Streamflow, Base Flow, and Ground-Water Recharge in the Housatonic River Basin, Western Massachusetts and Parts of Eastern New York and Northwestern Connecticut

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Abstract

This report presents the results of a study of streamflow, base flow, and ground-water recharge in the Housatonic River Basin in western Massachusetts, eastern New York, and northwestern Connecticut. Detailed hydrologic information is needed for efficient management and optimal use of surface-water and ground-water sources and for development of future public-water supplies in the study area.

Streamflows for selected flow durations from 1 to 99 percent and the August median streamflows were estimated for 11 long-term streamflow-gaging stations in and near the study area. Estimates of streamflow and associated standard errors were determined for selected flow durations from 50 to 99 percent and the August median streamflows for 21 low-flow partial-record stations and for selected flow durations from 1 to 99 percent and the August median streamflows for two partial-record stations and seven short-term discontinued streamflow-gaging stations. Median streamflows per square mile for the 10-, 50-, and 90-percent flow durations and the August median streamflows were 3.90, 1.01, 0.185, and 0.248 cubic feet per second per square mile. Streamflows per square mile at selected flow-duration discharges between 1 and 99 percent at the 41 stations were related to basin characteristics to explain differences in streamflow characteristics. Basin characteristics included basin elevations, extent of stratified-drift deposits, land use, aspect, and underlying bedrock geology types. Most streamflow differences were positively correlated to basin elevation differences, most likely because precipitation increases with elevation, and to stratified-drift deposits, which allow more precipitation to recharge the ground water and to discharge later than do till and bedrock deposits.

Mean base flow was computed from continuous records of daily mean discharge at 11 long-term streamflow-gaging stations in and near the study area. Mean annual base flow ranged from 13.4 to 24.5 inches per year. Minimum annual base flow ranged from 45 to 72 percent of mean annual rates at the 11 long-term stations, and the ratio of base flow to streamflow (base-flow index) ranged from 0.55 to 0.80. Base-flow durations between 1 and 99 percent were calculated from streamflow records at the 11 long-term streamflow-gaging stations. Base flow accounted for 45.5 to 85.0 percent of total annual streamflow at the 1- and 99-percent flow durations.

Ground-water-recharge rates were computed from continuous records of daily mean discharge at 11 long-term streamflow-gaging stations in and near the study area. Mean annual ground-water-recharge rates ranged from 17.5 to 22.4 inches per year at 10 of the 11 long-term stations. Mean annual ground-water-recharge rates ranged from 2 to 7 inches per year higher than base flow. Minimum annual ground-water-recharge rates ranged from 48 to 72 percent of mean annual ground-water-recharge rates. Mean annual potential ground-water recharge was estimated from monthly climatological data collected at six climatological stations in and near the study area. Mean potential ground-water recharge ranged from about 17.9 to 28.9 inches per year, with a median value of 22.6 inches per year.

This median value compares well to that calculated by use of streamflow records at the 11 streamflow-gaging stations (20.0 inches per year).

Streamflows per square mile for the 10-, 50-, and 90-percent flow durations at stations in and near the study area were similar to those computed for other unregulated long-term continuous streamflow-gaging stations in central and eastern Massachusetts. Base-flow and ground-water-recharge rates in the study area compared closely to results from other studies in southeastern Massachusetts and Rhode Island, which were based on the same computational methods.

INTRODUCTION

Thirteen of the 26 Massachusetts communities partly or completely within the Housatonic River Basin (fig. 1) obtain their public-water supplies from a combination of surface-water and ground-water sources. Surface water supplies most of the public water in the Massachusetts part of the basin (Michele Drury, Massachusetts Department of Environmental Management, written commun., 1997). Concerns about the ability of surface-water supplies to meet recently instituted Federal drinking-water regulations could cause some communities in the basin to investigate ground water as an alternative source of supply. In upland areas of the Berkshire Mountains (eastern part of the basin) and Taconic Mountains (western part of the basin), stratified-drift deposits in many narrow stream valleys are potential sources of ground water. The Housatonic River Valley (central part of the basin) has extensive stratified-drift deposits and is another potential source of ground water. Efficient management and optimal development of surface-water and ground-water sources require information about streamflow, base flow (ground-water discharge), and ground-water recharge in the basin.

Water from the Housatonic River and its tributaries also is used for hydroelectric-power generation, paper and pulp manufacturing, fishing, and recreation. Thus, an improved understanding of the general hydrology in the study area is needed to balance these uses with public water-supply needs and the need to maintain stream habitat for fish, aquatic biota, and wildlife.

To provide the data and other information needed by water resource planners and managers, the U.S. Geological Survey (USGS), in cooperation with the Massachusetts Department of Environmental Management (MDEM), Division of Resource Conservation, Office of Water Resources, began a study of a part of the Housatonic River Basin in March 1994. This study is one of several done under the Massachusetts Chapter 800 legislation of 1979, which provides monies for quantitative assessments of ground-water resources and related hydrologic studies in basins of the State. Information in this report will be useful to water managers for determining water supply, developing water management plans, and determining the characteristics of streamflow and base flow to streams in the study area.

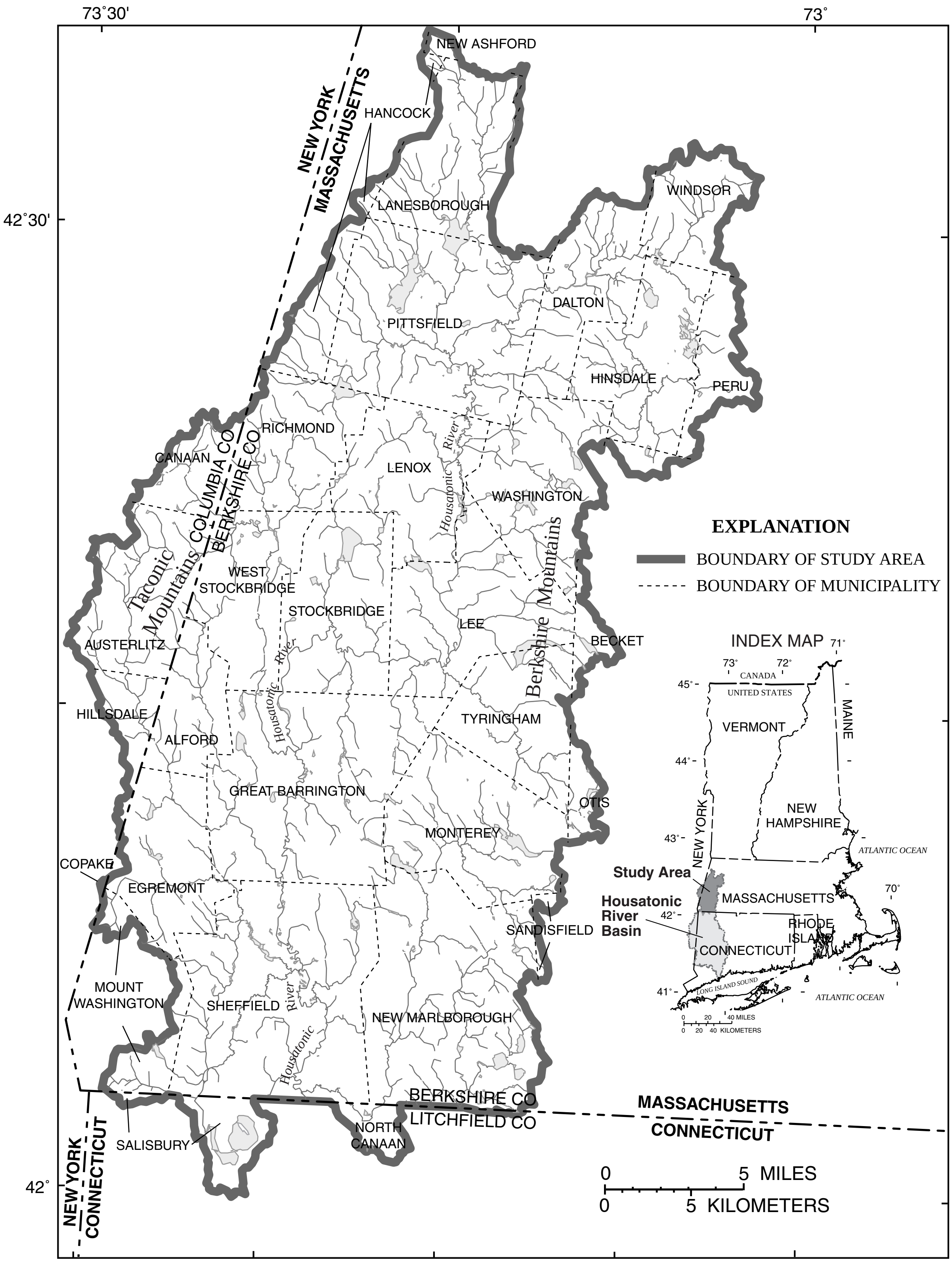
Purpose and Scope

This report provides estimates of (1) streamflow, (2) base flow (ground-water discharge) to streams, and (3) ground-water recharge in that part of the Housatonic River Basin located in western Massachusetts, eastern New York, and northwestern Connecticut. The report is based on hydrologic and geologic data collected during 1994–96 and on historical data in USGS data bases.

Streamflows were estimated for 41 subbasins in and near the study area. Base flows were estimated for 11 of the 41 subbasins. Ground-water-recharge rates were estimated by analysis of streamflow and climatological data. In addition, the relations of streamflow, base flow, and ground-water recharge to subbasin characteristics (topography, geology, and land use) were evaluated.

Previous Investigations

The Housatonic River Basin has been the subject of several studies by the USGS during the past 30 years. Studies done in the early 1960’s to the early 1970’s provide a general overview of the quantity and quality of surface water and ground water and surficial and bedrock geology in the western Massachusetts and eastern New York parts of the basin (Norvitch, 1966; Norvitch and Lamb, 1966; and Norvitch and others, 1968) and in the western Connecticut part of the basin (Cervione and others, 1972; Wilson and others, 1974). During the late 1970’s and early 1980’s, several parts



Base from U.S. Geological Survey Digital Line Graphs, 1:100,000, 1989 Universal Transverse Mercator Projection, Zone 18

Figure 1. Location of study area in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut.

of the basin were investigated for distribution and transport of polychlorinated biphenyls (PCBs); results of these studies are presented in Frink and others (1982), Gay and Frimpter (1985), and Kulp (1991). Hydrologic characteristics of streams in the Massachusetts part of the basin are described by Wandle and Lippert (1984). Reaeration coefficients were estimated for three sites on Karner Brook at South Egremont, Mass. (Parker and DeSimone, 1992).

During 1992–95, the entire Housatonic River Basin in western Massachusetts, eastern New York, and western Connecticut was part of the USGS's National Water-Quality Assessment (NAWQA) Program for the Connecticut, Housatonic, and Thames River Basins study unit. Water-quality data from the NAWQA Program have been published for inorganic and organic constituents and grain-size distribution in streambed sediment (Breault and Harris, 1997; Harris, 1997), organochlorine compounds and trace elements in fish tissue (Coles, 1996, 1998), and general surface- and ground-water quality (Gadoury and others, 1994, 1995; Grady and Mullaney, 1998). Results of analysis of nutrients, suspended sediments, and pesticides in surface-water and ground-water samples collected from 1972 through 1992 are reported by Zimmerman and others (1996) as part of the NAWQA Program. Additional information regarding the distribution and transport of PCBs in the Housatonic River Basin has been published by other Federal and State agencies and consulting firms. This information is available from the Massachusetts Department of Environmental Protection (Springfield, Mass.) and the U.S. Environmental Protection Agency (Boston, Mass.)

Acknowledgments

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DESCRIPTION OF STUDY AREA

The 1,953-square mile Housatonic River Basin drains 504 mi^2 of western Massachusetts, 217 mi^2 of eastern New York, and 1,232 mi^2 of western Connecticut before discharging into Long Island Sound. The study area (fig. 1) is confined to the 504 mi^2 in Massachusetts, 26 mi^2 of New York, and 10 mi^2 of Connecticut. In Massachusetts, the study area has 26 communities and is completely within Berkshire County. Those parts of the study area in New York and Connecticut have four communities within Columbia County and two communities within Litchfield County, respectively.

The central part of the study area is the lowland area of the Housatonic River Valley, which is bordered by the Berkshire Mountains to the east and the Taconic Mountains to the west. Elevations in the study area range from about 635 ft above sea level at the Massachusetts–Connecticut border to about 2,600 ft above sea level in the headwaters (Simcox, 1992, p. 85).

Geology

The lowlands of the Housatonic River Valley in the study area are underlain primarily by carbonate rocks (mostly limestone, dolomite, and marble), the Berkshire Mountains are primarily gneissic rocks (mostly granite biotite gneiss) with small areas of quartzitic rocks (mostly quartzite, quartzite conglomerate, and feldspathic quartzite), and the Taconic Mountains are primarily schistose rocks (mostly quartz-mica schist) (Norvitch and others, 1968, sheet 4) (fig. 2). The depth to bedrock ranges from land surface to 300 ft or more below land surface in the southern part of the study area in the Housatonic River Valley, and from land surface to 150 ft below land surface in upland stream valleys (Norvitch and others, 1968, sheet 4). A bedrock map, constructed on the basis of tectonic and lithochemical characteristics and physiography produced for the Connecticut, Housatonic, and Thames River Basins as a part of the USGS NAWQA Program (Robinson and others, 1999), is consistent with the bedrock description by Norvitch and others (1968, sheet 4).

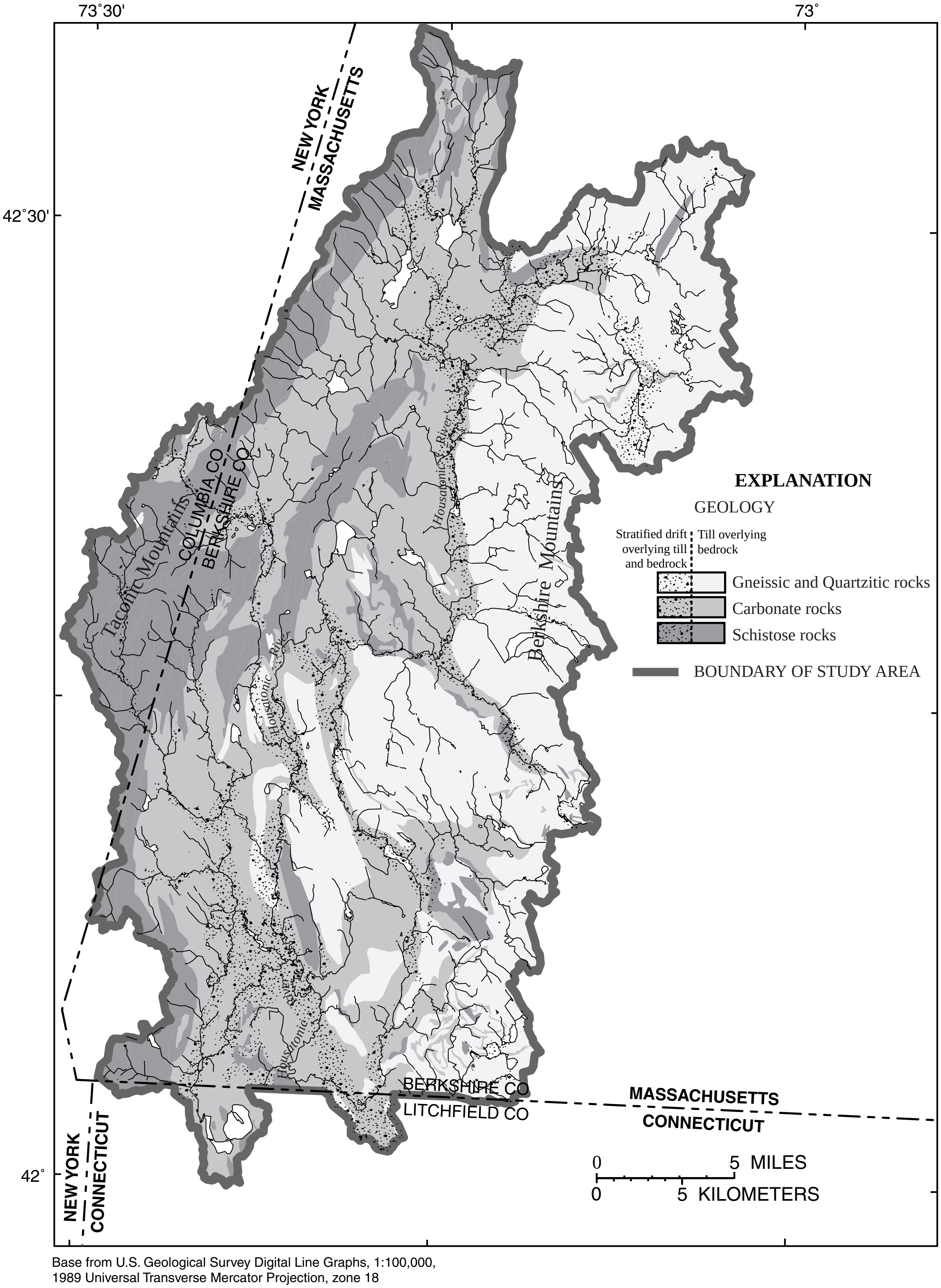


Figure 2. Distribution of underlying bedrock types and stratified-drift and till deposits in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut. (Compiled from Stone and others, 1985; Robinson and others, 1999.)

Surficial materials that were deposited during the last glacial period overlie most of the bedrock in the study area. The last glacial period began with the southeastward advance of the Hudson–Champlain ice lobe of the Laurentide ice sheet across the study area about 28,000 years ago (Warren and Stone, 1986, p. 172, 190). The retreat of the glacial ice lobe began about 19,000 to 20,000 years ago (J.R. Stone, U.S. Geological Survey, oral commun., 1997) and ended before 14,000 years ago (Warren and Stone, 1986, p. 190). Surficial deposits are primarily till in the upland areas and underlie about 83 percent of the study area (fig. 2). Till, an unsorted, unstratified mixture of clay, silt, sand, gravel, cobbles, and boulders, was deposited by glaciers on bedrock throughout much of the study area. Warren and Stone (1986, p. 174) report that the till is sandy and ranges from 0 to 50 ft in thickness.

Stratified-drift deposits overlie till primarily in the upland stream valleys and in the Housatonic River Valley (fig. 2) and underlie about 17 percent of the study area. Stratified drift is a common term for sorted and layered glaciofluvial and glaciolacustrine deposits. Glaciofluvial deposits are materials of all grain sizes (clay, silt, sand, gravel, and cobbles) deposited by glacial meltwater streams in outwash plains and valleys. Glaciolacustrine deposits generally consist of clay, silt, and fine sand deposited in temporary lakes that were present after the retreat of the glacial ice sheet. Warren and Stone (1986, p. 177, 190) report that the stratified-drift deposits in the study area are primarily glaciolacustrine deposits derived from seven glacial lakes in the Housatonic River Valley and the valleys of its major tributaries that drain from the northwest. Norvitch and others (1968, sheet 4) reported that stratified-drift sediment grains generally are coarser in the upland stream valleys than in the Housatonic River Valley. The Housatonic River Valley was occupied during the last glacial period by two glacial lakes (Warren and Stone, 1986, p. 177), which would account partially for the fine sediment grains in the valley. The stratified-drift deposits range in thickness from 0 to about 150 ft in upland valleys and from 0 to 300 ft or more in the Housatonic River Valley (Norvitch and others, 1968, sheet 4).

Climate

Three NOAA climatological stations have been operated in the Massachusetts part of the study area (fig. 3). Climatological data were collected at Lanesborough (station 194075) from 1971–79, 1981–84, 1987–90, and 1993, Great Barrington Airport (station 193213) from 1961–90, and Stockbridge (station 198181) from 1951–80 (U.S. Department of Commerce, National Oceanic Atmospheric Administration, 1983; 1993). Mean annual temperatures for the periods of record were 43.4, 45.2 and 45.6˚F at Lanesborough, Great Barrington Airport, and Stockbridge, respectively. The lowest mean monthly temperatures were 19.0, 20.1, and 21.6˚F during January at Lanesborough, Great Barrington Airport, and Stockbridge, respectively, and highest mean monthly temperatures were 66.4 and 68.1˚F during July at Lanesborough and Great Barrington Airport, respectively, and 66.2˚F during August at Stockbridge.

Mean annual precipitation amounts for the periods of record were 48.8, 43.9, and 44.8 in. at Lanesborough (station 194075), Great Barrington Airport (station 193213), and Stockbridge (station 198181), respectively. Precipitation was distributed uniformly throughout the year at the three stations. At Great Barrington Airport and Stockbridge, February was the driest month, when mean precipitation was about 2.9 and 2.7 in.; August was the wettest month, when mean precipitation was about 4.3 and 4.6 in, respectively. February was the driest month, and May was the wettest month at Lanesborough when mean precipitation was about 3.2 and 5.3 in., respectively. Mean annual snowfall at Stockbridge was about 71.4 in. (U.S. Department of Agriculture, Soil Conservation Service, 1988, p. 138).

The Lanesborough climatological station (194075), at an elevation of 1,240 ft above sea level, had lower mean temperatures and higher mean precipitation than the stations at Great Barrington Airport (193213) and Stockbridge (198181), which are at elevations of 730 and 860 ft above sea level, respectively. Low mean temperatures and high mean precipitation have been recorded at two high-elevation NOAA climatological stations near the study area (fig. 3), Cummington Hill, Mass. (station 191774) and Norfolk 2 SW, Conn. (station 195445) at elevations of 1,610 and 1,340 ft above sea level.

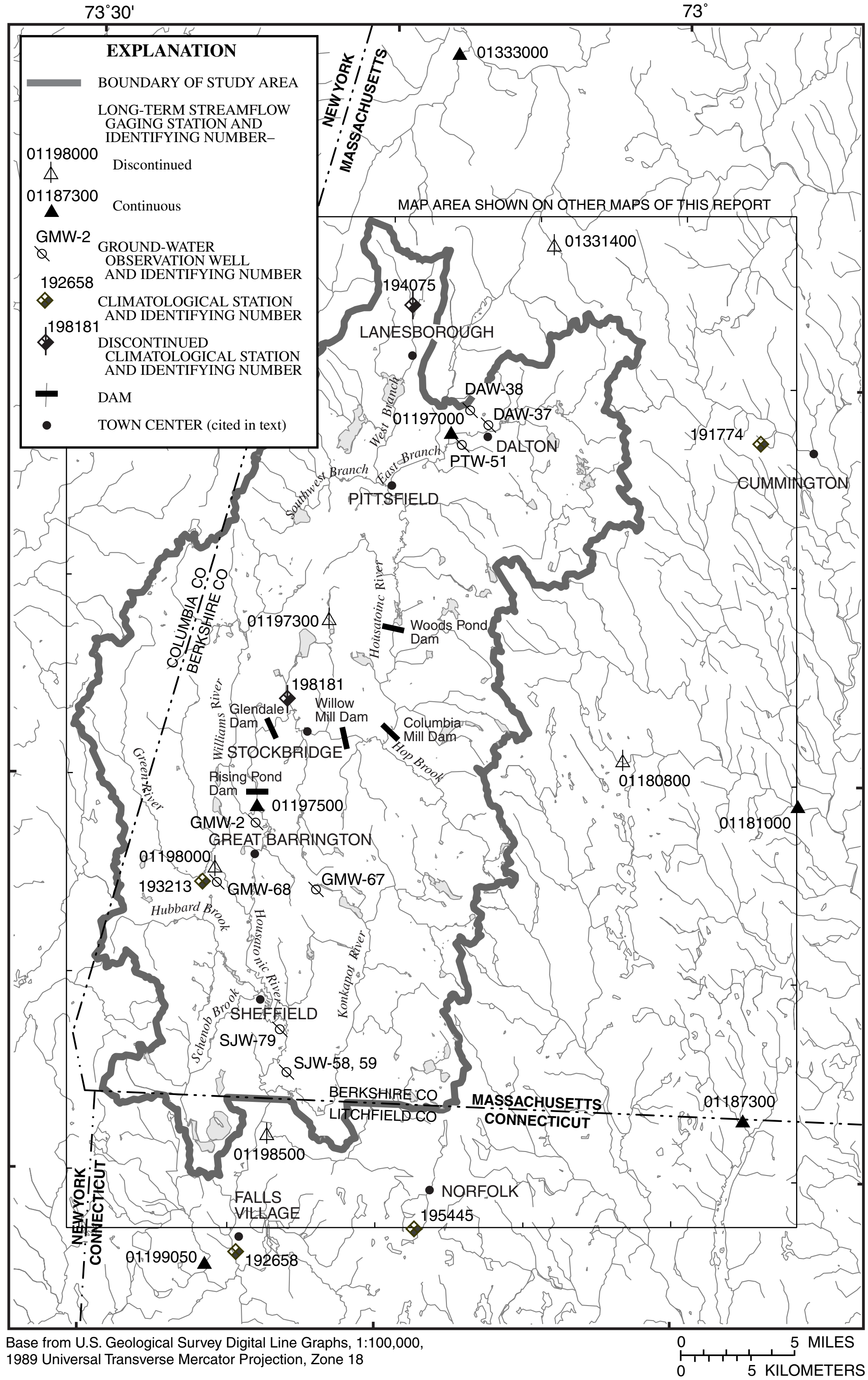


Figure 3. Location of long-term continuous and discontinued streamflow-gaging stations, ground-water observation wells, and climatological stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut.

Climatological records for 1961–90 at these two stations indicate that the mean annual temperature was 44.4 and 44.1˚F, and the mean annual precipitation was 46.0 and 51.5 in., respectively. Thus, in and near the study area, where elevations range from 635 to 2,600 ft above sea level, temperatures decrease and precipitation increases with elevation.

Hydrology

The Housatonic River is formed by the confluence of the East Branch Housatonic River and the West Branch Housatonic River at Pittsfield, Mass. From the headwaters to the streamflow-gaging station (01197500) near Great Barrington, Mass. (fig. 3), the Housatonic River flows 49.7 mi, with a mean channel slope of 16.5 ft/mi (Wandle and Lippert, 1984, p. 19). The drainage area upstream from the streamflow-gaging station near Great Barrington is 282 mi^2. There are five large dams (Woods Pond, Columbia Mill, Willow Mill, Glendale, and Rising Pond) and two small dams (Bickford and Dymon, 1990, p. 35) on the Housatonic River from Pittsfield to the streamflow-gaging station near Great Barrington. Between the Great Barrington streamflow-gaging station and the Massachusetts–Connecticut border (fig. 3), the Housatonic River is about 21 mi in length, has no dams, and has a mean channel slope of 2 ft/mi.

Tributaries having drainage basins larger than 20 mi^2 in the study area are the East Branch Housatonic River, West Branch Housatonic River, Southwest Branch Housatonic River, Hop Brook, Williams River, Green River, Schenob Brook, Hubbard Brook, and Konkapot River (fig. 3). The only subbasin where streamflows are altered substantially is the East Branch Housatonic River. It is affected by transfers of water from reservoirs in the subbasin to an adjacent subbasin for use by the city of Pittsfield and other communities. Streamflow in the Housatonic River is affected by regulation of the East Branch Housatonic River and by the five large dams that use water for hydroelectric power generation and paper-mill processes.

Ground-water levels in western Massachusetts generally increase from October through March and April as a result of recharge from precipitation. Ground-water levels generally decline from May through September, when evapotranspiration rates exceed recharge from precipitation records from three of the eight USGS observation wells in the study area (fig. 3) show long-term water-level fluctuations (changes in ground-water storage) (fig. 4). Observation wells used to monitor ground-water levels in stratified drift are wells PTW-51 and SJW-59/SJW-58 (well SJW-58 replaced well SJW-59 in October 1987 and is less than 50 ft away from well SJW-59). Hydrographs from observation well GMW-2 show water-level fluctuations in till.

The long-term water-level records (fig. 4) adequately describe typical water-level fluctuations across the study area, but the magnitude of annual water-level fluctuations may vary spatially. Seasonal variations are the primary component of water-level fluctuations in the three wells, and no long-term trends in the hydrographs are apparent. The drought of 1964–66 is evident in the water-level records for all three observation wells, and the drought of 1980–81 is evident in the water-level record for observation wells PTW-51 and SJW-59/SJW-58.

The water level in observation well SJW-59/SJW-58 fluctuated less than 5 ft annually and had gentle rises and declines that are common for wells in stratified drift (fig. 4). The water-level fluctuations in observation well SJW-59/SJW-58 are the result of its topographic location in the wide, flat Housatonic River Valley (fig. 3). The maximum annual water-level fluctuation in observation well PTW-51 was about 14 ft during the drought of 1964–66 (fig. 4). Fluctuations of this magnitude are considered unusual for a well completed in stratified drift. Water-level fluctuations in well PTW-51 are most likely amplified by the well's location on a terrace (Frimpter, 1981, p. 7) and 100 ft from a stream. Frimpter (1981, p. 13–17) reported that ground-water levels in stratified-drift wells on hillsides and terraces generally fluctuate more than ground-water levels in valley wells. Annual water-level fluctuations in observation well GMW-2 (till) were greater than 9 ft (fig. 4). Fluctuations of this magnitude are common in till because till has less storage capacity than stratified drift. The water-level fluctuations in observation well GMW-2 also may be affected by the well's location about 50 ft from an ephemeral stream.

