35	21.8
01411120	.18	6.15	330	15.7	18.3	3.32	0.8
01411122	1.68	3.10	315	14.8	16.1	2.40	2.0
01411300	30.8	23.0	50	7.48	65.4	5.99	13.6
01411456	9.78	28.4	432	8.74	32.9	3.20	5.6
01411500	112	19.4	446	4.62	32.0	3.84	20.7
01412000	23.2	14.9	597	6.62	19.1	4.16	9.8
01412500	2.56	3.04	113	22.8	4.38	4.17	3.3
01412800	28.0	8.04	152	11.1	11.9	3.01	9.2
01440000	65.0	11.2	35	34.0	87.2	11.3	27.1
01443280	12.8	17.3	240	19.9	40.7	3.23	6.4
01443500	126	18.1	226	7.18	49.5	8.62	33.0
01445000	31.0	17.2	295	10.3	52.4	3.47	10.4
01445430	92.4	21.5	203	2.97	46.2	9.12	29.0
01445490	4.28	11.6	258	86.1	59.1	3.83	4.0

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01445500	106	20.5	203	3.75	48.4	9.90	32.4
01446000	36.6	12.9	103	22.0	46.5	6.69	15.6
01446564	.87	25.5	95	75.0	49.4	3.42	1.7
01446600	10.5	7.79	107	110	75.5	4.41	6.8
01451500	80.8	2.74	598	12.6	32.0	7.55	24.7
01452500	44.5	2.97	605	24.7	19.0	7.81	18.6
01455200	35.4	10.4	351	32.9	47.4	9.81	18.6
01456000	68.9	18.5	845	23.1	57.2	7.51	22.8
01457000	139	12.8	611	16.7	48.8	17.0	48.6
01459010	1.23	10.8	83	181	57.9	3.98	2.2
01459500	97.4	5.74	328	14.2	59.0	8.14	28.2
01462197	.74	1.81	94	191	70.6	5.26	2.0
01463620	34.3	33.6	256	7.84	14.2	7.61	16.2
01463812	.25	10.5	2,860	53.5	1.79	4.02	1.0
01464000	90.5	25.0	1,450	4.31	10.4	5.81	22.9
01464400	41.1	35.5	418	8.06	29.4	2.96	11.0
01464405	1.13	35.1	158	39.6	30.9	6.60	2.7
01464500	81.5	28.6	284	4.07	34.6	5.21	20.6
01464515	17.5	20.5	156	10.9	26.3	9.32	12.8
01464520	24.6	21.0	216	9.98	22.8	12.5	17.6
01464524	.66	20.6	1,430	19.9	6.45	4.65	1.8
01464525	.79	26.6	2,360	32.3	11.0	3.88	1.8
01464530	19.6	22.4	150	11.1	21.8	4.94	9.8
01464533	.58	24.3	134	23.0	22.5	8.98	2.3
01464538	5.42	36.8	142	16.5	14.9	6.61	6.0
01464582	10.9	41.1	122	12.5	17.4	5.04	7.4
01465000	134	1.11	951	9.11	26.6	6.47	29.4
01465500	208	1.58	1,000	8.70	26.0	9.02	43.3
01465785	2.20	.97	2,600	45.6	10.2	4.14	3.0
01465790	5.38	2.24	3,990	29.0	10.8	4.12	4.7
01465798	21.4	2.73	4,870	15.0	6.66	6.97	12.2
01465850	64.9	38.5	161	4.65	43.2	6.80	21.0
01465880	47.1	27.8	1,040	10.4	35.0	3.48	12.8
01466000	2.81	15.2	6	9.00	79.7	7.76	4.7
01466500	2.34	11.3	8	14.8	80.5	7.28	4.1
01467000	118	28.8	316	5.00	57.2	6.05	26.7
01467042	38.1	.94	2,660	18.6	12.4	5.06	13.9
01467048	50.1	1.02	3,880	13.1	12.2	8.55	20.7
01467057	5.77	8.68	2,340	12.3	4.64	3.50	4.5
01467069	12.8	19.2	1,630	8.43	9.94	4.43	7.5

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01467081	8.99	13.9	2850	9.68	6.29	8.36	8.7
01467086	16.2	.56	6250	27.3	4.57	5.52	9.5
01467087	30.0	.34	11100	22.4	4.25	5.71	13.1
01467130	5.06	18.0	1770	18.5	25.6	3.18	4.0
01467150	17.1	11.1	2400	11.1	17.8	5.94	10.1
01467160	5.32	16.5	2,430	15.1	11.4	7.67	6.4
01467305	1.36	1. 00	5,380	30.8	1.37	4.70	2.5
01467317	.60	1.94	5,200	40.8	.04	4.58	1.7
01467330	20.8	10.4	1,930	19.7	21.2	3.68	8.8
01467351	7.16	9.15	2,900	26.4	26.5	5.01	6.0
01472198	38.0	3.43	286	48.7	52.0	5.20	14.1
01472199	23.0	3.18	195	40.3	60.0	11.2	16.0
01472500	152	4.34	284	28.4	58.0	5.90	29.9
01473000	279	3.06	411	22.4	50.0	4.42	35.1
01473120	53.7	2.12	938	14.5	34.0	5.49	17.2
01475000	6.05	7.70	2,420	18.4	12.8	3.20	4.4
01475017	.41	17.7	997	51.4	23.1	3.05	1.1
01475019	14.1	8.67	1,910	17.4	16.5	4.74	8.2
01475033	.73	5.51	551	54.3	20.4	1.29	1.0
01475300	5.18	.28	1,400	36.6	22.7	3.46	4.2
01475510	37.5	.36	3,230	20.3	13.1	9.72	19.1
01475530	4.78	.46	5,410	91.4	3.37	4.37	4.6
01475550	21.8	.45	10,800	31.5	3.78	6.59	12.0
01475850	15.8	.30	786	29.8	42.4	5.38	9.2
01476500	31.5	.30	903	21.1	42.4	11.4	19.0
01477000	60.6	1.80	1060	22.7	32.8	7.85	21.8
01477102	.80	3.86	192	55.5	10.8	5.04	2.0
01477110	14.6	11.9	244	14.9	20.2	4.74	8.3
01477120	25.9	12.6	224	13.2	19.5	4.76	11.1
01477480	13.8	16.8	102	13.6	18.5	6.09	9.2
01477500	18.5	15.5	100	13.4	17.1	5.40	10.0
01477800	7.34	.23	2,930	66.4	7.29	5.07	6.1
01478000	20.8	2.26	1,310	21.7	23.7	8.67	13.4
01478040	40.6	4.71	1,250	17.6	25.1	8.08	18.1
01482310	1.05	4.92	390	32.0	13.3	3.10	1.8
01482500	14.6	11.8	111	15.1	12.6	4.83	8.4
01483000	20.3	16.7	79	15.0	26.4	4.46	9.5
01483200	4.06	17.7	73	14.8	30.7	4.33	4.2
01483290	1.20	10.4	88	11.7	7.34	4.79	2.4
01483400	.51	18.0	88	28.2	7.44	2.30	1.1

Table 3. Values of basin characteristics for streamflow-gaging stations in New Jersey and surrounding states used in the regression analysis.—Continued

[USGS, U.S. Geological Survey; mi², square miles; ft/mi, feet per mile; mi, miles, 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope]

USGS station number	Drainage area (mi²)	Storage (percent)	1990 population density (persons per mi²)	10-85 stream slope (ft/mi)	Forest cover (percent)	Basin shape index	Main channel length (mi)
01483500	9.15	11.3	101	8.22	9.40	3.75	5.9
01483700	31.0	16.1	490	4.95	14.0	6.04	13.7
01483720	2.54	3.33	742	14.3	9.95	2.51	2.5
01484000	12.9	18.0	141	6.23	14.4	3.70	6.9
01484002	.88	3.91	113	14.6	10.3	5.92	2.3
01484050	2.91	4.74	111	12.3	10.2	4.19	3.5
01488500	46.8	27.7	67	2.49	8.30	3.21	12.3
01489000	7.33	1.64	54	5.56	19.8	5.01	6.1
01490600	8.90	36.6	62	5.33	11.9	4.05	6.0
01490800	4.00	3.97	71	7.85	37.7	4.49	4.2
01491000	117	23.1	93	2.75	21.0	4.15	22.0
01491010	2.11	16.7	34	4.22	11.9	5.24	3.3
01491050	3.51	1.00	83	4.76	25.5	5.37	4.3
01495000	53.2	1.64	220	16.6	23.2	11.8	25.1

Table 4. Ranges of values for basin characteristics used to develop the flood-frequency regression equations.

[mi², square mile; ft/mi, feet per mile; 10-85, elevation at points 10- and 85- percent along the main channel length of the stream, used to calculate stream slope; GP, Glaciated Piedmont flood-frequency region; IN, Inner Coastal flood-frequency region; OC, Outer Coastal flood-frequency region; UP, Unglaciated Piedmont flood-frequency region; VR, Valley and Ridge and New England flood-frequency region; Min., minimum value; Max., maximum value]

Flood-frequency region	Drainage area (mi²)		Storage (percent)		1990 population density (persons per mi²)		10-85 main channel slope (ft/mi)	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
GP	1.27	56.4	0.62	11.6	645	13,492	9.37	176.0
IN	.41	118	1.00	41.1	34	5,382	2.49	55.5
OC	.18	124	3.04	46.3	6	1,387	1.79	39.6
UP	.25	779	.23	32.0	83	11,084	4.31	191.0
VR	.87	763	2.36	30.1	35	1,493	2.56	268.0
ALL	**.18**	**779**	**.23**	**46.3**	**6**	**13,492**	**1.79**	**268.0**

Land Use

The land uses for drainage basins entirely within New Jersey were derived from a GIS data set developed from 2002 digital infrared aerial photography, NJDEP 2002 Landuse/Landcover by Watershed Management Area (WMA) (New Jersey Department of Environmental Protection, 2007) through use of the Anderson method of classification. Land uses for drainage basins extending outside New Jersey were derived from the 2001 National Land Cover Data (NLCD) data set (Yang and others, 2003). The land-use coverage divides the land area into a series of polygon segments that are assigned a single land-use classification, as in Level 1 classifications in the Anderson system (Anderson and others, 1976). Level 1 classification consists of the major land-use categories, including agriculture, urban, wetland, forested, barren, and water areas. Each polygon segment is assumed to be uniform in land-use category.

Anderson Level 1 land-use classifications used for basin characteristics in this study are forest, urban, water, and wetlands. Land use categorized as storage is the percentage of water and wetland land-use areas in a drainage basin. The urban land-use category is a composite of residential, commercial, and industrial uses. A raster data set of the land-use coverage was created for data processing. For each site the 2002 land-use data set and (or) 2001 NLCD data set was overlaid on the drainage-basin polygon and clipped to the basin boundary. Percentages of each land-use type were calculated as the sum of the areas of the selected land-use type divided by the total area of the basin.

Main Channel Length

The ArcHydro Tools (Environmental Systems Research Institute, Inc., 2007) were used to measure main channel length. The ArcHydro Tools method for measuring main channel length uses the longest flow path of the NHD (U.S. Geological Survey, 1999a) stream network in the basin. The main channel length is defined as the distance measured along the main channel from the drainage-basin outlet to the basin divide, which extends the flow path from the upstream end of the stream to the basin divide. The extension to the basin divide follows a path in which the greatest volume of water would travel. The main channel length is measured in miles.

Basin Slope 10–85 Method

Main channel slope of a drainage basin was determined using the 10–85 method. This method computes the stream slope as the difference in elevation between two points located 10 percent and 85 percent of the distance along the main channel length, from the stream outlet to the basin divide, divided by the distance between the two points along the main channel (fig. 5). The elevation data presented in this report are from the conditioned DEM. The 10–85 stream slope is measured in feet per mile. The following is the equation for the 10–85 stream-slope calculation:

$$S_{10-85} = \left(\frac{E_{85} - E_{10}}{0.75L} \right) , \qquad (3)$$

where

S_{10-85} is the basin slope, in feet per mile,

E_{85}–E_{10} is the difference in elevation between the 85- and 10-percent points on the main channel, in feet; and

$0.75L$ is the distance between the 85- and 10-percent points along the main channel, in miles.

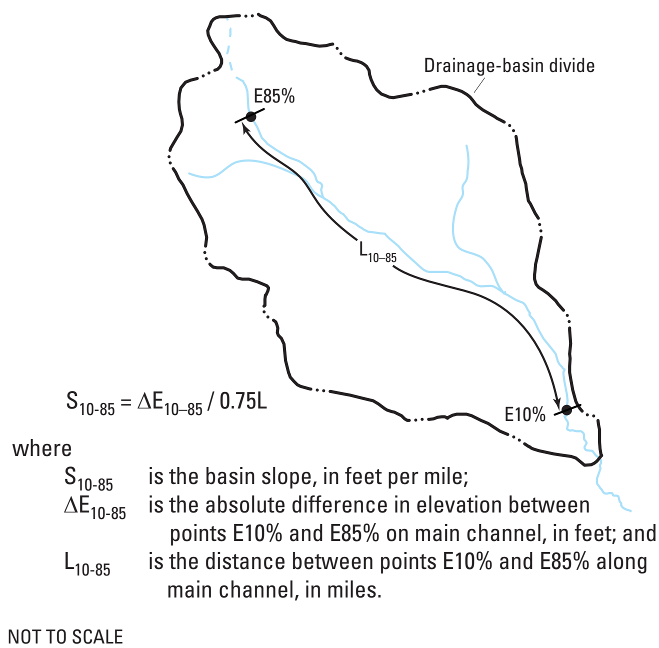


Figure 5. Schematic diagram showing a drainage basin, the main channel of a stream, and the points used to compute the stream slope using the basin slope 10–85 method.

Population Density

Population density, in persons per square mile, was calculated for each of the 254 streamflow-gaging-station drainage basins, using the 1990 National census block group data (U.S. Census Bureau, 2007). The population in each census block encompassing a drainage basin was summed and divided by the drainage area to determine the population density for the basin.

$$PopDen = \Sigma POP/DA \text{ ,} \qquad (4)$$

where

PopDen is the 1990 population density for the drainage basin, in persons per square mile;

POP is the population from 1990 National census block group data for the drainage basin; and

DA is the drainage area, in square miles.

Development of Flood-Frequency Regression Equations

Estimates of flow at specific frequencies for gaged locations in New Jersey were computed by submitting annual maximum flood-peak flows observed at streamflow-gaging stations to the USGS computer program PeakFQ. Output from that program includes the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return-interval flows, in cubic feet per second. Input to PeakFQ includes the annual peak-flow time series for each streamflow-gaging station; utilizing the log-Pearson Type III distribution, the estimated flow at specified return intervals is computed. The results are summarized in Appendix 2 as flood-frequency estimates from observed data from the systematic record. These data were then used in the determination of the final regional regression equations.

