PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS WATER RESOURCES COMMISSION
BOSTON, MASSACHUSETTS

INTRODUCTION

FACTORS FOR CONVERTING INCH-POUND UNITS TO INTERNATIONAL SYSTEM OF UNITS (SI), WITH ABBREVIATIONS

Multiply inch-pound units	By	To obtain SI units
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
acre	4,047	square meter (m^2)
	0.4047	hectometer (hm^2)
	Volume	
gallon (gal)	3.785×10^{-3}	cubic meter (m^3)
million gallons (Mgal)	3.785×10^{-3}	cubic hectometer (hm^3)
million gallons per square mile ($Mgal/mi^2$)	1.461×10^{-3}	cubic hectometer per square kilometer (hm^3/km^2)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second (m^3/s)
gallon per day (gal/d)	3.785×10^{-3}	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
million gallons per day per square mile [$(Mgal/d)/mi^2$]	0.01691	cubic meter per second per square kilometer [$(m^3/s)km^2$]
	Hydraulic Units	
foot pound second (ft/s)	0.3048	meter per second (m/s)
square foot per day (ft^2/d)	0.0929	square meter per day (m^2/d)
	Temperature	
degree Fahrenheit (°F)	5/9 (°F – 32)	degree Celsius (°C)
	Specific Capacity	
gallon per minute per foot [(gal/min)/ft]	0.207×10^{-3}	cubic meter per second per meter [$m^3/s)/m$]
	Specific Conductance	
micromho per centimeter at 25°C (µmho/cm at 25°C)	1	microsiemens per centimeter at 25°C(µS/cm at 25°C)

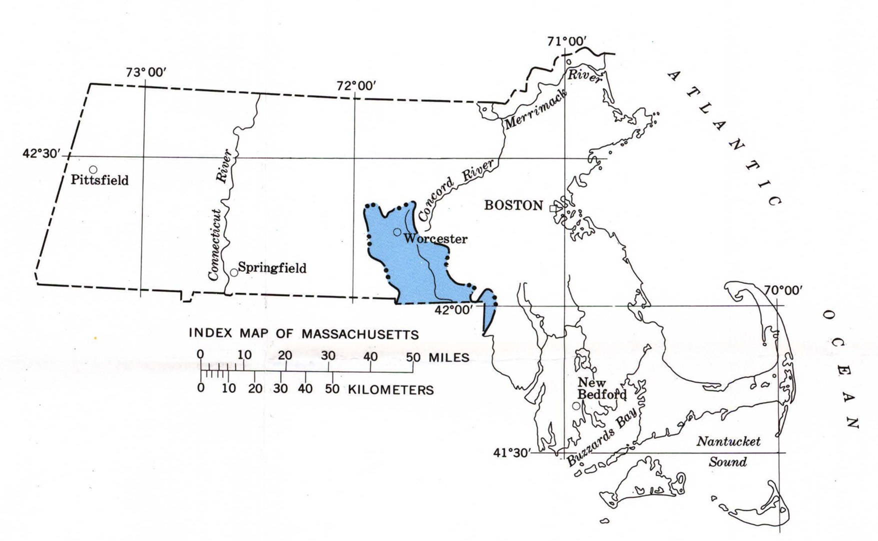


FIGURE 1—LOCATION OF THE BLACKSTONE RIVER BASIN IN MASSACHUSETTS.

This report describes streamflow, ground-water resources, and pumpage of water for public supply in the Blackstone River basin in Massachusetts. The report is intended to provide information for development and management of water resources. Current increases in population, per capita use, and industrial activity is increasing demand for water. Water demand is growing most rapidly in the towns outside of Worcester, all of which obtain their water supplies from wells. The report is one of a series of map reports prepared in cooperation with Massachusetts Water Resources Commission, that describes the water resources of major river basins in the State.

The Blackstone River heads in brooks 6 miles northwest of Worcester and flows southeast to enter Rhode Island just upstream from Woonsocket. The river drains about 330 mi^2 in Massachusetts, which includes parts or all of 29 towns and the city of Worcester.