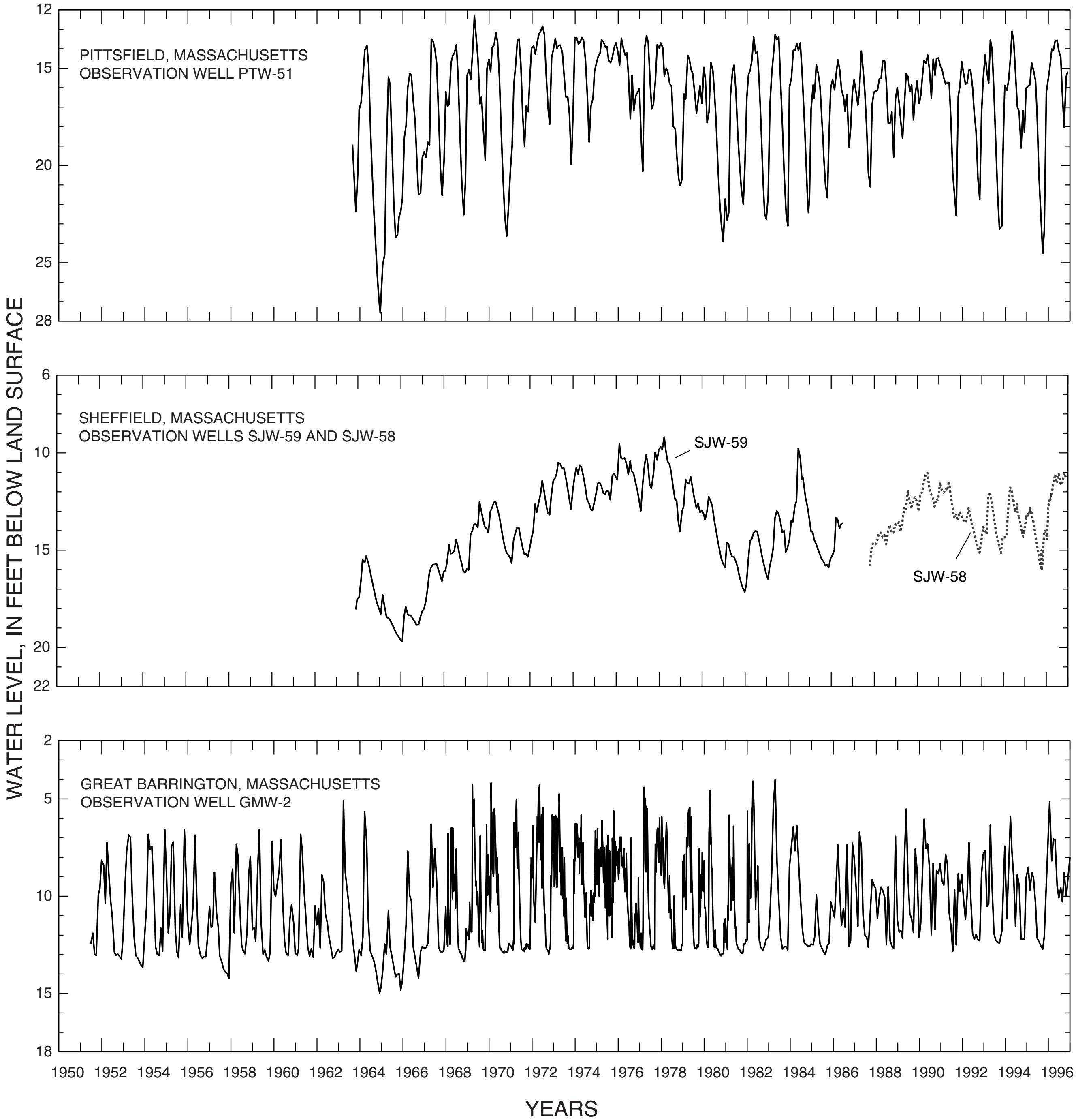


Figure 4. Water-level fluctuations for selected observation wells in the Housatonic River Basin, western Massachusetts, 1951–96. (Locations of wells are shown in fig. 3.)

Ground-water levels were measured weekly at six USGS observation wells, including well SJW–58 (long-term observation well SJW–59/SJW–59), from June 1994 to April 1996 (location shown in fig. 3, and water-level measurements provided in table 1). Water-level fluctuations in these six stratified-drift wells ranged from 2 to 9 ft and had the same seasonal variations as the three long-term USGS observation wells.

Water Use

In 1994 and 1995, public water-supply systems provided about 14.99 and 16.27 Mgal/d (table 2), respectively, to about 76,000 water users in the Massachusetts part of the study area (Michele Drury, written commun., 1997). Of the 26 communities partly or completely in the Massachusetts part of the study area, 7 communities used surface water exclusively as their public-water supply, 4 communities used ground water exclusively, and 2 communities used both supplies (fig. 5 and table 2). Homeowners in the other 13 communities take their water from private wells. Surface water supplied 92 percent of the total public water in the Massachusetts part of the study area during 1995. The city of Pittsfield used about 58 percent of the total publicly supplied water in the Massachusetts part of the study area. Only 0.19 Mgal/d of the total public water used in the Massachusetts part of the study area was not returned to the hydrologic environment during 1995. This water was pumped from well GW-3 in Lanesborough, Mass. (fig. 5), within the study area, was piped to areas of Lanesborough adjacent and north of the study area, and was not returned (Michele Drury, written commun., 1997).

Total water used in the Massachusetts part of the study area was calculated in table 2 and does not include: (1) supplies less than 0.01 Mgal/d, (2) unavailable data, and (3) water sold by the city of Pittsfield to other communities. Additionally, several apartment complexes, trailer parks, other housing developments, private schools, retreats, and resorts have their own water supplies, which are not reported in table 2. Industrial water use in the Massachusetts part of the study area was 12.52 Mgal/d during 1995 (Darin Hersh, Massachusetts Department of Environmental Protection, written commun., 1996), and industrial water supplies came from surface-water sources and ground-water wells in stratified-drift deposits and bedrock along the East Branch Housatonic River and the Housatonic River. The quantity of public water supplied in the Massachusetts part of the study area has not changed much during the last 31 years, as Norvitch and others (1968) reported 15.51 Mgal/d supplied in 1964 and Bratton (1991) reported 16.79 Mgal/d supplied in 1986.

Land Use

The study area is mainly rural with sparsely settled woodlands, agricultural lands, and wetlands. Population in the study area was reported to be about 95,000 people in the mid-1960’s (Norvitch and others, 1968, sheet 1) and 92,000 people in 1990. Population is expected to continue to decline slightly until 2010 and increase thereafter (Michele Drury, written commun., 1997).

The study area is 67 percent forest, 12 percent agriculture/open, 10 percent urban, 7 percent wetland (forested and nonforested), 2 percent water bodies, and 2 percent barren/exposed rock/mining. Table 20 (at back of report) lists land uses calculated at USGS streamflow-gaging stations for each subbasin in the study area. Land-use information is from geographic information system data layers (MassGIS, 1997, p. 72 and 73). Several State forests, a State park, State areas of critical environmental concerns, and the Appalachian Trail are in the study area. The only urban and suburban area is the city of Pittsfield, Mass. Agricultural land is mainly in the Housatonic River Valley in the southern half of the study area. The study area contains 113 ponds and lakes, of which 70 are larger than 0.02 mi^2 (Michele Drury, written commun., 1997).

Table 1. Site descriptions and water levels measured in U.S. Geological Survey observation wells completed in stratified-drift deposits in the Housatonic River Basin, western Massachusetts, 1994–96

[Location of wells shown on figure 3. USGS, U.S. Geological Survey; ft, foot]

Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)
USGS well: DAW-37.[1] **Site identification: 422831073100101.**[2] Lithology: sand and gravel. Elevation of land surface: 1,130 ft.[3]							
JUL 13, 1994	23.26	DEC 04, 1994	23.95	JUN 08, 1995	22.71	OCT 01, 1995	25.38
21	22.05	11	23.97	11	22.58	08	25.69
27	21.83	18	23.77	19	23.49	12	25.93
AUG 05	21.76	25	23.19	21	23.18	15	25.58
09	22.12	JAN 13, 1995	23.50	24	22.88	22	25.84
17	22.29	22	22.90	JUL 02	22.88	29	25.55
23	22.31	29	22.89	06	23.08	NOV 05	25.18
SEP 02	22.28	FEB 04	22.60	09	23.21	18	24.76
06	21.30	11	23.30	15	23.08	26	24.06
15	22.16	22	22.89	23	22.17	DEC 03	24.30
21	22.35	MAR 01	22.93	30	22.17	09	24.08
25	22.05	12	22.62	AUG 02	22.84	16	24.06
OCT 02	22.36	19	22.57	06	23.32	23	23.98
06	22.72	26	22.74	10	23.46	30	24.01
09	22.22	APR 02	22.40	13	23.51	JAN 14, 1996	24.10
16	22.55	11	22.57	20	24.13	24	23.06
23	22.56	19	22.25	22	24.16	27	22.45
30	22.88	29	22.44	27	24.36	FEB 15	22.52
NOV 06	22.15	MAY 07	22.23	SEP 02	24.72	25	22.16
12	22.91	14	21.91	05	24.48	28	21.96
18	23.63	20	22.32	10	24.75	MAR 13	22.17
20	24.13	21	21.98	20	25.23	30	22.23
27	23.51	JUN 04	22.39	24	25.22		
USGS Well: DAW-38.[1] **Site Identification: 422903073105701.**[2] Lithology: sand and gravel. Elevation of land surface: 1,138 ft.[3]							
JUL 06, 1994	5.32	NOV 27, 1994	7.04	JUN 08, 1995	5.18	OCT 08, 1995	6.93
13	5.64	DEC 04	6.72	11	5.27	12	6.73
21	5.83	11	6.15	19	5.40	15	6.58
27	5.74	18	6.15	21	5.49	22	5.91
AUG 05	5.89	25	6.15	24	5.64	29	4.93
09	6.05	JAN 14, 1995	6.00	JUL 02	5.89	NOV 05	4.84
17	6.19	29	4.88	06	6.03	12	4.96
23	5.67	FEB 04	5.08	09	6.13	18	4.34
SEP 02	5.80	11	5.40	15	6.17	26	4.60
06	6.02	22	5.74	23	6.41	DEC 03	5.02
15	6.46	MAR 01	5.76	30	6.30	09	5.28
21	6.66	12	4.82	AUG 02	6.41	16	5.52
25	6.72	19	4.30	06	6.33	23	5.75
OCT 02	6.20	26	4.27	10	6.28	30	5.88
06	6.17	APR 02	4.49	13	6.39	JAN 13, 1996	6.13
09	6.25	11	4.80	20	6.64	21	5.24
16	6.46	19	4.48	22	6.74	27	4.02
23	6.59	29	4.35	27	6.98	FEB 10	3.89
30	6.73	MAY 07	4.66	SEP 02	7.20	25	4.16
NOV 06	6.85	14	4.82	05	7.24	MAR 10	4.15
12	6.96	20	4.98	10	7.40	24	3.19
18	7.08	21	5.13	24	7.39	31	3.74
20	7.10	JUN 04	5.14	OCT 01	7.47		

Table 1. Site descriptions and water levels measured in U.S. Geological Survey observation wells completed in stratified-drift deposits in the Housatonic River Basin, western Massachusetts, 1994–96—*Continued*

Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)
USGS Well: GMW-67.[1] **Site Identification: 421047073182001.**[2] Lithology: sand and gravel. Elevation of land surface: 930 ft.[3]							
AUG 03, 1994	5.80	FEB 10, 1995	4.55	AUG 08, 1995	8.03	NOV 11, 1995	3.82
11	5.95	22	5.34	11	8.15	13	2.22
17	6.19	28	5.36	18	8.42	15	1.68
23	5.45	MAR 10	3.82	23	8.64	18	2.37
SEP 01	5.69	15	2.95	24	8.65	27	3.37
06	6.05	23	3.12	SEP 01	8.95	DEC 07	4.18
15	6.65	30	3.86	05	9.09	16	4.69
21	6.86	APR 04	4.20	07	9.13	29	5.42
28	6.87	12	4.69	11	9.26	JAN 17, 1996	6.21
OCT 06	7.09	14	3.92	20	9.46	21	2.78
19	7.40	22	4.01	22	9.50	26	1.49
29	7.49	28	4.28	24	9.45	29	1.12
NOV 11	7.64	MAY 05	4.74	28	9.49	FEB 07	2.99
18	7.76	10	5.03	OCT 01	9.56	21	4.21
28	7.63	20	5.36	07	9.07	23	3.41
DEC 05	6.55	JUN 07	5.39	12	9.07	27	2.98
12	4.43	19	5.86	15	9.00	MAR 12	3.80
22	4.52	27	6.35	22	7.08	20	2.77
JAN 03, 1995	3.75	JUL 06	6.89	23	7.05	23	2.97
13	4.18	14	7.28	26	6.82	28	3.09
21	2.06	20	7.56	30	4.30	APR 01	3.42
28	3.12	26	7.81	NOV 02	3.90		
31	3.57	AUG 02	8.03	07	3.99		
USGS Well: GMW-68.[1] **Site Identification : 421101073235201.**[2] Lithology: sand and gravel. Elevation of land surface: 720 ft.[3]							
JUN 10, 1994	9.94	DEC 22, 1994	11.59	JUN 27, 1995	11.64	NOV 02, 1995	12.05
15	10.16	JAN 03, 1995	11.02	JUL 06,	11.88	07	11.64
22	10.44	13	10.68	14	12.06	11	11.47
29	10.73	21	10.24	20	12.21	13	11.33
JUL 07	11.00	28	9.67	26	12.35	15	11.01
13	11.23	31	9.53	AUG 02	12.49	18	10.63
21	11.49	FEB 10	9.76	08	12.61	27	10.08
27	11.57	22	10.15	11	12.64	DEC 07	10.23
AUG 03	11.64	28	10.17	18	12.76	16	10.42
11	11.75	MAR 10	9.84	24	12.84	29	10.80
17	11.85	14	9.63	SEP 01	12.95	JAN 17, 1996	11.25
23	11.93	23	9.37	07	13.02	21	9.98
SEP 01	11.88	30	9.48	11	13.08	22	9.70
06	11.94	APR 04	9.62	21	13.22	26	9.06
SEP 15	12.05	12	9.90	22	13.22	29	8.00
21	12.14	14	9.93	24	13.25	FEB 07	7.82
28	12.17	22	10.12	28	13.30	21	8.52
OCT 06	12.17	27	10.22	OCT 01	13.34	23	8.20
19	12.21	MAY 05	10.35	08	13.22	27	8.23
29	12.30	10	10.45	12	13.20	MAR 12	8.81
NOV 11	12.39	20	10.69	15	13.17	20	8.67
18	12.45	30	10.94	22	13.03	23	8.79
28	12.51	JUN 07	11.15	23	12.96	28	8.97
DEC 05	12.39	14	11.31	26	12.73	APR 01	9.07
12	12.13	20	11.46	30	12.41		

Table 1. Site descriptions and water levels measured in U.S. Geological Survey observation wells completed in stratified-drift deposits in the Housatonic River Basin, western Massachusetts, 1994–96—*Continued*

Date		Water level below land surface (feet)	Date		Water level below land surface (feet)	Date		Water level below land surface (feet)	Date		Water level below land surface (feet)
USGS Well: SJW-58.[1] **Site Identification: 420351073193602.**[2] Lithology: sand and silt. Elevation of land surface: 680 ft.[3]											
JUN	10, 1994	12.38	JAN	03, 1995	13.73	JUL	06, 1995	14.33	NOV	02, 1995	15.15
	15	12.46		13	13.58		14	14.46		07	14.86
	22	12.47		21	13.36		20	14.59		10	14.76
	29	12.60		28	13.29		26	14.71		12	14.69
JUL	07	12.84		31	13.24	AUG	02	14.84		17	14.48
	13	12.90	FEB	10	13.19		08	14.91		24	14.18
	22	13.07		22	13.22		11	14.95		30	14.05
	27	13.00		28	13.22		17	15.08	DEC	08	14.01
AUG	03	12.86	MAR	10	13.12		24	15.24		13	14.02
	11	12.89		14	13.09		25	15.26		29	14.18
	17	12.97		23	13.04	SEP	01	15.40	JAN	05, 1996	14.28
	23	13.97		30	13.02		07	15.53		17	14.44
SEP	01	13.05	APR	04	13.00		08	15.56		21	13.89
	07	13.12		12	13.05		15	15.63		26	13.41
	15	13.20		14	13.03		22	15.77		29	13.05
	22	13.29		22	13.10		28	15.85	FEB	01	12.83
	28	13.33		27	13.17		29	15.87		09	12.65
OCT	06	13.45	MAY	05	13.26	OCT	06	15.90		21	12.78
	19	13.65		10	13.33		12	15.95		23	12.55
	29	13.80		20	13.44		13	15.97	MAR	01	12.32
NOV	11	13.99		30	13.57		19	16.03		11	12.40
	18	14.12	JUN	07	13.79		22	15.98		20	12.09
	28	14.22		14	13.89		23	15.93		23	12.09
DEC	05	14.30		20	14.02		26	15.82		29	12.11
	12	14.28		27	14.15		29	15.53	APR	01	12.13
	22	14.11									
USGS Well: SJW-79.[1] **Site Identification: 420527073201301.**[2] Lithology: sand and silt. Elevation of land surface: 670 ft.[3]											
JUN	10, 1994	4.04	DEC	05, 1994	4.40	MAY	30, 1995	4.05	OCT	12, 1995	4.58
	15	4.18		12	3.82	JUN	07	4.28		13	4.58
	22	4.33		22	4.00		14	4.40		19	4.28
	29	4.49	JAN	03, 1995	3.78		20	4.53		22	3.82
JUL	07	4.63		13	3.50		27	4.65		23	3.83
	13	4.79		21	3.54	JUL	06	4.76		26	3.91
	22	4.97		28	3.71		14	4.85		29	3.64
	27	4.34		31	3.76		20	4.92	NOV	02	3.74
AUG	03	4.13	FEB	10	3.92		26	4.99		07	3.80
	11	4.53		22	3.76	AUG	02	5.00		10	3.83
	17	4.66		28	3.55		08	4.91		12	3.49
	23	3.96	MAR	10	3.50		11	4.93		17	3.60
SEP	01	4.29		14	3.54		17	5.08		24	3.74
	07	4.49		23	3.67		24	5.20	DEC	08	3.83
	15	4.69		30	3.77		25	5.22		13	3.88
	22	4.80	APR	04	3.80	SEP	01	5.34		29	3.94
	28	4.66		12	3.82		07	5.43	JAN	05, 1996	3.99
OCT	06	4.63		14	3.72		08	5.44		17	3.97
	19	4.86		22	3.80		15	5.54		21	3.31
	29	4.89		28	3.87		22	5.57		26	3.40
NOV	11	4.92	MAY	05	3.97		28	5.42		29	3.26
	18	4.97		10	4.02		29	5.40	FEB	01	3.56
	28	4.82		20	4.04	OCT	06	5.05		09	3.70

Table 1. Site descriptions and water levels measured in U.S. Geological Survey observation wells completed in stratified-drift deposits in the Housatonic River Basin, western Massachusetts, 1994–96—*Continued*

Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)	Date	Water level below land surface (feet)
FEB 21, 1996	3.54	MAR 01, 1996	3.56	MAR 20, 1996	3.40	MAR 29, 1996	3.69
23	3.49	15	3.57	23	3.48	APR 01	3.68

[1]USGS well: DAW, Dalton, Mass.; GMW, Great Barrington, Mass.; SJW, Sheffield, Mass.

[2]Site identification: Unique number for each site based on the latitude and longitude of the site. The first six digits are latitude, the next seven are longitude and the final two digits are a sequence number to uniquely identify each site.

[3]Elevation of land surface: Datum is sea level. Approximate elevations interpolated from U.S. Geological Survey 7.5-minute topographic quadrangles.

STREAMFLOW

Streamflow variations at a station can be characterized by constructing flow-duration curves, which represent the percentage of time streamflows were equaled or exceeded during a selected period (Searcy, 1959). Flow-duration curves for a stream differ depending on the time period selected due to such factors as short- and long-term changes in climate, and human-induced changes in land use, water use, regulation for power generation, or stream channeling. The longer the period selected for the flow-duration analysis, the more representative the flow-duration curve will be of long-term conditions at the station.

Flow-duration curves are useful for comparing streams in terms of streamflow per unit area of a drainage basin. Differences in streamflow per unit area among subbasin can be attributed to many factors, including: (1) climate; (2) surficial geology; (3) bedrock geology; (4) human influences, such as irrigation, diversions, dam regulations, and ground-water pumpage; (5) potential ground-water underflow; (6) other physical characteristics of a basin, such as slope, elevation, aspect, length of streams, size of wetlands, and size of water bodies; and (7) land use. The combination of these factors affects the overall streamflow regime of a basin.

Flow-duration analyses were done for selected subbasins to characterize streamflows in the study area. Flow-duration statistics determined using data from these subbasins were then divided by their drainage areas to determine streamflow per square mile. Correlation statistics were calculated to determine which physical basin characteristics were related to streamflow per square mile.

The August median flow was also estimated for streams in the study area. The August median streamflow has been recommended by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 1981) as the minimum streamflow for summertime maintenance of biota habitat in New England. It is also being considered as a uniform aquatic base-flow policy for water-resources planning and management by several Massachusetts State environmental agencies (Ries, 1997, p. 2).

Flow Durations and Estimates of August Median Streamflow

Flow durations were determined for 41 stations in and near the study area—21 low-flow partial-record (LFPR) stations, 2 partial-record (PR) stations, 7 short-term (operated less than 10 years) discontinued streamflow-gaging stations, and 11 long-term (operated 10 years or more) continuous and discontinued streamflow-gaging stations. Methods used for flow-duration analyses differed depending on station type and quantity of available data.

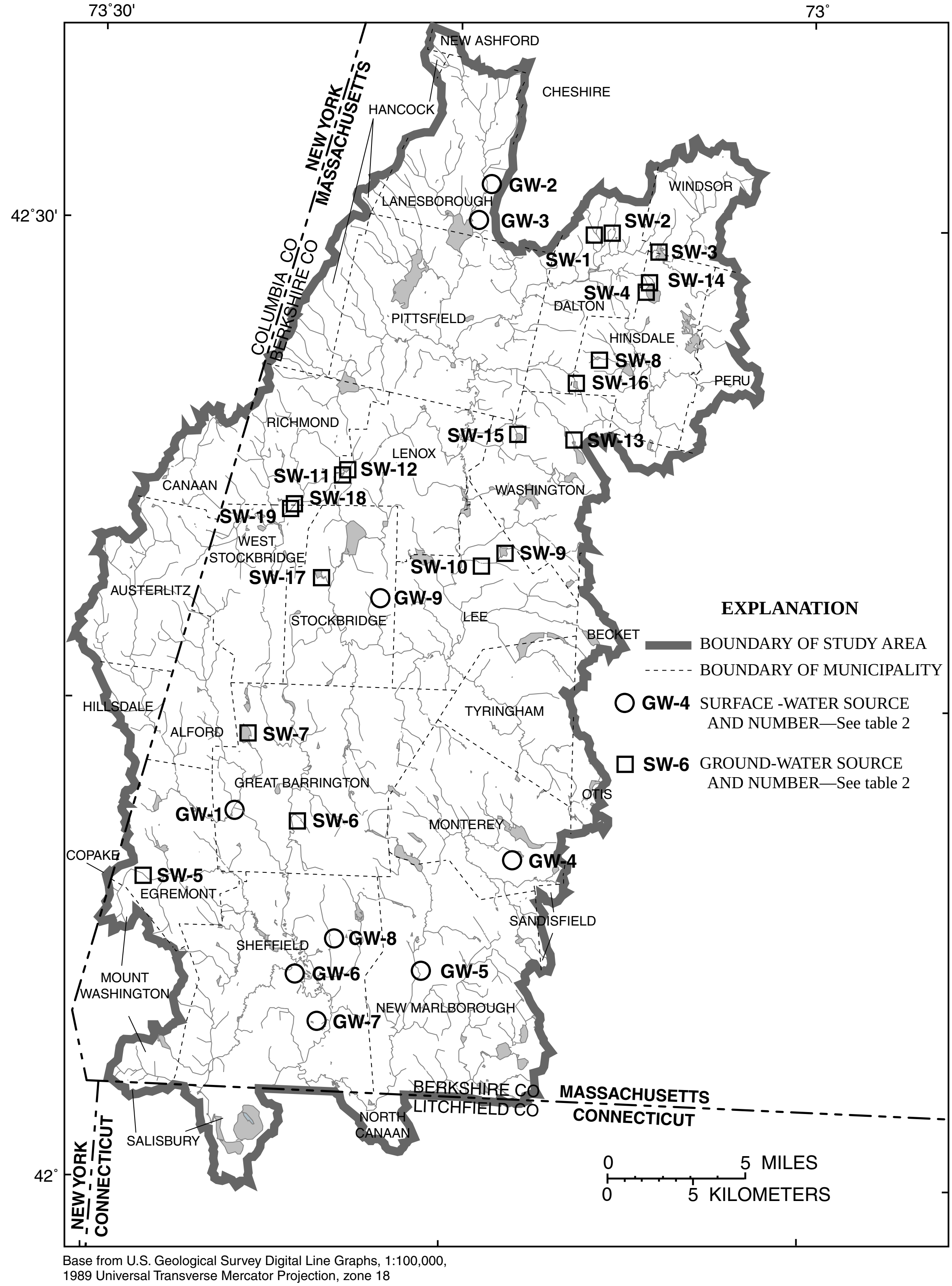
The four different station types in this study are differentiated by streamflow conditions, the timing of data collection, and the quantity of data collected. At LFPR stations, generally 8 to 12 streamflow measurements were made during base-flow conditions during a 2- to 3-year period. At PR stations, generally more than 20 streamflow measurements or periodic estimates of daily mean discharge were made throughout the range of streamflow conditions during a 2- to 3-year period. Short-term discontinued streamflow-gaging stations were those at which continuous daily mean discharge data were collected for 1 to less than 10 years and are currently (1998)

Table 2. Water use by municipalities within the Massachusetts part of the Housatonic River Basin, 1994–95

[Municipality: Location shown in figure 5. Source type and No.: GW, ground water; SW, surface water. Average water use: 1994 and 1995 data are from Massachusetts Department of Environmental Protection, written commun., 1996. No.: number; Mgal/d, million gallons per day; --, no data; <, actual value is less than value shown; *, not operating]

Municipality and water supplier	Source type and No.	Average water use (Mgal/d)	
		1994	1995
ALFORD			
No public-water supply			
BECKET			
No public-water supply			
CHESHIRE			
No public-water supply			
DALTON			
Dalton Fire District			
Off Holiday Road (Anthony Intake)	SW-1	--	0
Egypt Reservoir	SW-2	--	.14
Windsor Reservoir	SW-3	<0.01	.29
Pittsfield Department of Public Works			
Cleveland Reservoir	SW-4	1.22	1.39
EGREMONT			
South Egremont Water Company			
Karner Brook	SW-5	.11	.12
GREAT BARRINGTON			
Great Barrington Fire District			
East Mount Reservoir	SW-6	0	0
Green River Infiltration Gallery	GW-1	1.05	.94
Housatonic Water Works Company			
Long Pond, Division St.	SW-7	.41	.36
HANCOCK			
No public-water supply			
HINSDALE			
Hinsdale Department of Public Works			
Belmont Reservoir	SW-8	.18	.22
LANESBOROUGH			
Lanesborough Fire and Water District			
Bridge Street, Well 1	GW-2	(*)	(*)
Miner Street, Well 2	GW-3	.28	.26
LEE			
Lee Water Department			
Leahy (upper) Reservoir	SW-9	.11	.10
Vanetti Reservoir	SW-10	.86	.76
LENOX			
Lenox Water Department			
Lower Root Reservoir	SW-11	.70	.73
Upper Root Reservoir	SW-12	--	--
MONTEREY			
Monterey Water Company			
Sandisfield Road, Well 1	GW-4	--	.01
MOUNT WASHINGTON			
No public-water supply			
NEW ASHFORD			
No public-water supply			
NEW MARLBOROUGH			
Millers River Takers Association			
Miller River Road Well	GW-5	<0.01	<0.01
OTIS			
No public-water supply			
PERU			
No public-water supply			
PITTSFIELD			
Pittsfield Department of Public Works			
Ashley Lake Reservoir	SW-13	.03	.29
Cleveland Reservoir	SW-14	6.07	6.23
Farnham Reservoir	SW-15	3.27	2.72
Sackett Reservoir	SW-16	.15	.26
Water sold to other municipalities		--	.91
RICHMOND			
No public-water supply			
SANDISFIELD			
No public-water supply			
SHEFFIELD			
Sheffield Water Company			
Hubbard Brook Well	GW-6	.05	.06
Old Mass Pike Well	GW-7	.05	.06
Water Farm Springs	GW-8	.03	.01
STOCKBRIDGE			
Stockbridge Water Department			
Lake Averic	SW-17	.37	.36
Hill Water Department			
Rattlesnake Mountain Springs	GW-9	(*)	(*)
TYRINGHAM			
No public-water supply			
WASHINGTON			
No public-water supply			
WEST STOCKBRIDGE			
West Stockbridge Water Company			
Sartori Springs	SW-18	.05[1]	.05[1]
Sartori Quarry	SW-19		
WINDSOR			
No public-water supply			

[1] Michele Drury (Massachusetts Department of Environmental Management, written commun., 1997).