The State was divided into five flood-frequency regions based on geographic distribution of the residuals from the initial OLS regression runs, the physiographic map (Parker and others, 1964), and a soils map (Quakenbush and Tedrow, 1954). The five flood-frequency regions are shown in figure 2. The flood-frequency regions for New Jersey are the following:

- Valley and Ridge (VR), northwestern New Jersey including the glaciated portion of the New England physiographic province, the entire Valley and Ridge physiographic province, and the Upper Passaic River Basin;
- Glaciated Piedmont (GP), northeastern New Jersey within the area of the Piedmont physiographic province, and the Lower Passaic River Basin downstream from Chatham, NJ (the southern extent of the GP is the terminal moraine);
- Unglaciated Piedmont (UP), within the area of the Piedmont physiographic province in New Jersey, excluding the Passaic River Basin, with the northern extent as the boundary with the New England physiographic province, the eastern extent as the terminal moraine, and the southern extent as the Fall Line;
- Inner Coastal Plain (IN), consisting of the streams tributary to the Raritan River east of the Fall Line, the Raritan Bay, the Atlantic Ocean north of Shark River Basin, and Delaware River south of Trenton, NJ, and
- Outer Coastal Plain (OC), consisting of the streams tributary to the Atlantic Ocean south of Sandy Hook, NJ, including the Shark River Basin, and to Delaware Bay north to and including the Cohansey River Basin.

In order to develop only one set of equations that could be used for the entire State—one equation for each recurrence interval—a constant regional coefficient that allows regression parameters to vary with the flood-frequency region was used.

All response (recurrence-interval peak flows) and explanatory (basin characteristic) variables were transformed to logarithms, base 10, within the regression analysis to obtain linear relations between the response variables and the explanatory variables and to achieve equal variance about the regression line. A one (1) was added to the percentage of storage and population-density explanatory variables so that no values would be equal to zero.

Equation development was done in two phases. In the first phase, peak-flow statistics for each flood-frequency recurrence interval were related to basin characteristics using the Ordinary Least Squares (OLS) regression method. OLS, commonly referred to as linear regression, is used to describe the covariation between some variable of interest and one or more other variables (Helsel and Hirsch, 2002). The regression iterations using OLS were performed using the statistical software package Minitab (Minitab, 2006). This step was performed to identify those basin characteristics that were significant at the 95-percent confidence interval.

Multiple linear regression analysis using Generalized Least Squares (GLS) was used for the second phase to derive the final regression equations that best fit the data. GLS is considered to be a more accurate regression technique for hydrologic regressions as it accounts for differences in record length, the variance of flows, and cross-correlation among the stations used in the analysis (Tasker and Stedinger, 1989). The software package GLSNet was used for the analysis. Regression analysis was performed using the variables obtained from the OLS method that were determined to be significant. After regression analyses were performed, the residuals were examined to assess goodness of fit and determine whether regional trends existed.

Regression Analysis and Resultant Equations

In this report, flood magnitude for a selected frequency is expressed as a function of basin characteristics. The general form of the mathematical model used is

$$Q_T = b_0 x_1^{b1} x_2^{b2} x_3^{b3} \ldots x_n^{bn}, \quad (5)$$

where

Q_T is the estimated flood discharge for a selected recurrence interval, T;
b_0 is the intercept also referred to as the regional regression constant (K) in this report;
$x_1, x_2, x_3, \ldots x_n$ are basin characteristics; and
$b_1, b_2, b_3, \ldots b_n$ are the fitting coefficients.

The coefficients were estimated by weighted multiple linear regression, GLS analysis of the following equivalent logarithmic relation:

$$\log Q_T = \log b_0 + b_1 \log x_1 + b_2 \log x_2 + b_3 \log x_3 + \ldots + b_n \log x_n\ , \quad (6)$$

where

Q_T is the estimated flood discharge for a selected recurrence interval, T;
$b_0, b_1, b_2, \ldots b_n$ are regression coefficients; and
$x_1, x_2, x_3, \ldots x_n$ are basin characteristics.

Multiple-regression analysis was used in a forward-stepwise procedure to include or exclude independent variables (basin characteristics) in the model. The regression analysis was run using the effective years of record, N_e, as a weighting factor (table 1). The variables included in the final equations are those that are significant at a prescribed confidence level—that is, those variables that when included in the regression equation account for a sufficiently large portion of the total variance so that the relation is unlikely to have resulted from chance alone. The basin characteristics used in developing the flood-frequency regression equations are drainage area, 10–85 basin slope, percentage of storage, 1990 population density, and flood-frequency region.

After the regression analysis was completed, a final set of equations was produced. The final combination of variables chosen for the regression equations had the lowest standard error, and all variables were significant at the 95-percent confidence interval when run using the GLSNet.

The best-fit equations are as follows:

$$Q_2 = K_{TR}(DA)^{0.753}\ (Storage + 1)^{-0.054}\ (Slope)^{0.251}\ (PopDen + 1)^{0.127} \quad (7)$$

$$Q_5 = K_{TR}(DA)^{0.741}\ (Storage + 1)^{-0.084}\ (Slope)^{0.254}\ (PopDen + 1)^{0.104} \quad (8)$$

$$Q_{10} = K_{TR}(DA)^{0.736}\ (Storage + 1)^{-0.104}\ (Slope)^{0.258}\ (PopDen + 1)^{0.092} \quad (9)$$

$$Q_{25} = K_{TR}(DA)^{0.732}\ (Storage + 1)^{-0.127}\ (Slope)^{0.263}\ (PopDen + 1)^{0.079} \quad (10)$$

$$Q_{50} = K_{TR}(DA)^{0.729}\ (Storage + 1)^{-0.144}\ (Slope)^{0.267}\ (PopDen + 1)^{0.070} \quad (11)$$

$$Q_{100} = K_{TR}(DA)^{0.728}\ (Storage + 1)^{-0.158}\ (Slope)^{0.271}\ (PopDen + 1)^{0.062} \quad (12)$$

$$Q_{500} = K_{TR}(DA)^{0.725}\ (Storage + 1)^{-0.189}\ (Slope)^{0.278}\ (PopDen + 1)^{0.043}\ , \quad (13)$$

where

$Q_2, Q_5, \ldots Q_{500}$ are the peak-flow discharges for floods with recurrence intervals of 2 years, 5 years,…500 years, in cubic feet per second;
K_{TR} is the coefficient for the recurrence interval for the specified flood-frequency region (table 5);
DA is the drainage area, in square miles;
$Storage$ is the percentage of the basin covered by streams, lakes, and wetlands;
$Slope$ is the 10–85 basin slope, in feet per mile; and
$PopDen$ is the population density, in persons per square mile.

Table 5. Values for the regional constant coefficent (K_{TR}) for the peak-flow regression equations.

[OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated Piedmont flood-frequency region; GP, Glaciated Piedmont flood-frequency region; VR, Valley and Ridge and New England flood-frequency region; IN, Inner Coastal Plain flood-frequency region]

Recurrence interval (years)	Flood-frequency region				
	OC	UP	GP	VR	IN
2	8.9	37.8	20.6	13.8	17.5
5	18.1	75.3	40	28.5	37.6
10	26.5	108	56.7	42	56.2
25	39.7	159	82.2	63.6	86.2
50	51.5	204	105	83.2	114
100	65.1	256	130	106	146
500	105	408	205	176	241

Accuracy of the Flood-Frequency Regression Equations

The accuracy of a flood-frequency regression equation can be expressed as the standard error of estimate, standard error of prediction, or equivalent years of record. The standard error of estimate is a measure of how accurately the estimated peak-flow discharges, generated using an equation, agree with the peak-flow statistics generated from station records that were used to create the equation. The standard error of estimate is derived from the model error and is based on the scatter of data around the fitted equation. The standard error does not account for changes in drainage area covered by the equation, changes in flood activity over time, or other changes. The standard error of prediction is derived from the sum of the model error and the sampling error, and is a measure of how accurately the estimated peak discharge generated using an equation will predict the true value of peak discharge for the selected recurrence interval. Another measure of the reliability of flood-frequency regression equations, equivalent years of record, was proposed by Hardison (1971). Equivalent years of record is the number of actual years of record needed to provide estimates equal in accuracy to those computed by the regression equations. The standard errors of the flood-frequency regression equations are ranges of error, expressed as a percentage of the estimated values, within which two-thirds of the estimates would be expected to fall, with smaller errors indicating more accurate values.

Values describing the accuracy of the regression equations for this study are defined by use of the standard error of estimate, the standard error of prediction, and the equivalent years of record; the results are listed in table 6. The standard errors of estimate for this study range from 49 to 63.9 percent; these values are slightly higher than those reported by Stankowski (1974), which range from 48 to 54 percent, possibly because of the greater variability of annual peak-flow data resulting from the use of a greater number of stations in the analysis. The standard errors of prediction for this study range from 50.3 to 66.3 percent. The equivalent years of record for this study range from 1 to 6.

Limitations of Regression Equations

The regression equations given in this report are appropriate only for unregulated or slightly regulated, non-tidal streams in New Jersey. Flood-magnitude and -frequency estimates for highly regulated reaches below reservoirs may be available in flood-insurance studies published by FEMA. Peak-flow magnitude and frequency estimates for gaging stations along the main stem Delaware River are given in Schopp and Firda (2008). Although data for stations in adjacent States were used in this study, comparable reports on studies conducted in those states are recommended for use in the respective States (Lumia, 2006; Ries and Dillow, 2006; and Stuckey and Reed, 2000). The accuracy of the regression equations is known only within the range of the basin characteristics used to develop the equations. The accuracy of the equations will be reduced if the values of explanatory variables are outside the range of the values used to develop the regression equations. The range of values for each basin characteristic used in the regression analysis is given in table 4. If the basin characteristics associated with an ungaged site are near or outside the range limits, the regression equations could produce an error substantially larger than those reported here.

Flood Frequency and Magnitude at Gaged Sites

Peak flow at a gaging station is computed as a weighted average of $Q_{T(r)}$ (the computed flood discharge from the regression equation) and $Q_{T(o)}$ (the flood discharge based on the log-Pearson Type III distribution using the procedures

Table 6. Accuracy of peak-flow discharges predicted using flood-frequency regression equations for New Jersey.

Recurrence interval (years)	Average standard error		Equivalent years of record (years)
	Estimate (percent)	Prediction (percent)	
2	49	50.3	1
5	49.4	50.9	2
10	50.5	52.2	3
25	52.6	54.5	4
50	54.7	56.8	5
100	57.1	59.5	5
500	63.9	66.3	6

outlined in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982)). The weighted average flood discharge, $Q_{T(w)}$, is based on the effective number of years of peak-flow record at the gaging station (table 1) and on the equivalent years of record from table 6. The equation used to compute the weighted average is as follows:

$$\log Q_{T(w)} = \frac{N_e(\log Q_{T(o)}) + E(\log Q_{T(r)})}{N_e + E} \,, \qquad (14)$$

where

- $Q_{T(w)}$ is the weighted peak-flow discharge, in cubic feet per second, for recurrence interval T, in years;
- $Q_{T(o)}$ is the peak-flow discharge, in cubic feet per second, based on the log-Pearson Type III analysis of the gaging-station peak-flow record, for recurrence interval T, in years;
- $Q_{T(r)}$ is the peak-flow discharge, in cubic feet per second, from the regression equation for recurrence interval T, in years;
- N_e is the effective number of years of gaged peak-flow record from table 1, which is equal to the years of peak-flow record, N, if no historical information is available; and
- E is the equivalent number of years of record of the regression equation from table 6.

Equation 14 is equation (8.6) in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The results of this computation for the stations used in this study are listed as the weighted estimate in Appendix 2.

The computation of a weighted peak-flow discharge can be illustrated by computing the weighted 100-year peak flow for the gaging station 01394500, Rahway near Springfield, NJ. For that gaged site, the basin characteristics are drainage area, 24.9 mi^2; channel slope, 34.1 ft/mi; percentage of lakes and wetlands (storage), 2.73 percent; and population density, 3,980 persons/mi^2. The gaging station is located in flood-frequency region GP (Glaciated Piedmont), according to table 1.

By using the appropriate regional regression equation, the 100-year peak-flow discharge is determined as follows:

$$\begin{aligned} Q_{100(r)} &= 130(DA)^{0.728}(Storage+1)^{-0.158}(Slope)^{0.271}(PopDen+1)^{0.062}, \\ &= 130(24.9)^{0.728}(2.73+1)^{-0.158}(34.1)^{0.271}(3{,}980+1)^{0.062}, \\ &= 4{,}770 \text{ ft}^3/\text{s} \;. \end{aligned}$$

In Appendix 2, $Q_{T(o)}$, the observed 100-year peak flow from the log-Pearson Type III analysis, is 6,470 ft^3/s. By using equation 14 given at the beginning of this section, the observed peak flow and the peak-flow value estimated from the regional regression equation can be combined as follows:

$$\begin{aligned} \log Q_{T(w)} &= \frac{N_e(\log Q_{T(o)}) + E(\log Q_{T(r)})}{N_e + E} \,, \\ &= \frac{67 \text{ years}(\log 6{,}470 \text{ ft}^3/\text{s}) + 5 \text{ years}(\log 4{,}770 \text{ ft}^3/\text{s})}{67+5} \,, \\ &= 3.801 \,, \\ Q_{T(w)} &= 6{,}330 \text{ ft}^3/\text{s} \;. \end{aligned}$$

Estimation of Flood Frequency and Magnitude at Ungaged Sites

Estimation of flood frequency and magnitude for an ungaged site is computed using a regional regression equation. Flood frequency and magnitude can be computed for ungaged sites with a drainage-basin area outside the ratio of 1/3 to 3 times the area of the drainage basin of the nearest streamflow-gaging station on the same stream. If the drainage-basin area for the ungaged site lies in more than one flood-frequency region, the flood-frequency estimate will be weighted by the percentage of the drainage basin within each region. The computation of flood discharge at an ungaged site is illustrated with the following example.

The 100-year peak-flow discharge is computed for an ungaged site on a stream in Atlantic County in southern New Jersey. The drainage-basin characteristics are drainage area, 15.5 mi^2; percentage of lakes and wetlands, 5.5 percent; channel slope, 3.2 ft/mi; and population density, 75 persons/mi^2.