Kettle Brook, the headwater of the Blackstone River, rises in Paxton on the west slope of Little Asnebumskit Hill at an elevation of abut 1,300 feet. The Blackstone River begins in the southern part of Worcester at the confluence of the Mill River, a stream that runs southward through Worcester, and the Middle River formed by Kettle Brook and other brooks from the west and north. At this point, the elevation of Blacktone River is 490 feet. The river flows southeast 31 miles through a narrow valley surrounded by till and bedrock uplands to the Rhode Island line. There, the elevation of the river is 160 feet. The overall gradient is about 10 feet per mile.

Several streams are tributary to the Blackstone River between Worcester and the Rhode Island State line: the Quinsigamond, Mumford, West, Mill, and, finally, the Peters River, just upstream from the Rhode Island line. Streams draining from the western uplands tend to have steep gradients. The elevation of Singletary Brook, for example, decreases from about 700 feet at its origin in the uplands of Sutton to 385 feet at its confluence with the Blackstone River 5½ miles to the east. The gradient of the brook is 57 ft/mi.

The Blackstone River basin is underlain by granite and metamorphic rocks such as granite gneiss, schist, slate, and quartzite. These rock formations have been deformed and consolidated by folding and recrystallization.

The advance of ice during continental glaciation, which eroded hills and deposited till, produced many drumlin-type elliptical hills whose long axes generally trend north-south. Erosion overdeepened some reaches of south-trending valleys. Stratified drift accumulated in lowlands and valleys during stagnation and melting of the ice sheet. The stratified sand and gravel deposited by melt-water streams form the principal aquifer of the basin.

Population of the Blackstone River basin in Massachusetts is estimated to have been about 262,000 in 1970 (Massachusetts Department of Commerce and Development, 1971). This represents a decline of about 4,600 from a peak of 266,611 in 1950. A decline of about 26,900 in Worcester in those 20 years was almost balanced by growth in the suburbs and rural towns. Towns on the east and west sides of the basin—Upton, Mendon, Sutton, and Douglas—retain a rural character and have the lowest population densities. At present (1979) only Mendon and Millville remain without population centers large enough to require public water-supply systems.

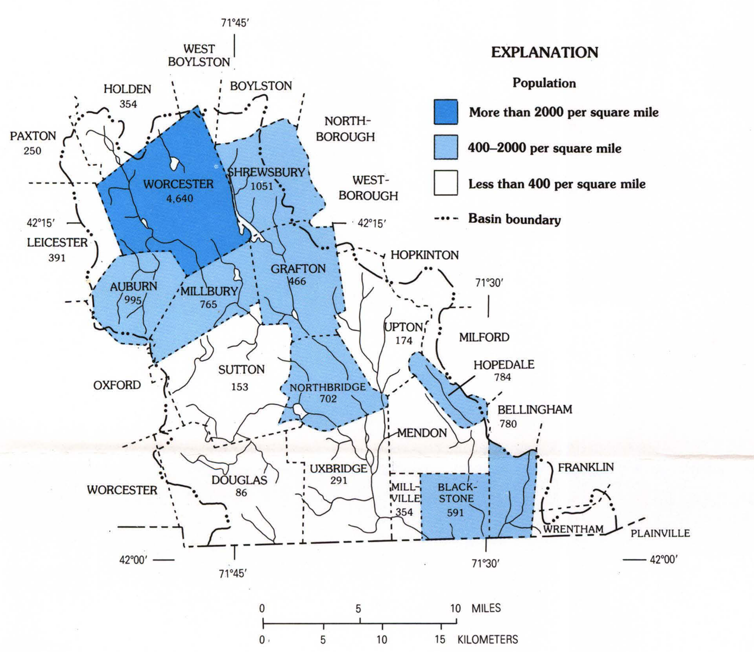
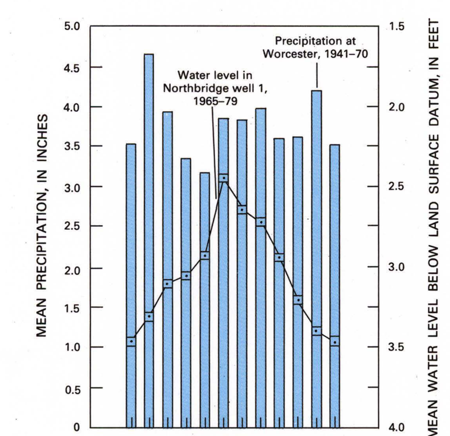