Base from U.S. Geological Survey Digital Line Graphs, 1:100,000,
1989 Universal Transverse Mercator Projection, zone 18

Figure 5. Location of surface-water and ground-water sources used for public-water supplies in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut.

discontinued. Long-term continuous and discontinued (not currently operated) streamflow-gaging stations have daily mean discharge data for at least 10 years. In this report, the 11 long-term continuous and discontinued streamflow-gaging stations will be referred to as long-term stations and the 21 LFPR stations, 2 PR stations, and 7 short-term discontinued streamflow-gaging stations (when data from all 30 short-term stations are reported together) will be referred to as short-term stations.

Long-Term Stations

Two long-term continuous and one long-term discontinued streamflow-gaging stations were operated in the study area during 1994–96 (fig. 3 and table 3). Two of these three stations measured streamflows that were sometimes regulated for water use and flood control. In addition to these three long-term stations, data from two long-term discontinued streamflow-gaging stations inside the study area and four long-term continuous and three long-term discontinued streamflow-gaging stations outside but near the study area (fig. 3 and table 3) also were used for analyses of streamflow. The 11 long-term stations (four inside and seven outside the study area) were selected because they have at least 10 years of record, minimal effects from regulation, and have drainage areas, precipitation, and geology that are representative of the study area. Streamflows for selected flow durations were computed from the respective periods of record (only complete water years[1]) for the 11 long-term stations and are shown in table 4. Streamflow measurements made at 3 of the 11 long-term stations as a part of this study are also listed in table 21 (at back of report).

Streamflows per square mile for selected flow durations were computed for the periods of record for the 11 long-term stations and are shown in table 5. Streamflows per square mile for the 1-, 10-, 30-, 50-, 70-, 90-, and 99-percent flow durations and August median streamflows ranged from 9.52 to 17.5, 3.40 to 5.71, 1.62 to 2.36, 0.843 to 1.20, 0.373 to 0.752, 0.119 to 0.447, 0.005 to 0.243, and 0.156 to 0.585 $(ft^3/s)/mi^2$, respectively. Median streamflows per square mile at the 1-, 10-, 30-, 50-, 70-, 90-, and 99-percent flow durations and for the August median streamflow were 12.9, 4.30, 1.84, 1.04, 0.566, 0.197, 0.080, and 0.272 $(ft^3/s)/mi^2$, respectively.

Short-Term Stations

Streamflows were estimated for 21 LFPR stations (fig. 6 and table 6) for selected flow durations ranging from the 50th to 99th percentiles and for the August median streamflow. The 50th to 99th percentiles were selected because streamflow was measured at the LFPR stations only during median- to low-flow periods; therefore, data were not available to estimate streamflows accurately at durations less than the 50th percentile.

In addition, streamflows were estimated for two PR stations and seven short-term discontinued streamflow-gaging stations (fig. 6 and table 6). Because high-flow as well as median- to low-flow measurements were made at these stations, it was possible to estimate streamflows for selected flow durations ranging from the 1st to 99th percentiles and for the August median streamflow.

Streamflow measurements (table 21) at the 21 LFPR stations in the study area (fig. 6 and table 6) were correlated with concurrent daily mean discharges from at least 5 of the 11 nearby long-term streamflow-gaging stations. Generally, data from the five long-term stations closest to each LFPR station were used in the correlation. A scatterplot of log-transformed streamflow at each LFPR station and same-day log-transformed daily mean discharges at each of the selected five long-term stations was made to determine the nature and quality of the relation between stations. When the scatterplots indicated a log-linear relation, the maintenance of variance extension, type 1 (MOVE.1) technique (Hirsch, 1982), was used to provide an equation that relates streamflow at the LFPR station to that at the long-term station. The streamflows at the long-term stations for the selected flow durations and for the August median streamflows were substituted into the equation to obtain the corresponding flow-duration discharge and August median streamflow for the LFPR station. When the scatterplots of concurrent log-transformed streamflow data indicated a curved (nonlinear) relation, a graphical technique (Searcy, 1959) was used to fit by visual inspection a smooth curve through each scatterplot of the untransformed data points. Flow-duration discharges and August median streamflows for the

[1]A water year is the 12-month period beginnning October 1 and ending September 30. It is designated by the calendar year in which it ends.

Table 3. Description of long-term continuous and discontinued streamflow-gaging stations used in streamflow, base-flow, and ground-water-recharge analyses in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Location shown in figure 3. Latitude and longitude are given in degrees, minutes, seconds. Period of record (water years): A water year is the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends. No., number; USGS, U.S. Geological Survey; mi^2, square mile; --, no remarks]

USGS station No.	Station name	Latitude ° ′ ″	Longitude ° ′ ″	Period of record (water years)	Drainage area (mi^2)	Remarks
01180800[1]	Walker Brook near Becket Center, Mass.	42 15 49	73 02 48	1963–77	2.94	--
01181000	West Branch Westfield River at Huntington, Mass.	42 14 14	72 53 46	1935–present	94.0	Prior to 1950, some diurnal fluctuation at low flow caused by mill upstream.[2]
01187300	Hubbard River near West Hartland, Conn.	42 02 14	72 56 22	1938–55, 1957–present	19.9	--
01197000	East Branch Housatonic River at Coltsville, Mass.	42 28 10	73 11 49	1937–present	57.6	Flow regulated by power plants upstream and, since 1949, by Cleveland Reservoir; regulation greater prior to 1955.[2]
01197300	Marsh Brook at Lenox, Mass.	42 20 59	73 17 56	1963–74	2.12	--
01197500	Housatonic River near Great Barrington, Mass.	42 13 55	73 21 19	1914–present	282	Regulation at low flow by powerplants upstream; high flows slightly affected by retarding reservoir since 1973.[2]
01198000	Green River near Great Barrington, Mass.	42 11 31	73 23 28	1952–71, 1994–96	51.0	--
01198500	Blackberry River at Canaan, Conn.	42 01 26	73 20 32	1949–71	43.8	--
01199050	Salmon Creek at Lime Rock, Conn.	41 56 32	73 23 29	1962–present	29.4	--
01331400[1]	Dry Brook near Adams, Mass.	42 35 20	73 06 48	1963–74	7.67	--
01333000	Green River at Williamstown, Mass.	42 42 32	73 11 50	1950–present	42.6	Slight diurnal fluctuation at times caused by mill upstream.[2]

[1] Data for Walker Brook and Dry Brook were not used in the flow-duration analysis of low-flow partial-record, partial-record, and short-term discontinued streamflow-gaging stations, because data from the stations were not collected during water years 1994–95. Data from the two stations were used in the base-flow and ground-water-recharge analyses.

[2] From Socolow and others (1996).

long-term stations were entered into these curves to determine the corresponding flow-duration discharges and August median streamflows at the LFPR stations. Detailed descriptions of the MOVE.1 and graphical techniques as applied to low-flow analyses are discussed in Ries (1994a, p. 22–24).

At the 2 PR stations and 7 short-term discontinued streamflow-gaging stations, either individual streamflow measurements (table 21) or daily mean discharges were correlated with the concurrent daily mean discharges from at least 5 of the 11 nearby long-term streamflow-gaging stations. The analysis procedure for the 2 PR stations and 7 short-term streamflow-gaging stations was the same as that used for the 21 LFPR stations except when the plots of concurrent log-transformed streamflow data indicated a curved (nonlinear) relation. For curved relations, the LOWESS (LOcally WEighted Scatterplot Smoothing) (Cleveland, 1979) statistical method was used, as described by Helsel and Hirsch (1992, p. 286–291), because the large number of measurements used in the relation would make it difficult to visually draw the best smooth curve through the data and to calculate the root mean square error by hand. The LOWESS statistical method determined a smooth (curved) line

Table 4. Streamflows for selected flow durations and August median streamflows at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 3 and described in table 3. No., number; USGS, U.S. Geological Survey]

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second												
	1	2	3	5	7	10	15	20	25	30	35	40	45
01180800	51.0	39.0	32.0	25.7	21.3	16.8	12.2	9.41	7.72	6.47	5.39	4.72	4.05
01181000	1,530	1,090	867	662	546	434	322	252	208	173	149	128	110
01187300	339	250	195	146	118	92.0	67.0	53.0	42.0	35.0	30.0	26.0	22.0
01197000	713	536	440	340	283	228	174	139	116	98.0	86.0	75.0	67.0
01197300	32.0	25.0	22.0	17.0	15.0	12.0	9.20	7.40	6.00	5.00	4.20	3.50	3.00
01197500	2,800	2,290	1,960	1,590	1,380	1,150	904	746	633	540	472	419	370
01198000	535	397	338	268	228	188	146	119	99.0	84.0	72.0	59.0	50.0
01198500	566	405	330	241	199	160	123	101	84.0	71.0	61.0	53.0	46.0
01199050	280	207	175	137	117	100	81.0	69.0	60.0	53.0	46.0	41.0	36.0
01331400	134	94.1	75.8	58.2	48.3	37.7	26.9	20.6	17.1	14.4	12.4	10.5	8.85
01333000	521	397	336	266	222	183	144	118	99.0	84.0	73.0	63.0	55.0

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second													
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
01180800	3.54	3.04	2.61	2.19	1.78	1.43	1.11	0.800	0.580	0.473	0.420	0.360	0.320	0.280	0.800
01181000	95.0	81.0	69.0	56.0	46.0	37.0	30.0	23.0	18.0	14.0	12.0	10.0	8.90	7.10	23.0
01187300	19.0	16.0	13.0	10.0	8.20	6.30	4.70	3.30	2.37	1.90	1.50	1.10	0.840	0.500	3.10
01197000	60.0	53.0	47.0	42.0	38.0	35.0	31.0	27.5	24.0	21.0	19.0	17.0	15.0	14.0	29.0
01197300	2.40	2.00	1.80	1.40	1.20	.900	.620	.440	.270	.150	.080	.040	.020	.010	.560
01197500	331	298	266	240	212	190	168	149	126	112	100	85.0	75.0	56.0	165
01198000	43.0	36.0	30.0	25.0	19.0	15.0	11.0	8.40	6.40	5.30	4.70	4.20	3.80	3.20	8.40
01198500	40.0	35.0	30.0	26.0	22.0	18.0	14.0	11.0	8.70	7.10	6.10	5.00	4.40	3.50	12.0
01199050	31.0	28.0	25.0	22.0	19.0	16.0	13.0	11.0	8.60	7.30	6.20	5.20	4.60	3.90	12.0
01331400	7.52	6.47	5.53	4.66	3.75	2.97	2.33	1.79	1.31	.992	.680	.403	.290	.160	1.90
01333000	47.0	42.0	36.0	31.0	27.0	22.0	18.0	14.0	11.0	9.10	7.00	6.20	5.60	4.80	15.0

through the concurrent log-transformed streamflow data. Data points of the LOWESS smooth line were retransformed to original units. Flow-duration discharges and August median streamflows at the PR stations and short-term streamflow-gaging stations were determined with the LOWESS smooth-line data points and the corresponding flow-duration discharges and August median streamflows at the long-term stations. Retransforming the flow-duration discharge and August median streamflow data (that is, taking the antilog) can introduce a bias. Because this retransformation bias was assumed to be small, it was not addressed in this study.

Information on the flow-duration analysis for each of the 30 short-term stations is presented in table 7, including the method of analysis, nearby gaging stations and number of streamflow measurements or daily mean streamflows used in the relations, and correlation coefficients. Correlation coefficients, which measure the strength of the linear relation between the short-term and long-term stations, are reported for the MOVE.1 analyses.

Correlation coefficients and linearity of each relation were used to determine which of the long-term stations would be used to obtain the estimated flow-duration discharges and August median streamflow at each of the 30 short-term stations.

Table 5. Streamflows per square mile for selected flow durations and August median streamflow per square mile at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 3 and described in table 3. No.: number; USGS, U.S. Geological Survey]

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second per square mile												
	1	2	3	5	7	10	15	20	25	30	35	40	45
01180800	17.3	13.3	10.9	8.74	7.24	5.71	4.15	3.20	2.63	2.20	1.83	1.61	1.38
01181000	16.3	11.6	9.22	7.04	5.81	4.62	3.43	2.68	2.21	1.84	1.59	1.36	1.17
01187300	17.0	12.6	9.80	7.34	5.93	4.62	3.37	2.66	2.11	1.76	1.51	1.31	1.11
01197000	12.4	9.31	7.64	5.90	4.91	3.96	3.02	2.41	2.01	1.70	1.49	1.30	1.16
01197300	15.1	11.8	10.4	8.02	7.08	5.66	4.34	3.49	2.83	2.36	1.98	1.65	1.42
01197500	9.93	8.12	6.95	5.64	4.89	4.08	3.21	2.65	2.24	1.91	1.67	1.49	1.31
01198000	10.5	7.78	6.63	5.25	4.47	3.69	2.86	2.33	1.94	1.65	1.41	1.16	.980
01198500	12.9	9.25	7.53	5.50	4.54	3.65	2.81	2.31	1.92	1.62	1.39	1.21	1.05
01199050	9.52	7.04	5.95	4.66	3.98	3.40	2.76	2.35	2.04	1.80	1.56	1.39	1.22
01331400	17.5	12.3	9.88	7.59	6.30	4.92	3.51	2.69	2.23	1.88	1.62	1.37	1.15
01333000	12.2	9.32	7.89	6.24	5.21	4.30	3.38	2.77	2.32	1.97	1.71	1.48	1.29

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second per square mile														
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
01180800	1.20	1.03	0.888	0.745	0.605	0.486	0.378	0.272	0.197	0.161	0.143	0.122	0.109	0.095	0.272
01181000	1.01	.862	.734	.596	.489	.394	.319	.245	.191	.149	.128	.106	.095	.076	.245
01187300	.955	.804	.653	.503	.412	.317	.236	.166	.119	.095	.075	.055	.042	.025	.156
01197000	1.04	.920	.816	.729	.660	.608	.538	.477	.417	.365	.330	.295	.260	.243	.503
01197300	1.13	.943	.849	.660	.566	.425	.292	.208	.127	.071	.038	.019	.009	.005	.264
01197500	1.17	1.06	.943	.851	.752	.674	.596	.528	.447	.397	.355	.301	.266	.199	.585
01198000	.843	.706	.588	.490	.373	.294	.216	.165	.125	.104	.092	.082	.075	.063	.165
01198500	.913	.799	.685	.594	.502	.411	.320	.251	.199	.162	.139	.114	.100	.080	.274
01199050	1.05	.952	.850	.748	.646	.544	.442	.374	.293	.248	.211	.177	.156	.133	.408
01331400	.980	.844	.721	.608	.489	.387	.304	.233	.171	.129	.089	.053	.038	.021	.248
01333000	1.10	.986	.845	.728	.634	.516	.423	.329	.258	.214	.183	.146	.131	.113	.352

Long-term stations with low correlation and (or) curved (nonlinear) relations in comparison to other long-term stations were not used in the analyses.

The final estimates of streamflow for the selected flow durations and August median streamflows were computed by using two modified equations of Hardison and Moss (1972). Equation 2 of Hardison and Moss (1972) was modified by Ries (1997, p. 5) to obtain the variance of the estimated flow-duration discharge and August median streamflow on the basis of the relation of the short-term stations and the long-term streamflow-gaging station.

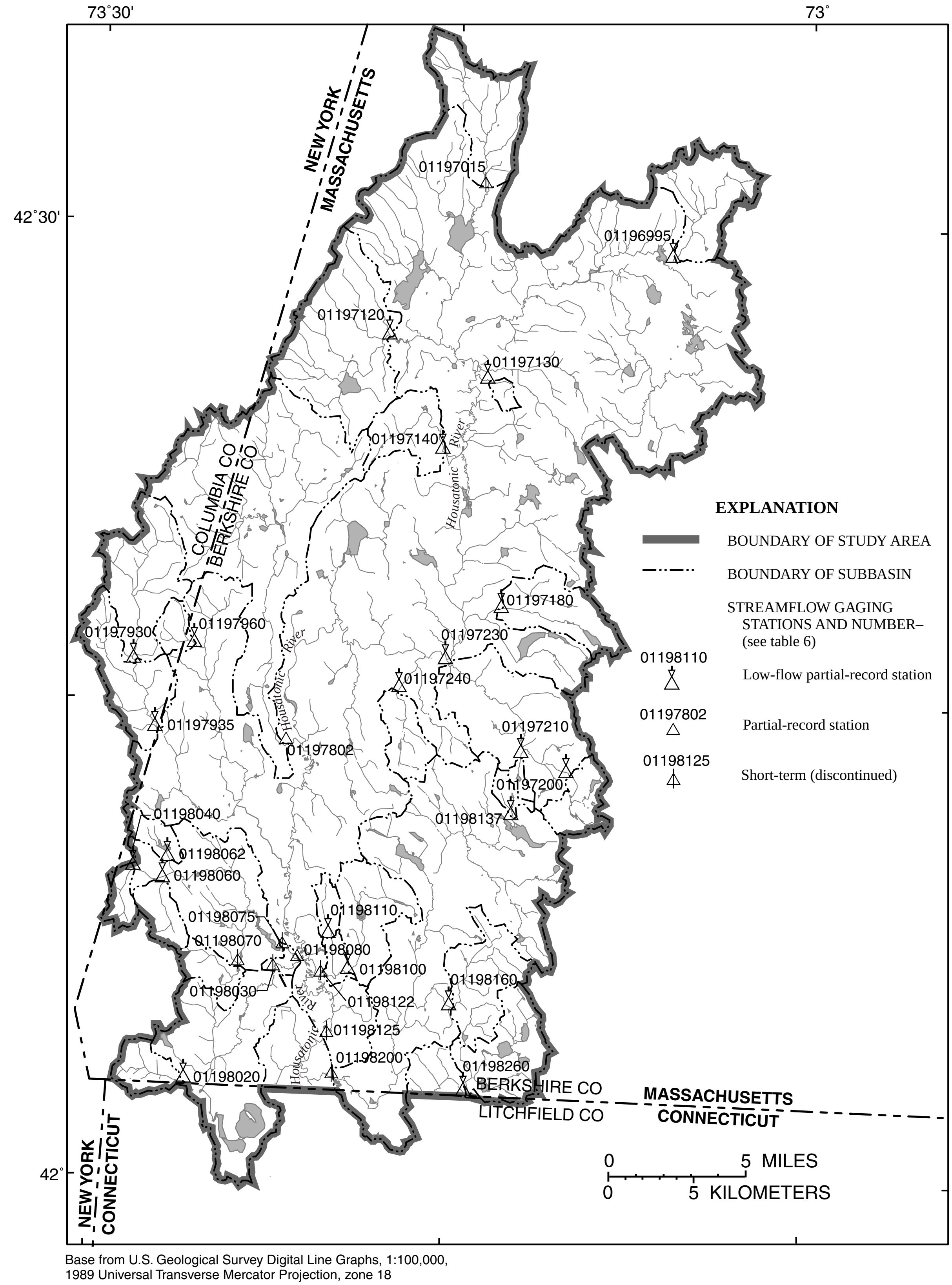


Figure 6. Location of low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations used in flow-duration analysis for the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut.

Table 6. Description of low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, for which streamflow estimates are provided

[USGS station No.: Location shown in figure 6. Latitude and longitude are given in degrees, minutes, seconds. No., number; USGS, U.S. Geological Survey; ft, foot; mi^2, square mile; --, no remarks]

USGS station No.	Station name and location	Latitude ° ′ ″	Longitude ° ′ ″	Drainage area (mi^2)	Remarks
	Low-Flow Partial-Record Stations				
01196995	Windsor Brook near Hinsdale, Mass., at bridge on Old Windsor Road	42 29 03	73 05 50	8.81	--
01197120	Southwest Branch Housatonic River at Pittsfield, Mass., at bridge on Mungerford Street	42 26 28	73 17 47	20.4	--
01197130	Sykes Brook near Pittsfield, Mass., at culvert on East New Lenox Road	42 25 07	73 13 35	.81	--
01197140	Yokun Brook near Lenox, Mass., 30 ft downstream from twin culvert on East Street	42 22 51	73 15 26	5.92	--
01197180	Greenwater Brook at East Lee, Mass., at bridge on private land near U.S. Highway 20	42 17 59	73 12 53	7.64	--
01197200	Hop Brook near Tyringham, Mass., at wooden bridge 100 ft beyond end of Sodem Road	42 12 49	73 09 55	4.05	--
01197210	Unnamed Tributary near Tyringham, Mass., at culvert on Monterey Road	42 13 21	73 11 53	.76	--
01197230	Hop Brook near South Lee, Mass., at bridge on Meadow Street	42 16 13	73 15 06	22.1	--
01197240	West Brook near South Lee, Mass., at bridge on Beartown Mountain Road	42 15 22	73 17 11	4.11	--
01197930	Green River at Green River, N.Y., at bridge on dirt road	42 16 07	73 28 16	11.7	--
01197935	Green River near Green River, N.Y., 200 ft downstream of private wooden bridge on dirt road of State Highway 71, 50 ft west of New York–Mass. State line	42 13 59	73 27 17	20.5	--
01197960	Scribner Brook near Alford, Mass., at private wooden bridge 600 ft on dirt road off West Road	42 16 42	73 25 46	1.95	--
01198020	Sages Ravine Brook near Taconic, Conn., 1,000 ft upstream from State Highway 41	42 02 58	73 25 49	3.41	--
01198040	Karner Brook near South Egremont, Mass., 100 ft off dirt road off Mount Washington Road	42 09 37	73 28 09	1.79	--
01198060	Fenton Brook near South Egremont, Mass., at bridge on Mount Washington Road	42 09 17	73 26 51	2.94	--
01198062	Unnamed Tributary near South Egremont, Mass., at culvert on State Highway 23	42 09 55	73 26 40	2.14	--
01198100	Ironworks Brook near Sheffield, Mass., at bridge on County Road	42 06 32	73 18 59	8.27	--
01198110	Soda Creek near Sheffield, Mass., at culvert on Water Farm Road (formerly Fink Road)	42 07 35	73 19 49	1.58	--
01198137	Unnamed Tributary at Monterey, Mass., at culvert on Hupi Road	42 11 26	73 12 15	1.15	--
01198160	Umpachene Brook at Southfield, Mass., at bridge on Canaan–Southfield Road	42 05 26	73 14 40	8.56	--
01198260	Whiting River near Canaan Valley, Conn., at bridge on Campbell Falls Road, 500 ft north of Mass.–Conn. State line	42 02 46	73 14 00	8.94	--

Table 6. Description of low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, for which streamflow estimates are provided—*Continued*

USGS station No.	Station name and location	Latitude ° ′ ″	Longitude ° ′ ″	Drainage area (mi^2)	Remarks
		Partial-Record Stations			
01197802[1]	Williams River near Great Barrington, Mass., at railroad bridge 200 ft south of Division Street	42 13 39	73 21 46	43.2	--
01198080[1]	Schenob Brook at Sheffield, Mass., at bridge on U.S. Highway 7	42 06 51	73 21 05	50.0	Affected by backwater from the Housatonic River, 0.25 mi downstream, during medium to high flows
		Short-Term Discontinued Streamflow-Gaging Stations			
01197015[2]	Town Brook at Lanesborough, Mass., at bridge on Bridge Street	42 31 12	73 13 48	10.6	--
01198030[3]	Schenob Brook near Sheffield, Mass., at bridge on Berkshire School Road	42 06 33	73 22 09	23.3	--
01198070[3]	Willard Brook near Sheffield, Mass., 125 ft downstream of Berkshire School Road	42 06 41	73 23 38	3.20	Occasional regulation by pond upstream from station[5]
01198075[3]	Hubbard Brook at Sheffield, Mass., at bridge on Cook Road	42 07 13	73 2146	25.8	Occasional regulation by pond upstream from station[5]
01198122[4]	Ironworks Brook at Sheffield, Mass., at bridge on East Road	42 06 31	73 20 08	11.2	--
01198125[4]	Housatonic River near Ashley Falls, Mass., on bridge on U.S. Highway 7	42 04 29	73 20 03	465	--
01198200[4]	Konkapot River at Ashley Falls, Mass., at bridge on U.S. Highway 7	42 03 11	73 19 35	61.1	Regulation upstream at Lake Garfield during spring and fall[6]

[1] Partial-record station during water years 1994–96.
[2] Streamflow-gaging station during water years 1980–83.
[3] Streamflow-gaging station during water years 1971–72.
[4] Streamflow-gaging station during water years 1994–96.
[5] From U.S. Geological Survey (1974).
[6] From Socolow and others (1996).

Table 7. Summary of flow-duration analysis at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Location shown in figure 6 and are described in table 6. Gaging stations used in relations: Locations shown in figure 3 and described in table 3, LOWESS, LOcally WEighted Scatterplot Smoothing; MOVE.1, maintenance of variance extension, type 1; No., number; USGS, U.S. Geological Survey; --, not applicable]

USGS station No.	Method of analysis	Nearby gaging stations used in relation	Number of streamflow measurements or daily mean streamflows used in relation	Correlation coefficient
Low-Flow Partial-Record Stations				
01196995	MOVE.1	01181000	11	0.89
		01197000	10	.95
		01198000	11	.87
		01333000	11	.89
01197120	MOVE.1	01181000	15	.81
		01197000	15	.87
		01198000	15	.93
		01199050	15	.88
01197130	MOVE.1	01197000	13	.78
		01197300	13	.66
		01198000	14	.73
		01333000	14	.66
01197140	MOVE.1	01181000	14	.78
		01187300	13	.87
		01197000	13	.67
		01197300	14	.83
		01198000	14	.84
		01333000	14	.74
01197180	MOVE.1	01181000	15	.88
		01187300	15	.81
		01197000	15	.76
		01198000	13	.82
		01199050	15	.77
01197200	MOVE.1	01181000	14	.70
		01187300	14	.77
		01197300	12	.86
		01198000	14	.90
		01198500	14	.79
01197210	MOVE.1	01181000	14	.82
		01187300	14	.79
		01197300	12	.54
		01198000	14	.71
		01198500	14	.84
01197230	MOVE.1	01181000	15	.90
		01197300	15	.75
		01198000	14	.79
		01199050	15	.88
Low-Flow Partial-Record Stations—*Continued*				
01197240	MOVE.1	01181000	14	0.85
		01187300	13	.94
		01197300	13	.93
		01198000	14	.92
		01198500	14	.86
01197930	MOVE.1	01187300	13	.89
		01197000	12	.87
		01197300	11	.80
		01198000	13	.90
01197935	MOVE.1	01187300	11	.92
		01197000	10	.94
		01197300	10	.88
		01198000	11	.97
		01198500	11	.86
		01199050	11	.77
01197960	MOVE.1	01197000	11	.91
		01197300	11	.81
		01198000	12	.91
		01199050	12	.75
01198020	MOVE.1	01187300	13	.84
		01197300	11	.75
		01198000	13	.93
		01198500	13	.94
		01199050	13	.93
01198040	MOVE.1	01187300	13	.87
		01197300	11	.73
		01198000	13	.94
		01199050	13	.85
01198060	Graphical	01181000	17	--
		01187300	17	
		01197000	16	
		01198000	17	
		01199050	17	
01198062	MOVE.1	01187300	10	.83
		01197300	9	.87
		01198000	10	.96
		01198500	10	.88
		01199050	10	.95

Table 7. Summary of flow-duration analysis at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Method of analysis	Nearby gaging stations used in relation	Number of streamflow measurements or daily mean streamflows used in relation	Correlation coefficient
Low-Flow Partial-Record Stations—*Continued*				
01198100	Graphical	01181000	12	--
		01187300	12	
		01198000	12	
		01198500	12	
		01199050	12	
01198110	MOVE.1	01181000	13	0.85
		01187300	13	.79
		01198000	13	.89
		01198500	13	.83
		01199050	13	.84
01198137	Graphical	01181000	11	--
		01187300	11	
		01197300	10	
		01198000	11	
		01198500	10	
01198160	MOVE.1	01181000	14	.85
		01187300	14	.83
		01197300	12	.80
		01198000	14	.87
		01198500	14	.81
01198260	MOVE.1	01181000	11	.85
		01187300	11	.89
		01198000	11	.89
		01198500	11	.96
		01199050	11	.85
Partial-Record Stations				
01197802[1]	LOWESS	01181000	223	--
		01187300	223	
		01197000	223	
		01198000	223	
		01198500	71	
		01199050	223	
01198080[1,]	MOVE.1[2]	01181000	23	0.98
		01187300	23	.98
		01198000	23	.98
		01198500	21	.98
		01199050	23	.98
	Drainage-area ratio	01198030 and 01198075	--	--
Short-Term Discontinued Streamflow-Gaging Stations				
01197015[3]	MOVE.1	01181000	1,083	0.92
		01187300	1,083	.89
		01199050	1,083	.89
		01333000	1,083	.98
01198030[4]	MOVE.1	01181000	24	.94
		01187300	24	.96
		01198000	17	.95
		01198500	10	.92
		01199050	23	.98
01198070[4]	MOVE.1	01181000	18	.96
		01187300	18	.94
		01197300	12	.88
		01198000	12	.87
		01198500	12	.98
		01199050	18	.96
01198075[4]	MOVE.1	01181000	16	.93
		01187300	16	.88
		01197300	10	.93
		01198000	10	.97
		01198500	10	.96
		01199050	16	.91
01198122[5]	LOWESS	01181000	445	--
		01187300	445	
		01197000	445	
		01198000	445	
		01198500	73	
		01199050	445	
01198125[5]	LOWESS	01181000	564	--
		01187300	564	
		01197500	564	
		01198000	555	
		01198500	75	
		01199050	564	
01198200[5]	LOWESS	01181000	501	--
		01187300	501	
		01197000	501	
		01198000	501	
		01198500	78	
		01199050	501	

[1] Partial-record station during water years 1994–96.