All of Atlantic County is in flood-frequency region OC, according to figure 2. By using the appropriate regional regression equation, the 100-year peak-flow discharge is

$$\begin{aligned} Q_{100(r)u} &= 65.1(DA)^{0.728}(Storage+1)^{-0.158}(Slope)^{0.271}(PopDen+1)^{0.062}, \\ &= 65.1(15.5)^{0.728}(5.5+1)^{-0.158}(3.2)^{0.271}\;(76)^{0.062}, \\ &= 639 \text{ ft}^3/\text{s} \,. \end{aligned}$$

Estimation of Flood Frequency and Magnitude for an Ungaged Site Upstream or Downstream from a Gaged Site

For ungaged sites near streamflow-gaging stations on the same stream, the flood discharge can be estimated using a ratio of the drainage area for the ungaged site to the drainage area for the gaged site. The ungaged site must be on the same stream as the streamflow-gaging station, and the drainage area should be approximately between 1/3 and 3 times the area of the drainage basin (U.S. Geological Survey, 2002). Use of this method gives increasing weight to the flood estimates for the streamflow-gaging stations as the drainage-area ratio approaches 1 and full weight to the flood-frequency regression equations for ungaged sites with a drainage area less than 1/3 or greater than 3 times the drainage area of the streamflow-gaging station. The use of limits that are reciprocals of each other allows for equal transfers up- and downstream. Regional regression equations should be used for instances when the ratio of the ungaged drainage area to the drainage area of the streamflow-gaging station is outside the range 1/3 to 3.

To obtain a weighted peak-discharge estimate ($Q_{T(w)u}$) for the ungaged site for recurrence interval *T*, the weighted streamflow-gaging-station estimate from the upstream or downstream station ($Q_{T(w)g}$) must first be determined using equation (14). This estimate is then used to obtain a flood-discharge estimate ($Q_{T(u)g}$) for the selected flood frequency for the ungaged site by use of the following equation (Ries and Dillow, 2006):

$$Q_{T(u)g} = \left(\frac{DA_u}{DA_g} \right)^b Q_{T(w)g} , \tag{15}$$

where

$Q_{T(u)g}$ is the estimated peak-flow discharge, in cubic feet per second, for recurrence interval T, for the selected flood frequency for the ungaged site;

DA_u is drainage area for the ungaged site;

DA_g is drainage area for the upstream or downstream streamflow-gaging station;

b is the exponent for drainage area for each flood-frequency region (table 7), as determined by computing the mean of the drainage-area exponents for all recurrence intervals from regressions of flood frequencies against drainage area as the only explanatory variable; and

$Q_{T(w)g}$ is the weighted peak-flow discharge, in cubic feet per second, for recurrence interval T, for the selected flood frequency for the gaged site, from equation (14) or Appendix 2.

The equivalent years of record at the ungaged site, N_u, relative to the gaged site can be computed using the following equations. If the value of N_u is a negative number, the drainage-area ratio with the upstream or downstream station is outside the range of 1/3 to 3; therefore, the regression equations should be used to calculate a peak-flow discharge estimate for the selected flood frequency for the ungaged site.

If the streamflow-gaging station is upstream from the ungaged site, then

$$N_u = N_g \frac{3DA_g - DA_u}{DA_g(3-1)} , \tag{16}$$

and if the streamflow-gaging station is downstream from the ungaged site, then

$$N_u = N_g \frac{DA_u - 0.33DA_g}{DA_g(1-0.33)} , \tag{17}$$

where

N_g is years of record at the station,

N_u is equivalent years of record at the ungaged site,

DA_g is drainage area for the upstream or downstream streamflow-gaging station, and

DA_u is drainage area for the ungaged site.

The weighted estimate for recurrence interval, *T*, at the ungaged site ($Q_{T(w)u}$) can be computed by following equation (14), where $Q_{T(u)g}$ from equation (15) is substituted in place of $Q_{T(o)}$; N_u from equation (16) or (17) is substituted in place of N_e, equivalent years of record, *E*, from table 6; and $Q_{T(r)u}$ is calculated from the regional regression equation.

The following example illustrates the calculations for determining the weighted flow for a 100-year flood at an ungaged site that is near a streamflow-gaging station on Walnut Brook near Flemington, NJ (01397500). The ungaged site is downstream from the gaging station. The drainage area of the gaged site is 2.23 mi^2. The drainage area of the ungaged site is 3.00 mi^2. Both sites are in flood-frequency region Unglaciated Piedmont (UP).

Table 7. Value of exponent, *b*, for flood-frequency regions in New Jersey used in regional regression analysis.

[GP, Glaciated Piedmont flood-frequency region; IN, Inner Coastal Plain flood-frequency region; OC, Outer Coastal Plain flood-frequency region; UP, Unglaciated Piedmont flood-frequency region; VR, Valley and Ridge and New England flood-frequency region]

Flood-frequency region	Exponent *b*
GP	0.68
IN	.66
OC	.73
UP	.58
VR	.59

- For the gaged site:

DA = 2.23 mi²; *Storage* = 16.9 percent; *Slope* = 155 ft/mi; *PopDen* = 184 persons/mi²; and *N* = 71 yr.

$Q_{100(w)g}$ = 2,840 ft³/s, from equation (14) or Appendix 2, and

- For the ungaged site:

DA = 3.00 mi²; *Storage* = 15.2 percent; *Slope* = 92 ft/mi; *PopDen* = 250 persons/mi², and

$Q_{100(r)u}$ = 1,760 ft³/s from the regional regression equation.

$$Q_{T(u)g} = \left(\frac{DA_u}{DA_g}\right)^b Q_{T(w)g} \ ,$$

$$= \left(\frac{3.00}{2.23}\right)^{0.58} 2,840 \ ,$$

$$= 3,370 \text{ ft}^3/\text{s} \ .$$

$$N_u = N_g \frac{3DA_g - DA_u}{DA_g(3-1)}$$

$$= 71 \frac{3(2.23) - 3.00}{2.23(3-1)}$$

$$= 59 \text{ yrs} \ .$$

$$\log Q_{T(w)u} = \frac{N_u(\log Q_{T(u)g}) + E(\log Q_{T(r)u})}{N_u + E} \ ,$$

$$= \frac{59(\log 3,370) + 5(\log 1,760)}{59 + 5} \ ,$$

$$= 3.506 \ ,$$

$$Q_{T(w)u} = 3,210 \text{ ft}^3/\text{s} \ .$$

Estimation of Flood Frequency and Magnitude for a Site Between Gaged Sites

Flood-frequency estimates may be needed for an ungaged site located between two gaged sites on the same stream. The drainage-basin area of the ungaged site is in the same regression region as those of the two gaged sites, and the drainage-basin ratios of the ungaged site to the nearest upstream and downstream streamflow-gaging stations are within the range of 1/3 to 3. If the area of the ungaged site is within the range of 1/3 to 3 times the drainage-basin area of only one of the gaged sites, follow the equation stated above for estimating flood frequency upstream or downstream from a gaged site. If the drainage-basin ratios of the ungaged site to both of the gaged sites are outside the range of 1/3 to 3, use the regional regression equation to compute the flood-frequency estimate.

For an ungaged site with a drainage-basin area within the range of 1/3 to 3 times the drainage-basin areas of both of the nearest streamflow-gaging stations, peak flow for the *T*-year recurrence interval for the ungaged site ($Q_{T(u)}$) and number of years of record for the ungaged site (N_u) are estimated using drainage area, weighted flood discharge, and number of years of record from the two selected gaged stations. Equation (14) is then used to estimate the weighted peak discharge ($Q_{T(w)u}$) for the ungaged site.

Because the site is ungaged, a direct determination of flow at the site for a given recurrence interval is not possible. An interpolated value can be obtained by using the following equation (Ries and Dillow, 2006):

$$Q_{T(u)} = \left[\frac{A_u - A_{gu}}{A_{gd} - A_{gu}} * \left(\frac{Q_{Tgd}}{A_{gd}} - \frac{Q_{Tgu}}{A_{gu}}\right) + \frac{Q_{Tgu}}{A_{gu}}\right] * A_u \ , \quad (18)$$

where

- A_u is the drainage area for the ungaged site;
- A_{gu} is the drainage area for the upstream streamflow-gaging station;
- A_{gd} is the drainage area for the downstream streamflow-gaging station;
- $Q_{T(u)}$ is the peak-flow discharge for the *T*-year recurrence interval for the ungaged site, in cubic feet per second;
- Q_{Tgu} is the weighted peak-flow discharge from the upstream streamflow-gaging station, in cubic feet per second; and
- Q_{Tgd} is the weighted peak-flow discharge from the downstream streamflow-gaging station, in cubic feet per second.

Equation (14) used to compute the weighted average, is also used to calculate a final weighted estimate for the *T*-year flood for the ungaged site located between two gaged sites on the same stream. The value of $Q_{T(u)}$ from equation (18) is used in equation (14) in place of $Q_{T(o)}$. The value of N_u for use in equation (14), inserted in place of *N*, is calculated by determining the arithmetically weighted average of the number of years of record for the upstream and downstream streamflow-gaging stations, using the difference in the two drainage areas as the weighting factor. The calculation can be done using the following equation:

$$N_u = \frac{N_{gd}(A_u - A_{gu}) + N_{gu}(A_{gd} - A_u)}{A_{gd} - A_{gu}} \ , \quad (19)$$

where

- A_u, A_{gu}, and A_{gd} are defined in the previous equation,
- Nu is the number of years of record for the ungaged site,
- N_{gu} is the number of years of record for the

upstream streamflow-gaging station, and
N_{gd} is the number of years of record for the downstream streamflow-gaging station.

The following example illustrates the calculations for determining the peak flow for a 100-year flood for an ungaged site that is between two streamflow-gaging stations on Beden Brook. The ungaged site has a drainage area of 10.0 mi^2, percentage of storage of 12.9 percent, 10–85 slope of 41.2 ft/mi, and population density of 430 persons/mi^2. The upstream streamflow-gaging station is 01401520, Beden Brook near Hopewell, NJ; the drainage area is 6.60 mi^2, $Q_{100(gu)}$ is 9,010 ft^3/s, and the number of years of record N_{gu} is 19. The downstream streamflow-gaging station is 01401600, Beden Brook near Rocky Hill, NJ; the drainage area is 27.0 mi^2, $Q_{100(gd)}$ is 15,200 ft^3/s, and the number of years of record N_{gd} is 40. All three sites are in flood-frequency region Unglaciated Piedmont (UP). To estimate the flood frequency ($Q_{100(u)}$) for the ungaged site, the regional regression equation is used, along with the basin characteristics from table 3.

Equation (19) is used to calculate $Q_{100(u)}$ with the drainage areas and peak-flood values as defined above; the data also can be found in table 3 and Appendix 2.

$$Q_{100(u)} = \left[\frac{10-6.6}{27-6.6} * \left(\frac{14{,}200}{27} - \frac{7{,}800}{6.6}\right) + \frac{7{,}800}{6.6}\right] * 10$$
$$= 10{,}700 \text{ ft}^3/\text{s} .$$

Equation (19) is used to calculate N_u with drainage areas and years of record as defined above; the data also can be found in tables 1 and 3.

$$N_u = \frac{40(10-6.6)+19(27-10)}{27-6.6}$$
$$= 22 \text{ yr} .$$

Using the regression-equation estimate for the ungaged site, $Q_{100(u)}$ = 3,600 ft^3/s, and determining the associated equivalent years of record from table 6, the weighted peak flow is estimated for the ungaged site using equation (14).

$$\log Q_{100(w)} = \frac{22(\log 10{,}700) + 5(\log 3{,}600)}{22+5}$$
$$= 3.942$$
$$Q_{100(w)} = 8{,}750 \text{ ft}^3/\text{s} .$$

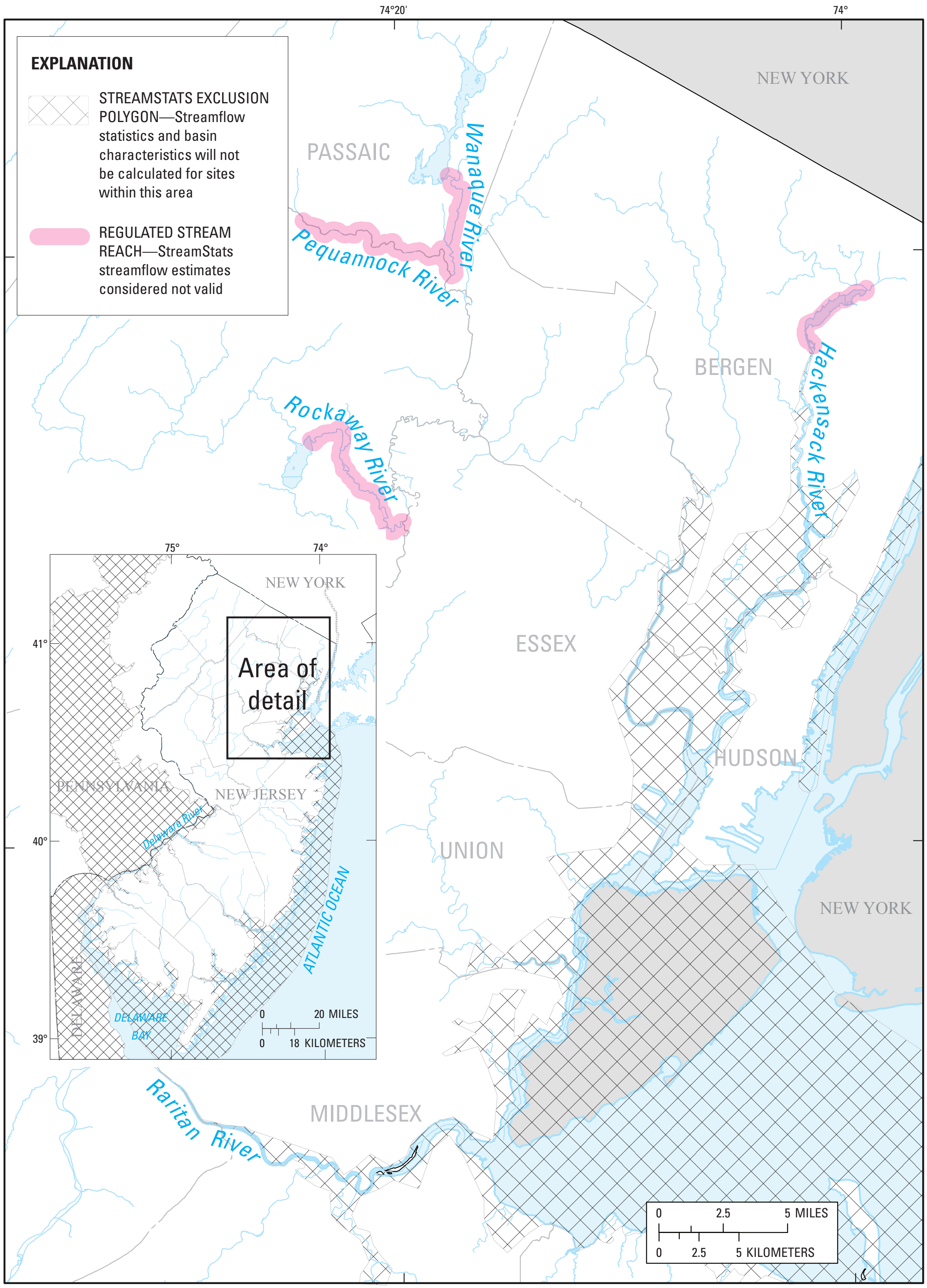
StreamStats

StreamStats is an interactive, map-based USGS Web application that allows users to easily obtain streamflow statistics and basin characteristics for USGS streamflow-gaging stations as well as for ungaged sites along a stream. StreamStats was developed cooperatively by the USGS and the Environmental Systems Research Institute, Inc. (ESRI) (can be accessed at *http://www.esri.com*), and was designed for national implementation. The application uses a GIS and digital map data, allowing the user to automatically determine flood magnitude and frequency and values of basin characteristics for gaged and ungaged sites. For ungaged sites on streams, the application calculates values of basin characteristics and estimates streamflow statistics using updated flood-frequency regression equations.