FIGURE 2—POPULATION DENSITY OF TOWNS AND CITIES IN THE BLACKSTONE RIVER BASIN IN MASSACHUSETTS, 1975.

HYDROLOGIC CYCLE



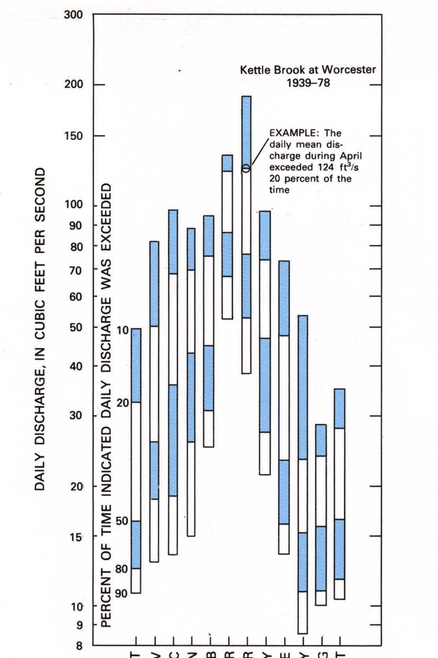


FIGURE 3—ANNUAL CYCLE OF STREAM RUNOFF AND GROUND-WATER LEVELS.

During the growing season, streamflow and ground-water levels decline from a peak in early spring to a low in late summer in direct response to lack of recharge due to high evapotranspiration and from drainage from aquifer storage. Most of the precipitation that infiltrates the soil during this declining period is transpired by vegetation. During the nongrowing season, the period from early fall to early spring, evapotranspiration is minimal and recharge from precipitation raises ground-water levels, which increases discharge thereby increasing stream runoff. During the early spring, snowmelt may also contribute to these increases. These annual cyclical trends in runoff and ground-water levels are typical of the basin.