[2] Used a combined weighted estimate of the MOVE.1 results from stations 01198030, 01198075, and 01198080, and a drainage-area ratio factor.

[3] Streamflow-gaging station during water years 1980–83.

[4] Streamflow-gaging station during water year 1971–72.

[5] Streamflow-gaging station during water years 1994–96.

Equation 13 of Hardison and Moss (1972) was modified to obtain the weighted estimate of flow-duration discharges and August median streamflow:

$$ {}_{p,u} = \frac{Q_{p,u,n}/V_{p,u,n} + \ldots + Q_{p,u,n}/V_{p,u,n}}{1/V_{p,u,n} + \ldots + 1/V_{p,u,n}}, \qquad (1) $$

where

$Q_{p,u}$ is the weighted (combined) estimated flow-duration discharge exceeded "*p*" percent of the time or August median streamflow at the short-term station, "*u*;"

$Q_{p,u,n}$ is the estimated flow-duration discharge exceeded "*p*" percent of the time or August median streamflow, which was determined by using MOVE.1 equations, graphical techniques, or LOWESS statistical methods between the short-term station "*u*" and each long-term station, "*n*;" and

$V_{p,u,n}$ is the variance of the estimated flow-duration discharge exceeded "*p*" percent of the time or August median streamflow [from modified equation 2 of Hardison and Moss (1972)] calculated on the basis of the relation of the short-term station "*u*" and each long-term station, "*n*" (K.G. Ries, U.S. Geological Survey, written commun., 1996).

Equation 1 does not take into account the additional variance from measurement errors of streamflow at the LFPR and PR stations and errors in the daily mean discharge records at the short-term streamflow-gaging stations and the long-term stations used in the relation. Because a base period was not used for the long-term stations, estimated flow-duration discharges and August median streamflows at the 30 short-term stations are not for a specific period of record. The estimates represent long-term conditions.

Streamflows in Schenob Brook at Sheffield, Mass. (station 01198080), were estimated by combining the weighted estimate based on the MOVE.1 results at station 01198080 with the sum of the weighted MOVE.1 estimates for upstream stations on Schenob Brook near Sheffield, Mass. (station 01198030), and on Hubbard Brook at Sheffield, Mass. (station 01198075). A drainage-area ratio factor was applied to correct for the additional area (fig. 6 and tables 6 and 7). The combined estimates given by equation 1 were obtained by weighting the estimates by the variance at each of the stations. This method was used because it provided the most reliable estimates of streamflows in Schenob Brook at Sheffield, Mass..

Final estimates of streamflow for the selected flow durations and the August median streamflows at the 30 short-term stations are presented in table 8. Estimated streamflows at most of the 30 short-term stations reflect natural flow conditions because all water used in each subbasin is returned to the stream within the subbasin. Town Brook (station 01197015) streamflows are reduced by about 0.01 $(ft^3/s)/mi^2$, if it is assumed that all public-supply water leaving this subbasin (0.19 Mgal/d, as measured in 1995) comes from well GW-3 (fig. 5). Other stations could be affected by regulation of pond levels upstream from the stations (table 6).

The standard errors of the weighted estimates of each flow-duration discharge and August median streamflow were computed for the 30 short-term stations by using two equations. First, the weighted variance of each estimated flow-duration discharge and August median streamflow were computed by using the following equation (Kernell Ries, U.S. Geological Survey, written commun., 1996):

$$ {}_{p,u} = \frac{1}{1/V_{p,u,n} + \ldots + 1/V_{p,u,n}}, \qquad (2) $$

where

$V_{p,u}$ is the weighted (combined) variance of the estimated duration discharge exceeded "*p*" percent of the time or August median streamflow at the short-term station, "*u*."

Second, the weighted variance of each flow-duration discharge and August median streamflow at the 30 short-term stations calculated from equation 2 were then input into the following equation (Ries, 1997, p. 6) to compute the standard error, in percent, for the final estimate of streamflow for the selected flow duration and August median streamflow:

$$ SE_f = 100\sqrt{\exp((5.318V_{p,u}) - 1)}, \qquad (3) $$

where

SE_f is the standard errors, in percent, of the final (weighted) estimate of streamflow for the selected flow duration and August median streamflow.

The standard errors, in percent, are presented in table 9 for the selected flow-duration discharges and August median streamflows at the 30 short-term stations.

Table 8. Estimated streamflows for selected flow durations and estimated August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 6 and described in table 6. No., number; USGS, U.S. Geological Survey]

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second														
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
Low-flow partial-record stations															
01196995	7.33	5.78	4.51	3.49	2.69	2.06	1.52	1.09	0.787	0.582	0.471	0.368	0.301	0.241	1.17
01197120	19.6	16.2	13.4	11.0	8.87	7.21	5.68	4.51	3.49	2.80	2.38	1.99	1.75	1.45	4.77
01197130	.389	.337	.293	.250	.213	.178	.144	.117	.095	.078	.067	.056	.048	.042	.125
01197140	10.5	8.04	6.07	4.36	3.23	2.27	1.55	1.00	.653	.448	.327	.222	.161	.105	1.03
01197180	6.51	6.01	5.52	5.00	4.54	4.10	3.66	3.25	2.87	2.59	2.37	2.14	1.97	1.74	3.27
01197200	6.68	5.73	4.93	4.10	3.41	2.76	2.16	1.67	1.28	1.02	.843	.665	.552	.396	1.69
01197210	2.94	2.17	1.58	1.09	.754	.494	.310	.190	.118	.079	.057	.038	.027	.015	.198
01197230	20.5	17.3	14.6	12.1	9.94	8.13	6.47	5.15	4.00	3.20	2.71	2.25	1.97	1.63	5.38
01197240	13.9	8.58	5.46	3.48	2.25	1.46	.849	.488	.274	.157	.105	.067	.048	.030	.582
01197930	8.57	7.47	6.52	5.58	4.81	4.12	3.40	2.79	2.26	1.90	1.63	1.35	1.14	.897	2.82
01197935	20.0	16.8	14.1	11.6	9.65	7.85	6.07	4.70	3.54	2.84	2.32	1.83	1.50	1.14	4.92
01197960	3.44	2.56	1.94	1.45	1.07	.803	.550	.394	.261	.184	.138	.102	.078	.061	.453
01198020	7.55	6.45	5.45	4.52	3.71	2.96	2.26	1.76	1.31	1.05	.852	.663	.545	.400	1.84
01198040	1.48	1.36	1.24	1.12	1.01	.895	.776	.678	.577	.511	.453	.394	.352	.295	.686
01198060	2.36	2.02	1.70	1.37	1.12	.888	.677	.514	.378	.292	.223	.147	.097	.036	.503
01198062	2.70	2.21	1.79	1.41	1.10	.831	.592	.428	.293	.221	.168	.121	.094	.063	.414
01198100	5.23	4.74	4.27	3.82	3.35	2.91	2.43	2.01	1.58	1.24	.907	.517	.264	.005	1.96
01198110	1.85	1.57	1.32	1.09	.883	.704	.546	.421	.321	.258	.214	.170	.143	.107	.402
01198137	.596	.525	.466	.410	.342	.285	.218	.162	.117	.085	.061	.039	.024	.005	.152
01198160	5.21	4.60	4.07	3.50	3.01	2.54	2.09	1.69	1.37	1.13	.966	.797	.687	.529	1.63
01198260	6.03	5.03	4.12	3.31	2.63	2.04	1.54	1.15	.852	.680	.556	.434	.359	.263	1.11
Partial-record stations															
01197802[1]	39.7	34.8	30.4	26.3	23.2	20.6	17.8	14.5	11.6	9.16	7.40	5.68	4.53	3.38	15.0
01198080[1]	48.1	41.9	36.0	30.1	25.3	20.7	16.4	12.9	9.99	8.23	6.98	5.73	4.94	3.83	12.9
Short-term discontinued streamflow-gaging stations															
01197015[2]	9.85	8.57	7.30	6.03	5.08	4.09	3.25	2.50	1.91	1.55	1.29	1.03	0.884	0.680	2.53
01198030[3]	20.5	17.9	15.3	12.8	10.7	8.75	6.95	5.42	4.20	3.47	2.93	2.38	2.03	1.54	5.37
01198070[3]	4.94	4.41	3.90	3.36	2.92	2.47	2.04	1.66	1.35	1.14	.994	.839	.741	.595	1.70
01198075[3]	26.5	23.2	20.2	17.1	14.5	12.0	9.55	7.59	5.97	4.95	4.23	3.53	3.09	2.47	7.72
01198122[4]	9.20	7.95	6.75	5.56	4.54	3.58	2.66	1.90	1.28	.887	.646	.440	.311	.210	2.02
01198125[4]	571	509	450	393	342	295	251	212	176	153	136	118	106	84.8	219
01198200[4]	66.4	60.3	54.3	48.3	43.5	39.0	34.3	29.6	25.3	22.1	19.7	17.3	15.5	13.3	29.8

Table 8. Estimated streamflows for selected flow durations and estimated August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second												
	1	2	3	5	7	10	15	20	25	30	35	40	45
Partial-record stations													
01197802[1]	406	309	258	204	173	143	113	93.0	78.0	66.6	58.4	51.5	45.1
01198080[1]	570	423	347	269	226	185	143	117	97.9	83.8	72.8	63.6	55.2
Short-term discontinued streamflow-gaging stations													
01197015[2]	134	98.1	79.7	61.2	50.6	41.0	31.2	25.2	20.9	17.7	15.3	13.3	11.4
01198030[3]	247	182	149	115	96.6	79.1	61.0	50.0	41.8	35.8	31.1	27.1	23.5
01198070[3]	37.9	29.6	25.2	20.4	17.7	15.0	12.1	10.3	8.88	7.82	6.96	6.22	5.54
01198075[3]	268	202	169	133	113	93.7	73.7	61.1	51.8	44.8	39.1	34.4	30.2
01198122[4]	100	76.3	63.5	50.2	42.4	34.8	27.0	22.0	18.5	16.0	14.0	12.1	10.6
01198125[4]	4,880	3,840	3,260	2,630	2,280	1,920	1,530	1,280	1,090	942	827	732	644
01198200[4]	520	401	337	270	231	193	154	130	112	98.5	88.7	80.2	72.9

[1] Partial-record station during water years 1994–96.
[2] Streamflow-gaging station during water years 1980–83.
[3] Streamflow-gaging station during water years 1971–72.
[4] Streamflow-gaging station during water years 1994–96.

Table 9. Standard errors of estimated streamflows for selected flow durations and August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 6 and described in table 6. Estimated streamflows for associated standard errors are shown in table 8. No., number; USGS, U.S. Geological Survey]

USGS station No.	Standard errors of streamflow equaled or exceeded at indicated percentage of time, in percent														
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
Low-flow partial-record stations															
01196995	21.8	20.4	19.1	17.9	17.0	16.3	16.1	16.5	17.9	19.4	20.9	23.1	24.7	27.4	14.1
01197120	17.4	16.5	15.6	14.8	14.0	13.4	12.9	12.9	13.3	14.1	15.0	16.3	17.4	19.3	11.4
01197130	19.6	18.2	16.9	15.6	14.4	13.3	12.6	12.5	13.3	14.4	15.6	17.5	19.1	21.2	11.6
01197140	27.7	26.0	24.3	22.5	21.0	19.6	18.5	18.0	18.6	19.7	21.2	23.6	25.7	29.3	16.1
01197180	8.58	8.06	7.54	6.97	6.51	6.09	5.75	5.57	5.67	5.94	6.28	6.88	7.42	8.37	5.00
01197200	19.9	18.9	18.1	17.1	16.2	15.3	14.5	13.8	13.8	14.3	15.1	16.5	17.8	20.5	12.6
01197210	39.3	36.7	34.3	31.5	29.1	26.7	24.8	23.7	24.0	25.4	27.1	29.8	32.4	37.4	21.6
01197230	17.7	16.7	15.8	14.8	13.9	13.2	12.7	12.7	13.1	13.8	14.6	15.9	17.0	18.8	11.1
01197240	32.6	31.2	30.0	28.8	27.8	27.1	26.7	27.1	28.9	31.0	33.2	36.5	39.3	43.9	23.7
01197930	16.5	15.6	14.8	14.0	13.3	12.8	12.4	12.2	12.5	13.0	13.7	14.9	16.1	18.1	10.8
01197935	16.3	15.6	15.0	14.3	13.8	13.3	13.0	12.9	13.3	14.1	15.0	16.4	17.6	19.7	11.5
01197960	33.8	32.1	30.6	29.1	27.8	26.9	26.0	26.0	26.7	28.0	29.7	32.5	34.9	38.7	23.9
01198020	18.2	17.5	16.9	16.3	15.7	15.2	14.8	14.7	15.1	15.8	16.6	18.1	19.5	21.9	13.1
01198040	12.1	11.6	11.1	10.6	10.1	9.67	9.24	9.03	9.11	9.46	9.95	10.8	11.6	13.1	8.21
01198060	57.6	53.9	50.1	46.2	42.8	39.8	37.3	36.0	36.6	38.5	40.8	44.7	48.2	54.9	31.1
01198062	22.9	22.1	21.3	20.6	20.0	19.6	19.3	19.5	20.4	21.7	23.2	25.7	27.9	31.9	15.7
01198100	57.5	53.5	49.3	45.1	41.0	37.1	33.6	31.2	30.4	31.4	33.1	36.5	39.7	46.2	27.0
01198110	20.4	19.3	18.3	17.1	16.0	15.0	14.1	13.5	13.5	13.9	14.4	15.6	16.6	18.8	11.3
01198137	45.5	43.4	41.6	39.5	38.0	36.6	35.8	35.9	37.9	40.7	43.9	48.8	53.2	61.4	28.3
01198160	15.0	14.3	13.6	12.7	12.1	11.4	10.9	10.5	10.7	11.2	11.8	12.9	13.9	15.8	8.84
01198260	19.6	18.7	17.7	16.7	15.8	14.9	14.3	14.1	14.6	15.4	16.4	17.9	19.2	21.7	11.7
Partial-record stations															
01197802[1]	6.46	6.73	6.54	6.67	6.86	7.12	7.49	7.98	8.70	9.32	9.90	10.7	11.4	12.4	5.52
01198080[1]	6.42	6.46	6.55	6.70	6.92	7.22	7.63	8.16	8.89	9.53	10.1	10.9	11.6	12.6	6.28
Short-term discontinued streamflow-gaging stations															
01197015[2]	7.73	7.76	7.85	8.01	8.24	8.56	9.00	9.60	10.5	11.2	11.9	12.9	13.7	15.0	6.71
01198030[3]	9.28	9.30	9.41	9.61	9.91	10.3	10.9	11.7	12.8	13.7	14.5	15.7	16.6	18.2	9.34
01198070[3]	7.50	7.66	7.91	8.27	8.69	9.24	9.92	10.8	11.8	12.7	13.4	14.5	15.3	16.7	9.29
01198075[3]	9.11	9.33	9.67	10.1	10.7	11.4	12.4	13.5	14.8	15.9	16.9	18.3	19.3	21.0	11.6
01198122[4]	9.15	9.18	9.28	9.47	9.74	10.1	10.6	11.3	12.4	13.3	14.1	15.3	16.2	17.8	7.77
01198125[4]	5.32	5.34	5.40	5.51	5.67	5.89	6.19	6.60	7.19	7.70	8.17	8.87	9.40	10.3	4.50
01198200[4]	4.84	4.86	4.91	5.01	5.15	5.35	5.62	5.99	6.52	6.99	7.42	8.05	8.53	9.32	4.12

Table 9. Standard errors of estimated streamflows for selected flow durations and August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Standard errors of streamflow equaled or exceeded at indicated percentage of time, in percent												
	1	2	3	5	7	10	15	20	25	30	35	40	45
Partial-record stations													
01197802[1]	12.7	11.6	10.9	10.1	9.47	8.83	8.10	7.59	7.21	6.93	6.73	6.58	6.49
01198080[1]	12.5	11.4	10.8	9.88	9.29	8.66	7.93	7.43	7.07	6.81	6.63	6.51	6.44
Short-term discontinued streamflow-gaging stations													
01197015[2]	15.0	13.7	12.9	11.9	11.2	10.5	9.61	9.02	8.58	8.26	8.02	7.86	7.76
01198030[3]	18.4	16.8	15.8	14.5	13.7	12.7	11.7	10.9	10.4	9.96	9.67	9.46	9.33
01198070[3]	13.9	12.6	11.8	10.8	10.1	9.42	8.63	8.11	7.77	7.55	7.42	7.37	7.40
01198075[3]	17.4	15.7	14.7	13.3	12.5	11.5	10.5	9.85	9.41	9.13	8.97	8.92	8.97
01198122[4]	17.9	16.4	15.5	14.2	13.4	12.5	11.4	10.7	10.2	9.80	9.51	9.31	9.19
01198125[4]	10.3	9.43	8.90	8.20	7.72	7.21	6.62	6.21	5.91	5.68	5.52	5.41	5.34
01198200[4]	9.42	8.63	8.14	7.50	7.06	6.59	6.04	5.67	5.39	5.18	5.03	4.92	4.86

[1] Partial-record station during water years 1994–96.
[2] Streamflow-gaging station during water years 1980–83.
[3] Streamflow-gaging station during water years 1971–72.
[4] Streamflow-gaging station during water years 1994–96.

Estimated flow-duration discharges and estimated August median streamflows at the 30 short-term stations (table 8) were divided by their respective drainage areas to compare differences in discharge characteristics between the short-term and long-term stations (table 10). Estimated streamflows for the 1-, 10-, and 30-percent flow durations (only estimated at the two PR stations and seven short-term discontinued streamflow-gaging stations) ranged from 8.51 to 12.5, 3.11 to 4.67, and 1.43 to 2.44 $(ft^3/s)/mi^2$, respectively. Median values of streamflows estimated for the 1-, 10-, and 30-percent flow durations were 10.5, 3.63, and 1.65 $(ft^3/s)/mi^2$, respectively. Estimated streamflows for the 50-, 70-, 90-, and 99-percent flow durations and estimated August median streamflows at all 30 short-term stations ranged from 0.480 to 3.87, 0.263 to 1.09, 0.067 to 0.421, 0.004 to 0.228, and 0.124 to 0.540 $(ft^3/s)/mi^2$, respectively. Median values of streamflows estimated for the 50-, 70-, 90-, and 99-percent flow durations and August median streamflows were 0.945, 0.510, 0.183, 0.066, and 0.238 $(ft^3/s)/mi^2$, respectively. The ranges and median of the estimated streamflows for the selected flow durations between 1 and 99 percent at the short-term stations compare well to those previously reported for the 11 long-term stations.

Friesz (1996, p. 38–40) reported that the average flow-duration discharge was 0.280 and 0.147 $(ft^3/s)/mi^2$ at the 90th and 99th percentiles, respectively, at 26 stations in the Deerfield River Basin (5 mi to the northeast of the study area), where an average of 6.99 percent of each subbasin is underlain by stratified drift. The average flow-duration discharge was 0.211 and 0.080 $(ft^3/s)/mi^2$ at the 90th and 99th percentiles, respectively, at the 41 stations in the study area, where an average of 7.11 percent of each subbasin is underlain by stratified-drift deposits. These small differences in low flows per square mile for subbasins in the Deerfield and Housatonic River Basins could be the result of differences in orographic effects on precipitation or due to standard error.

Estimated streamflows for the 10-percent flow duration at the 20 stations (2 partial-record, 7 short-term discontinued, and 11 long-term streamflow-gaging stations; the 21 LFPR stations were excluded) in and near the study area ranged from 3.11 to 5.71 $(ft^3/s)/mi^2$, with a median of 3.90 $(ft^3/s)/mi^2$ (tables 5 and 10). The 10-percent flow duration at 15 other long-term streamflow-gaging stations (with little to no regulation) in central and eastern Massachusetts (Socolow and others, 1996) ranged from 3.64 to 4.86 $(ft^3/s)/mi^2$, with a median of 4.19 $(ft^3/s)/mi^2$. The 50- and 90-percent flow durations ranged from 0.480 to 3.87 $(ft^3/s)/mi^2$ and 0.067 to 0.447 $(ft^3/s)/mi^2$, respectively, with medians of 1.01 and 0.185 $(ft^3/s)/mi^2$, respectively, at the 41 stations in and near the study area. At the other 15 stations throughout Massachusetts, the 50- and 90-percent flow durations ranged from 0.859 to 1.32 $(ft^3/s)/mi^2$ and 0.075 to 0.322 $(ft^3/s)/mi^2$, respectively, with medians of 1.11 and 0.225 $(ft^3/s)/mi^2$, respectively. Streamflow-duration estimates from this study compare well to results from the other long-term stations in central and eastern Massachusetts.

Estimated August median streamflows ranged from 0.124 to 0.585 $(ft^3/s)/mi^2$, with a median of 0.248 $(ft^3/s)/mi^2$ at all 41 stations in and near the study area. This compares well to the results of a statewide study reported by Ries (1997, p. 11), which found that the median value of the estimated August median streamflows was 0.271 $(ft^3/s)/mi^2$ and ranged from 0.056 to 0.759 $(ft^3/s)/mi^2$ at 53 stations in the western part of Massachusetts (roughly all sites west of 72 degrees west longitude). Estimated August median streamflow was close in value to the 85-percent flow duration at each of the 41 stations (30 stations had values equal to or slightly less than 85-percent flow duration, and 11 stations had values slightly greater than 85-percent flow duration) (tables 5 and 10). Ries (1997, p. 18) reported that the statewide estimated August median streamflow in Massachusetts occurs at about the 84-percent flow duration.

Table 10. Estimated streamflows per square mile for selected flow durations and estimated August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 6 and described in table 6. No., number; USGS, U.S. Geological Survey]

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second per square mile														
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
Low-flow partial-record stations															
01196995	0.832	0.656	0.512	0.396	0.305	0.234	0.173	0.124	0.089	0.066	0.053	0.042	0.034	0.027	0.133
01197120	.961	.794	.657	.539	.435	.353	.278	.221	.171	.137	.117	.098	.086	.071	.234
01197130	.480	.416	.362	.309	.263	.220	.178	.144	.117	.096	.083	.069	.059	.052	.154
01197140	1.77	1.36	1.02	.736	.546	.383	.262	.169	.110	.076	.055	.038	.027	.018	.174
01197180	.852	.787	.723	.654	.594	.537	.479	.425	.376	.339	.310	.280	.258	.228	.428
01197200	1.65	1.42	1.22	1.01	.842	.681	.533	.412	.316	.252	.208	.164	.136	.098	.417
01197210	3.87	2.86	2.08	1.43	.992	.650	.408	.250	.155	.104	.075	.050	.036	.020	.261
01197230	.928	.783	.661	.548	.450	.368	.293	.233	.181	.145	.123	.102	.089	.074	.243
01197240	3.38	2.09	1.33	.847	.547	.355	.207	.119	.067	.038	.026	.016	.012	.007	.142
01197930	.732	.638	.557	.477	.411	.352	.291	.238	.193	.162	.139	.115	.097	.077	.241
01197935	.976	.820	.688	.566	.471	.383	.296	.229	.173	.139	.113	.089	.073	.056	.240
01197960	1.76	1.31	.995	.744	.549	.412	.282	.202	.134	.094	.071	.052	.040	.031	.232
01198020	2.21	1.89	1.60	1.33	1.09	.868	.663	.516	.331	.308	.250	.194	.160	.117	.540
01198040	.827	.760	.693	.626	.564	.500	.434	.379	.322	.285	.253	.220	.197	.165	.383
01198060	.803	.687	.578	.466	.381	.302	.230	.175	.129	.099	.076	.050	.033	.012	.171
01198062	1.26	1.03	.836	.659	.514	.388	.277	.200	.137	.103	.079	.057	.044	.029	.193
01198100	.632	.573	.516	.462	.405	.352	.294	.243	.191	.150	.110	.063	.032	.013	.237
01198110	1.17	.994	.835	.690	.559	.446	.346	.266	.203	.163	.135	.108	.091	.068	.254
01198137	.518	.457	.405	.357	.297	.248	.190	.141	.102	.074	.053	.034	.021	.004	.132
01198160	.609	.537	.475	.409	.352	.297	.244	.197	.160	.132	.113	.093	0.08	.062	.190
01198260	.674	.563	.461	.370	.294	.228	.172	.129	.095	.076	.062	.049	.040	.029	.124
Partial-record stations															
01197802[1]	0.919	0.806	0.704	0.609	0.537	0.477	0.412	0.336	0.269	0.212	0.171	0.131	0.105	0.078	0.347
01198080[1]	.962	.838	.720	.602	.506	.414	.328	.258	.200	.165	.140	.115	.099	.077	.258
Short-term discontinued streamflow-gaging stations															
01197015[2]	0.921	0.801	0.682	0.564	0.475	0.382	0.304	0.234	0.179	0.145	0.121	0.096	0.083	0.064	0.236
01198030[3]	.903	.789	.674	.564	.471	.385	.306	.239	.185	.153	.129	.105	.089	.068	.237
01198070[3]	1.54	1.37	1.22	1.05	.910	.769	.636	.517	.421	.355	.310	.261	.231	.185	.530
01198075[3]	1.03	.899	.783	.663	.562	.465	.370	.294	.231	.192	.164	.137	.120	.096	.299
01198122[4]	.821	.710	.603	.496	.405	.320	.238	.170	.114	.079	.058	.039	.028	.019	.180
01198125[4]	1.23	1.10	.968	.845	.735	.634	.540	.456	.378	.329	.292	.254	.228	.182	.471

Table 10. Estimated streamflows per square mile for selected flow durations and estimated August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station No.: Locations shown in figure 6 and described in table 6. No., number; USGS, U.S. Geological Survey]

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second per square mile														
	50	55	60	65	70	75	80	85	90	93	95	97	98	99	August median
01198200[4]	1.09	.987	.889	.791	.712	.638	.561	.484	.414	.362	.322	.283	.254	.218	.488

Table 10. Estimated streamflows per square mile for selected flow durations and estimated August median streamflows at low-flow partial-record stations, partial-record stations, and short-term discontinued streamflow-gaging stations in the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Streamflow equaled or exceeded at indicated percentage of time, in cubic feet per second per square mile												
	1	2	3	5	7	10	15	20	25	30	35	40	45
Partial-record stations													
01197802[1]	9.40	7.15	5.97	4.72	4.00	3.31	2.62	2.15	1.81	1.54	1.35	1.19	1.04
01198080[1]	11.4	8.46	6.94	5.38	4.52	3.70	2.86	2.34	1.96	1.68	1.46	1.27	1.10
Short-term discontinued streamflow-gaging stations													
01197015[2]	12.5	9.17	7.45	5.72	4.73	3.83	2.92	2.36	1.95	1.65	1.43	1.24	1.07
01198030[3]	10.9	8.02	6.56	5.07	4.26	3.48	2.69	2.20	1.84	1.58	1.37	1.19	1.04
01198070[3]	11.8	9.22	7.85	6.36	5.51	4.67	3.77	3.21	2.77	2.44	2.17	1.94	1.73
01198075[3]	10.4	7.83	6.55	5.16	4.38	3.63	2.86	2.37	2.01	1.74	1.52	1.33	1.17
01198122[4]	8.93	6.81	5.67	4.48	3.79	3.11	2.41	1.96	1.65	1.43	1.25	1.08	.950
01198125[4]	10.5	8.26	7.01	5.66	4.90	4.13	3.29	2.75	2.34	2.03	1.78	1.57	1.38
01198200[4]	8.51	6.56	5.52	4.42	3.78	3.16	2.52	2.13	1.83	1.61	1.45	1.31	1.19

[1]Partial-record station during water years 1994–96.
[2]Streamflow-gaging station during water years 1980–83.
[3] Streamflow-gaging station during water years 1971–72.
[4] Streamflow-gaging station during water years 1994–96.