The flood-frequency regression equations formulated from this study for the State of New Jersey have been input into the USGS National Streamflow Statistics (NSS) (Turnipseed and Ries, 2007) program and are used to solve peak-flow frequency estimates within the Web application. Using the updated flood-frequency regression equations, the user will be able to choose a point anywhere along a stream, and the GIS will automatically delineate the drainage-basin boundary, calculate values for selected basin characteristics, and obtain peak-flow frequency estimates. In cases where the drainage-basin area of the ungaged site is within the range of 1/3 to 3 times the drainage-basin area of the nearest streamflow-gaging station on the same stream, the application will use the area-weighted ratio to determine the peak-flow frequency estimate. The application uses the equation described in the section “Estimation of Flood Frequency and Magnitude for an Ungaged Site Upstream or Downstream from a Gaged Site.” The user can select existing USGS streamflow-gaging stations and obtain peak-flow frequency statistics and other flow data with a link to the National Water Information System Web interface (NWIS-WEB).

A StreamStats Web application has been developed and implemented for use in New Jersey. The basin characteristics available for data retrieval for a delineated drainage basin, gaged or ungaged, are drainage-basin area, in square miles; basin shape index; mean basin elevation, in feet; longest flow-path length, in miles; percentage of forest cover; 2000 population density, in persons per square mile (although 1990 population density was used for the development of the regression equations in this study, the StreamStats application will offer the more current 2000 population-density data); 10–85 basin slope, in feet per mile; percentage of storage; sum of length of streams in basin, in miles; percentage of urban land cover; and percentage of wetland land cover. Tidal areas and highly regulated stream reaches on the Rockaway, Wanaque, Hackensack, Pequannock, and Delaware Rivers (fig. 6) have been excluded from basin delineation and statistics estimation on the StreamStats website.

A detailed description of the application can be found in the USGS fact sheet by Ries and others (2004). Complete StreamStats application user instructions are provided through the links on the StreamStats web site at *http://streamstats.usgs.gov*. The Web site also provides links to (1) general limitations of the application, (2) other State applications, (3) definitions of terms, (4) downloadable presentations and other technical information about the application, and (6) contact information.



Base from U.S. Geological Survey digital line graph files, 1:24,000, Universal Transverse Mercator projection, Zone 18, NAD 83

Figure 6. Highly regulated stream reaches on the Hackensack, Rockaway, Wanaque, and Pequannock Rivers and tidal areas excluded from basin delineation and statistics estimation on the StreamStats Web site.

Summary

This study was performed by the U.S. Geological Survey in cooperation with the New Jersey Department of Environmental Protection and the U.S. Army Corps of Engineers. The report presents the flood-frequency statistics and basin characteristics used to develop regression equations to estimate flood magnitudes at the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals for unregulated or slightly regulated rural or urban streams in New Jersey with drainage areas greater than 0.4 mi^2. Multiple-regression analyses were used to define the relations between flood discharge and basin characteristics. Results of the analyses indicated that peak flow at a site is related to the drainage area, main channel slope, percentage of lake and wetland area, population density, and flood-frequency region. The State was divided into five flood-frequency regions in order to refine the regression equations. The standard errors of estimate ranged from 49 to 63.9 percent. Gaging-station data used in the analyses are listed in this report.

The regional regression equations provided in this report can be used to improve the estimates of flood magnitude and frequency at gaged sites by weighting together the log-Pearson Type III data and the estimated data from the regression equations, according to their equivalent years of record. Weighted flood-frequency estimates are listed for all New Jersey gaged sites used in the regression analysis.

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References Cited

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

Dalrymple, Tate, 1960, Flood frequency analysis: U.S. Geological Survey Water-Supply Paper 1543-A, 80 p.

Environmental Systems Research Institute, Inc., 2007, Hydro Data Model, accessed August 29, 2007, at *http://support.esri.com/index.cfm?fa=downloads.dataModels.filteredGateway&dmid=15*.

Federal Emergency Management Agency, 1995, Flood insurance study, Bergen County, New Jersey (All Jurisdictions): Washington, D.C., Federal Emergency Management Agency, v. 1–5, unpaginated.

Federal Emergency Management Agency, 2007, Flood insurance study, Passaic County, New Jersey: Washington, D.C., Federal Emergency Management Agency, v. 1–5, unpaginated.

Federal Emergency Management Agency, 1985, Flood insurance study, Morris County, New Jersey: Washington, D.C., Federal Emergency Management Agency.

Fenneman, N.M., 1938, Physiography of Eastern United States: New York, McGraw-Hill, 714 p.

Hardison, C.H., 1971, Prediction error of regression estimates of streamflow characteristics at ungaged sites, *in* Geological Survey research 1971, chap. C: U.S. Geological Survey Professional Paper 750-C, p. C228–C236.

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in Water Resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 510 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: Hydrology Subcommittee Bulletin 17B (Distributed by U.S. Geological Survey, Office of Water Data Coordination, Reston, Va.), 183 p.

Lins, H.F., 2005, Streamflow trends in the United States… from the National Streamflow Information Program: U.S. Geological Survey Fact Sheet 2005–3017, 4 p.

Lumia, Richard, 1991, Regionalization of flood discharges for rural, unregulated streams in New York, excluding Long Island: U.S. Geological Survey Water-Resources Investigations Report 90-4197, 119 p.

Lumia, Richard, 2000, Development of a contour map showing generalized skew coefficients of annual peak discharges of rural, unregulated streams in New York, excluding Long Island: U.S. Geological Survey Water-Resources Investigations Report 00-4022, 11 p.

Lumia, R., Freehafer, D.A., and Smith, M.J., 2006, Magnitude and frequency of floods in New York: U.S. Geological Survey Scientific Investigations Report 2006–5112, 153 p.

McCall, J.E., and Lendo, A.C., 1970, A modified streamflow data program for New Jersey: U.S. Geological Survey Open-File Report, 46 p., 1 app.

Minitab, Inc., 2006, Minitab 15 Statistical Software: State College, PA, LEAD Technologies, Inc.

New Jersey Department of Environmental Protection and New Jersey Geological Survey, 2000, Watersheds (Subwatersheds by name–DEPHUC14): Trenton, N.J.

New Jersey Department of Environmental Protection, 2007, NJDEP 2002 Landuse/Landcover by Watershed Management Area (WMA): Trenton, N.J.

Parker, G.G., Hely, A.G., Keighton, W.B., Olmstead, F.H., and others, 1964, Water resources of the Delaware River basin: U.S. Geological Survey Professional Paper 381, 200 p.

Quakenbush, G.A., and Tedrow, J.C.F., 1954, Land type areas of New Jersey: New Brunswick, New Jersey, New Jersey Agricultural Experiment Station, Rutgers University, 1 map, scale 1:506,880.

Ries, K.G., III, Steeves, P.A., Coles, J.D., Rea, A.H., and Stewart, D.W., 2004, StreamStats: A U.S. Geological Survey web application for stream information: U.S. Geological Survey Fact Sheet 2004–3115, 4 p.

Ries, K.G., and Dillow, J.J.A., 2006, Magnitude and frequency of floods on nontidal streams in Delaware: U.S. Geological Survey Scientific Investigations Report 2006–5146, 59 p.

Roland, M.A., and Stuckey, M.H., 2008, Regression equations for estimating flood flows at selected recurrence intervals for ungaged streams in Pennsylvania: U.S. Geological Survey Scientific Investigations Report 2008–5102, 57 p.

Sauer, V.B., 1974, Flood characteristics of Oklahoma streams: U.S. Geological Survey Water-Resources Investigations Report 52-73, 301 p.

Schopp, R.D., and Firda, G.D., 2008, Flood magnitude and frequency of the Delaware River in New Jersey, New York, and Pennsylvania: U.S. Geological Survey Open-File Report 2008–1203, 9 p.

Stankowski, S.J., 1972, Population density as an indirect indicator of urban and suburban land-surface modifications, *in* Geological Survey Research 1972, chap. B: U.S. Geological Survey Professional Paper 800-B, p. B219–B224.

Stankowski, S.J., 1974, Magnitude and frequency of floods in New Jersey with effects of urbanization: Trenton, N.J., New Jersey Department of Environmental Protection, Special Report 38, 45 p.

Steeves, P.A., 2002, NHD Watershed: Tools and applications, *in* Symposium on Terrain Analysis for Water Resources Applications, December 16–18, 2002, University of Texas, Austin, Texas, accessed July 9, 2007, at *http://www.crwr.utexas.edu/terrainAnalysis/presentations/121802/track2%20(rm%20122)/steeves/NHD%20Watershed.ppt*.

Stuckey, M.H., and Reed, L.A., 2000, Techniques for estimating magnitude and frequency of peak flows for Pennsylvania streams: U.S. Geological Survey Water-Resources Investigations Report 00-4189, 43 p.

Tasker, G.D., and Stedinger, A.M., 1986, Regional skew with weighted LS regression: Journal of Water Resources Planning and Management, v. 3, no. 2, p. 225–237.

Tasker, G.D., and Stedinger, A.M., 1989, An operational GLS model for hydrologic regression: Journal of Hydrology, v. 3, p. 361–375.

Thomas, D.M., 1964, Floods in New Jersey, magnitude and frequency: Trenton, N.J., New Jersey Department of Conservation and Economic Development, Circular 13, 145 p.

Thomas, D.M., and Benson, M.A., 1970, Generalization of streamflow characteristics from drainage basin characteristics: U.S. Geological Survey Water-Supply Paper 1975, 55 p.

Tice, R.H., 1968, Magnitude and frequency of floods in the United States, part 1-B, North Atlantic slope basins, New York to York River: U.S. Geological Survey Water-Supply Paper 1672, 585 p.

Turnipseed, D.P., and Ries, K.G., III, 2007, The National Streamflow Statistics Program: Estimating high and low streamflow statistics for ungaged sites: U.S. Geological Survey Fact Sheet 2007–3010, 4 p.

U.S. Army Corps of Engineers, 1983, Generalized skew study for the Delaware River basin: Special projects memo no. 83-1, 43 p.

U.S. Census Bureau, 2007, Census 2000 summary file 1 technical documentation: Washington, D.C., U.S. Census Bureau, 637 p.

U.S. Census Bureau, 2008, Census 2000 State and county quick facts, accessed on June 20, 2008, at *http://www.census.gov/main/www/cen2000.html*.

U.S. Geological Survey, 1999a, The national hydrography data set, accessed November 27, 2006, at *http://nhd.usgs.gov/* .

U.S. Geological Survey, 1999b, The national elevation data set, accessed November 27, 2006, at *http://ned.usgs.gov/* .

U.S. Geological Survey, 2002, Low-flow statistics for Pennsylvania streams, documentation of statistics computation methodology: U.S. Geological Survey, New Cumberland, Pennsylvania, accessed June 1, 2009, at *http://pa.water.usgs.gov/pc38/flowstats/* .

Vermeule, C.C., 1894, Report on water-supply, water power, the flow of streams and attendant phenomena: Geological Survey of New Jersey, Volume III of the Final Report of the State Geologist: Trenton, N.J., 351 p., 2 app.

Water Resources Council, Hydrology Committee, 1967, A uniform technique for determining flood flow frequencies, Bulletin 15: Washington, D.C.

Workforce New Jersey Public Information Network, 2000, Table 6, New Jersey resident population by municipality: 1930–1990, accessed February 23, 2007, at *http://www.wnjpin.state.nj.us/OneStopCareerCenter/LaborMarketInformation/lmi01/poptrd6.htm.*

Yang, Limin, Huang, Chengquan, Homer, C.G., Wylie, B.K., and Coan, M.J., 2003, An approach for mapping large-area impervious surfaces: Synergistic use of Landsat 7 ETM+ and high spatial resolution imagery, accessed July 9, 2007, at *http://landcover.usgs.gov/pdf/imppaperfinalwithall.pdf.*

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Appendixes 1–2

Appendix 1. Results of skew analysis for 119 streamflow-gaging stations in New Jersey and surrounding States.

[USGS, U.S. Geological Survey; Hst. period, years specified for historic data adjustment; --, not applicable]