FLOW DURATION

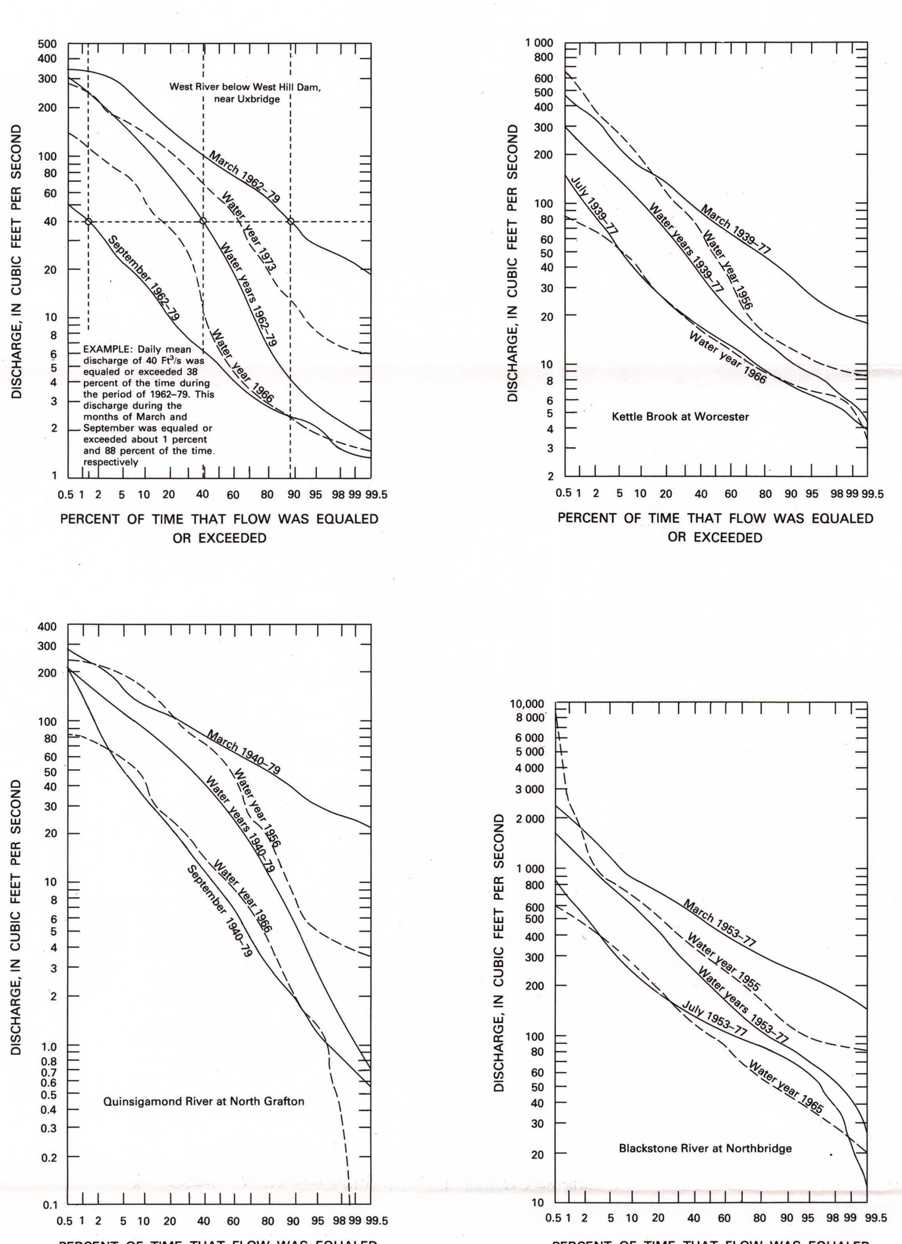


FIGURE 4—FLOW DURATION CURVES FOR SELECTED SITES.

The flow-duration curves for the stream-gaging stations show the percentage of time daily mean discharges were equaled or exceeded. In addition to showing the duration curve for the entire period of available annual records, duration curves for the months of highest and lowest median monthly flows are included. Also, the duration curves for the year of highest and lowest annual runoff within the period of record are shown. The annual period used in the duration curves is the water year, the 12-month period ending September 30 of the year designated.

The geology and hydrology of a basin determine the shape of the duration curve. These characteristics include precipitation, snowmelt, evapotranspiration, topography, channel storage, ground-water storage, and regulation of flow. As an example, the high end of the duration curve for period of record for West River below West Hill Dam, near Uxbridge has a gentle slope. The gentle slope indicates that the stream is not flashy during periods of high flow. This is the result of the attenuation of high flows by West Hill Dam, a U.S. Army Corps of Engineers flood control dam.

HIGH STREAMFLOW

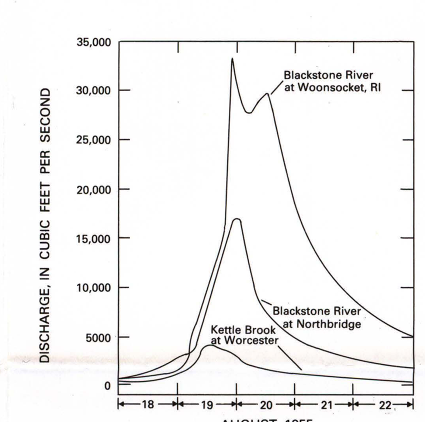


FIGURE 5—FLOOD HYDROGRAPHS OF THE 1955 FLOOD ON KETTLE BROOK AND BLACKSTONE RIVER.