Factors Affecting Streamflow

Estimated streamflows per square mile for selected flow durations between 1 and 99 percent and the August median streamflows at all 41 stations (tables 5 and 10) were compared to measure the effect of basin characteristics and climatic conditions on flow. Individual factors (basin and climatic characteristics), as well as the combination (interaction) of factors, affect the overall streamflow regime of a basin.

Basin characteristics measured for all 41 subbasins (table 20) were

- drainage area;
- mean, minimum, and maximum basin elevation;
- mean basin slope;
- stream length;
- area of stratified drift;
- mean, minimum, and maximum elevation of stratified-drift deposits;
- urban area;
- agricultural and open area;
- forested area;
- area of water bodies;
- area of forested wetlands;
- area of nonforested wetlands;
- area of barren, exposed rock, and mining;
- area of north, east, south, and west aspect and flat area (no aspect); and the
- areas of three different bedrock geology types determined on the basis of tectonic and lithochemical characteristics and the physiography map of the Connecticut, Housatonic, and Thames River Basins developed for the NAWQA project in this area (Robinson and others, 1999).

Several additional characteristics were calculated from the measured basin characteristics (table 20). All measured basin characteristics were determined from existing digital data bases by using a geographic information system (GIS).

Relations between streamflows and basin characteristics were examined in three ways and are shown in tables 11, 12, and 13. Correlation coefficients for relations of selected logarithms of streamflows from the 50- to 99-percent flow durations and the August median streamflows to the logarithms of specific basin characteristics are shown for all 41 stations in table 11. Streamflow statistics and basin characteristics were transformed to logarithms to normalize their distributions. Correlation coefficients for relations of selected logarithms of streamflows from the 1- to 99-percent flow durations and the August median streamflows to the logarithms of specific basin characteristics are shown in table 12 for 20 stations (the 21 LFPR stations were excluded because they did not have streamflows from the 1- to 45-percent durations). Relations shown in table 13 are the same as those for table 12 because they are based on 10 years or more of streamflow records, but only the 11 long-term stations were included in the analysis.

Surficial Geology

Previous studies in New England have found that streams with large percentages of stratified-drift area in their drainage basins generally have higher flow per unit area at low flows and lower flow per unit area at high flows than do stations with small percentages of stratified-drift area in their drainage basins (Thomas, 1966; Tasker, 1972; Cervione, 1982, p. 16–18; Lapham, 1988, p. 13, 14; de Lima, 1991, p. 22, 23; Bent, 1995, p. 18–22; Friesz, 1996, p. 38–40). This relation between percentage of stratified-drift area in a basin and streamflow per unit area of the basin is a result of the fact that stratified drift allows greater amounts of precipitation to be recharged, to be stored, and then discharged during low-flow periods, than does till and bedrock. The percentage of stratified-drift area is correlated strongly with streamflow per square mile for lower flows (90- and 99-percent flow duration), August median streamflow per square mile (tables 11, 12, and 13), and for higher flows (1- and 10-percent flow duration) (tables 12 and 13).

For the 90- and 99-percent flow durations, streamflows per square mile were positively correlated to percentage of stratified-drift area, with correlation coefficients ranging from 0.45 to 0.71 and 0.51 to 0.84, respectively (tables 11, 12, and 13). Although the percentage of basin area underlain by stratified drift at the 41 stations ranges only from 0 to 28 percent (table 20, at back of report), it appears that small differences in percentage of stratified drift can result in large differences in streamflow per square mile at low-flow durations. For example, of the 11 long-term stations, streamflows per square mile for the 90- to 99-percent flow durations were higher for the East Branch Housatonic River (station 01197000), the Housatonic River (station 01197500), and Salmon Creek (station 01199050) than for the other stations (table 5). The subbasins for these three stations are underlain by 13 to 15 percent stratified drift (table 20, at back of report), a large value compared to the other long-term stations.

Table 11. Correlation coefficients for the relations between streamflow and basin characteristics at low-flow partial-record stations, partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[n, number of stations; ft, foot; $(ft^3/s)/mi^2$, cubic feet per second per square mile; mi, mile; mi^2, square miles; %, percent]

Log basin characteristic	Correlation coefficients (n=41)				
	Log 50-percent flow duration $[(ft^3/s)/mi^2]$	Log 70-percent flow duration $[(ft^3/s)/mi^2]$	Log 90-percent flow duration $[(ft^3/s)/mi^2]$	Log 99-percent flow duration $[(ft^3/s)/mi^2]$	Log August median streamflow $[(ft^3/s)/mi^2]$
Log basin drainage area (mi^2)	-0.15	0.10	0.42	0.44	0.36
Log minimum basin elevation (ft)	.08	-.19	-.37	-.28	-.31
Log maximum basin elevation (ft)	.14	.37	.46	.45	.49
Log mean basin elevation (ft)	.19	.06	-.05	.06	.01
Log basin relief (ft)[1]	.07	.39	.56	.49	.56
Log basin ground-water head (ft)[2]	.13	.34	.47	.49	.46
Log mean basin slope (GRID) (%)	.14	.32	.32	.19	.36
Log mean basin slope (TIN) (%)	.16	.39	.40	.27	.44
Log stream density (mi/mi^2)	.03	-.14	-.15	.07	-.16
Log stratified drift area (%)[3]	-.16	.15	.45	.51	.40
Log stratified-drift area + 0.1/total stream length (mi^2/mi)	-.10	.24	.52	.54	.47
Log urban area (%)[3]	-.50	-.24	.16	.13	.05
Log agriculture and open area (%)[3]	-.12	.05	.17	.03	.13
Log forest area (%)	.10	-.08	-.17	-.06	-.18
Log water bodies area (%)[3]	.01	.21	.35	.24	.28
Log forested wetlands area (%)[3]	.09	.16	.13	.08	.13
Log nonforested wetlands area (%)[3]	-.08	.02	.10	-.02	.09
Log total wetlands area (%)[3]	.12	.14	.06	-.04	.06
Log total water bodies and wetlands area (%)[3]	.14	.21	.14	.02	.15
Log barren, rocks, and mining area (%)[3]	-.41	-.11	.24	.19	.14
Log north aspect area (%)	.10	.05	.12	.31	.08
Log east aspect area (%)	.45	.45	.14	.04	.22
Log south aspect area (%)	-.19	-.09	.05	-.01	.02
Log west aspect area (%)	-.30	-.28	-.06	-.10	-.09
Log flat area (%)[3]	-.50	-.24	.16	.13	.05
Log gneissic and quartzitic rocks area (%)[3]	-.14	-.18	-.06	-.06	-.13
Log carbonate rocks area (%)[3]	-.07	.10	.17	-.06	.14
Log schistose rocks area (%)[3]	-.01	.14	.22	.36	.22

[1] Basin relief is the difference between maximum and minimum basin elevation.

[2] The difference between mean and minimum basin elevation is a surrogate for basin ground-water head in unconsolidated deposits (Ries, 1994a, p. 30).

[3] A value of 0.01 was added to the basin characteristic for all stations before the logarithm was determined because some basins had a value of zero, and the logarithm can not be determined for zero.

Table 12. Correlation coefficients for the relations between streamflow and basin characteristics at partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[n, number of stations; ft, foot; $(ft^3/s)/mi^2$, cubic feet per second per square mile; mi, mile; mi^2, square miles; %, percent]

Log basin characteristic	Correlation coefficients (n=20)							
	Log 1-percent flow duration $[(ft^3/s)/mi^2]$	Log 10-percent flow duration $[(ft^3/s)/mi^2]$	Log 30-percent flow duration $[(ft^3/s)/mi^2]$	Log 50-percent flow duration $[(ft^3/s)/mi^2]$	Log 70-percent flow duration $[(ft^3/s)/mi^2]$	Log 90-percent flow duration $[(ft^3/s)/mi^2]$	Log 99-percent flow duration $[(ft^3/s)/mi^2]$	Log August median streamflow $[(ft^3/s)/mi^2]$
Log basin drainage area (mi^2)	-0.43	-0.45	-0.35	-0.12	0.13	0.45	0.56	0.34
Log minimum basin elevation (ft)	.38	.42	.25	.08	.01	-.13	-.27	-.05
Log maximum basin elevation (ft)	-.24	-.10	.16	.31	.44	.51	.52	.47
Log mean basin elevation (ft)	.58	.54	.32	.22	.17	.17	.09	.18
Log basin relief (ft)[1]	-.48	-.42	-.11	.12	.30	.46	.52	.39
Log basin ground-water head (ft)[2]	.00	-.12	-.10	.07	.19	.42	.52	.30
Log mean basin slope (GRID) (%)	-.20	-.03	.25	.23	.22	.12	.04	.17
Log mean basin slope (TIN) (%)	-.25	-.13	.15	.17	.16	.10	.06	.11
Log stream density (mi/mi^2)	-.15	-.02	.06	.19	.13	.16	.32	.09
Log stratified drift area (%)[3]	-.64	-.55	-.20	.16	.43	.66	.79	.56
Log stratified-drift area + 0.1/total stream length (mi^2/mi)	-.51	-.46	-.13	.16	.39	.53	.59	.46
Log urban area (%)[3]	-.06	.29	.52	.52	.56	.40	.16	.52
Log agriculture and open area (%)[3]	-.59	-.61	-.44	-.38	-.11	.04	-.02	.07
Log forest area (%)	.36	.10	-.15	-.17	-.26	-.17	.12	-.28
Log water bodies area (%)[3]	-.39	-.40	-.29	.00	.13	.31	.52	.20
Log forested wetlands area (%)[3]	-.37	-.25	-.12	.03	.08	.14	.05	.13
Log non-forested wetlands area (%)[3]	-.24	-.05	.06	.17	.24	.23	.04	.28
Log total wetlands area (%)[3]	-.11	.00	.00	.09	.07	.07	-.07	.07
Log total water bodies and wetlands area (%)[3]	-.34	-.16	.04	.21	.26	.24	.07	.27
Log barren, rocks, and mining area (%)[3]	.19	.21	.05	.05	.01	.06	-.07	.04
Log north aspect area (%)	-.07	-.27	-.28	-.04	.06	.31	.50	.14
Log east aspect area (%)	-.05	.15	.34	.37	.19	.04	.18	.01
Log south aspect area (%)	-.18	-.18	-.26	-.30	-.17	-.11	-.16	-.04
Log west aspect area (%)	-.16	-.33	-.53	-.62	-.41	-.22	-.28	-.18
Log flat area (%)[3]	-.06	.29	.52	.52	.56	.40	.16	.52
Log gneissic and quartzitic rocks area (%)[3]	.22	.10	-.14	-.08	-.05	.08	.12	.03
Log carbonate rock area (%)[3]	-.76	-.58	-.21	-.04	.22	.29	.15	.35
Log schistose rocks area (%)[3]	-.24	-.31	-.18	-.24	-.18	-.10	-.18	-.10

[1] Basin relief is the difference between maximum and minimum basin elevation.

[2] The difference between mean and minimum basin elevation is a surrogate for basin ground-water head in unconsolidated deposits (Ries, 1994a, p. 30).

[3] A value of 0.01 was added to the basin characteristic for all stations before the logarithm was determined because some basins had a value of zero, and the logarithm can not be determined for zero.

Table 13. Correlation coefficients for the relations between streamflow and basin characteristics at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[n, number of stations; ft, foot; $(ft^3/s)/mi^2$, cubic feet per second per square mile; mi, mile; mi^2, square miles; %, percent]

Log basin characteristics	Correlation Coefficients (n=11)							
	Log 1-percent flow duration $[(ft^3/s)/mi^2]$	Log 10-percent flow duration $[(ft^3/s)/mi^2]$	Log 30-percent flow duration $[(ft^3/s)/mi^2]$	Log 50-percent flow duration $[(ft^3/s)/mi^2]$	Log 70-percent flow duration $[(ft^3/s)/mi^2]$	Log 90-percent flow duration $[(ft^3/s)/mi^2]$	Log 99-percent flow duration $[(ft^3/s)/mi^2]$	Log August median streamflow $[(ft^3/s)/mi^2]$
Log basin drainage area (mi^2)	-0.61	-0.72	-0.65	-0.23	0.15	0.56	0.70	0.39
Log minimum basin elevation (ft)	.32	.50	.43	.31	.17	-.05	-.26	.06
Log maximum basin elevation (ft)	-.49	-.32	-.01	.29	.54	.62	.51	.60
Log mean basin elevation (ft)	.42	.39	.19	.37	.34	.36	.22	.31
Log basin relief (ft)[1]	-.60	-.62	-.37	-.09	.25	.48	.48	.40
Log basin ground-water head (ft)[2]	-.21	-.50	-.59	-.23	.05	.44	.59	.23
Log mean basin slope (GRID) (%)	-.36	-.22	.08	-.04	.09	.04	-.04	.11
Log mean basin slope (TIN) (%)	-.37	-.28	.00	-.07	.06	.03	-.05	.10
Log stream density (mi/mi^2)	-.08	.06	.08	.23	.07	.10	.31	.02
Log stratified drift area (%)[3]	-.70	-.69	-.44	-.02	.42	.71	.84	.60
Log stratified-drift area + 0.1/total stream length (mi^2/mi)	-.64	-.72	-.47	-.13	.36	.58	.61	.51
Log urban area (%)[3]	-.21	.30	.67	.75	.70	.37	-.01	.58
Log agriculture and open area (%)[3]	-.59	-.55	-.29	-.34	.04	.14	-.03	.22
Log forest area (%)	.32	-.08	-.40	-.27	-.36	-.12	.36	-.38
Log water bodies area (%)[3]	-.34	-.48	-.47	-.05	.11	.38	.68	.19
Log forested wetlands area (%)[3]	-.18	-.13	-.20	-.19	-.10	.01	-.07	.02
Log nonforested wetlands area (%)[3]	.10	.31	.27	.18	.20	.14	-.10	.25
Log total wetlands area (%)[3]	.29	.36	.08	-.04	-.13	-.12	-.26	-.08
Log total water bodies and wetlands area (%)[3]	-.16	-.02	.02	.11	.19	.16	-.09	.26
Log barren, rocks, and mining area (%)[3]	.39	.41	.08	-.02	-.11	-.08	-.24	-.06
Log north aspect area (%)	.02	-.40	-.63	-.31	-.10	.28	.54	.03
Log east aspect area (%)	-.07	.18	.36	.37	.09	-.09	.13	-.09
Log south aspect area (%)	-.32	-.22	-.10	-.07	.05	.06	-.04	.14
Log west aspect area (%)	-.30	-.34	-.30	-.36	-.04	.10	-.19	.17
Log flat area (%)[3]	-.21	.30	.67	.75	.70	.37	-.01	.58
Log gneissic and quartzitic rocks area (%)[3]	.41	.10	-.34	-.12	-.12	.16	.35	-.04
Log carbonate rocks area (%)[3]	-.76	-.53	-.12	-.07	.31	.33	.09	.46
Log schistose rocks area (%)[3]	-.34	-.46	-.36	-.51	-.30	-.19	-.28	-.15

[1] Basin relief is the difference between maximum and minimum basin elevation.

[2] The difference between mean and minimum basin elevation is a surrogate for basin ground-water head in unconsolidated deposits (Ries, 1994a, p. 30).

[3] A value of 0.01 was added to the basin characteristic for all stations before the logarithm was determined because some basins had a value of zero, and the logarithm can not be determined for zero.

For the 1- and 10-percent flow durations, streamflows per square mile were negatively correlated to percentage of stratified-drift area, with correlation coefficients -0.64 and -0.55 for the 20-station analysis (table 12), respectively, and -0.70 and -0.69 for the 11 long-term station analysis (table 13), respectively. It appears that small differences in percentage of stratified drift can result in large differences in discharge per square mile at high-flow durations. For example, streamflows per square mile for the 1- to 10-percent flow duration were higher for Walker Brook (station 01180800), West Branch Westfield River (station 01181000), Hubbard River (station 01187300), Marsh Brook (station 01197300), and Dry Brook (station 01331400) than for the other stations (table 5). This might be caused by the low infiltration rates of till and bedrock, which underlie more than 95 percent of each of the five subbasins (table 20, at back of report). During intense or prolonged rainfall or snowmelt, these five subbasins have higher runoff rates and consequently higher streamflow per square mile than the other six subbasins, which are underlain by 85 to 93 percent till and bedrock.

Bedrock Geology

Several studies in the northeastern United States have investigated the effects of bedrock geology on streamflows (mainly low flows), including Hely and Olmsted (1963), Schneider (1965), Trainer and Watkins (1975, p. 42–49), and Smith and others (1982). Analyses of the streamflows for the effects of bedrock type were difficult because only 7 of the 41 subbasins in and near the study area are completely underlain by one bedrock type and only another 5 of the 41 subbasins are underlain by more than 90 percent of one bedrock type (table 20). Carbonate rocks underlay a maximum of 74 percent of any one subbasin. Hely and Olmsted (1963, p. B17) reported that the relation of low flows to bedrock type is difficult to describe quantitatively where subbasins are underlain by several geologic formations.

Correlation analysis of all 41 stations found no relation between streamflows and percentage of different type bedrock areas between the 50- and 99-percent flow durations (table 11). Analysis for 20 stations (table 12) and for 11 long-term stations (table 13) showed a negative correlation between high streamflows (1- and 10-percent flow durations) and percentage of carbonate bedrock area ranging from -0.76 to -0.53. Correlation coefficients for streamflows and percentage of schistose bedrock area indicate a negative correlation ranging from -0.34 to -0.51 between the 1- and 50-percent flow durations for the 11 long-term stations (table 13). Only the 1- and 99-percent flow durations were positively correlated (0.41 and 0.35) to percentage of gneissic and quartzitic bedrock area (table 13). Low flows for the 70- and 90-percent flow durations and August median streamflows showed positive correlations (0.31 to 0.46) to percentage of carbonate bedrock at the 11 long-term stations (table 13). Some correlation coefficients of streamflows (high and low flows) with percentage of carbonate bedrock area are similar to those of streamflows with percentage of stratified-drift area (tables 12 and 13). Stratified-drift deposits are primarily in areas of carbonate bedrock and thus could affect the test of the relation of streamflows to percentage carbonate bedrock area. Hely and Olmsted (1963, B18) stated that stratified drift tends to conceal the effects of bedrock geology on streamflow. In addition, other geologic properties (such as the number, size, and degree of interconnection of joints, fractures, and bedding planes) may mask the effects of the bedrock type on streamflows.

Estimates of streamflows per square mile for the 90- and 99-percent flow durations in tables 5 and 10 and primary bedrock type and percentage of basin underlain by stratified drift in table 20 are varied and inconsistent. Some stations had greater flows for the 90- and 99-percent flow durations than other nearby stations underlain by the same bedrock type; these include two stations (01197180 and 01197200) in the Berkshire Mountains underlain mainly with gneissic and quartzitic rocks and some stratified drift, two stations (01198020 and 01198040) in the Taconic Mountains underlain completely with schistose rocks and no stratified drift; and three stations (01198070, 01198125, and 01198200) in the Housatonic River Valley underlain mainly by carbonate rocks and some stratified drift (stations 01198070 and 01198125) and by gneissic and quartzitic rocks and some stratified drift (station 01198200). Again, the interaction of factors (basin and climatic characteristics) may mask the effects of individual factors on streamflows.

Climate

Mean annual precipitation and temperature differ among the six climatological stations in and near the study area primarily due to station elevation. Mean annual precipitation and temperature at the six climatological stations range from 43.9 to 51.5 in. and from and 43.4 to 45.6˚F, respectively. Elevations of the climatological stations range from 730 to 1,640 ft above sea level. As elevation increases, precipitation increases and temperature decreases. Knox and Nordenson (1955) and Dingman (1981) reported that mean annual precipitation increases with increasing elevation in New England. Thus, more streamflow per square mile would be expected from subbasins at high elevations due to high precipitation and low temperature (less evapotranspiration). Simcox (1992, p. 5, 6) shows that in western Massachusetts precipitation and runoff increase with elevation. One inch of additional annual precipitation with 50 percent lost to evapotranspiration corresponds to an additional 0.037 $(ft^3/s)/mi^2$ of streamflow from a subbasin.

Basin characteristics related to water availability, such as annual precipitation, annual runoff, and basin elevation (for example, mean basin elevation and relief), correlate with each other and with low flow (Wandle and Randall, 1994, p. 5). Numerous studies in New England and eastern New York (Hely and Olmsted, 1963; Dingman, 1978, 1981; Male and Ogawa, 1982; DeAngelis and others, 1984; Barnes, 1986; Risley, 1994; Wandle and Randall, 1994) have found that precipitation, runoff, and basin elevation characteristics are related to low flows. In this study, elevation-related basin characteristics (minimum, maximum, and mean basin elevation), relief (maximum minus minimum basin elevation), ground-water head (mean minus minimum basin elevation) (Ries, 1994a, 1994b, 1997), and mean basin slope may be surrogates for precipitation and evapotranspiration.

Streamflows per square mile between the 90- and 99-percent flow durations and August median streamflow ranging from 0.23 to 0.62 (tables 11, 12, and 13) were positively correlated with maximum basin elevation, relief, and ground-water head. High relief, ground-water head, and mean basin slope generally would be associated with subbasins having high maximum elevations. At high flows (1- and 10-percent flow durations), mean basin elevation was positively correlated to streamflow (0.39 to 0.58), and relief was negatively correlated (-0.42 to -0.62) to streamflow in analyses of 20 stations and 11 long-term stations (tables 12 and 13). Maximum basin elevation and ground-water head were negatively correlated to high flows (1- and 10-percent flow durations) only in the 11 long-term-station analysis (table 13).

Aspect may be a surrogate for evapotranspiration because north aspects tend to have lower temperatures (less exposure to direct sunlight and lower temperature during exposure) and thus less evapotranspiration than do south aspects. In this study, percentage of north aspect area was positively correlated (0.28 to 0.54) to streamflows for the 90- and 99-percent flow durations in analyses of 20 stations and 11 long-term stations (tables 12 and 13). This result was expected because low evapotranspiration makes a relatively high volume of water available for streamflow. For the 41-station analysis, percentage of north aspect area had a positive correlation with streamflow for the 99-percent flow duration (table 11). Percentage of west aspect area was negatively correlated (-0.33 to -0.62) to streamflows mainly between the 10- and 70-percent flow durations in analyses of the 20 stations (table 12). The 11 long-term stations percentage of west aspect area was negatively correlation (-0.30 to -0.36) to streamflows between the 1- and 50-percent flow durations (table 13). On west aspects, the air temperature is high late in the day when sunlight is direct. Thus, west aspects have high evapotranspiration, and less water is available for streamflows. Percentage of flat area (no aspect) was positively correlated (0.37 to 0.75) to streamflow between the 30- and 90-percent flow durations and August median streamflows in analyses of 20 stations and 11 long-term stations (tables 12 and 13). The reasons for the positive relation between percentage of flat area and these particular flow durations are unknown.

Other Physical Features

Drainage area was positively correlated (0.34 to 0.70) with low flows per square mile for the 90- and 99-percent flow durations (tables 11, 12, and 13) and August median streamflows and negatively correlated (-0.35 to -0.72) with high flows for the 1-, 10-, and 30-percent flow durations (tables 12 and 13). Percentage of stratified drift plus 0.1 divided by stream length was positively correlated with streamflows per square mile (0.46 to 0.61) at the 90- and 99-percent flow durations and August median streamflows (tables 11, 12, and 13). Studies by Ries (1994a, 1994b, 1997) used drainage area and area of stratified drift plus 0.1 divided by stream length in equations to estimate low flows and August median streamflows in Massachusetts.

Some land uses affected streamflows per square mile (tables 11, 12, and 13). Percentage of urban area was positively correlated (0.37 to 0.75) to streamflows between the 30- and 90-percent flow durations and August median streamflows (tables 12 and 13). Percentage of agricultural and open area was negatively correlated (-0.29 to -0.61) to streamflows between the 1- and 50-percent flow durations (tables 12 and 13). In general, wetlands and water bodies were not negatively correlated to low flows (tables 11 and 12) as Wandle and Randall (1994) had found previously for sites in New England.

Effects of surface- and ground-water withdrawals on streamflows (Bent, 1995, p. 21–26) in subbasins in the study area (fig. 5 and table 2) were not evident because most subbasins had little to no water withdrawals. All water withdrawals were returned to the subbasins upstream from the stations excluding the East Branch Housatonic River (station 01109700).

Streamflow from a basin could be underestimated if ground water flows through stratified-drift deposits beneath the stream at the measuring point (Jacob, 1938; Randall and others, 1988, p. 24, 25; Dickerman and Bell, 1993, p. 9). If the minimum basin elevation equaled the minimum elevation of stratified drift (table 20), it was assumed that stratified-drift deposits are present at the measuring point. Seven of the 41 stations have subbasins with no stratified-drift deposits overlying bedrock or till, thus ground-water underflow is negligible because ground-water flow through till and bedrock is small relative to streamflow. Only 5 of the 21 LFPR stations (01197230, 01197930, 01197935, 01198060, and 01198160) have stratified drift at the measuring point (minimum elevation of stratified drift equals minimum basin elevation) (table 20). Seventeen of the other 20 stations have stratified-drift deposits underlying their measuring point. The ground-water favorability map for the Housatonic River Basin developed by Norvitch (1966, sheet 1), and figure 6 and table 20 of this report (which show station locations and list subbasins where stratified drift is located at the measuring point), indicate that groundwater could be flowing beneath stations at station measuring points where ground-water yields are estimated to be greater than 10 gal/min. The actual amount of ground-water underflow at each station would depend on the saturated thickness, lateral extent, and water-transmitting properties of the stratified drift, and the water-table gradient and direction of ground-water flow at the measuring point. However, no information currently exists on the saturated thickness and water-table gradients for the stratified-drift aquifers in the study area.

BASE FLOW

Base flow (ground-water discharge) is that part of streamflow that discharges from an aquifer to the stream channel upstream from the measuring point. Ground water discharges continuously to streams and is typically the principal component of streamflow 3 to 7 days after a peak in streamflow caused by precipitation or snowmelt. Estimates of annual base flow are useful in assessing potential water supplies. During most years, ground-water levels and base flow decrease during the growing season. Annual base flow can vary significantly with annual precipitation and longer term variations in ground-water storage.

Long-Term Stations

Two computer programs were used to determine base flow from the 11 long-term streamflow-gaging stations in and near the study area (fig. 3 and table 3). These computer programs, HYSEP (Sloto and Crouse, 1996) and PART (Rutledge, 1998), automate hydrograph-separation procedures to estimate mean daily base flow from streamflow records. The computer program HYSEP includes three algorithms originally developed by Pettyjohn and Henning (1979). The local minimum algorithm of HYSEP, which provides the lowest or most conservative estimate, was used in this study.

Estimates of minimum, maximum, and mean annual streamflow and base flow at the 11 long-term stations are presented in table 14. Mean annual base flow ranged from 13.4 to 21.4 in/yr as determined by using the HYSEP program and from 15.2 to 24.5 in/yr as determined by using the PART program; the estimate using the PART program is always greater by 1 to 3 in/yr. The minimum annual base flow occurred in water year 1965 at all 11 long-term stations, and the minimums ranged from about 45 to 72 percent lower than their respective means. The maximum annual base flow occurred during different years at the 11 long-term stations and ranged from 34 to 82 percent higher than the respective means.