USGS station number	Station name	Years of peak record	Hst. period	Station skew	Unbiased station skew	Skew region
01368000	Wallkill River near Unionville, NY	51	62	1.010	1.129	Non-Coastal Plain
01368500	Rutgers Creek at Gardnerville, NY	41	--	1.254	1.438	Non-Coastal Plain
01369000	Pochuck Creek near Pine Island, NY	41	--	0.488	0.559	Non-Coastal Plain
01369500	Quaker Creek at Florida, NY	43	--	0.242	0.276	Non-Coastal Plain
01377500	Pascack Brook at Westwood, NJ	73	--	0.641	0.694	Non-Coastal Plain
01378385	Tenakill Brook at Closter, NJ	42	--	0.239	0.273	Non-Coastal Plain
01378590	Metzler Brook at Englewood, NJ	43	--	0.482	0.549	Non-Coastal Plain
01378690	Passaic River near Bernardsville, NJ	40	--	0.407	0.468	Non-Coastal Plain
01379000	Passaic River near Millington, NJ	89	--	0.212	0.226	Non-Coastal Plain
01379500	Passaic River near Chatham, NJ	70	--	0.314	0.341	Non-Coastal Plain
01380500	Rockaway River above Reservoir, at Boonton, NJ	69	--	0.068	0.074	Non-Coastal Plain
01381500	Whippany River at Morristown, NJ	86	--	-0.097	-0.104	Non-Coastal Plain
01381900	Passaic River at Pine Brook, NJ	40	--	-0.301	-0.346	Non-Coastal Plain
01383500	Wanaque River at Awosting, NJ	89	--	0.354	0.378	Non-Coastal Plain
01384000	Wanaque River at Monks, NJ	52	--	-0.536	-0.598	Non-Coastal Plain
01384500	Ringwood Creek near Wanaque, NJ	64	--	0.656	0.718	Non-Coastal Plain
01386000	West Brook near Wanaque, NJ	49	72	0.222	0.249	Non-Coastal Plain
01387500	Ramapo River near Mahwah, NJ	96	103	0.505	0.537	Non-Coastal Plain
01387880	Pond Brook at Oakland, NJ	35	--	0.733	0.859	Non-Coastal Plain
01388000	Ramapo River at Pompton Lakes, NJ	85	--	0.393	0.421	Non-Coastal Plain
01389030	Preakness Brook near Preakness, NJ	29	--	0.940	1.134	Non-Coastal Plain
01389534	Peckman River at Ozone Avenue, at Verona, NJ	29	61	0.694	0.838	Non-Coastal Plain
01389765	Molly Ann Brook at North Haledon, NJ	29	62	0.970	1.171	Non-Coastal Plain
01389900	Fleischer Brook at Market Street, at Elmwood Park, NJ	39	--	1.508	1.740	Non-Coastal Plain
01390500	Saddle River at Ridgewood, NJ	53	62	1.005	1.119	Non-Coastal Plain
01390900	Ramsey Brook at Allendale, NJ	33	--	0.252	0.298	Non-Coastal Plain
01391500	Saddle River at Lodi, NJ	42	--	-0.131	-0.150	Non-Coastal Plain
01393450	Elizabeth River at Ursino Lake, at Elizabeth, NJ	55	--	-0.039	-0.043	Non-Coastal Plain
01394500	Rahway River near Springfield, NJ	67	--	1.144	1.246	Non-Coastal Plain
01395000	Rahway River at Rahway, NJ	86	--	0.426	0.456	Non-Coastal Plain
01396000	Robinsons Branch at Rahway, NJ	66	69	0.337	0.368	Non-Coastal Plain
01396500	South Branch Raritan River near High Bridge, NJ	90	111	0.317	0.338	Non-Coastal Plain
01396582	Spruce Run at Main Street, at Glen Gardner, NJ	26	--	-0.126	-0.155	Non-Coastal Plain
01396660	Mulhockaway Creek at Van Syckel, NJ	30	--	-0.314	-0.377	Non-Coastal Plain
01397000	South Branch Raritan River at Stanton, NJ	92	--	0.072	0.077	Non-Coastal Plain
01397500	Walnut Brook near Flemington, NJ	71	--	0.105	0.114	Non-Coastal Plain
01398000	Neshanic River at Reaville, NJ	77	--	0.689	0.743	Non-Coastal Plain
01398045	Back Brook tributary near Ringoes, NJ	29	--	-0.185	-0.223	Non-Coastal Plain
01398107	Holland Brook at Readington, NJ	26	--	1.445	1.778	Non-Coastal Plain
01398500	North Branch Raritan River near Far Hills, NJ	86	88	0.222	0.237	Non-Coastal Plain

Appendix 1. Results of skew analysis for 119 streamflow-gaging stations in New Jersey and surrounding States.—Continued

[USGS, U.S. Geological Survey; Hst. period, years specified for historic data adjustment; --, not applicable]

USGS station number	Station name	Years of peak record	Hst. period	Station skew	Unbiased station skew	Skew region
01399500	Lamington (Black) River near Pottersville, NJ	86	--	0.382	0.409	Non-Coastal Plain
01399510	Upper Cold Brook near Pottersville, NJ	25	--	1.340	1.662	Non-Coastal Plain
01399525	Axle Brook near Pottersville, NJ	29	--	-0.208	-0.251	Non-Coastal Plain
01399670	South Branch Rockaway Creek at Whitehouse Station, NJ	30	--	0.094	0.113	Non-Coastal Plain
01400000	North Branch Raritan River near Raritan, NJ	85	111	0.534	0.572	Non-Coastal Plain
01400500	Raritan River at Manville, NJ	96	111	0.654	0.695	Non-Coastal Plain
01400730	Millstone River at Plainsboro, NJ	36	--	0.039	0.046	Coastal Plain
01400900	Stony Brook at Glenmoore, NJ	40	--	0.257	0.296	Non-Coastal Plain
01400930	Baldwins Creek at Pennington, NJ	48	--	-0.182	-0.205	Non-Coastal Plain
01400950	Hart Brook near Pennington, NJ	39	--	-0.038	-0.044	Non-Coastal Plain
01401000	Stony Brook at Princeton, NJ	54	--	0.515	0.572	Non-Coastal Plain
01401301	Millstone River at Carnegie Lake, at Princeton, NJ	50	84	-0.395	-0.442	Non-Coastal Plain
01401595	Rock Brook near Blawenburg, NJ	40	--	0.672	0.773	Non-Coastal Plain
01401600	Beden Brook near Rocky Hill, NJ	40	--	0.463	0.532	Non-Coastal Plain
01401650	Pike Run at Belle Mead, NJ	28	197	1.038	1.260	Non-Coastal Plain
01401870	Six Mile Run near Middlebush, NJ	40	--	0.326	0.375	Non-Coastal Plain
01402000	Millstone River at Blackwells Mills, NJ	87	--	0.400	0.428	Non-Coastal Plain
01402600	Royce Brook tributary near Belle Mead, NJ	29	195	1.621	1.956	Non-Coastal Plain
01403060	Raritan River below Calco Dam, at Bound Brook, NJ	76	306	0.272	0.293	Non-Coastal Plain
01403400	Green Brook at Seeley Mills, NJ	39	110	0.654	0.755	Non-Coastal Plain
01403500	Green Brook at Plainfield, NJ	72	--	0.701	0.759	Non-Coastal Plain
01403540	Stony Brook at Watchung, NJ	33	110	0.953	1.126	Non-Coastal Plain
01405400	Manalapan Brook at Spotswood, NJ	51	--	0.166	0.186	Coastal Plain
01405500	South River at Old Bridge NJ	49	--	-0.058	-0.065	Coastal Plain
01407290	Big Brook near Marlboro, NJ	28	--	-0.921	-1.118	Coastal Plain
01407705	Shark River near Neptune City, NJ	41	--	0.555	0.636	Coastal Plain
01407760	Jumping Brook near Neptune City, NJ	41	--	-0.430	-0.493	Coastal Plain
01407830	Manasquan River near Georgia, NJ	27	--	-0.083	-0.101	Coastal Plain
01408000	Manasquan River at Squankum, NJ	76	--	-0.320	-0.345	Coastal Plain
01408015	Mingamahone Brook at Farmingdale, NJ	39	--	0.357	0.412	Coastal Plain
01408029	Manasquan River near Allenwood, NJ	39	--	-0.833	-0.961	Coastal Plain
01408120	North Branch Metedeconk River near Lakewood, NJ	35	--	-0.364	-0.426	Coastal Plain
01408500	Toms River near Toms River, NJ	79	--	-0.003	-0.003	Coastal Plain
01409000	Cedar Creek at Lanoka Harbor, NJ	39	--	0.648	0.748	Coastal Plain
01409400	Mullica River near Batsto, NJ	50	--	0.156	0.175	Coastal Plain
01409500	Batsto River at Batsto, NJ	78	--	-0.198	-0.213	Coastal Plain
01409810	West Branch Wading River near Jenkins, NJ	25	--	-0.879	-1.090	Coastal Plain
01410000	Oswego River at Harrisville, NJ	77	--	0.154	0.166	Coastal Plain
01410150	East Branch Bass River near New Gretna, NJ	30	--	1.313	1.576	Coastal Plain
01411000	Great Egg Harbor River at Folsom, NJ	82	--	0.373	0.400	Coastal Plain

Appendix 1. Results of skew analysis for 119 streamflow-gaging stations in New Jersey and surrounding States.—Continued

[USGS, U.S. Geological Survey; Hst. period, years specified for historic data adjustment; --, not applicable]

USGS station number	Station name	Years of peak record	Hst. period	Station skew	Unbiased station skew	Skew region
01411300	Tuckahoe River at Head of River, NJ	37	--	0.836	0.972	Coastal Plain
01411500	Maurice River at Norma, NJ	75	140	0.838	0.905	Coastal Plain
01412000	Menantico Creek near Millville, NJ	44	--	0.944	1.073	Coastal Plain
01412500	West Branch Cohansey River at Seeley, NJ	54	--	0.976	1.084	Coastal Plain
01440000	Flat Brook near Flatbrookville, NJ	84	--	0.232	0.249	Non-Coastal Plain
01443500	Paulins Kill at Blairstown, NJ	84	--	0.281	0.301	Non-Coastal Plain
01445000	Pequest River at Huntsville, NJ	63	--	0.249	0.273	Non-Coastal Plain
01445500	Pequest River at Pequest, NJ	56	--	-0.104	-0.115	Non-Coastal Plain
01446000	Beaver Brook near Belvidere, NJ	78	--	-0.036	-0.039	Non-Coastal Plain
01455200	Pohatcong Creek at New Village, NJ	38	--	-0.096	-0.111	Non-Coastal Plain
01456000	Musconetcong River near Hackettstown, NJ	75	--	-0.078	-0.084	Non-Coastal Plain
01457000	Musconetcong River near Bloomsbury, NJ	89	--	-0.001	-0.001	Non-Coastal Plain
01459500	Tohickon Creek near Pipersville, PA	40	--	0.170	0.196	Non-Coastal Plain
01464000	Assunpink Creek at Trenton, NJ	42	125	0.044	0.050	Non-Coastal Plain
01464400	Crosswicks Creek at New Egypt, NJ	26	--	1.115	1.372	Coastal Plain
01464500	Crosswicks Creek at Extonville, NJ	67	69	-0.165	-0.180	Coastal Plain
01464538	Crafts Creek at Columbus, NJ	30	--	0.147	0.176	Coastal Plain
01465850	South Branch Rancocas Creek at Vincentown, NJ	42	68	-0.434	-0.496	Coastal Plain
01466000	Middle Branch Mt Misery Brook in Byrne State Forest, NJ	25	--	0.599	0.743	Coastal Plain
01466500	McDonalds Branch in Byrne State Forest, NJ	54	--	-0.012	-0.013	Coastal Plain
01467000	North Branch Rancocas Creek at Pemberton, NJ	86	--	-0.241	-0.258	Coastal Plain
01467048	Pennypack Creek at Lower Rhawn St. Brg., Philadelphia, PA	40	--	0.454	0.522	Non-Coastal Plain
01467081	South Branch Pennsauken Creek at Cherry Hill, NJ	39	--	0.773	0.892	Coastal Plain
01467150	Cooper River at Haddonfield, NJ	44	67	0.192	0.218	Coastal Plain
01467160	North Branch Cooper River near Marlton, NJ	26	64	0.841	1.035	Coastal Plain
01467305	Newton Creek at Collingswood, NJ	43	--	0.328	0.374	Coastal Plain
01467317	South Branch Newton Creek at Haddon Heights, NJ	44	--	-0.256	-0.291	Coastal Plain
01475000	Mantua Creek at Pitman, NJ	59	124	1.023	1.127	Coastal Plain
01475510	Darby Creek near Darby, PA	27	--	-0.510	-0.623	Non-Coastal Plain
01475550	Cobbs Creek at Darby, PA	27	--	-0.204	-0.249	Non-Coastal Plain
01477000	Chester Creek near Chester, PA	74	--	0.582	0.629	Non-Coastal Plain
01477120	Raccoon Creek near Swedesboro, NJ	41	--	-0.262	-0.300	Coastal Plain
01482500	Salem River at Woodstown, NJ	61	124	-0.236	-0.259	Coastal Plain
01483200	Blackbird Creek at Blackbird, DE	52	--	0.187	0.209	Coastal Plain
01483500	Leipsic River near Cheswold, DE	33	--	0.818	0.967	Coastal Plain
01483700	St. Jones River at Dover, DE	47	--	-0.461	-0.520	Coastal Plain
01484000	Murderkill River near Felton, DE	31	--	-0.545	-0.650	Coastal Plain
01484100	Beaverdam Branch at Houston, DE	47	--	-0.080	-0.090	Coastal Plain
01487500	Trap Pond outlet near Laurel, DE	26	--	-0.451	-0.555	Coastal Plain

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01368000	VR	1,700	2,010	1,710	2,390	3,160	2,420	2,930	4,040	2,990	3,740	5,270	3,850	4,440	6,200	4,580	5,220	7,280	5,410	7,430	9,920	7,700
01368500	VR	1,550	1,150	1,540	2,380	1,950	2,360	3,110	2,600	3,080	4,270	3,550	4,210	5,350	4,320	5,250	6,630	5,210	6,480	10,700	7,560	10,300
01369000	VR	1,200	1,820	1,220	1,720	2,900	1,780	2,110	3,750	2,220	2,690	4,940	2,890	3,160	5,860	3,430	3,690	6,920	4,060	5,120	9,570	5,710
01369500	VR	370	371	370	551	619	554	689	818	698	885	1,100	904	1,050	1,330	1,080	1,220	1,590	1,260	1,700	2,260	1,770
01370000	VR	4,030	4,600	4,040	5,620	7,260	5,680	6,840	9,340	6,970	8,580	12,300	8,840	10,000	14,600	10,400	11,600	17,200	12,100	16,000	23,800	16,800
01370500	VR	5,140	4,930	5,130	6,910	7,760	6,970	8,180	9,970	8,350	9,910	13,100	10,300	11,300	15,500	11,900	12,700	18,300	13,500	16,500	25,300	18,000
01371000	VR	3,150	1,720	3,080	4,780	2,900	4,640	5,950	3,870	5,730	7,520	5,310	7,230	8,760	6,480	8,420	10,000	7,840	9,650	13,300	11,400	12,900
01373690	VR	513	542	516	1,070	914	1,050	1,590	1,220	1,520	2,430	1,670	2,250	3,230	2,030	2,920	4,170	2,450	3,690	7,070	3,540	5,940
01374130	VR	225	360	238	315	630	362	380	857	475	468	1,190	649	538	1,480	794	611	1,800	966	798	2,670	1,430
01374250	VR	372	520	378	671	883	684	939	1,180	960	1,370	1,620	1,400	1,780	1,970	1,800	2,260	2,380	2,280	3,760	3,440	3,710
01377475	GP	328	271	325	582	423	568	801	538	769	1,140	695	1,070	1,450	820	1,340	1,800	951	1,640	2,840	1,270	2,500
01377490	GP	240	480	253	306	724	342	351	900	417	411	1,140	522	456	1,320	602	503	1,510	692	620	1,960	910
01377500	GP	849	1,560	861	1,450	2,310	1,470	1,980	2,860	2,010	2,830	3,600	2,870	3,620	4,170	3,650	4,560	4,770	4,570	7,510	6,200	7,410
01378350	GP	168	488	195	196	772	271	213	995	351	232	1,310	471	245	1,560	566	258	1,830	679	285	2,510	961
01378385	GP	472	811	482	723	1,240	747	916	1,560	959	1,190	1,990	1,260	1,420	2,330	1,510	1,670	2,690	1,780	2,350	3,570	2,500
01378590	GP	194	196	194	274	297	275	333	370	335	417	468	421	485	544	491	559	622	566	755	807	761
01378615	GP	397	287	391	546	423	536	642	521	628	762	647	745	850	744	833	937	843	920	1,140	1,070	1,130
01378690	VR	740	369	728	1,360	618	1,320	1,920	820	1,840	2,830	1,110	2,670	3,680	1,350	3,440	4,690	1,620	4,340	7,880	2,310	7,140
01379000	VR	817	857	818	1,170	1,320	1,170	1,430	1,660	1,440	1,790	2,130	1,800	2,070	2,470	2,090	2,370	2,860	2,400	3,140	3,780	3,180
01379500	VR	1,300	1,100	1,300	1,800	1,670	1,800	2,150	2,090	2,150	2,630	2,650	2,630	3,000	3,050	3,000	3,380	3,510	3,390	4,350	4,600	4,370
01379700	VR	408	679	433	654	1,100	716	860	1,430	968	1,180	1,900	1,350	1,460	2,270	1,670	1,780	2,690	2,040	2,740	3,740	3,060
01379773	VR	116	256	123	182	423	201	234	553	268	308	736	367	371	879	449	440	1,040	542	629	1,450	791
01379790	VR	208	376	217	321	620	345	410	810	454	538	1,080	615	646	1,290	748	765	1,530	899	1,090	2,140	1,300
01380500	VR	2,020	1,920	2,020	3,030	2,980	3,030	3,770	3,780	3,770	4,770	4,890	4,780	5,570	5,720	5,580	6,410	6,680	6,430	8,550	9,000	8,590
01381400	VR	685	602	677	1,650	985	1,550	2,690	1,290	2,410	4,660	1,730	3,930	6,730	2,070	5,460	9,460	2,470	7,380	19,400	3,460	14,000
01381500	VR	929	1,040	931	1,380	1,650	1,390	1,700	2,140	1,710	2,120	2,820	2,150	2,450	3,360	2,500	2,780	3,960	2,850	3,610	5,460	3,730
01381800	VR	793	1,450	863	1,050	2,240	1,240	1,230	2,830	1,570	1,470	3,640	2,050	1,670	4,240	2,420	1,870	4,940	2,840	2,390	6,590	3,890
01381900	VR	3,420	4,870	3,470	4,700	7,350	4,830	5,540	9,210	5,800	6,590	11,800	7,060	7,370	13,600	8,000	8,140	15,800	9,010	9,950	21,000	11,400
01383500	VR	483	836	488	895	1,330	905	1,270	1,710	1,280	1,870	2,250	1,890	2,430	2,660	2,440	3,090	3,130	3,090	5,170	4,290	5,110
01384000	VR	1,030	1,060	1,030	1,730	1,690	1,730	2,260	2,180	2,260	3,010	2,870	3,000	3,620	3,410	3,600	4,280	4,020	4,260	6,010	5,530	5,960