Table 14. Estimates of minimum, maximum, and mean annual streamflow and base flow, and base-flow indexes derived from the computer programs HYSEP and PART at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[A water year is the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends. HYSEP (Sloto and Crouse, 1996); PART (Rutledge, 1998). USGS station No.: Locations shown in figure 3 and described in table 3. Base-flow index is mean annual base flow divided by mean annual streamflow. Streamflow and base flow are in inches per year. No., number; USGS, U.S. Geological Survey; --, not applicable]

USGS station No.	Period of record computed (water years)	Number of water years	Water year	Minimum	Water year	Maximum	Mean	Standard deviation	Base-flow index
				Annual streamflow					
01180800	1964–77	14	1965	14.4	1972	44.5	30.8	8.21	--
01181000	1936–95	60	1965	10.6	1972	42.9	27.4	7.46	--
01187300	1939–55, 1957–95	56	1965	11.0	1955	43.8	27.1	7.86	--
01197000	1937–95	59	1965	10.0	1945	36.6	24.9	6.42	--
01197300	1964–74	11	1965	10.6	1973	45.6	31.0	8.99	--
01197500	1914–95	82	1965	10.1	1928	46.4	25.2	6.30	--
01198000	1952–71, 1995	21	1965	8.17	1952	31.4	21.0	5.64	--
01198500	1950–71	22	1965	7.62	1956	37.9	22.8	7.87	--
01199050	1962–95	34	1965	7.31	1976	34.0	22.2	6.49	--
01331400	1964–74	11	1965	12.8	1972	41.7	26.9	8.44	--
01333000	1950–95	46	1965	10.1	1975	40.1	26.0	6.33	--
				Annual base flow derived by using HYSEP computer program (local minimum algorithm)					
01180800	1964–77	14	1965	10.0	1972	26.5	18.3	4.41	0.59
01181000	1936–95	60	1965	7.14	1972	24.5	15.3	3.57	.56
01187300	1939–55, 1957–95	56	1965	6.82	1945	22.8	14.9	3.88	.55
01197000	1937–95	59	1965	7.18	1972	21.4	15.0	3.39	.60
01197300	1964–74	11	1965	6.08	1972	30.6	21.4	6.55	.69
01197500	1914–95	82	1965	5.94	1928	27.2	15.5	4.03	.61
01198000	1952–71, 1995	21	1965	6.03	1952	21.0	14.2	3.45	.68
01198500	1950–71	22	1965	4.56	1956	20.0	13.4	3.89	.59
01199050	1962–95	34	1965	5.79	1976	25.3	15.9	4.45	.72
01331400	1964–74	11	1965	8.20	1972	25.2	16.2	4.79	.60
01333000	1950–95	46	1965	7.21	1952	23.8	16.8	3.51	.64
				Annual base flow derived by using PART computer program					
01180800	1964–77	14	1965	11.1	1972	28.9	20.2	4.72	0.66
01181000	1936–95	60	1965	8.27	1978	24.6	16.9	3.88	.62
01187300	1939–55, 1957–95	56	1965	7.73	1978	23.1	15.9	3.84	.59
01197000	1937–95	59	1965	7.96	1945	23.8	16.5	3.76	.66
01197300	1964–74	11	1965	7.08	1972	33.4	24.5	7.25	.79
01197500	1914–95	82	1965	7.36	1928	32.0	17.6	4.68	.70
01198000	1952–71, 1995	21	1965	6.99	1952	24.6	16.7	4.05	.80
01198500	1950–71	22	1965	5.55	1956	23.2	15.2	4.36	.67
01199050	1962–95	34	1965	6.24	1976	23.4	17.4	4.77	.79
01331400	1964–74	11	1965	9.33	1972	24.7	17.6	4.68	.65
01333000	1950–95	46	1965	8.30	1975	29.0	19.6	4.27	.75

To compare data on an equal basis, the mean base flow for the period of record through water year 1995 was divided by the mean streamflow for that same period as a climate-based standardizing procedure for each station. For example, if a station had only 10 years of record and those 10 years had above-normal precipitation and thus above-normal streamflows, the mean base flow would be above normal. This standardizing procedure is referred to as the base-flow index (BFI) by Nathan and McMahon (1990). Rutledge and Mesko (1996, p. B26, B27) found that the ratio of 30-year estimates to 10-year estimates for median the BFI was 1.0 for 89 streamflow-gaging stations in the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces of the eastern United States, but for the medians of mean streamflow, base flow, and ground-water recharge the ratio was not 1.0. A test of the BFI method of standardization was done for the study area, which is located in the New England physiographic province, by calculating the median BFI for randomly chosen 5-year periods for all 11 long-term stations and comparing this median to the median BFI for the 11 stations by using their complete period of record as listed in table 14. The result was a ratio of 1.03 between the 5-year median BFI and the complete-period-of-record median BFI. These results compare well to the results obtained by Rutledge and Mesko (1996, p. B26, B27) given that 5-year instead of 10-year periods were used and that only 11 and not 89 long-term stations were used.

BFIs ranged from 0.55 to 0.72 and from 0.59 to 0.80 at the 11 long-term stations by using HYSEP and PART, respectively (table 14). The median BFIs were 0.60 and 0.67 at the 11 long-term stations, respectively. BFIs (ranging from 0.61 to 0.71) calculated by using HYSEP and PART for 3 long-term streamflow-gaging stations in southeastern Massachusetts and Rhode Island, where stratified-drift deposits underlying the subbasins are less than 28 percent (Bent, 1995, p. 12, 27, 28), were similar to the BFIs for the 11 long-term stations in and near the study area, where stratified-drift deposits underlying the subbasins are less than 15 percent. Rutledge and Mesko (1996, B26, B27) found a median BFI of 0.67 for the Blue Ridge physiographic province north of latitude 37˚N (the same median BFI as for the study area calculated by using PART). The Blue Ridge physiographic province is underlain by bedrock types similar to those underlying the study area (Rutledge and Mesko, 1996, p. B5).

BFIs (HYSEP and PART results) at the 11 long-term stations were positively correlated with mean basin slope (both GRID and TIN) (0.39 and 0.60), percentage of urban area (0.43 and 0.46), percentage of agricultural and open area (0.62 and 0.65), percentage of flat area (no aspect) (0.43 and 0.46), and percentage of carbonate bedrock area (0.72 and 0.79) (table 15). BFIs (HYSEP and PART results) were negatively correlated with mean basin elevation (-0.40 and -0.42), percentage of forest area (-0.64 and -0.65), percentage of total wetland (forested and nonforested wetlands) area (-0.26 and -0.41), percentage of barren area (-0.37 and -0.48), percentage of north aspect (-0.54 for both), and percentage of gneissic and quartzitic bedrock area (-0.83 and -0.89) (table 15).

Mean basin slope and mean basin elevation were positively and negatively correlated, respectively, with base flow (table 13) when both would be expected to be positive. Elevation-related characteristics may be a surrogate for precipitation (higher elevations or relief equal greater precipitation and runoff). Mean basin slope may also be a surrogate for the ground-water-table gradient. Higher ground-water-table gradients would be expected for subbasins with higher mean basin slopes. Thus, higher mean basin slope would be expected to result in greater base flow because of the higher ground-water-table gradients.

Several positive and negative correlations between BFIs and land use may be related to evapotranspiration. For example, evapotranspiration may be low in an urban area where there is more impervious land surface and in an agricultural or open area where there are few trees and where crops transpire during only about 4 months of the year. Thus, the percentages of these land uses are positively correlated to BFIs. Forest and wetland areas, where conifer trees transpire year round and deciduous trees transpire about 6 months of the year, would be expected to have higher evapotranspiration rates and negative correlation to BFIs. Percentage of barren area resulted in the opposite correlation than expected as related to evapotranspiration. North aspects would be expected to have lower evapotranspiration rates, and thus their percentages should show positive correlations to BFIs. But the correlation for percentage of north aspect was negative in this analysis for unknown reasons. The percentage of flat area had a positive correlation for unknown reasons.

Table 15. Correlation coefficients for the relation of base-flow and ground-water-recharge characteristics to basin characteristics at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[Base flow index is mean annual base flow divided by mean annual streamflow. Recharge index is mean annual ground-water recharge divided by mean annual streamflow. Base-flow index calculated by using computer programs HYSEP (Sloto and Crouse, 1996) and PART (Rutledge, 1998). Recharge index calculated by using computer program RORA (Rutledge, 1998). ft, foot; mi, mile; mi^2, square mile; mi/mi^2, mile per square mile; %, percent).

Log basin characteristics	Correlation coefficients (n=11)			Log basin characteristics	Correlation coefficients (n=11)		
	Log base flow index (HYSEP)	Log base flow index (PART)	Log recharge index (RORA)		Log base flow index (HYSEP)	Log base flow index (PART)	Log recharge index (RORA)
Log basin drainage area (mi^2)	-0.18	-0.09	-0.05	Log water bodies area (%)[3]	-0.28	-0.31	-0.34
Log minimum basin elevation (ft)	.12	.05	-.04	Log forested wetlands area (%)[3]	-.16	-.02	.12
Log maximum basin elevation (ft)	.26	.34	.30	Log nonforested wetlands area (%)[3]	-.04	.10	.01
Log mean basin elevation (ft)	-.40	-.42	-.52	Log total wetlands area (%)[3]	-.41	-.26	-.21
Log basin relief (ft)[1]	.17	.25	.30	Log total water bodies and wetlands area (%)[3]	.04	-.00	.07
Log basin ground-water head (ft)[2]	-.38	-.34	-.31	Log barren, rocks, and mining area (%)[3]	-.48	-.37	-.34
Log mean basin slope (GRID) (%)	.48	.60	.61	Log north aspect area (%)	-.54	-.54	-.57
Log mean basin slope (TIN) (%)	.39	.49	.56	Log east aspect area (%)	.13	.15	.11
Log stream density (mi/mi^2)	-.08	-.11	-.16	Log south aspect area (%)	.26	.20	.24
Log stratified drift area (%)[3]	.24	.31	.16	Log west aspect area (%)	.23	.28	.41
Log stratified-drift area + 0.1/total stream length (mi^2/mi)	.23	.32	.26	Log flat area (%)[3]	.43	.46	.38
Log urba arean (%)[3]	.43	.46	.38	Log gneissic and quartzitic rocks area (%)[3]	-.89	-.83	-.88
Log agriculture and open area (%)[3]	.62	.65	.68	Log carbonate rocks area (%)[3]	.72	.79	.81
Log forest area (%)	-.64	-.66	-.68	Log schistose rocks area (%)[3]	.28	.30	.49

[1] Basin relief is the difference between maximum and minimum basin elevation.

[2] The difference between mean and minimum basin elevation is a surrogate for basin ground-water head in unconsolidated deposits (Ries, 1994a, p. 30).

[3] A value of 0.01 was added to the basin characteristic for all stations before the logarithm was determined because some basins had a value of zero, and the logarithm can not be determined for zero.

Correlation results determined for BFI and underlying bedrock type (table 15) were compared to well yields from the three bedrock types found in the study area. Several studies of well yields for the three bedrock types in the study area have produced inconsistent results. For example, Norvitch and others (1968, sheet 4) reported median well yields of 9 gal/min for carbonate rocks, 5 gal/min for schistose rocks, 15 gal/min for gneissic rocks, and 20 gal/min for quartzitic rocks in that part of the Housatonic River Basin in Massachusetts. Cervione and others (1972, p. 58, 59) reported that in the northwestern Connecticut part of the Housatonic River Basin (adjacent to and south of the study area) bedrock wells had median yields of about 12 gal/min for carbonate rocks, 7 gal/min for granular rocks (gneiss, granite, diorite, and related rocks), and 5 gal/min for schistose rocks. Hansen and Simcox (1994, p. 25) reported that wells (domestic, commercial, and industrial) completed in carbonate rocks of western Massachusetts had a median yield of 25 gal/min, and wells completed in crystalline rock (including schistose, gneissic, and quartzitic rocks) for the entire State of Massachusetts had a median yield of 6 gal/min. These results make it difficult to determine a relation between base flow, underlying bedrock type, and bedrock well yields. Rutledge and Mesko (1996, B15-B17) also found mixed results in comparing base-flow characteristics of specific basins to well yields from different types of underlying rocks. Nelms and others (1995, p. 20–29) concluded that base-flow characteristics may provide only a relative indication of potential ground-water yield for areas in the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces of the eastern United States.

Base-flow duration discharges between 1 and 99 percent were computed by using the estimated daily mean base flows (derived from HYSEP) for the 11 long-term stations (table 16). These base-flow-duration discharges indicate the percentages of time that ground water of various flow rates is discharged from the basin upstream from the station. Comparison of the ratio of base flow to streamflow showed Marsh Brook (station 01197300) and the Housatonic River (station 01197500) to have low values between the 75- and 99-percent flow durations (table 16). For Marsh Brook, the inconsistent values are likely due to rounding of low values of base flows and streamflows by the statistical computer program. Low ratios for the Housatonic River are most likely due to regulation of the river, where daily mean discharges were as low as 1 ft^3/s during the period of record (1914–95). These two stations were not included in the averaging of the percentage of streamflow that is base flow for individual durations between the 75- and 99-percent flow durations. The average ratios between the 1- and 50-percent and the 50- and 99-percent flow durations ranged from 0.455 to 0.756 and 0.742 to 0.850 (table 16), respectively.

The ground-water component of streamflow is larger at flow durations greater than 50 percent than for flow durations less than 50 percent. Streamflows near the 99-percent flow duration generally are the result of periods of no rainfall during the summer and are usually entirely base flow; however, even flows between the 90- and 99-percent flow durations sometimes can contain surface runoff. For example, a rainstorm that occurs when streamflows are at the 98-percent flow duration could cause streamflow to increase to the 93-percent flow duration through added surface runoff. In this example, the streamflow for the 93-percent flow duration would not be entirely base flow. Conversely, streamflows as low as the 40-percent flow duration can be entirely base flow following a wet year (John Mullaney, U.S. Geological Survey, written commun., 1998).

Short-Term Stations

Base flow for selected flow durations at the 30 short-term stations (fig. 6 and table 6) can be determined by two different methods by using the information (or data) contained in tables 3, 7, 8, and 16. The first method of base-flow determination consists of multiplying the estimated flow-duration discharges between 1 and 99 percent in table 8 by the average proportion of the streamflow that is base flow for the respective flow duration (table 16). For example, the 90-percent flow duration for Windsor Brook near Hinsdale, Mass. (station 01196995), is 0.787 ft^3/s (table 8), and the average ratio of base flow to streamflow (at 9 of the 11 long-term stations) for the 90-percent flow-duration is 0.807 (table 16); the product of these values, 0.635 ft^3/s, is the base flow at the 90-percent flow duration.

The second method of base-flow determination is the same as the first, except that it utilizes only the long-term stations that related best to each individual short-term station (table 7) for the respective flow duration (table 16). Four long-term stations [01181000, 01197000, 01198000, and 01333000 (fig. 3 and table 3)] were related to station 01196995 (table 7). For example, the average ratio of base flow to streamflow at the four long-term stations (0.747, 0.796, 0.892, and 0.799) is 0.808. Multiplying the streamflow of 0.787 ft^3/s for the Windsor Brook station (01196995) by 0.808 gives a base flow at the 90-percent flow duration of 0.636 ft^3/s. In these examples, the two methods produced similar results but that may not always be true for other stations and flow durations. In particular, estimates of base flow could be underestimated if ground-water underflow occurs in the subbasin.

GROUND-WATER RECHARGE

Ground-water recharge is the amount of precipitation that infiltrates through the land surface and reaches the water table. Generally, ground-water recharge in the study area occurs from October through April, when evapotranspiration is low. From May through September, evapotranspiration generally exceeds precipitation, resulting in little to no ground-water recharge. Estimates of annual ground-water-recharge rates are useful in assessing potential water supplies. During droughts, aquifers might not receive recharge for an extended time period. Annual recharge rates can vary significantly with annual precipitation.

Table 16. Streamflow, base flow, and ratio of base flow to streamflow for selected flow durations derived from the computer program HYSEP at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[HYSEP (Sloto and Crouse, 1996). USGS station No.: Locations shown in figure 3 and described in table 3. No., number; USGS, U.S. Geological Survey]

USGS station No.	Equaled or exceeded at indicated percentage of time												
	1	2	3	5	7	10	15	20	25	30	35	40	45
Streamflow, in cubic feet per second													
01180800	51.0	39.0	32.0	25.7	21.3	16.8	12.2	9.41	7.72	6.47	5.39	4.72	4.05
01181000	1,540	1,100	868	669	551	438	326	254	209	176	150	129	111
01187300	339	255	207	147	123	94.2	68.0	54.3	43.3	36.4	30.2	26.5	22.8
01197000	719	543	442	346	285	229	175	141	117	100	86.8	76.2	68.0
01197300	32.8	26.2	22.9	18.2	15.4	12.5	9.50	7.48	6.07	5.07	4.25	3.59	3.00
01197500	2,950	2,340	2,000	1,660	1,390	1,170	928	756	639	554	478	423	374
01198000	536	409	344	273	233	191	148	120	101	85.0	71.8	59.7	50.7
01198500	565	414	336	250	204	164	125	102	85.6	72.3	62.2	53.7	46.5
01199050	284	211	177	139	121	100	82.4	70.7	60.9	53.5	47.1	41.5	36.6
01331400	134	94.1	75.8	58.2	48.3	37.7	26.9	20.6	17.1	14.4	12.4	10.5	8.85
01333000	527	409	343	270	224	186	145	119	99.7	85.2	73.6	63.9	55.5
Base flow derived by using HYSEP computer program (local minimum algorithm), in cubic feet per second													
01180800	22.5	17.5	15.7	12.6	11.0	9.16	7.08	5.82	5.07	4.49	3.93	3.50	3.07
01181000	556	455	407	337	290	245	193	161	141	123	107	93.3	81.1
01187300	140	109	91.7	69.0	61.8	51.1	40.8	33.5	28.8	25.4	22.0	19.2	16.7
01197000	301	247	218	179	154	131	107	89.8	78.8	69.8	62.4	55.5	49.0
01197300	21.0	17.4	14.6	11.4	9.89	8.04	6.38	5.28	4.40	3.77	3.15	2.61	2.24
01197500	1,410	1,240	1,090	940	898	705	572	482	420	368	326	289	258
01198000	273	231	203	166	145	122	102	86.5	75.1	64.5	55.1	47.4	40.9
01198500	214	178	159	130	117	98.0	79.4	67.5	57.3	50.2	43.4	38.4	33.6
01199050	135	118	104	91.4	81.1	73.3	61.8	54.2	47.5	42.0	37.2	32.9	29.3
01331400	58.6	46.7	41.5	32.3	25.5	20.1	15.7	13.4	11.6	10.1	8.76	7.65	6.75
01333000	240	205	184	156	137	116	94.7	81.2	71.1	62.0	54.5	48.0	42.5
Ratio of base flow to streamflow													
01180800	0.441	0.449	0.491	0.490	0.516	0.545	0.580	0.618	0.657	0.694	0.729	0.742	0.758
01181000	.361	.414	.469	.504	.526	.559	.592	.634	.675	.699	.713	.723	.731
01187300	.413	.427	.443	.469	.502	.542	.600	.617	.665	.698	.728	.725	.732
01197000	.419	.455	.493	.517	.540	.572	.611	.637	.674	.698	.719	.728	.721
01197300	.640	.664	.638	.626	.642	.643	.672	.706	.725	.744	.741	.727	.747
01197500	.478	.530	.545	.566	.646	.603	.616	.638	.657	.664	.682	.683	.690
01198000	.509	.565	.590	.608	.622	.639	.689	.721	.744	.759	.767	.794	.807
01198500	.379	.430	.473	.520	.574	.598	.635	.662	.669	.694	.698	.715	.723
01199050	.475	.559	.588	.658	.670	.733	.750	.767	.780	.785	.790	.793	.801
01331400	.437	.496	.547	.555	.528	.533	.584	.650	.678	.701	.706	.729	.763
01333000	.455	.501	.536	.578	.612	.624	.653	.682	.713	.728	.740	.751	.766
Average[1]	.455	.499	.528	.554	.580	.599	.635	.667	.694	.715	.728	.737	.749

Table 16. Streamflow, base flow, and ratio of base flow to streamflow for selected flow durations derived from the computer program HYSEP at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Equaled or exceeded at indicated percentage of time													
	50	55	60	65	70	75	80	85	90	93	95	97	98	99
Streamflow, in cubic feet per second														
01180800	3.54	3.04	2.61	2.19	1.78	1.43	1.11	0.800	0.580	0.473	0.420	0.360	0.320	0.280
01181000	95.6	81.6	69.4	57.0	46.6	37.9	30.4	24.1	18.2	14.7	12.5	10.4	8.83	7.22
01187300	19.5	16.7	13.8	10.8	8.27	6.24	4.77	3.45	2.42	1.93	1.56	1.16	.840	.540
01197000	60.4	54.0	48.0	43.4	39.1	35.2	31.5	27.8	24.0	21.3	19.5	17.1	15.8	13.9
01197300	2.52	2.15	1.80	1.48	1.22	.920	.640	.430	.260	.150	.070	.032	.020	.010
01197500	333	300	267	241	215	191	170	149	126	112	99.5	85.1	73.0	56.0
01198000	43.3	36.7	31.0	25.3	19.6	15.3	11.8	8.48	6.41	5.38	4.85	4.21	3.84	3.29
01198500	40.4	35.0	30.6	26.5	22.3	18.2	14.4	11.6	8.74	7.17	6.12	5.03	4.36	3.49
01199050	32.0	28.5	25.0	22.2	19.4	16.6	14.0	11.3	8.58	7.16	6.28	5.14	4.51	3.78
01331400	7.52	6.47	5.53	4.66	3.75	2.97	2.33	1.79	1.31	.992	.680	.403	.290	.160
01333000	48.2	42.2	36.8	31.7	27.0	23.0	18.9	15.0	11.5	9.20	7.77	6.32	5.58	4.83
Base flow derived by using HYSEP computer program (local minimum algorithm), in cubic feet per second														
01180800	2.68	2.29	1.89	1.53	1.28	1.03	0.780	0.600	0.470	0.408	0.370	0.314	0.290	0.250
01181000	70.0	59.4	50.2	41.6	34.1	27.9	22.7	18.2	13.6	11.6	10.2	8.39	7.31	6.09
01187300	14.1	11.8	9.47	7.56	5.86	4.60	3.47	2.55	1.87	1.50	1.25	.860	.660	.480
01197000	44.2	40.3	36.6	33.4	30.3	27.7	25.2	22.3	19.1	17.0	15.6	13.8	12.9	11.7
01197300	1.91	1.65	1.39	1.15	.920	.650	.450	.300	.180	.069	.040	.020	.010	.010
01197500	231	204	183	163	144	126	109	92.8	75.9	65.1	54.9	42.2	34.0	24.9
01198000	34.8	29.3	25.1	19.5	15.1	12.1	9.67	7.41	5.72	4.98	4.47	3.87	3.53	3.11
01198500	30.0	26.4	22.5	18.8	15.5	13.0	10.8	8.88	6.97	5.82	5.06	4.22	3.67	2.78
01199050	25.9	23.1	20.6	18.2	15.8	13.6	11.5	9.37	7.41	6.26	5.41	4.56	4.13	3.47
01331400	5.87	5.03	4.19	3.37	2.77	2.20	1.73	1.36	1.03	.746	.500	.287	.210	.100
01333000	37.6	33.0	28.8	25.1	21.8	18.3	14.7	11.8	9.19	7.70	6.59	5.47	4.95	4.35
Ratio of base flow to streamflow														
01180800	0.757	0.753	0.724	0.699	0.719	0.720	0.703	0.750	0.810	0.863	0.881	0.872	0.906	0.893
01181000	.732	.728	.723	.730	.732	.736	.747	.755	.747	.789	.816	.807	.828	.843
01187300	.723	.707	.686	.700	.709	.737	.727	.739	.773	.777	.801	.741	.786	.889
01197000	.732	.746	.763	.770	.775	.787	.800	.802	.796	.798	.800	.807	.816	.842
01197300	.758	.767	.772	.777	.754	.707	.703	.698	.692	.460	.571	.625	.500	1.00
01197500	.694	.680	.685	.676	.670	.660	.641	.623	.602	.581	.552	.496	.466	.445
01198000	.804	.798	.810	.771	.770	.791	.819	.874	.892	.926	.922	.919	.919	.945
01198500	.743	.754	.735	.709	.695	.714	.750	.766	.797	.812	.827	.839	.842	.797
01199050	.809	.811	.824	.820	.814	.819	.821	.829	.864	.874	.861	.887	.916	.918
01331400	.781	.777	.758	.723	.739	.741	.742	.760	.786	.752	.735	.712	.724	.625
01333000	.780	.782	.783	.792	.807	.796	.778	.787	.799	.837	.848	.866	.887	.901
Average[1]	.756	.755	.751	.742	.744	.760	.765	.785	.807	.825	.832	.828	.847	.850

[1] The average ratio of base flow to streamflow excludes stations 01197300 (Marsh Brook) and 01197500 (Housatonic River) between the 75- and 99-percent flow durations because of low or inconsistent ratios. The low or inconsistent ratios between the 80- and 99-percent flow duration for Marsh Brook (station 01197300) are most likely due to rounding of very low values of base flows and streamflows by the statistical computer program. Inconsistent ratios for the Housatonic River (station 01197500) are most likely due to regulation of the river, where daily mean discharges were reduced to as low as 1 cubic foot per second during the period of record (1914–95).

Streamflow Hydrograph Analysis

The computer program RORA (Rutledge, 1998, p. 5, 17–26) was used with the recession-curve-displacement method to estimate ground-water recharge for each peak in streamflow during the period of record. The recession-curve-displacement method uses the pre-peak and post-peak recession periods to extrapolate the change in the total potential ground-water discharge as estimated at a critical time after the peak. Total potential base flow to the stream at the critical time when the streamflow hydrograph becomes log-linear again is about one-half of the total volume of water that recharged the ground-water system during the peak (Rutledge, 1998, p. 19). The method applies to flow systems driven by areally diffuse recharge that is roughly concurrent with peaks in streamflow (Rutledge, 1998, p. 3).

Streamflow records at the 11 long-term stations (fig. 3 and table 3) in and near the study area were analyzed to assess ground-water-recharge rates and responses to climatic conditions. Mean annual ground-water-recharge rates ranged from 17.5 to 22.4 in/yr at 10 of the 11 long-term stations, and the mean recharge was 28.1 in/yr for Marsh Brook (station 01197300) (table 17). The median mean annual ground-water recharge rate was 20.0 in/yr at the 11 long-term stations. These estimates of mean annual ground-water recharge may be conservative because they do not take into account ground-water underflow in the stratified-drift aquifer beneath the stream channel and surrounding areas.

The estimates of mean annual ground-water recharge were compared to other ground-water-recharge rates for subbasins primarily underlain by till and bedrock in Massachusetts and the rest of New England. The estimates of mean annual ground-water recharge at the 11 long-term stations in and near the study area, where the areal percentage of stratified-drift deposits underlying the subbasins was less than 15 percent, were similar to mean ground-water-recharge rates (19.7 to 22.6 in/yr) calculated by using RORA for 3 subbasins underlain by less than 28 percent stratified drift in southeastern Massachusetts and Rhode Island (Bent, 1995, p. 12, 27). Mean ground-water-recharge rates determined in this study for subbasins underlain primarily by till and bedrock are higher than those previously reported for areas of New England, which range from 3 to 19 in/yr (ENSR Consulting and Engineering, 1992; Harte and Mack, 1992).

Table 17. Estimates of minimum, maximum, and mean annual ground-water recharge and recharge indexes derived from the computer program RORA at long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[A water year is the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends. RORA (Rutledge, 1998). USGS station No.: Locations shown in figure 3 and described in table 3. Recharge index is mean annual ground-water recharge divided by mean annual streamflow in table 14. Ground-water recharge is in inches per year. No., number; USGS, U.S. Geological Survey]

USGS station No.	Period of record computed (water years)	Number of water years	Water year	Minimum	Water year	Maximum	Mean	Standard deviation	Recharge index
Annual ground-water recharge derived by using RORA computer program									
01180800	1964–77	14	1965	11.6	1973	29.8	22.4	5.18	0.73
01181000	1936–95	60	1965	9.57	1978	29.9	20.0	4.76	.73
01187300	1939–55, 1957–95	56	1965	8.95	1978	29.3	19.8	4.87	.73
01197000	1937–95	59	1965	8.24	1978	27.5	19.1	4.43	.77
01197300	1964–74	11	1965	7.88	1973	38.4	28.1	8.21	.91
01197500	1914–95	82	1965	8.65	1928	36.6	20.4	5.77	.81
01198000	1952–71, 1995	21	1965	7.56	1960	27.6	18.6	4.88	.89
01198500	1950–71	22	1965	6.42	1960	26.4	17.5	5.29	.77
01199050	1962–95	34	1965	7.16	1976	29.1	19.5	5.35	.88
01331400	1964–74	11	1965	10.4	1972	27.8	20.4	5.45	.76
01333000	1950–95	46	1965	9.66	1975	33.2	22.2	4.82	.85

The differences in the ground-water-recharge rates for till and bedrock areas are mostly due to differences in analysis methodology and the climatic conditions during analyses reported by ENSR Consulting and Engineering (1992) and Harte and Mack (1992) for New England, which could have been wetter or drier than the normal long-term climatic conditions during the analyses for the 11 long-term stations in and near the study area.