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01384500	VR	435	510	436	727	866	731	982	1,160	990	1,390	1,580	1,400	1,760	1,930	1,770	2,200	2,320	2,210	3,570	3,360	3,550
01385000	VR	175	239	178	322	393	328	450	515	457	649	687	654	828	823	827	1,030	976	1,020	1,640	1,360	1,580
01386000	VR	594	589	594	951	970	952	1,230	1,280	1,230	1,650	1,720	1,650	1,990	2,070	2,000	2,380	2,470	2,390	3,440	3,480	3,440
01386500	VR	118	97	117	199	165	196	265	221	260	362	300	353	444	365	431	535	438	517	787	626	753
01387250	VR	1,770	1,190	1,710	3,110	1,940	2,920	4,300	2,530	3,920	6,210	3,390	5,460	7,970	4,060	6,840	10,100	4,840	8,430	16,600	6,800	13,100
01387300	VR	622	562	615	1,030	966	1,020	1,370	1,300	1,350	1,900	1,790	1,870	2,370	2,200	2,320	2,900	2,660	2,820	4,490	3,900	4,270
01387350	VR	157	263	164	285	447	301	402	599	429	592	818	631	772	997	815	978	1,200	1,030	1,670	1,730	1,690
01387400	VR	2,590	1,500	2,540	4,410	2,450	4,260	6,050	3,200	5,760	8,720	4,280	8,130	11,200	5,130	10,300	14,300	6,110	13,000	23,900	8,610	21,000
01387410	VR	323	162	318	576	291	563	799	402	773	1,160	567	1,110	1,480	707	1,410	1,870	868	1,760	3,040	1,310	2,830
01387420	VR	2,790	1,600	2,730	4,870	2,610	4,690	6,710	3,410	6,360	9,650	4,570	8,950	12,400	5,490	11,300	15,600	6,550	14,100	25,500	9,240	22,300
01387450	GP	563	954	574	903	1,510	929	1,170	1,930	1,220	1,550	2,530	1,630	1,860	3,010	1,960	2,210	3,530	2,340	3,140	4,830	3,330
01387500	VR	2,950	2,080	2,940	5,130	3,360	5,090	7,040	4,360	6,960	10,100	5,810	9,930	12,900	6,940	12,600	16,300	8,240	15,900	26,600	11,500	25,700
01387880	VR	398	299	394	625	480	617	816	621	801	1,110	818	1,080	1,380	970	1,330	1,680	1,140	1,610	2,600	1,560	2,450
01388000	VR	3,360	2,410	3,350	5,770	3,810	5,720	7,840	4,910	7,740	11,100	6,470	10,900	14,000	7,670	13,700	17,300	9,050	16,800	27,400	12,500	26,400
01388500	VR	5,760	4,180	5,730	10,100	6,490	9,990	13,600	8,260	13,400	18,700	10,700	18,300	23,000	12,600	22,300	27,800	14,800	26,900	40,700	20,100	39,000
01389030	GP	647	307	632	918	475	888	1,120	599	1,070	1,410	766	1,330	1,650	896	1,550	1,910	1,030	1,780	2,610	1,370	2,390
01389500	VR	7,080	7,770	7,090	10,600	11,700	10,600	13,100	14,700	13,100	16,600	18,800	16,700	19,500	21,800	19,600	22,400	25,400	22,500	30,100	33,900	30,300
01389534	GP	1,050	473	1,030	1,520	725	1,470	1,900	913	1,810	2,450	1,170	2,290	2,920	1,370	2,710	3,450	1,580	3,170	4,930	2,090	4,440
01389765	GP	562	404	555	795	620	783	981	780	962	1,260	996	1,230	1,490	1,170	1,450	1,760	1,340	1,700	2,510	1,770	2,380
01389900	GP	137	146	137	181	225	183	215	284	220	263	363	272	303	425	316	348	489	364	469	644	493
01390450	GP	1,410	911	1,400	2,260	1,430	2,220	2,910	1,830	2,840	3,820	2,390	3,700	4,560	2,850	4,390	5,370	3,330	5,150	7,500	4,540	7,120
01390500	GP	989	1,230	995	1,690	1,870	1,700	2,340	2,350	2,340	3,420	3,000	3,390	4,470	3,500	4,390	5,770	4,040	5,620	10,100	5,350	9,610
01390810	GP	473	556	476	746	835	751	983	1,040	987	1,360	1,300	1,350	1,710	1,500	1,690	2,130	1,720	2,080	3,410	2,220	3,250
01390900	GP	284	269	283	454	411	451	590	514	584	790	652	775	960	758	936	1,150	869	1,110	1,680	1,140	1,600
01391000	GP	1,060	904	1,060	1,790	1,340	1,770	2,390	1,660	2,350	3,310	2,070	3,220	4,120	2,390	3,990	5,050	2,730	4,850	7,760	3,510	7,330
01391485	GP	280	315	283	376	477	390	444	594	472	532	749	583	601	868	670	672	991	762	850	1,290	989
01391500	GP	1,570	2,250	1,590	2,500	3,310	2,540	3,190	4,080	3,250	4,140	5,100	4,220	4,890	5,880	4,990	5,680	6,710	5,790	7,680	8,680	7,810
01392000	GP	400	438	402	683	663	682	928	830	919	1,310	1,050	1,280	1,660	1,230	1,600	2,070	1,410	1,970	3,300	1,840	3,050
01392170	GP	840	650	828	1,240	988	1,210	1,570	1,240	1,520	2,040	1,580	1,960	2,450	1,850	2,330	2,910	2,130	2,740	4,200	2,800	3,860
01392210	GP	1,030	830	1,020	1,360	1,250	1,350	1,600	1,570	1,600	1,940	1,990	1,950	2,210	2,330	2,230	2,500	2,680	2,530	3,260	3,510	3,320

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01392500	GP	2,220	1,030	2,160	3,230	1,570	3,100	3,970	1,980	3,750	4,970	2,550	4,620	5,760	3,000	5,320	6,590	3,470	6,040	8,710	4,620	7,880
01393450	GP	1,700	1,130	1,690	2,460	1,660	2,430	2,950	2,040	2,900	3,550	2,550	3,480	3,980	2,940	3,900	4,390	3,340	4,300	5,320	4,280	5,220
01394000	GP	495	511	496	859	778	852	1,160	975	1,140	1,590	1,240	1,540	1,970	1,440	1,880	2,380	1,660	2,240	3,530	2,180	3,240
01394500	GP	1,210	1,500	1,220	2,000	2,250	2,010	2,720	2,810	2,720	3,920	3,560	3,900	5,070	4,150	5,010	6,470	4,770	6,350	11,100	6,270	10,700
01395000	GP	1,380	1,890	1,390	2,260	2,790	2,270	2,980	3,440	3,000	4,090	4,320	4,100	5,060	4,980	5,060	6,170	5,690	6,140	9,410	7,370	9,270
01396000	GP	1,120	921	1,120	1,750	1,330	1,740	2,240	1,620	2,210	2,960	1,990	2,900	3,570	2,270	3,490	4,250	2,550	4,130	6,140	3,210	5,890
01396500	VR	1,890	1,220	1,880	2,920	1,920	2,900	3,730	2,450	3,690	4,900	3,200	4,830	5,890	3,760	5,790	6,980	4,410	6,840	9,980	5,990	9,730
01396582	VR	1,270	462	1,230	1,800	764	1,720	2,160	1,000	2,040	2,640	1,350	2,470	3,000	1,620	2,800	3,380	1,930	3,140	4,310	2,730	4,010
01396660	UP	1,370	1,110	1,360	2,100	1,790	2,080	2,620	2,310	2,590	3,320	3,040	3,290	3,870	3,610	3,840	4,440	4,260	4,410	5,850	5,820	5,840
01397000	UP	4,470	6,400	4,500	6,980	9,740	7,040	8,980	12,200	9,080	11,900	15,500	12,000	14,400	17,900	14,600	17,200	20,800	17,400	25,000	27,400	25,100
01397500	UP	375	407	376	765	663	762	1,130	856	1,120	1,720	1,130	1,690	2,270	1,340	2,210	2,930	1,580	2,840	4,950	2,150	4,730
01398000	UP	3,240	1,830	3,220	5,490	2,870	5,420	7,510	3,650	7,370	10,800	4,730	10,500	13,800	5,540	13,300	17,400	6,480	16,700	28,900	8,690	27,400
01398045	UP	761	332	743	1,100	550	1,060	1,330	717	1,270	1,630	953	1,550	1,870	1,140	1,770	2,110	1,350	2,000	2,700	1,870	2,560
01398107	UP	887	884	887	1,370	1,450	1,380	1,770	1,890	1,780	2,410	2,510	2,420	2,980	3,000	2,980	3,650	3,560	3,640	5,680	4,940	5,540
01398500	VR	1,390	888	1,380	2,360	1,460	2,340	3,170	1,920	3,130	4,390	2,570	4,310	5,460	3,100	5,340	6,660	3,700	6,490	10,100	5,220	9,780
01399190	VR	77	369	106	115	593	186	144	766	268	188	1,010	393	225	1,200	490	267	1,410	608	383	1,930	905
01399200	VR	174	424	195	253	670	307	314	858	410	401	1,120	560	474	1,320	679	554	1,540	817	772	2,080	1,170
01399500	VR	723	750	723	1,220	1,190	1,220	1,640	1,520	1,640	2,300	1,990	2,290	2,880	2,340	2,850	3,550	2,740	3,500	5,520	3,730	5,400
01399510	VR	185	163	184	374	281	367	575	379	554	955	522	895	1,360	639	1,250	1,910	773	1,720	4,010	1,120	3,440
01399525	UP	449	257	441	670	460	656	827	629	808	1,040	883	1,020	1,200	1,100	1,190	1,370	1,340	1,370	1,800	2,000	1,830
01399670	UP	1,010	1,260	1,020	1,410	2,030	1,450	1,710	2,600	1,790	2,140	3,420	2,290	2,500	4,040	2,700	2,890	4,770	3,160	3,960	6,490	4,390
01399700	UP	2,310	2,750	2,340	2,950	4,410	3,100	3,380	5,680	3,690	3,950	7,490	4,570	4,380	8,890	5,240	4,830	10,500	6,030	5,930	14,400	8,000
01399830	UP	8,440	7,550	8,400	12,900	11,700	12,800	16,600	14,700	16,400	22,500	18,900	22,100	27,700	22,100	26,900	33,800	25,900	32,600	52,300	34,600	49,100
01400000	UP	8,770	7,970	8,760	13,000	12,300	13,000	16,300	15,400	16,300	21,200	19,900	21,100	25,300	23,200	25,200	29,800	27,100	29,600	42,500	36,200	42,100
01400300	UP	839	609	824	1,040	960	1,030	1,190	1,220	1,190	1,400	1,580	1,430	1,570	1,850	1,620	1,760	2,160	1,840	2,260	2,870	2,410
01400350	UP	207	205	207	360	333	356	487	431	477	679	566	654	848	672	805	1,040	790	973	1,590	1,070	1,430
01400500	UP	15,600	14,100	15,600	22,100	21,200	22,100	27,000	26,300	27,000	34,100	33,400	34,100	40,100	38,500	40,000	46,700	44,600	46,600	64,800	58,500	64,400
01400630	IN	797	816	798	1,130	1,310	1,140	1,340	1,680	1,380	1,620	2,180	1,700	1,820	2,560	1,940	2,020	2,980	2,190	2,500	3,930	2,790
01400730	IN	1,340	1,220	1,340	2,180	1,940	2,170	2,810	2,480	2,780	3,710	3,210	3,660	4,440	3,760	4,360	5,230	4,370	5,120	7,300	5,740	7,070
01400775	IN	434	236	424	761	384	731	1,040	492	979	1,460	639	1,340	1,820	751	1,650	2,240	872	2,000	3,460	1,140	2,990