Mean annual ground-water-recharge rates determined with RORA were from 3 to 7 and 2 to 4 in/yr greater than base-flow rates determined by use of HYSEP and PART, respectively (tables 14 and 17). Rutledge (1998, p. 39) and Rutledge and Mesko (1996, p. B20, B21) attributed this difference between mean ground-water recharge and base flow to the loss of water to riparian evapotranspiration. Riparian evapotranspiration is defined as the loss of water in stream channels to evaporation and the loss of water in the saturated zone near the stream to evapotranspiration. The differences between ground-water-recharge rates (RORA) and base-flow rates (HYSEP) are slightly greater than those observed (1 to 4 in/yr higher) in southeastern Massachusetts and Rhode Island (Bent, 1995, p. 27, 28). Estimated rates of riparian evapotranspiration in the study area are similar to those reported by Rutledge and Mesko (1996, p. B20, B21) for the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces of the eastern United States.

Ground-water-recharge rates were at a minimum at all 11 long-term stations during water year 1965 and ranged from 48 to 72 percent less than the respective long-term means at the stations (table 17). In southeastern Massachusetts and Rhode Island, Bent (1995, p. 27) also found that the minimum annual ground-water-recharge rate can be less than 50 percent of the respective long-term means. Water year 1965 is considered a drought year, and the effects of this drought can also be observed in the ground-water-level hydrographs of observation wells GMW-2, PTW-51, and SJW-59/SJW-58 (fig. 4) in the study area. Ground-water-recharge rates reached their maximum in different years at different stations and ranged from 33 to 79 percent greater than the respective long-term means. Similar differences between maximum and mean annual ground-water-recharge rates (33 to 79 percent greater) were found in southeastern Massachusetts and Rhode Island (Bent, 1995, p. 27). Water years 1976 and 1978, which were the years of maximum ground-water-recharge rates for several stations (table 17), also were observed to have the highest ground-water levels in observation well SJW-59/SJW-58 (fig. 4). Water levels in this observation well rise and decline gradually in response to climatological conditions, whereas the other two wells (GMW-2 and PTW-51) have water levels that are affected by their close proximity to a stream.

The ground-water-recharge rates were standardized by using the same technique as described previously for base flow. The ratio of mean annual ground-water-recharge rate to mean annual streamflow at the 11 long-term stations, referred to as recharge index in this report, ranged from 0.73 to 0.91 (table 17), with a median of 0.77. The recharge index was used to compare the 11 long-term stations to their basin characteristics (table 15). Important positive correlations to recharge index were mean basin slope (both GRID and TIN) (0.61 and 0.56), percentage of agricultural and open area (0.68), percentage of west aspect (0.41), percentage of schistose bedrock area (0.49), and percentage of carbonate bedrock area (0.81). Important negative correlations to recharge index were mean basin elevation (-0.52), percentage of forest area (-0.68), percentage of north aspect (-0.57), and percentage of gneissic and quartzitic bedrock area (-0.88).

Many of these correlation results between recharge index and basin characteristics are similar to those obtained previously for base flow. This is because mean annual ground-water discharge and recharge have been shown to be positively related (Rutledge, 1998, p. 39; Rutledge and Mesko, 1996, p. B20, B21). Additionally, to obtain the BFI and recharge indexes, mean annual base flow and ground-water recharge are divided by mean annual streamflow. The reasons for the positive and negative correlations between recharge index and basin characteristics are similar to the reasons previously discussed for base flow.

In other studies of ground-water recharge and basin and climatic characteristics, Rutledge and Mesko (1996, p. B22–B25) found that the relation of recharge to water-yielding capacity of rocks was generally not clear for the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces of the eastern United States. But they found that recharge was positively related to precipitation and in most cases basin relief which is most analogous to mean basin slope (in percent) in this study.

Climatological Data Analysis

Mean potential ground-water recharge was estimated from monthly mean climatological data by using methods described by Thornthwaite and Mather (1957). Monthly mean temperature and precipitation data for 30-year periods of record were analyzed for six NOAA climatological stations in and near the study area (fig. 3 and table 18).

Mean potential ground-water recharge, calculated as mean precipitation minus mean potential evapotranspiration, ranged from about 17.9 to 29.0 in/yr, with a median value of 22.6 in/yr (table 18). The calculation of mean potential ground-water recharge assumes that there is no direct runoff of precipitation and that all precipitation minus evapotranspiration is recharge. Little to no direct runoff would be expected in areas underlain mainly by stratified-drift deposits. Mean potential ground-water recharge generally increased with increasing elevation. Mean potential ground-water recharge at three high-elevation climatological stations (Cummington Hill and Lanesborough, Mass., and Norfolk 2 SW, Conn., fig. 3) was high because of low mean potential evapotranspiration (high precipitation and low temperatures at higher elevations) (table 18). The estimated mean potential ground-water-recharge rates compare well with the mean annual ground-water-recharge rates computed by using the streamflow-hydrograph analysis (RORA) (table 17). Bent (1995, p. 27, 28) also reported that estimates of mean potential ground-water-recharge rates in southeastern Massachusetts (underlain mainly by stratified-drift deposits), as determined by Barlow and Hess (1993, p. 17, 18) by using the Thornthwaite and Mather (1957) method, were similar to those obtained by using streamflow-hydrograph analysis (RORA method).

The Great Barrington Airport, Mass. (station 3213), is located 1 mi southwest of the Green River streamflow-gaging station (01198000) (fig. 3) and is only 30 ft higher in elevation. Monthly mean temperature and monthly total precipitation at Great Barrington Airport, Mass., were analyzed by using the Thornthwaite and Mather (1957) method for water years 1952–71 and 1995, the same period that ground-water recharge at the Green River streamflow-gaging station was analyzed by using the RORA method (Rutledge, 1998) (table 17). Mean potential ground-water recharge at the Great Barrington Airport was 21.0 in/yr for water years 1952–71 and 1995.

Table 18. Estimates of mean annual potential evapotranspiration and ground-water recharge derived from the Thornthwaite and Mather (1957) method at climatological stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[NOAA climatological station No.: Location shown in figure 3. All climatological station information and temperature and precipitation data are from National Oceanic Atmospheric Administration (NOAA) (1983; 1993). Latitude and longitude are given in degrees and minutes. Mean annual potential ground-water recharge equals mean annual precipitation minus mean annual evapotranspiration; No., number; ft, foot; in/yr, inches per year; ˚F, degrees Fahrenheit]

NOAA climatological station name	NOAA climatological station No.	Latitude ° ′	Longitude ° ′	Elevation above sea level (ft)	Period of record analyzed by NOAA	Mean annual temperature (˚F)	Mean annual precipitation (in/yr)	Mean annual potential evaptranspiration (in/yr)	Mean annual potential ground-water recharge (in/yr)
Cummington Hill, Mass.	1774	42 28	72 56	1,610	1961–90	44.4	46.0	22.6	23.4
Falls Village, Conn.	2658	41 57	73 22	550	1961–90	47.6	42.6	24.7	17.9
Great Barrington Airport, Mass.	3213	42 11	73 24	730	1961–90	45.2	44.8	23.1	21.7
Lanesborough, Mass.	4075	42 33	73 14	1,240	1971–79, 1981–84, 1987–90, 1993	43.4	48.8	22.0	26.8
Norfolk 2 SW, Conn.	5445	41 58	73 13	1,340	1961–90	44.1	51.5	22.5	29.0
Stockbridge, Mass.	8181	42 18	73 20	860	1951–80	45.6	43.9	23.2	20.7

This 21.0 in/yr is about 2.4 in/yr higher than results obtained by analyzing the streamflow record at Green River near Great Barrington for the same period by using RORA. The median of mean potential ground-water recharge (Thornthwaite and Mather method) for the 6 climatological stations is 22.4 in/yr (table 18), and the median mean annual ground-water-recharge rate (RORA method) at the 11 streamflow-gaging stations is 20.0 in/yr (table 17). Unlike the RORA method, the Thornthwaite and Mather method does not account for direct runoff of precipitation and riparian evapotranspiration of precipitation, which recharge the ground-water aquifer. Direct runoff would be expected in areas underlain mainly by till and bedrock, like the study area.

A general water budget for water years 1952–71 and 1995 can be constructed for the Green River subbasin (table 19) by using climatological data from the Great Barrington Airport (station 193213) and streamflow data for the Green River streamflow-gaging station (01198000) (fig. 3). Direct runoff and riparian evapotranspiration were 2.5 in/yr higher when base flow was calculated with HYSEP rather than PART. Because the mean annual precipitation for this 21-year period (table 19) is 5.3 in less than the mean annual for 1961–90 (table 18), the water budget would be slightly larger for all components if the period of 1961–90 was used for analysis.

SUMMARY AND CONCLUSIONS

Concerns about the ability of current surface-water supplies to meet recently instituted Federal drinking-water regulations could cause some communities in the Housatonic River Basin in Massachusetts to investigate ground-water sources of supply in the study area. Efficient management and optimal development of current and future surface-water and ground-water sources for public, industrial, hydroelectric power, and commercial uses, balanced with recreational uses and the amount of water required for stream habitat in the study area, require information about streamflow, base flow, and ground-water recharge.

The study area, which covers 504 mi^2 of western Massachusetts, 26 mi^2 of eastern New York, and 10 mi^2 of northwestern Connecticut in the Housatonic River Basin, is underlain by three generalized bedrock types. Carbonate rocks primarily underlie the lowland area of the Housatonic River Valley (central part of the study area), gneissic and quartzitic rocks primarily underlie the Berkshire Mountains (upland in eastern part of the study area), and schistose rocks primarily underlie the Taconic Mountains (upland in western part of the study area). Surficial deposits in the study area are primarily till and bedrock (83 percent) in the

Table 19. Water budget for the Green River subbasin in the Housatonic River Basin, western Massachusetts and part of eastern New York, water years 1952–71 and 1995

[A water year is the 12-month period beginning October 1 and ending September 30. It is designated by the calendar year in which it ends. Precipitation: Measured at Great Barrington Airport (climatological station number 3213, location shown in fig. 3 and described in table 18). Potential evapotranspiration: Calculated by using Thornthwaite and Mather (1957) method. Streamflow: Measured at U.S. Geological Survey streamflow-gaging station Green River near Great Barrington (01198000, location shown in figure 3 and described in table 3). Ground-water recharge: Calculated by using the computer program RORA (Rutledge, 1998). Base flow: First line shows base flow calculated by using the computer program HYSEP (local minimum algorithm) (Sloto and Crouse, 1996); second line shows base flow calculated by using the computer program PART (Rutledge, 1998). Direct runoff: Streamflow minus base flow. Riparian evapotranspiration: Ground-water recharge minus base flow. All budget values are in inches per year]

Number of water years	Mean annual precipitation	Mean annual potential evapotran-spiration	Mean annual streamflow	Mean annual ground-water recharge	Mean annual base flow	Mean annual direct runoff	Mean annual riparian evapotran-spiration
21	39.5	18.5	21.0	18.6	14.2	6.8	4.4
21	39.5	18.5	21.0	18.6	16.7	4.3	1.9

upland areas and stratified-drift deposits (17 percent) in the upland stream valleys and the Housatonic River Valley.

In 1995, 13 of the 26 communities in the Massachusetts part of the study area each used more than 0.01 Mgal/d of water for municipal supply. Total water use by the 13 communities was 16.27 Mgal/d, which supplied 76,000 water users. About 92 percent of the total municipal water supply came from surface-water withdrawals. The city of Pittsfield, Mass., accounted for 58 percent of the total withdrawals, which were transfered from the East Branch Housatonic River subbasin. Industrial water use was 12.52 Mgal/d for the Massachusetts part of the study area in 1995.

Streamflows for selected flow durations between 1 and 99 percent and August median streamflows were computed for six long-term continuous and five long-term discontinued streamflow-gaging stations in and near the study area. Estimates of streamflows and associated standard errors for selected flow durations between 50 and 99 percent and August median streamflows were determined for 21 low-flow partial-record stations and for selected flow durations between 1 and 99 percent and August median streamflows for 2 partial-record stations and 7 short-term discontinued streamflow-gaging stations in the study area. The estimated streamflows at the 30 short-term stations are indicative of long-term conditions. Streamflows at all 41 stations generally reflect natural conditions. The exceptions include several stations affected by short periods of pond fluctuations upstream. Also, the East Branch Housatonic River is affected by municipal water withdrawals from reservoirs, most of which are transferred out of the subbasin.

Streamflows for selected flow-duration discharges between 1 and 99 percent at all 41 stations were divided by their drainage areas to evaluate differences in streamflow among subbasins and to evaluate factors affecting streamflows. Median streamflows for the 1-, 50-, and 99-percent flow durations and August median streamflows at the 11 long-term stations were 12.9, 1.04, 0.080, and 0.272 $(ft^3/s)/mi^2$, respectively. Median streamflows for the 1-, 50-, and 99-percent flow durations and August median streamflows at the 30 short-term stations were 10.5, 0.945, 0.066, and 0.238 $(ft^3/s)/mi^2$, respectively. Streamflows per square mile at the 41 stations were related to basin characteristics of topography, stratified-drift deposits, land use, aspect, and bedrock geology. Streamflow was correlated positively with basin elevation, most likely because precipitation increases with elevation, and to stratified-drift deposits, which allow more precipitation to infiltrate into the ground water and discharge later to stream than do till and bedrock deposits.

Base flows were estimated for the study area by analyzing streamflow records at the 11 long-term streamflow-gaging stations with the USGS computer programs HYSEP and PART. Mean annual base flow computed by HYSEP (local minimum algorithm) and PART ranged from 13.4 to 21.4 in/yr and from 15.2 to 24.5 in/yr, respectively, with estimates from PART always greater by 1 to 3 in/yr. Base-flow duration discharges were determined from streamflow records at the 11 long-term stations by using the hydrograph-separation program HYSEP. Base flow at selected flow durations between 1 and 99 percent ranged from 45.5 to 85.0 percent of streamflow through the range of flow durations at the 11 long-term stations. Base-flow duration discharges at the 30 short-term stations were determined by multiplying the selected streamflow-duration discharges between 1 and 99 percent by the average proportion of the streamflow that is base flow. These proportions were estimated either from analysis of all 11 long-term stations or from analysis of the long-term stations that related best to each individual short-term station. Estimates of base flow per square mile could be underestimated at stations affected by ground-water underflow through stratified-drift deposits.

The USGS computer program RORA was used to estimate ground-water-recharge rates for the study area from streamflow records for the 11 long-term continuous and discontinued streamflow-gaging stations. Also, recharge was estimated by the Thornthwaite and Mather method from climatological data from six NOAA climatological stations in and near the study area. Estimates of mean ground-water-recharge rates at the 11 long-term stations ranged from 17.5 to 22.4 in/yr, with 1 station having a ground-water-recharge estimate of 28.1 in/yr. Estimates of mean potential ground-water-recharge rates at the 6 climatological stations ranged from 17.9 to 29.0 in/yr, with a median value of 22.6 in/yr. This median value compares well to that calculated by using streamflow data from the 11 streamflow-gaging stations (20.0 in/yr). The difference occurs because the Thornthwaite and Mather method (analysis of climatological data) does not account for direct runoff of precipitation and for riparian evapotranspiration of precipitation which recharge the ground-water aquifer. Estimates of annual ground-water-recharge rates indicate that, during drought years, ground-water-recharge rates could be less than one-half of the mean annual ground-water recharge rate. Mean ground-water-recharge rates calculated by RORA were 3 to 7 in/yr greater than mean base flow when determined by HYSEP and 2 to 4 in/yr greater when determined by PART. Thus, base flow could be used as a low estimate of ground-water-recharge rates.

Streamflows, base flows, and ground-water recharge determined for this study were compared to those of other studies in Massachusetts. Streamflows for the 10-, 50-, and 90-percent flow durations at 20 stations in and near the study area [3.90, 1.01, and 0.185 $(ft^3/s)/mi^2$, respectively] compared well to those computed for other unregulated, long-term continuous streamflow-gaging stations in central and eastern Massachusetts (4.19, 1.11, and 0.225 $(ft^3/s)/mi^2$, respectively). August median streamflows at the 41 stations in and near the study area corresponded to the 85-percent flow duration, which is very close to the flow duration of 84 percent previously reported. The median of the August median streamflows at the 41 stations was 0.248 $(ft^3/s)/mi^2$, which is similar to that previously reported for the western part of Massachusetts. Base flow and ground-water-recharge rates in the study area compared closely to other study results in southeastern Massachusetts and Rhode Island, which were based on the same computational methods.

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TABLES 20 and 21

Table 20. Basin characteristics determined by using a geographic information system at low-flow partial-record stations, partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut

[USGS station no.: Locations shown on figures 3 and 6 and described in tables 3 and 6. Basin relief: The difference between maximum and minimum basin elevation. Basin ground-water head: The difference between mean and minimum basin elevation and is a surrogate for basin ground-water head in unconsolidated deposits (Ries, 1994a, p. 30). GIS, geographic information system; No., number; USGS, U.S. Geological Survey; ft, foot; mi/mi^2, mile per square mile; mi^2, square mile; mi^2/mi, square mile per mile; --, not applicable]

USGS station No.	Drainage area (mi^2)	GIS-determined drainage area (mi^2)	Minimum basin elevation above sea level (ft)	Maximum basin elevation above sea level (ft)	Mean basin elevation above sea level (ft)	Basin relief (ft)	Basin ground-water head (ft)	Mean basin slope (GRID) (percent)	Mean basin slope (TIN) (percent)	Stream length (mi)	Stream density (mi/mi^2)	Stratified drift area (percent)	Stratifed drift/stream length (mi^2/mi) +0.1	Minimum elevation of stratified drift above sea level (ft)	Maximum elevation of stratified drift above sea level (ft)	Mean elevation of stratified drift above sea level (ft)	Ground-water relief (ft)
Low-Flow Partial-Record Stations																	
01196995	8.81	9.02	1,494	2,194	1,937	700	443	4.77	7.45	14.2	1.57	3.3	0.1211	1,608	1,904	1,895	296
01197120	20.4	20.4	1,042	2,093	1,375	1,051	333	8.08	15.9	33.9	1.66	.5	.1032	1,150	1,226	1,185	76
01197130	.81	.81	1,015	1,670	1,363	655	348	9.96	12.8	2.13	2.63	.0	.1000	--	--	--	--
01197140	5.92	5.95	995	2,075	1,346	1,080	351	8.59	13.4	7.23	1.22	.5	.1041	1,191	1,199	1,196	8
01197180	7.64	7.62	1,067	2,110	1,572	1,043	505	12.4	16.6	8.50	1.12	10.2	.1918	1,169	1,522	1,345	353
01197200	4.05	4.05	1,070	1,897	1,523	827	453	8.22	13.4	5.00	1.23	7.4	.1600	1,346	1,439	1,382	93
01197210	.76	.76	1,016	1,697	1,440	681	424	9.85	13.2	1.3	1.71	.0	.1000	--	--	--	--
01197230	22.1	22.2	896	1,900	1,379	1,004	483	10.7	14.4	26.4	1.19	12.6	.2057	896	1,439	986	543
01197240	4.11	4.11	1,407	2,057	1,763	650	356	6.44	9.97	7.14	1.74	.0	.1000	--	--	--	--
01197930	11.7	11.8	985	1,949	1,416	964	431	10.7	13.8	22.1	1.87	6.9	.1371	985	1,325	1,122	340
01197935	20.5	20.6	865	1,949	1,344	1,084	479	11.3	14.5	36.2	1.76	7.5	.1401	865	1,325	1,051	450
01197960	1.95	1.96	1,031	1,896	1,521	865	490	12.7	17.2	4.67	2.38	1.0	.1043	1,185	1,263	1,224	78
01198020	3.41	3.35	900	2,389	1,832	1,489	932	13.9	21.1	2.68	.800	.9	.1112	1,016	1,707	1,494	691
01198040	1.79	1.91	1,103	1,875	1,594	772	491	13.6	18.0	1.93	1.01	.0	.1000	--	--	--	--
01198060	2.94	2.91	796	2,001	1,409	1,205	613	18.9	22.7	2.22	.763	2.7	.1360	796	911	833	115
01198062	2.14	2.13	801	1,277	967	476	166	4.54	8.92	2.13	1.00	.0	.1000	--	--	--	--
01198100	8.27	8.27	783	1,703	1,085	920	302	7.87	13.0	9.52	1.15	.1	.1010	975	994	984	19
01198110	1.58	1.59	777	1,644	1,094	867	317	11.5	16.5	1.77	1.11	.0	.1000	--	--	--	--
01198137	1.15	1.17	1,298	1,713	1,544	415	246	5.51	7.81	1.80	1.54	.0	.1000	--	--	--	--
01198160	8.56	8.46	1,026	1,700	1,387	674	361	6.22	9.07	10.1	1.19	3.2	.1267	1,026	1,275	1,131	249
01198260	8.94	8.87	1,000	1,680	1,428	680	428	4.27	7.84	12.0	1.35	9.7	.1717	1,156	1,538	1,402	382

Table 20. Basin characteristics determined by using a geographic information system at low-flow partial-record stations, partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Urban area (percent)	Agricultural and open area (percent)	Forest area (percent)	Water bodies area (percent)	Forested wetlands area (percent)	Nonforested wetlands area (percent)	Total wetlands area (percent)	Total wetlands, water bodies area (percent)	Barren, rocks, mining area (percent)	Road density (mi/mi^2)	North aspect area (percent)	East aspect area (percent)	South aspect area (percent)	West aspect area (percent)	Flat area (percent)	Gneissic and quartzitic rocks area (percent)	Carbonate rocks area (percent)	Schistose rocks area (percent)
Low-Flow Partial-Record Stations—*Continued*																		
01196995	3.3	8.4	74.9	0.0	8.6	2.5	11.1	11.2	2.1	2.24	12.8	19.2	30.0	38.0	0.0	95.0	0.0	5.0
01197120	10.3	13.7	60.6	1.8	5.6	2.8	8.4	10.2	5.2	2.48	15.9	40.2	27.5	16.4	.0	.0	57.6	42.3
01197130	1.2	.0	93.8	.0	.0	.0	.0	.0	4.9	1.48	73.1	7.7	3.8	15.4	.0	100	.0	.0
01197140	11.5	4.0	72.7	.3	4.4	4.9	9.3	9.6	2.2	2.45	18.0	62.6	14.8	4.6	.0	.0	55.9	44.1
01197180	5.5	.7	88.8	1.6	.0	1.4	1.4	3.0	2.0	2.68	19.5	8.3	41.1	30.7	.4	100	.0	.0
01197200	1.0	.2	86.2	2.7	5.7	2.7	8.4	11.1	1.5	1.15	16.6	31.2	21.2	30.5	.5	86.1	5.2	8.7
01197210	.0	5.3	89.5	2.6	2.6	.0	2.6	5.2	.0	1.89	29.0	44.9	5.8	20.3	.0	89.5	10.5	.0
01197230	1.4	9.7	76.6	.7	6.5	4.5	11.0	11.8	.8	1.28	26.0	22.2	21.3	30.4	.0	77.8	16.9	5.1
01197240	.2	.7	97.3	.0	.0	1.7	1.7	1.7	.0	2.39	30.6	21.5	12.1	35.8	.0	100	.0	.0
01197930	.8	4.8	92.4	.0	.7	.7	1.4	1.4	.0	--	12.6	25.3	25.8	36.1	.0	1.6	.0	98.1
01197935	.8	7.2	91.2	.0	.4	.4	.8	.8	.0	--	13.6	28.4	24.9	33.0	.0	.9	.0	98.9
01197960	.0	.0	100	.0	.0	.0	.0	.0	.0	.000	18.0	37.0	33.9	11.1	.0	.0	.0	100
01198020	.0	1.2	94.0	.0	3.6	.6	4.2	4.2	.6	1.43	16.6	49.5	21.5	12.3	.0	.0	.0	100
01198040	1.1	5.5	89.1	.0	.0	.0	.0	.0	4.4	2.07	20.2	39.3	11.5	29.0	.0	.0	.0	100
01198060	11.0	6.2	79.8	.0	.0	.0	.0	.0	3.1	1.82	35.5	37.3	4.7	22.6	.0	.0	33.3	66.7
01198062	7.6	13.3	55.7	.0	13.8	7.6	21.4	21.4	1.9	2.02	4.4	24.8	57.8	13.1	.0	.0	63.4	36.6
01198100	2.2	13.1	75.2	2.3	2.2	4.5	6.7	9.0	.5	1.91	9.8	27.9	27.1	35.0	.2	35.1	64.9	.0
01198110	1.3	11.3	85.5	.0	.0	.6	.6	.6	1.3	2.01	6.0	19.3	32.7	42.0	.0	69.2	5.0	25.8
01198137	3.4	1.7	91.5	.0	.0	2.6	2.6	2.6	.9	2.40	3.6	22.7	55.5	18.2	.0	94.0	6.0	.0
01198160	4.1	7.3	83.7	.4	1.5	2.4	3.9	4.3	.6	2.48	21.4	13.2	24.7	40.7	.0	69.8	18.1	12.2
01198260	1.4	3.1	76.2	4.8	6.7	7.5	14.2	19.0	.3	1.92	13.1	14.9	35.5	36.5	.1	92.1	6.9	1.0

Table 20. Basin characteristics determined by using a geographic information system at low-flow partial-record stations, partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Drainage area (mi^2)	GIS-determined drainage area (mi^2)	Minimum basin elevation above sea level (ft)	Maximum basin elevation above sea level (ft)	Mean basin elevation above sea level (ft)	Basin relief (ft)	Basin-groundwater head (ft)	Mean basin slope (GRID) (percent)	Mean basin slope (TIN) (percent)	Stream length (mi)	Stream density (mi/mi^2)	Stratified drift area (percent)	Stratifed drift/stream length (mi^2/mi) +0.1	Minimum elevation of stratified drift above sea level (ft)	Maximum elevation of stratified drift above sea level (ft)	Mean elevation of stratified drift above sea level (ft)	Groundwater relief (ft)
Partial-Record Stations																	
01197802	43.2	44.1	744	1,990	1,179	1,246	435	8.74	14.6	63.7	1.44	12.1	0.1840	744	1,201	917	457
01198080	50.0	50.8	658	2,528	1,020	1,870	362	8.06	19.6	65.6	1.29	25.6	.2982	658	1,707	711	1,049
Short-Term Discontinued Streamflow-Gaging Stations																	
01197015	10.6	10.6	1,125	2,594	1,552	1,469	427	11.1	15.8	18.5	1.75	5.1	0.1292	1,125	1,665	1,245	540
01198030	23.3	23.9	666	2,528	1,057	1,862	391	7.56	20.9	28.2	1.18	21.5	.2823	666	1,707	709	1,041
01198070	3.20	3.12	695	2,513	1,176	1,818	481	15.6	28.2	4.86	1.56	28.2	.2811	695	791	720	96
01198075	25.8	26.0	665	2,513	997	1,848	332	8.67	19.2	33.9	1.30	27.6	.3115	665	931	717	266
01198122	11.2	11.2	681	1,703	1,049	1,022	368	8.20	13.4	14.2	1.27	3.6	.1282	681	994	746	313
01198125	465	468	646	2,594	1,267	1,948	621	8.04	15.1	682	1.46	15.9	.2088	646	1,904	912	1,258
01198200	61.1	61.0	646	2,021	1,235	1,375	589	6.78	10.6	84.8	1.39	17.4	.2250	646	1,610	849	964
Long-Term Discontinued and Continuous Streamflow-Gaging Stations																	
01180800	2.94	2.95	1,297	1,814	1,589	517	292	4.76	7.09	6.98	2.37	4.1	0.1172	1,297	1,388	1,325	91
01181000	94.0	94.0	397	2,198	1,416	1,801	1,019	8.78	16.5	161	1.71	4.2	.1243	397	1,608	1,011	1,211
01187300	19.9	20.7	696	1,598	1,268	902	572	5.07	10.5	29.7	1.43	.3	.1020	1,014	1,299	1,158	285
01197000	57.6	57.5	996	2,199	1,649	1,203	653	5.76	9.37	85.9	1.49	14.6	.1974	997	1,904	1,377	907
01197300	2.12	2.18	1,017	1,786	1,219	769	202	9.29	15.6	2.31	1.06	.5	.1043	1,098	1,103	1,100	5
01197500	282	283	700	2,594	1,394	1,894	694	7.68	14.2	418	1.48	13.4	.1909	700	1,904	1,075	1,204
01198000	51.0	51.0	699	1,999	1,169	1,300	470	9.49	14.6	77.4	1.52	10.1	.1663	699	1,325	884	626
01198500	43.8	43.9	693	1,904	1,238	1,211	545	7.71	13.6	31.8	.724	12.6	.2733	693	1,592	1,091	899
01199050	29.4	29.4	623	2,312	1,182	1,689	559	8.61	15.6	43.2	1.47	15.2	.2035	623	1,208	761	585
01331400	7.67	7.68	1,163	2,198	1,760	1,035	597	8.18	13.0	3.80	.495	2.7	.1553	1,197	1,378	1,265	181
01333000	42.6	42.6	663	3,399	1,542	2,736	879	18.5	29.0	26.9	.631	11.5	.2822	663	1,499	977	836

Table 20. Basin characteristics determined by using a geographic information system at low-flow partial-record stations, partial-record stations, short-term discontinued streamflow-gaging stations, and long-term continuous and discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut—*Continued*