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01400795	IN	411	312	403	784	509	750	1,100	654	1,030	1,580	853	1,430	2,000	1,000	1,770	2,470	1,170	2,140	3,800	1,540	3,150
01400822	IN	63	112	66	88	190	98	104	249	124	125	331	161	141	396	190	157	467	223	197	631	302
01400850	UP	290	261	288	530	434	520	757	566	731	1,150	753	1,080	1,530	900	1,410	2,000	1,070	1,800	3,590	1,470	3,080
01400900	UP	2,410	1,310	2,380	3,230	2,080	3,170	3,800	2,650	3,720	4,560	3,440	4,460	5,150	4,040	5,040	5,760	4,740	5,640	7,290	6,370	7,170
01400930	UP	311	363	312	514	610	518	681	803	688	931	1,080	942	1,150	1,300	1,160	1,400	1,550	1,410	2,100	2,180	2,110
01400947	UP	1,620	1,810	1,640	3,000	2,850	2,980	4,110	3,610	4,020	5,720	4,670	5,470	7,050	5,460	6,640	8,500	6,370	7,900	12,300	8,520	11,100
01400950	UP	117	91	116	181	153	180	229	201	227	295	267	292	348	320	345	405	379	402	552	525	548
01400960	UP	320	215	308	700	344	638	1,080	440	932	1,750	571	1,410	2,420	670	1,880	3,260	782	2,420	6,090	1,040	4,180
01400970	UP	845	433	798	1,450	694	1,320	1,950	887	1,700	2,680	1,150	2,240	3,310	1,350	2,700	4,010	1,580	3,190	5,970	2,120	4,510
01401000	UP	3,450	2,590	3,430	4,750	4,000	4,720	5,720	5,020	5,680	7,060	6,430	7,020	8,150	7,480	8,100	9,320	8,690	9,270	12,400	11,500	12,300
01401160	IN	117	107	116	180	176	180	227	227	227	294	296	294	347	349	347	405	406	405	556	534	551
01401200	UP	163	601	191	259	906	323	338	1,120	444	458	1,390	621	564	1,590	761	685	1,820	925	1,040	2,310	1,350
01401301	UP	4,790	4,980	4,790	7,220	7,340	7,230	8,860	8,970	8,870	10,900	11,100	10,900	12,500	12,700	12,500	14,000	14,400	14,000	17,700	18,300	17,800
01401520	UP	1,230	907	1,210	2,290	1,440	2,210	3,320	1,840	3,120	5,080	2,390	4,610	6,830	2,810	6,060	9,010	3,290	7,800	16,400	4,420	13,500
01401595	UP	1,070	972	1,070	1,750	1,550	1,740	2,320	1,990	2,300	3,220	2,590	3,160	4,040	3,050	3,940	4,990	3,570	4,830	7,850	4,820	7,450
01401600	UP	3,450	1,850	3,400	5,590	2,910	5,460	7,360	3,680	7,100	10,100	4,750	9,610	12,400	5,550	11,700	15,200	6,480	14,200	23,100	8,650	21,200
01401650	UP	758	757	758	1,350	1,200	1,340	1,950	1,520	1,910	3,020	1,970	2,890	4,120	2,310	3,870	5,550	2,700	5,110	10,700	3,600	9,430
01401870	UP	1,340	1,180	1,330	2,910	1,790	2,850	4,500	2,220	4,340	7,320	2,800	6,910	10,200	3,230	9,490	13,800	3,710	12,700	26,100	4,790	23,300
01402000	UP	5,890	7,050	5,910	9,390	10,400	9,410	12,200	12,700	12,200	16,500	15,800	16,500	20,200	17,900	20,100	24,300	20,500	24,100	36,200	26,100	35,500
01402600	UP	275	165	270	443	266	430	605	342	579	884	447	828	1,160	528	1,070	1,510	617	1,370	2,740	828	2,390
01403060	UP	20,200	19,800	20,200	27,700	29,200	27,700	33,000	36,000	33,100	40,000	45,100	40,300	45,500	51,700	45,800	51,300	59,600	51,800	65,900	77,200	66,700
01403150	UP	357	347	357	552	543	551	717	685	714	972	877	960	1,200	1,020	1,180	1,470	1,180	1,430	2,260	1,550	2,130
01403395	UP	251	482	261	440	771	463	627	988	662	958	1,290	999	1,300	1,520	1,330	1,730	1,780	1,740	3,300	2,400	3,140
01403400	UP	612	738	616	1,110	1,180	1,110	1,580	1,510	1,580	2,370	1,980	2,330	3,130	2,340	3,050	4,080	2,750	3,930	7,180	3,710	6,710
01403500	UP	854	1,100	858	1,270	1,720	1,280	1,610	2,190	1,630	2,110	2,850	2,150	2,550	3,350	2,600	3,040	3,920	3,100	4,460	5,240	4,520
01403535	UP	303	369	306	614	624	615	939	828	928	1,540	1,130	1,490	2,180	1,370	2,070	3,020	1,640	2,810	6,140	2,330	5,460
01403540	UP	1,040	852	1,030	1,880	1,350	1,850	2,700	1,730	2,620	4,130	2,260	3,930	5,570	2,660	5,220	7,390	3,120	6,820	13,800	4,200	12,300
01403600	UP	2,170	1,900	2,160	3,400	2,910	3,360	4,470	3,660	4,380	6,170	4,680	5,960	7,720	5,440	7,370	9,560	6,310	9,010	15,300	8,280	13,900
01403900	UP	2,240	3,680	2,290	3,950	5,440	4,040	5,490	6,680	5,590	8,000	8,340	8,040	10,400	9,530	10,300	13,200	10,900	12,900	22,000	13,900	20,800
01405030	UP	1,800	2,130	1,820	3,070	3,150	3,080	4,130	3,860	4,090	5,730	4,790	5,570	7,130	5,450	6,810	8,730	6,210	8,200	13,300	7,860	12,000

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01405300	IN	960	977	962	1,350	1,550	1,380	1,620	1,970	1,690	1,990	2,530	2,130	2,270	2,960	2,470	2,570	3,430	2,840	3,330	4,460	3,730
01405400	IN	616	822	621	1,030	1,330	1,040	1,360	1,710	1,380	1,850	2,240	1,880	2,260	2,630	2,290	2,720	3,080	2,750	3,960	4,080	3,970
01405500	IN	1,680	1,730	1,680	2,630	2,740	2,630	3,320	3,470	3,330	4,260	4,470	4,280	5,010	5,210	5,030	5,790	6,040	5,810	7,750	7,890	7,770
01407000	IN	483	341	475	805	562	784	1,070	731	1,030	1,470	966	1,390	1,820	1,150	1,710	2,210	1,350	2,050	3,340	1,810	3,010
01407290	IN	803	315	781	1,100	522	1,060	1,280	679	1,220	1,470	897	1,400	1,600	1,070	1,530	1,720	1,260	1,650	1,970	1,690	1,920
01407500	IN	1,360	1,180	1,360	2,490	1,920	2,480	3,510	2,490	3,480	5,170	3,270	5,080	6,710	3,870	6,570	8,560	4,550	8,330	14,300	6,100	13,800
01407705	OC	416	176	409	766	274	742	1,080	347	1,030	1,610	444	1,510	2,100	515	1,940	2,690	594	2,460	4,580	773	4,090
01407760	OC	634	169	620	1,080	264	1,040	1,400	336	1,330	1,830	434	1,710	2,160	507	2,000	2,490	588	2,280	3,300	770	2,970
01407830	OC	584	206	567	756	319	724	864	404	818	998	517	936	1,090	600	1,020	1,190	694	1,110	1,410	902	1,320
01408000	OC	1,030	493	1,020	1,470	747	1,450	1,740	934	1,710	2,080	1,180	2,030	2,320	1,360	2,270	2,560	1,560	2,500	3,100	1,990	3,020
01408015	OC	190	96	187	305	151	297	397	193	382	532	247	506	647	288	610	775	333	724	1,130	435	1,040
01408029	OC	1,890	608	1,850	2,700	917	2,610	3,190	1,140	3,040	3,750	1,440	3,540	4,130	1,650	3,870	4,480	1,890	4,180	5,210	2,420	4,830
01408120	OC	506	425	503	746	637	740	905	790	896	1,110	992	1,100	1,250	1,130	1,240	1,400	1,300	1,390	1,740	1,640	1,730
01408500	OC	789	882	791	1,160	1,350	1,160	1,420	1,690	1,430	1,750	2,160	1,770	2,020	2,490	2,050	2,290	2,870	2,330	2,950	3,730	3,010
01409000	OC	396	454	398	559	726	568	681	934	699	853	1,220	887	994	1,440	1,040	1,150	1,690	1,210	1,550	2,270	1,650
01409095	OC	114	107	114	198	183	197	273	245	269	393	332	383	504	402	485	637	481	605	1,050	680	964
01409280	OC	98	176	102	148	295	161	186	389	210	241	520	284	287	623	344	336	740	412	471	1,030	592
01409375	OC	34	87	39	48	138	60	58	177	79	70	228	105	79	267	125	89	310	148	111	408	201
01409400	OC	481	313	477	776	481	764	1,000	603	978	1,330	764	1,290	1,600	878	1,540	1,900	1,010	1,820	2,690	1,300	2,540
01409403	OC	10	47	13	15	78	24	19	103	35	24	137	51	28	165	63	32	195	78	41	269	114
01409500	OC	519	458	518	801	720	799	998	916	995	1,250	1,180	1,250	1,450	1,380	1,450	1,650	1,600	1,650	2,130	2,120	2,130
01409810	OC	709	457	697	1,040	737	1,020	1,240	950	1,210	1,480	1,240	1,450	1,640	1,460	1,610	1,800	1,710	1,790	2,130	2,310	2,170
01410000	OC	376	425	377	574	701	577	721	917	728	924	1,220	939	1,090	1,450	1,110	1,260	1,720	1,290	1,710	2,380	1,760
01410150	OC	68	100	69	146	172	148	232	230	232	400	312	390	584	378	557	838	452	782	1,840	639	1,640
01410810	OC	96	147	99	123	228	133	138	288	158	157	368	194	169	427	218	182	492	248	208	638	313
01411000	OC	302	525	305	468	794	476	597	990	611	784	1,250	806	942	1,430	968	1,120	1,640	1,150	1,600	2,110	1,630
01411120	OC	11	9	11	18	16	18	22	21	22	28	28	28	33	34	33	37	41	38	47	57	50
01411122	OC	74	50	72	121	85	115	162	114	152	226	155	207	285	189	257	354	225	313	565	317	477
01411300	OC	214	270	216	344	441	349	455	573	464	628	755	640	784	893	796	967	1,050	977	1,520	1,430	1,510
01411456	OC	73	154	78	132	241	142	170	305	188	220	392	249	258	455	294	296	526	343	388	687	458

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01411500	OC	506	843	512	831	1,290	844	1,120	1,630	1,140	1,590	2,080	1,610	2,030	2,400	2,050	2,550	2,780	2,560	4,220	3,620	4,180
01412000	OC	185	296	188	311	463	318	424	590	435	607	761	620	780	887	790	988	1,030	992	1,650	1,350	1,610
01412500	OC	117	67	116	203	117	200	284	158	277	420	219	406	552	268	530	715	324	681	1,260	466	1,180
01412800	OC	445	336	439	858	552	831	1,200	723	1,140	1,690	964	1,580	2,110	1,150	1,950	2,560	1,360	2,330	3,760	1,880	3,350
01440000	VR	1,610	1,070	1,600	2,620	1,810	2,600	3,420	2,420	3,390	4,600	3,300	4,540	5,600	4,010	5,520	6,720	4,850	6,610	9,830	7,040	9,640
01443280	VR	186	341	198	244	556	282	285	724	358	340	959	470	384	1,140	559	429	1,350	663	544	1,870	927
01443500	VR	1,830	1,470	1,820	2,730	2,320	2,720	3,420	2,980	3,400	4,380	3,890	4,360	5,170	4,580	5,140	6,020	5,370	5,980	8,310	7,340	8,240
01445000	VR	272	579	278	416	929	433	527	1,200	557	685	1,570	738	816	1,860	885	959	2,180	1,050	1,350	2,990	1,500
01445430	VR	1,330	910	1,300	1,780	1,440	1,740	2,110	1,840	2,070	2,560	2,390	2,530	2,920	2,800	2,890	3,300	3,270	3,290	4,310	4,430	4,340
01445490	VR	131	223	139	214	374	236	287	495	326	401	669	464	507	808	584	631	966	725	1,010	1,370	1,130
01445500	VR	919	1,070	922	1,270	1,700	1,290	1,510	2,170	1,540	1,800	2,820	1,870	2,030	3,310	2,130	2,250	3,870	2,390	2,780	5,260	3,020
01446000	VR	505	707	508	768	1,170	779	958	1,540	980	1,220	2,070	1,260	1,420	2,490	1,480	1,630	2,970	1,710	2,170	4,200	2,320
01446564	VR	143	55	134	219	94	200	278	125	247	362	169	314	431	205	369	506	244	428	708	347	586
01446600	VR	459	425	457	811	728	805	1,130	977	1,110	1,640	1,340	1,600	2,120	1,640	2,050	2,700	1,990	2,580	4,520	2,900	4,210
01451500	VR	1,500	1,490	1,500	3,440	2,440	3,410	5,390	3,210	5,290	8,830	4,320	8,550	12,200	5,200	11,700	16,500	6,210	15,700	30,700	8,810	28,700
01452500	VR	569	1,130	581	1,140	1,860	1,170	1,700	2,450	1,740	2,710	3,310	2,750	3,720	4,000	3,740	5,010	4,790	4,990	9,500	6,820	9,240
01455200	VR	790	899	794	1,220	1,460	1,230	1,580	1,900	1,600	2,130	2,530	2,170	2,610	3,020	2,650	3,180	3,590	3,230	4,850	5,010	4,870
01456000	VR	745	1,470	757	1,110	2,290	1,140	1,370	2,910	1,430	1,710	3,760	1,810	1,980	4,400	2,120	2,260	5,140	2,440	2,950	6,910	3,250
01457000	VR	1,950	2,260	1,950	3,140	3,530	3,150	4,040	4,510	4,060	5,300	5,890	5,330	6,330	6,930	6,360	7,440	8,130	7,480	10,300	11,100	10,300
01459010	UP	191	249	196	335	422	346	477	558	491	729	751	734	986	906	966	1,320	1,080	1,260	2,500	1,520	2,200
01459500	UP	6,300	4,350	6,240	9,430	6,840	9,300	11,800	8,700	11,600	15,200	11,300	14,800	17,900	13,300	17,400	20,900	15,600	20,300	29,000	21,100	28,000
01462197	UP	275	190	267	380	337	374	451	458	452	541	638	564	608	789	654	677	961	757	841	1,410	1,020
01463620	IN	335	702	353	631	1,150	671	879	1,490	944	1,250	1,950	1,350	1,570	2,300	1,680	1,930	2,690	2,060	2,940	3,600	3,070
01463812	UP	249	87	234	511	138	459	769	175	658	1,220	225	986	1,660	264	1,300	2,220	305	1,680	4,090	400	2,910
01464000	UP	1,340	3,430	1,400	1,920	4,990	2,070	2,320	6,040	2,570	2,860	7,420	3,260	3,270	8,380	3,760	3,700	9,490	4,330	4,770	11,900	5,670
01464400	OC	985	438	959	1,500	669	1,440	1,930	839	1,820	2,580	1,070	2,380	3,160	1,230	2,870	3,820	1,410	3,430	5,790	1,820	5,040
01464405	OC	53	39	52	77	63	75	94	82	92	115	108	113	131	128	130	146	150	147	184	201	189
01464500	IN	1,600	1,170	1,590	2,570	1,900	2,550	3,280	2,430	3,240	4,230	3,180	4,170	4,970	3,740	4,890	5,730	4,370	5,630	7,630	5,820	7,480
01464515	IN	461	442	460	736	751	737	943	989	948	1,230	1,320	1,240	1,470	1,590	1,490	1,720	1,890	1,750	2,380	2,590	2,420
01464520	IN	942	582	907	1,370	976	1,310	1,690	1,280	1,610	2,120	1,700	2,010	2,480	2,030	2,360	2,850	2,400	2,720	3,850	3,270	3,650