USGS station No.	Urban area (percent)	Agricultural and open area (percent)	Forest area (percent)	Water bodies area (percent)	Forested wetlands area (percent)	Non-forested wetlands area (percent)	Total wetlands area (percent)	Total wetlands, water bodies area (percent)	Barren, rocks, mining area (percent)	Road density (mi/mi^2)	North aspect area (percent)	East aspect area (percent)	South aspect area (percent)	West aspect area (percent)	Flat area (percent)	Gneissic and quartzitic rocks area (percent)	Carbonate rocks area (percent)	Schistose rocks area (percent)
Partial-Record Stations—*Continued*																		
01197802	7.6	14.4	66.4	0.8	4.9	3.7	8.6	9.4	2.2	1.95	18.1	31.6	20.8	29.3	0.2	3.6	46.6	49.8
01198080	8.3	14.9	61.9	.7	7.4	4.8	12.2	12.9	2.0	2.15	24.1	37.9	18.7	19.2	.0	.0	69.4	30.6
Short-Term Discontinued Streamflow-Gaging Stations—*Continued*																		
01197015	10.1	19.2	68.2	0.0	0.0	0.2	0.2	0.2	2.4	2.27	4.5	40.2	16.2	39.4	0.0	0.0	46.2	53.7
01198030	7.4	13.7	60.8	.5	11.1	5.2	16.3	16.7	1.5	1.41	25.8	38.9	15.0	20.5	.0	.0	63.8	36.2
01198070	8.7	3.9	63.3	.3	13.5	8.7	22.2	22.5	1.6	3.25	16.7	70.0	10.7	2.7	.0	.0	67.3	32.7
01198075	8.6	16.0	63.3	.9	4.4	4.1	8.5	9.4	2.5	2.73	22.0	44.0	19.3	14.6	.0	.0	73.8	26.3
01198122	2.4	12.1	75.2	1.7	4.1	4.0	8.1	9.7	.6	1.97	9.4	25.2	27.6	38.1	.0	37.8	56.8	5.6
01198125	10.6	11.8	66.2	1.6	4.0	3.2	7.2	8.8	2.5	2.72	17.3	28.9	23.1	30.8	.0	33.5	42.5	24.0
01198200	4.7	12.1	75.4	1.5	1.5	3.7	5.2	6.7	1.0	2.48	20.5	21.0	26.3	32.2	.0	50.8	43.4	5.9
Long-Term Discontinued and Continuous Streamflow-Gaging Stations—*Continued*																		
01180800	11.9	0.7	83.7	1.7	0.0	1.0	1.0	2.7	1.0	--	12.2	58.5	21.3	7.0	1.0	100	0.0	0.0
01181000	4.1	2.3	90.0	1.2	.7	1.0	1.7	2.9	.7	--	22.3	35.0	20.9	20.7	1.1	80.4	.1	19.5
01187300	2.0	1.4	91.3	1.8	2.5	.0	2.5	4.3	1.2	1.60	22.5	36.2	21.5	18.7	.9	47.5	.0	52.7
01197000	7.9	6.0	72.2	1.8	7.1	2.7	9.8	11.5	2.3	2.77	15.6	21.8	28.4	34.2	.0	89.4	7.8	2.9
01197300	21.6	9.2	54.6	.0	6.0	6.9	12.9	12.8	1.8	4.11	1.9	32.5	30.1	35.4	.0	.0	54.1	45.9
01197500	12.7	8.4	66.7	2.2	4.0	3.2	7.2	9.4	2.9	3.19	17.6	27.0	25.0	30.1	.0	49.4	36.8	13.9
01198000	3.6	17.7	74.6	.5	1.7	.8	2.5	3.0	1.0	1.37	11.7	33.0	25.5	29.5	.0	1.5	34.5	64.1
01198500	5.3	13.1	75.1	1.0	1.7	2.2	3.9	4.9	1.6	--	24.7	16.9	25.6	32.6	.1	75.8	22.8	24.3
01199050	6.8	15.3	74.1	3.7	.0	.0	.0	3.7	.0	--	15.0	37.5	26.9	20.3	.0	.0	41.6	58.6
01331400	3.0	18.8	73.4	.0	.0	1.4	1.4	1.4	3.4	2.07	32.5	9.2	16.2	40.7	1.3	66.2	1.6	32.3
01333000	5.5	14.6	78.9	.0	.2	.3	.5	.5	.6	--	12.2	58.5	21.3	7.0	1.0	.0	46.2	53.7

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96

[Location of low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations are shown in figures 3 and 6 and described in tables 3 and 6. lat, latitude; long, longitude. Discharge is in cubic feet per second. ft, foot; mi, mile; mi^2, square mile]

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Low-flow partial-record stations							
01196995. Windsor Brook tributary to Windsor Reservoir, lat 42°29′03″, long 73°05′50″, Berkshire County, at bridge on Old Windsor Road, 3.5 mi northeast of Hinsdale, Massachusetts. Drainage area: 8.81 mi^2.							
8-09-94	0.80	10-06-94	4.53	7-06-95	0.44	8-22-95	0.30
9-06-94	1.15	6-08-95	4.30	8-02-95	.52	9-05-95	.27
9-21-94	1.02	6-19-95	1.57	8-10-95	1.10		
01197120. Southwest Branch Housatonic River tributary to West Branch Housatonic River, lat 42°26′28″, long 73°17′47″, Berkshire County, at Mungerford Street, 550 ft downstream from Smith Brook, 2.2 mi west of Pittsfield, Massachusetts. Drainage area: 20.4 mi^2.							
8-27-63	2.57	6-28-91	5.63	8-24-92	6.56	8-26-93	1.54
9-09-63	1.63	7-19-91	2.22	9-02-92	6.46	6-08-95	8.87
8-06-64	1.17	8-27-91	6.46	9-15-92	5.25	9-05-95	.75
9-07-65	2.55	7-28-92	5.52	7-01-93	5.16		
01197130. Sykes Brook tributary to Housatonic River, lat 42°25′07″, long 73°13′35″, Berkshire County, at culvert on East New Lenox Road, 2.5 mi southeast of Pittsfield, Massachusetts. Drainage area: 0.81 mi^2.							
8-26-63	0.12	9-06-94	0.12	6-19-95	0.14	8-22-95	0.04
7-29-64	.07	9-21-94	.08	7-06-95	.09	9-05-95	.04
9-08-65	.30	10-07-94	.25	8-02-95	.06		
8-09-94	.07	6-08-95	.25	8-10-95	.08		
01197140. Yokun Brook tributary to Housatonic River, lat 42°22′51″, long 73°15′26″, Berkshire County, 30 ft downstream from twin culverts on East Street, 1.7 mi south of Pittsfield city line and 2.2 mi northeast of Lenox, Massachusetts. Drainage area: 5.92 mi^2.							
8-26-63	0.20	8-10-94	1.14	7-06-95	0.65	8-06-96	4.19
9-10-63	.09	9-06-94	1.61	8-02-95	.31	8-20-96	.94
7-29-64	.13	10-06-94	3.43	8-10-95	1.48	9-05-96	1.17
9-07-65	1.51	6-08-95	1.83	8-21-95	.10		
7-12-94	1.08	6-19-95	0.98	9-05-95	.02		
01197180. Greenwater Brook tributary to Housatonic River, lat 42°17′59″, long 73°12′53″, Berkshire County, at bridge on private land near U.S. Highway 20, 0.3 mi east of East Lee, Massachusetts. Drainage area: 7.64 mi^2.							
8-26-63	1.50	7-12-91	2.37	8-24-92	4.85	10-07-93	2.99
7-28-64	1.90	7-18-91	2.35	9-02-92	3.80	6-08-95	6.02
9-07-65	1.83	8-28-91	2.83	7-01-93	3.06	9-05-95	1.58
6-28-91	3.46	7-28-92	3.24	7-19-93	2.61		
01197200. Hop Brook tributary to Housatonic River, lat 42°12′49″, long 73°09′55″, Berkshire County, at private wooden bridge 100 ft beyond end of Sodem Road, 3.0 mi southeast of Tyringham, Massachusetts. Drainage area: 0.76 mi^2.							
8-27-63	0.74	8-12-94	2.53	6-19-95	1.51	8-22-95	0.40
9-09-63	.56	9-08-94	4.84	7-06-95	1.13	9-05-95	.25
7-29-64	.69	10-07-94	2.26	8-02-95	.57		
9-07-65	1.41	6-08-95	2.09	8-10-95	1.03		
01197210. Unnamed tributary to Hop Brook, lat 42°13′21″, long 73°11′53″, Berkshire County, at culvert on Monterey Road, 1.6 mi south of Tyringham, Massachusetts. Drainage area: 0.76 mi^2.							
8-27-63	0.03	8-12-94	0.34	6-19-95	0.16	8-22-95	0.04
9-09-63	.05	9-08-94	.33	7-06-95	.23	9-05-95	.00
7-29-64	.03	10-07-94	.25	8-02-95	.12		
9-07-65	.01	6-08-95	.44	8-10-95	.21		

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96—*Continued*

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Low-flow partial-record stations—*Continued*							
01197230. Hop Brook tributary to Housatonic River, lat 42°16′13″, long 73°15′06″, Berkshire County, at bridge on Meadow Street, 1.4 mi southeast of South Lee, Massachusetts. Drainage area: 22.1 mi².							
8-28-63	2.04	6-28-91	4.84	7-29-92	6.50	7-26-93	1.46
9-09-63	1.59	7-09-91	3.38	8-24-92	17.0	6-08-95	11.8
8-06-64	1.88	7-12-91	3.74	9-02-92	7.41	9-05-95	1.53
9-07-65	2.56	8-28-91	2.60	7-01-93	2.80		
01197240. West Brook tributary to Beartown Brook, lat 42°15′22″, long 73°17′11″, Berkshire County, at bridge on Beartown Mountain Road, 1.6 mi south of South Lee, Massachusetts. Drainage area: 4.11 mi².							
8-05-64	0.04	9-06-94	0.54	6-20-95	1.11	8-22-95	0.03
11-12-64	.06	9-21-94	.26	7-06-95	1.81	9-05-95	.02
9-07-65	.24	10-06-94	.90	8-02-95	.10		
8-09-94	.55	6-08-95	4.81	8-10-95	.27		
01197930. Green River tributary to Housatonic River, lat 42°16′07″, long 73°28′16″, Columbia County, at bridge on dirt road, 0.4 mi north of Green River, New York. Drainage area: 11.7 mi².							
8-27-63	2.10	8-10-94	1.50	6-20-95	3.26	9-06-95	0.86
9-10-63	1.26	9-07-94	2.28	8-03-95	.97		
7-29-64	1.23	10-06-94	6.74	8-10-95	1.66		
9-08-65	2.38	6-07-95	6.27	8-23-95	.83		
01197935. Green River tributary to Housatonic River, lat 42°13′59″, long 73°27′17″, Columbia County, 200 ft downstream of private wooden bridge on dirt road on Massachusetts State line, 2.3 mi southeast of Green River, New York. Drainage area: 20.5 mi².							
8-10-94	3.08	10-06-94	13.6	7-06-95	3.31	8-23-95	1.10
9-07-94	4.69	6-07-95	11.9	8-03-95	1.55	9-06-95	.82
9-21-94	3.04	6-20-95	6.16	8-10-95	2.09		
01197960. Scribner Brook tributary to Alford Brook, lat 42°16′42″, long 73°25′46″, Berkshire County, at private wooden bridge 600 ft on dirt road off West Road, 3.0 mi north of Alford, Massachusetts. Drainage area: 1.95 mi².							
8-27-63	0.06	8-10-94	0.31	6-20-95	0.78	9-06-95	.02
9-10-63	.01	9-06-94	.32	8-03-95	.15		
7-29-64	.05	10-06-94	1.21	8-10-95	.18		
9-08-65	.41	6-07-95	1.84	8-23-95	.06		
01198020. Sages Ravine Brook tributary to Schenob Brook, lat 42°02′58″, long 73°25′49″, Litchfield County, 1,000 ft upstream from State Highway 41, 1.5 mi northwest of Taconic, Connecticut. Drainage area: 3.41 mi².							
8-27-63	0.70	8-10-94	2.32	6-20-95	1.76	9-06-95	0.29
9-10-63	.68	9-07-94	2.76	8-03-95	.87		
8-06-64	.50	10-06-94	5.43	8-10-95	.61		
9-08-65	.38	6-09-95	2.84	8-23-95	.31		
01198040. Karner Brook tributary to Hubbard Brook, lat 42°09′37″, long 73°28′09″, Berkshire County, at private wooden bridge 100 ft on dirt road off Mount Washington Road, 2.9 mi west of South Egremont, Massachusetts. Drainage area: 1.79 mi².							
8-27-63	0.38	8-10-94	0.59	6-20-95	0.74	9-06-95	0.25
9-09-63	.44	9-07-94	.85	8-03-95	.36		
8-05-64	.40	10-06-94	1.45	8-11-95	.37		
9-08-65	.32	6-09-95	1.02	8-23-95	.28		

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96—*Continued*

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Low-flow partial-record stations—*Continued*							
01198060. Fenton Brook tributary to Karner Brook, lat 42°09′17″, long 73°26′51″, Berkshire County, at bridge on Mount Washington Road, 1.8 mi west of South Egremont, Massachusetts. Drainage area: 2.94 mi^2.							
8-27-63	0.31	8-24-92	1.39	7-12-94	0.21	8-23-95	0.01
9-09-63	.27	9-02-92	.63	8-10-94	.52	9-06-95	.00
8-05-64	.03	7-01-93	.13	9-06-94	1.33		
9-08-65	.26	7-26-93	.00	10-06-94	1.67		
7-28-92	.68	8-25-93	.00	6-09-95	.90		
01198062. Unnamed tributary to Karner Brook, lat 42°09′55″, long 73°26′40″, Berkshire County, at culvert on State Highway 23, 1.7 mi west of South Egremont, Massachusetts. Drainage area: 2.14 mi^2.							
8-10-94	1.00	10-06-94	1.32	7-06-95	0.28	9-06-95	0.03
9-07-94	.89	6-09-95	.61	8-03-95	.08		
9-22-94	.37	6-20-95	.36	8-10-95	.14		
01198100. Ironworks Brook tributary to Housatonic River, lat 42°06′32″, long 73°18′59″, Berkshire County, at bridge on County Road, 2.1 mi east of Sheffield, Massachusetts. Drainage area : 8.27 mi^2.							
8-26-63	0.09	9-08-65	1.76	10-06-94	2.76	8-03-95	0.48
9-10-63	.08	8-11-94	1.72	6-09-95	3.03	8-10-95	.77
7-29-64	.04	9-08-94	3.29	6-21-95	1.41	8-23-95	.04
01198110. Soda Creek tributary to Ironworks Brook, lat 42°07′35″, long 73°19′49″, Berkshire County, at culvert on Water Farm Road (formerly Fink Road), 8 mi northeast of Sheffield, Massachusetts. Drainage area: 1.58 mi^2.							
8-26-63	0.11	8-12-94	0.58	6-21-95	0.50	9-06-95	0.11
9-10-63	.14	9-08-94	.49	8-03-95	.29		
7-29-64	.08	10-07-94	.75	8-10-95	.22		
9-08-65	.15	6-09-95	.87	8-23-95	.08		
01198137 Unnamed tributary to Garfield Lake, lat 42°03′11″, long 73°19′35″, Berkshire County, at culvert on Hupi Road, 0.9 mi north of Monterey, Massachusetts. Drainage area: 1.15 mi^2.							
8-12-94	0.23	10-07-94	0.39	7-06-95	0.11	8-22-95	0.00
9-08-94	.14	6-08-95	.36	8-02-95	.04	9-05-95	.00
9-21-94	.14	6-19-95	.20	8-10-95	.05		
01198137 Umpachene Brook tributary to Konkapot River, lat 42°05′26″, long 73°14′40″, Berkshire County, at bridge on Canaan–Southfield Road, 0.9 mi southwest of Southfield, Massachusetts. Drainage area: 8.56 mi^2.							
8-27-63	0.61	8-10-94	3.50	8-03-95	1.17	8-20-96	2.00
9-10-63	.81	9-06-94	1.08	8-10-95	1.13	9-06-96	1.78
8-06-64	.56	10-07-94	2.87	8-22-95	.58		
9-08-65	.96	6-09-95	3.03	9-06-95	.41		
7-12-94	1.44	6-19-95	2.08	8-06-96	3.79		
01198260 Whiting River tributary to Blackberry River, lat 42°02′46″, long 73°14′00″, Berkshire County, at bridge on Campbell Falls Road, 500 ft north of Massachusetts–Connecticut State line, 1.3 mi northeast of Canaan, Connecticut. Drainage Area: 3.79 mi^2.							
8-12-94	1.23	9-07-94	1.91	7-06-95	0.58	8-22-95	0.18
9-07-94	1.18	6-09-95	1.78	8-03-95	.59	9-06-95	.12
9-22-94	1.42	6-20-95	1.58	8-10-95	.18		

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96—*Continued*

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Partial-record stations							
01197802. Williams River tributary to Housatonic River, lat 42°13′39″, long 73°21′46″, Berkshire County, at railroad bridge 200 ft south of Division Street, 2.2 mi north of Great Barrington, Massachusetts. Drainage area: 43.2 mi^2. Operated as a partial-record station 1994–96.							
3-31-94	246	9-22-94	9.39	5-10-95	46.0	10-13-95	8.37
4-04-94	539	10-06-94	20.5	6-09-95	23.1	12-08-95	54.2
4-08-94	482	12-06-94	134	6-21-95	14.0	1-25-96	504
7-15-94	12.4	1-31-95	101	7-20-95	6.75	1-28-96	797
8-04-94	18.0	3-14-95	202	8-18-95	5.46	2-23-96	267
8-18-94	39.7	3-30-95	80.1	8-24-95	2.59	4-01-96	86.8
9-07-94	13.7	4-28-95	67.5	9-06-95	1.42		
01198080. Shenob Brook tributary Housatonic River, lat 42°06′51″, long 73°21′05″, Berkshire County, at bridge on U.S. Highway 7, 0.3 mi northeast of Sheffield, Massachusetts. Drainage area: 50.0 mi^2. Operated as a partial-record gaging station 1994–96.							
8-27-63	4.84	7-15-94	8.88	2-01-95	81.3	6-21-95	10.3
9-10-63	5.87	8-04-94	31.0	2-01-95	86.3	7-20-95	7.75
7-29-64	3.81	8-19-94	90.7	3-15-95	181	8-17-95	4.41
9-08-65	4.48	9-07-94	14.8	4-28-95	54.8	8-24-95	3.40
3-29-94	480	10-07-94	29.2	5-30-95	64.3	9-06-95	2.35
4-07-94	477	11-29-94	198	6-09-95	16.1		
Short-term discontinued streamflow-gaging stations							
01197015. Town Brook tributary to Pontoosuc Lake, lat 42°31′12″, long 73°13′48″, Berkshire County, at bridge on Bridge Street, 0.1 mi northwest of Lanesborough, Massachusetts. Drainage area: 10.6 mi^2. Operated as a continuous streamflow-gaging station 1980–83.							
01198030. Shenob Brook tributary to Housatonic River, lat 42°06′33″, long 73°22′09″, Berkshire County, at bridge on Berkshire School Road, 0.8 mi west of Sheffield, Massachusetts. Drainage area: 23.3 mi^2. Operated as a continuous stream flow-gaging station 1971–72.							
11-20-70	39.3	08-16-71	1.55	02-09-72	26.1	07-15-80	4.10
12-06-70	37.2	08-28-71	57.0	04-05-72	48.9	08-26-80	1.60
04-06-71	111	09-14-71	49.4	07-05-72	167	05-20-81	38.0
04-15-71	142	09-29-71	16.8	09-13-78	2.20	08-27-81	2.70
04-30-71	53.4	10-28-71	22.0	08-01-79	3.20	07-28-83	6.00
06-16-71	10.4	12-15-71	67.4	06-11-80	8.10	09-08-83	2.60
01198070. Willard Brook tributary to Housatonic River, lat 42°06′41″, long 73°23′38″, Berkshire County, 125 ft downstream from bridge on Berkshire School Road, 2.1 mi west of Sheffield, Massachusetts. Drainage area: 3.20 mi^2. Operated as a continuous streamflow-gaging station 1971–72.							
11-19-70	7.80	04-05-71	19.8	08-28-71	31.7	04-05-72	9.25
12-06-70	5.47	04-30-71	12.8	09-14-71	15.5	05-15-72	15.2
01-13-71	4.17	04-30-71	12.2	10-28-71	3.92	07-05-72	23.1
03-05-71	11.4	06-16-71	2.49	12-15-71	12.1		
04-06-71	14.3	08-17-71	.872	02-11-72	3.57		
01198075. Hubbard Brook tributary to Housatonic River, lat 42°07′13″, long 73°21′46″, Berkshire County, at bridge on Cook Road, 0.8 mi northwest of Sheffield, Massachusetts. Drainage area: 25.8 mi^2. Operated as a continuous streamflow-gaging station 1971–72 .							
01-19-70	28.9	04-06-71	111	08-17-71	6.59	02-11-72	18.7
12-06-70	28.9	04-15-71	126	09-14-71	62.9	04-05-72	58.1
01-13-71	15.5	04-30-71	73.8	10-28-71	28.0	05-18-72	146
03-05-71	74.8	06-16-71	9.22	12-15-71	92.6	07-05-72	283

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96—*Continued*

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Short-term discontinued streamflow-gaging stations—*Continued*							
01198122. Ironworks Brook tributary to Housatonic River, lat 42°06′31″, long 73°20′08″, Berkshire County, at bridge on East Road, 0.6 mi east of Sheffield, Massachusetts. Drainage area: 11.2 mi^2. Operated as a continuous streamflow-gaging station 1994–96.							
3-31-94	70.4	3-13-95	59.2	6-21-95	1.47	11-12-95	122
7-15-94	.74	3-30-95	13.1	7-06-95	.46	12-07-95	11.5
8-04-94	13.2	4-13-95	35.5	7-20-95	.28	1-24-96	185
9-08-94	3.76	4-28-95	12.2	8-18-95	.22	4-02-96	35.7
10-06-94	3.77	5-11-95	9.32	8-23-95	.03		
11-28-94	32.0	5-30-95	5.91	10-13-95	3.02		
2-01-95	17.7	6-09-95	4.30	10-28-95	283		
01198125. Housatonic River tributary to Long Island Sound, lat 42°04′29″, long 73°20′03″, Berkshire County, at bridge on U.S. Highway 7, 1.3 mi north of Ashley Falls, Massachusetts. Drainage area: 465 mi^2. Operated as a partial-record station 1992–94 and a continuous streamflow-gaging station 1994–1996.							
3-30-92	1,260	03-31-94	2,960	12-12-94	1,330	10-13-95	226
5-06-92	2,070	4-08-94	4,760	2-22-95	553	10-23-95	2,300
07-16-92	499	5-26-94	831	3-14-95	1,890	12-08-95	712
7-28-92	254	7-22-94	287	4-27-95	670	1-29-96	5,830
10-08-92	185	8-24-94	1,000	6-14-95	331	3-20-96	1,410
1-06-93	3,320	9-08-94	181	6-21-95	184	5-01-96	3,650
3-31-93	7,100	9-15-94	180	7-06-95	144	6-03-96	552
7-29-93	193	9-22-94	151	7-20-95	136	8-09-96	521
9-16-93	140	10-07-94	398	8-17-95	107	9-05-96	195
12-10-93	1,400	10-19-94	273	8-24-97	78.4	10-03-96	760
3-25-94	2,710	11-18-94	272	9-06-95	64.9	10-03-96	739
01198200. Konkapot River tributary to Housatonic River, lat 42°03′11″, long 73°19′35″, Berkshire County, at bridge on U.S. Highway 7, 0.5 mi southeast of Ashley Falls, Massachusetts. Drainage area: 61.1 mi^2. Operated as a crest-stage partial-record station 1963–71, a low-flow partial-record station 1963–65 and 1991–93, and a continuous streamflow-gaging station 1994–1996.							
8-26-63	17.3	8-25-93	19.4	4-13-95	319	12-08-95	81.3
9-10-63	16.7	3-29-94	416	4-28-95	66.3	1-18-96	81.3
8-06-64	13.7	4-07-94	595	5-05-95	61.2	1-28-96	1,120
9-08-65	16.3	8-03-94	91.2	5-11-95	49.3	2-21-96	257
6-27-91	45.7	8-23-94	144	6-09-95	39.9	4-02-96	244
7-12-91	34.4	9-08-94	27.7	4-13-95	319	6-03-96	66.3
7-19-91	22.3	10-07-94	85.0	6-21-95	22.0	7-01-96	50.2
8-28-91	26.1	10-19-94	25.3	7-20-95	23.1	7-12-96	40.5
9-02-92	23.6	11-29-94	206	8-17-95	13.9	8-09-96	59.0
9-17-92	23.6	12-06-94	318	9-06-95	10.5	9-05-96	25.9
7-01-93	23.6	2-01-95	102	10-13-95	23.1	9-19-96	230
7-26-93	5.11	3-15-95	233	10-29-95	693	10-02-96	119
Long-term discontinued streamflow-gaging stations							
01197300. Marsh Brook tributary to Lily Pond, lat 42°20′59″, long 73°17′56″, Berkshire County, at culvert on Hawthorne Road, 0.9 mi southwest of Lenox, Massachusetts. Drainage area: 2.12 mi^2. Operated as a continuous streamflow-gaging station 1963–74.							
7-13-94	0.48	9-21-94	0.56	6-19-95	0.50	8-10-95	0.40
8-09-94	.76	10-06-94	1.64	7-06-95	.24	8-22-95	.06
9-06-94	.91	6-08-95	1.89	8-02-95	.07		

Table 21. Streamflow measurements made and used in analyses at low-flow partial-record stations, partial-record stations, and short- and long-term discontinued streamflow-gaging stations in and near the Housatonic River Basin, western Massachusetts and parts of eastern New York and northwestern Connecticut, water years 1963–96—*Continued*

Date	Discharge	Date	Discharge	Date	Discharge	Date	Discharge
Long-term discontinued streamflow-gaging stations—*Continued*							
01198000. Green River tributary to Housatonic River, lat 42˚11′31″, long 73˚23′28″, Berkshire County, at bridge on Hurlburt Street, 1.5 mi west of Great Barrington, Massachusetts. Drainage area: 51.0 mi^2. Operated as a continuous streamflow-gaging station 1952–71, a partial-record station 1980–81, 1983, and 1991–93, and a continuous streamflow-gaging station 1994–96.							
6-11-80	23.0	7-01-93	13.1	11-29-94	135	10-23-95	158
7-15-80	12.0	7-26-93	4.81	1-21-95	342	11-12-95	1,050
8-26-80	5.90	8-25-93	6.49	1-31-95	109	12-08-95	57.7
5-20-81	126	3-18-94	172	3-14-95	241	1-18-96	40.0
8-27-81	9.30	3-24-94	359	4-13-95	163	2-23-96	325
7-28-83	6.70	4-07-94	1,080	5-11-95	46.3	3-20-96	152
9-08-83	2.30	4-08-94	580	5-30-95	51.1	4-01-96	92.1
6-27-91	23.6	7-14-94	10.0	6-07-95	30.4	5-01-96	601
7-12-91	12.1	8-04-94	23.8	6-21-95	14.3	6-03-96	48.3
7-19-91	9.68	8-18-94	67.2	7-17-95	6.15	7-01-96	40.0
8-28-91	13.9	9-07-94	20.4	7-20-95	5.76	8-09-96	52.2
7-28-92	15.1	9-15-94	14.5	8-18-95	4.11	9-05-96	15.2
8-24-92	15.4	9-22-94	11.5	8-24-95	3.13	9-19-96	122
9-02-92	11.3	10-06-94	32.5	9-06-95	2.44	9-19-96	102
9-17-92	12.3	11-18-94	21.5	10-13-95	11.2	10-01-96	92.9
01198500. Blackberry River tributary to Housatonic River, lat 42˚01′26″, long 73˚20′32″, Litchfield County, at bridge on U.S. Highway 44 0.7 mi southwest of Canaan, Connecticut. Drainage area: 43.8 mi^2. Operated as a continuous streamflow-gaging station 1949–71 and a partial-record station 1994–96.							
8-04-94	21.9	3-13-95	160	7-06-95	5.14	12-08-95	67.0
8-11-94	11.4	3-23-95	106	8-03-95	6.42	1-25-96	696
8-18-94	70.9	7-06-95	5.14	8-18-95	4.38	4-02-96	223
9-07-94	12.9	8-03-95	6.42	8-24-95	2.67	6-03-96	31.9
9-22-94	11.8	5-05-95	30.8	9-06-95	2.65		
10-07-94	16.0	6-09-95	16.5	10-13-95	12.7		
2-01-95	70.0	6-20-95	9.36	10-29-95	341		