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01464524	IN	53	58	53	74	97	78	90	127	97	111	168	124	128	200	146	145	234	170	189	313	229
01464525	IN	126	79	122	205	130	195	266	168	248	349	220	319	417	260	377	490	303	437	678	399	589
01464530	IN	820	481	797	1,540	814	1,460	2,130	1,070	1,980	3,010	1,430	2,720	3,760	1,710	3,350	4,580	2,030	4,020	6,820	2,790	5,800
01464533	IN	28	40	29	39	71	43	46	95	55	53	129	71	59	156	84	64	186	98	75	260	134
01464538	IN	223	195	222	408	331	403	564	435	552	804	580	778	1,010	694	969	1,250	819	1,190	1,940	1,120	1,800
01464582	IN	401	301	394	617	506	605	790	662	771	1,050	877	1,020	1,270	1,050	1,220	1,520	1,230	1,450	2,220	1,670	2,070
01465000	UP	4,480	6,030	4,540	6,080	9,520	6,290	7,310	12,200	7,730	9,080	16,000	9,850	10,600	19,000	11,600	12,200	22,400	13,600	16,600	30,600	18,800
01465500	UP	10,500	8,280	10,500	16,700	12,900	16,600	21,800	16,400	21,600	29,400	21,400	29,000	36,100	25,200	35,400	43,600	29,600	42,700	65,400	40,200	63,400
01465785	UP	667	467	650	925	762	904	1,120	992	1,100	1,380	1,320	1,370	1,590	1,580	1,590	1,820	1,870	1,830	2,430	2,580	2,470
01465790	UP	812	841	815	1,160	1,320	1,180	1,420	1,690	1,470	1,790	2,190	1,880	2,110	2,580	2,230	2,450	3,020	2,610	3,390	4,030	3,600
01465798	UP	3,110	2,050	3,080	4,600	3,130	4,530	5,720	3,940	5,600	7,300	5,040	7,090	8,600	5,870	8,320	10,000	6,810	9,640	13,800	8,950	13,200
01465850	IN	741	932	747	1,170	1,520	1,190	1,460	1,960	1,490	1,820	2,570	1,880	2,090	3,030	2,180	2,360	3,540	2,490	2,970	4,730	3,190
01465880	IN	1,020	1,160	1,030	1,620	1,840	1,640	2,120	2,340	2,150	2,890	3,030	2,920	3,570	3,550	3,570	4,370	4,120	4,310	6,750	5,400	6,390
01466000	OC	13	37	14	22	66	26	31	90	37	44	124	55	56	151	70	70	182	89	113	263	142
01466500	OC	10	38	11	17	68	19	23	93	27	31	130	38	38	159	48	46	193	59	67	281	88
01467000	IN	767	1,640	780	1,110	2,650	1,150	1,350	3,390	1,420	1,660	4,420	1,780	1,900	5,190	2,060	2,140	6,070	2,360	2,730	8,060	3,080
01467042	UP	2,600	3,210	2,640	3,570	5,050	3,730	4,270	6,460	4,600	5,200	8,450	5,820	5,940	10,000	6,790	6,720	11,800	7,880	8,700	16,000	10,600
01467048	UP	3,630	3,780	3,630	5,640	5,860	5,650	7,290	7,440	7,300	9,770	9,650	9,760	11,900	11,300	11,800	14,400	13,300	14,300	21,600	17,800	21,100
01467057	IN	581	292	556	887	483	834	1,100	629	1,020	1,390	833	1,270	1,610	993	1,460	1,830	1,170	1,650	2,380	1,570	2,130
01467069	IN	683	444	663	1,050	718	1,010	1,320	920	1,250	1,700	1,200	1,590	2,000	1,410	1,860	2,330	1,640	2,150	3,180	2,160	2,870
01467081	IN	573	384	567	813	621	803	997	798	983	1,260	1,040	1,240	1,480	1,230	1,450	1,730	1,430	1,700	2,400	1,880	2,330
01467086	UP	2,370	2,090	2,350	3,380	3,280	3,370	4,070	4,200	4,090	4,980	5,490	5,060	5,670	6,490	5,820	6,380	7,630	6,620	8,100	10,300	8,600
01467087	UP	6,270	3,430	6,120	8,730	5,300	8,450	10,400	6,730	9,990	12,600	8,730	12,000	14,300	10,300	13,700	16,000	12,000	15,300	20,200	16,100	19,400
01467130	IN	150	272	159	244	446	266	317	576	356	421	756	485	507	895	588	601	1,050	704	850	1,390	992
01467150	IN	802	638	797	1,230	1,030	1,220	1,570	1,330	1,550	2,070	1,750	2,040	2,500	2,070	2,460	2,980	2,420	2,920	4,310	3,220	4,180
01467160	IN	225	281	228	330	457	340	415	589	433	541	770	572	650	910	688	774	1,060	821	1,130	1,400	1,180
01467305	IN	182	150	181	222	261	224	248	351	255	280	481	297	304	589	331	328	707	368	384	993	460
01467317	IN	75	84	75	158	146	157	231	197	229	342	269	336	439	328	429	548	393	532	847	548	811
01467330	IN	450	833	472	839	1,360	886	1,220	1,760	1,290	1,880	2,320	1,950	2,540	2,760	2,580	3,380	3,250	3,350	6,270	4,360	5,840
01467351	IN	287	426	299	425	701	461	515	912	585	626	1,210	755	707	1,440	885	785	1,690	1,030	962	2,270	1,360

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01472198	VR	2,690	1,070	2,610	4,500	1,800	4,280	5,880	2,400	5,490	7,830	3,280	7,180	9,420	3,990	8,560	11,100	4,820	10,000	15,600	6,970	13,900
01472199	VR	1,450	670	1,410	2,130	1,140	2,050	2,590	1,530	2,470	3,170	2,110	3,020	3,620	2,590	3,460	4,060	3,130	3,900	5,120	4,570	5,010
01472500	UP	4,840	7,210	4,940	6,190	11,400	6,540	7,180	14,600	7,880	8,530	19,200	9,820	9,610	22,700	11,400	10,800	26,800	13,200	13,800	36,700	17,800
01473000	UP	15,000	11,400	14,900	23,200	17,900	23,100	28,800	22,900	28,600	35,900	29,900	35,600	41,100	35,400	40,800	46,200	41,700	46,000	58,200	57,100	58,100
01473120	UP	5,760	3,330	5,660	9,450	5,270	9,170	12,900	6,740	12,300	18,700	8,820	17,500	24,400	10,400	22,500	31,500	12,300	28,600	55,300	16,700	48,600
01475000	IN	119	338	124	231	561	242	348	733	367	563	974	589	790	1,170	817	1,090	1,370	1,110	2,220	1,860	2,190
01475017	IN	42	49	42	63	84	66	77	112	84	94	150	109	107	180	128	120	213	150	148	291	199
01475019	IN	400	607	418	530	1,000	591	610	1,300	732	704	1,730	931	770	2,060	1,080	833	2,430	1,260	971	3,270	1,670
01475033	IN	33	76	37	52	135	65	68	184	93	92	254	135	112	313	170	135	377	212	201	536	321
01475300	UP	675	798	681	1,090	1,320	1,110	1,420	1,740	1,450	1,880	2,350	1,940	2,250	2,840	2,340	2,660	3,390	2,780	3,750	4,770	3,940
01475510	UP	2,880	3,380	2,900	4,050	5,360	4,140	4,880	6,890	5,080	5,980	9,070	6,380	6,850	10,800	7,410	7,740	12,700	8,530	9,990	17,400	11,400
01475530	UP	813	1,110	833	1,550	1,790	1,580	2,270	2,320	2,280	3,510	3,080	3,430	4,740	3,680	4,530	6,280	4,360	5,860	11,500	6,000	10,100
01475550	UP	2,480	2,910	2,500	3,530	4,510	3,600	4,270	5,740	4,420	5,260	7,460	5,540	6,030	8,780	6,420	6,840	10,300	7,390	8,850	13,800	9,760
01475850	UP	1,150	1,630	1,170	1,930	2,700	1,980	2,590	3,550	2,680	3,590	4,800	3,740	4,470	5,800	4,650	5,480	6,950	5,700	8,400	9,830	8,650
01476500	UP	1,290	2,560	1,340	2,190	4,180	2,320	3,020	5,470	3,240	4,370	7,340	4,710	5,660	8,830	6,060	7,220	10,600	7,690	12,300	14,800	12,700
01477000	UP	2,970	4,170	2,990	5,310	6,590	5,350	7,490	8,450	7,530	11,100	11,100	11,100	14,600	13,100	14,500	18,900	15,500	18,700	33,000	21,200	32,100
01477102	IN	51	73	54	87	134	95	113	185	128	146	261	177	171	325	216	196	397	260	255	581	371
01477110	IN	308	455	317	579	779	599	822	1,030	851	1,210	1,390	1,240	1,580	1,690	1,600	2,010	2,010	2,010	3,330	2,790	3,200
01477120	IN	752	671	749	1,270	1,140	1,260	1,660	1,510	1,650	2,190	2,030	2,180	2,610	2,450	2,590	3,050	2,910	3,030	4,140	4,030	4,130
01477480	IN	393	375	392	575	648	582	697	863	718	853	1,170	904	969	1,420	1,050	1,090	1,690	1,210	1,360	2,360	1,590
01477500	IN	659	466	637	1,240	806	1,160	1,810	1,070	1,640	2,800	1,460	2,420	3,800	1,760	3,170	5,060	2,110	4,060	9,450	2,950	6,990
01477800	UP	1,610	1,320	1,600	2,720	2,160	2,700	3,650	2,820	3,610	5,060	3,770	4,980	6,310	4,540	6,180	7,730	5,410	7,550	11,800	7,530	11,400
01478000	UP	1,790	1,880	1,790	2,650	2,980	2,660	3,290	3,810	3,310	4,150	4,990	4,200	4,850	5,900	4,920	5,580	6,950	5,690	7,470	9,430	7,650
01478040	UP	2,150	2,850	2,220	3,510	4,410	3,640	4,600	5,560	4,790	6,230	7,170	6,460	7,620	8,370	7,830	9,190	9,760	9,360	13,600	13,000	13,400
01482310	IN	130	84	125	210	151	200	273	205	257	365	284	342	442	350	414	528	423	493	766	604	705
01482500	IN	726	413	719	1,370	719	1,350	1,900	963	1,860	2,650	1,310	2,570	3,280	1,600	3,160	3,970	1,920	3,810	5,760	2,700	5,480
01483000	IN	521	498	520	949	863	941	1,300	1,150	1,280	1,820	1,560	1,780	2,260	1,900	2,190	2,750	2,270	2,650	4,080	3,180	3,870
01483200	IN	147	146	147	268	258	268	371	346	370	530	473	526	671	577	663	833	692	820	1,300	975	1,270
01483290	IN	138	58	129	220	105	200	290	142	256	402	197	343	504	242	423	625	292	513	1,000	418	779
01483400	IN	24	37	26	32	66	38	38	90	50	46	124	68	52	153	83	58	183	100	72	260	143

Appendix 2. Flood-frequency estimates computed from observed streamflow-gaging station data, predicted from regression equations, and a weighted average for streamflow-gaging stations.—Continued

[USGS, U.S. Geological Survey; discharges are in cubic feet per second; O is the observed data calculated from the systematic record at the streamflow-gaging station, R is estimated from the regression equation, and W is the weighted estimate; GP, Glaciated Piedmont Physiographic Province; IN, Inner Coastal Physiographic Province; OC, Outer Coastal Physiographic Province; UP, Unglaciated Piedmont Physiographic Province; VR, Valley and Ridge Physiographic Province.]

USGS station number	Region	Estimated discharge for recurrence intervals, in cubic feet per second																				
		2-year			5-year			10-year			25-year			50-year			100-year			500-year		
		O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W	O	R	W
01483500	IN	217	247	218	415	434	416	606	582	604	937	795	922	1,260	968	1,220	1,680	1,160	1,610	3,080	1,640	2,850
01483700	IN	508	654	512	853	1,080	863	1,110	1,400	1,130	1,480	1,850	1,510	1,770	2,190	1,810	2,080	2,570	2,130	2,870	3,460	2,940
01483720	IN	143	147	143	269	259	267	378	349	371	547	480	528	697	588	663	869	707	814	1,370	999	1,230
01484000	IN	307	304	307	575	520	572	790	687	781	1,100	922	1,080	1,360	1,110	1,330	1,640	1,320	1,590	2,380	1,810	2,290
01484002	IN	19	52	23	32	97	43	44	134	65	66	189	101	87	235	133	114	287	172	205	420	286
01484050	IN	73	122	79	155	221	167	236	303	252	376	424	390	515	525	518	687	638	670	1,260	924	1,130
01488500	IN	1,040	568	1,030	1,960	959	1,930	2,710	1,250	2,640	3,800	1,670	3,660	4,710	1,990	4,520	5,690	2,350	5,420	8,290	3,210	7,810
01489000	IN	471	190	463	724	356	706	930	495	901	1,240	706	1,190	1,510	886	1,450	1,820	1,090	1,740	2,710	1,630	2,570
01490600	IN	221	192	218	315	329	318	394	434	403	512	580	531	618	695	642	739	822	767	1,100	1,130	1,110
01490800	IN	177	132	172	278	242	272	352	333	348	452	467	456	531	581	547	614	708	646	823	1,040	904
01491000	IN	1,850	1,220	1,840	3,330	2,030	3,280	4,530	2,640	4,440	6,280	3,500	6,100	7,770	4,170	7,510	9,400	4,920	9,040	13,800	6,700	13,100
01491010	IN	63	59	63	130	107	126	204	145	190	354	200	310	523	245	437	761	294	603	1,760	418	1,250
01491050	IN	63	113	69	105	212	124	144	296	179	212	423	272	277	533	356	359	655	459	640	981	769
01495000	UP	2,900	2,870	2,900	4,800	4,720	4,800	6,290	6,170	6,290	8,440	8,270	8,430	10,200	9,940	10,200	12,200	11,900	12,200	17,500	16,700	17,400

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http://nj.usgs.gov/

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