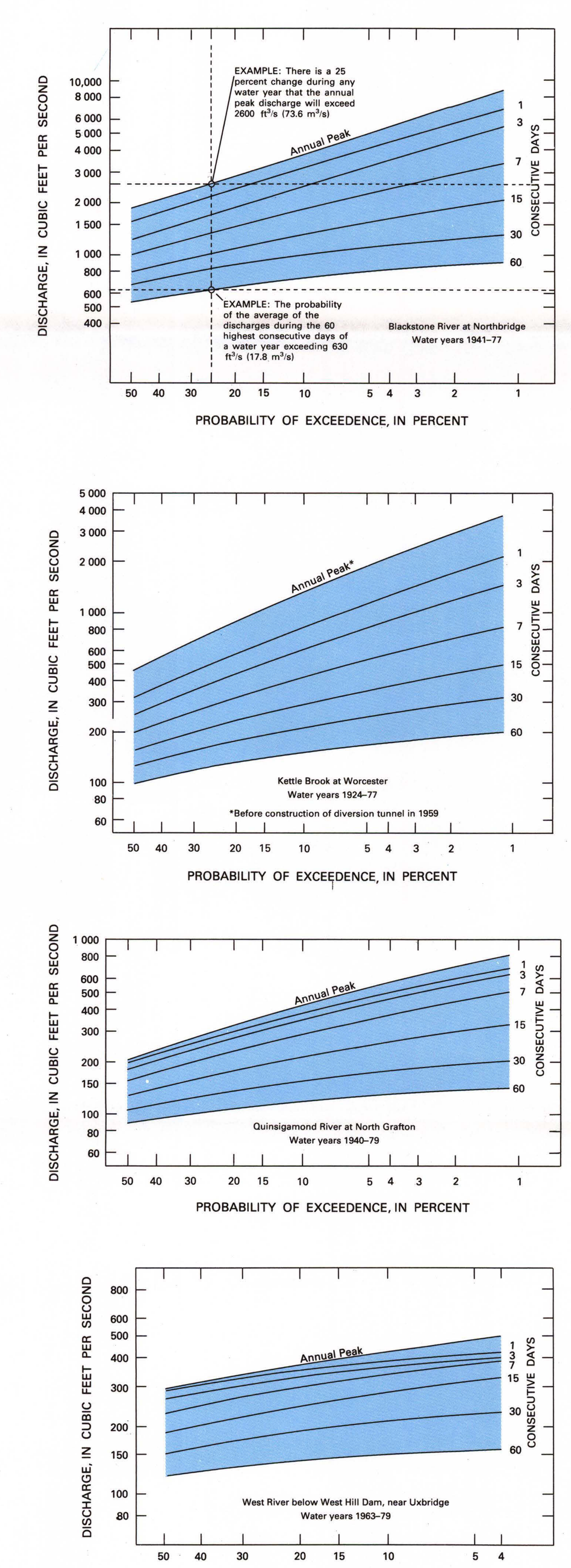


FIGURE 6—ANNUAL PEAK AND FLOOD VOLUME FREQUENCY CURVES.

Major floods and consequent damage have played a role in the history of the basin. The two largest and most devastating floods in recent times occurred in 1936 and 1955. Flood profiles and high-water marks for the Blackstone, Quinsigamond, and West Rivers and selected tributaries have been published for the March 1936 flood (Massachusetts Department of Public Works, 1936). High-water marks for Kettle Brook and Blackstone River have been published for the flood of 1955 (U.S. Geological Survey, 1960). The hydrographs of the 1955 flood for Kettle Brook and Blackstone River (fig. 5) illustrate the relation of the amplitude and the lag time of the peaks at various sites along the stream reach. The early peak at Woonsocket resulted from failure of Horseshoe Dam on the Mill River. The secondary peak at Woonsocket, in relation to amplitude and lag time, probably corresponds to the other peaks under natural flooding.

Flood control has been steadily improved since 1936. Two flood-control structures, built by the U.S. Army Corps of Engineers, have effectively reduced flood damage. A diversion tunnel on Kettle Brook in Auburn directs major flood flows around the city of Worcester. A dam and reservoir on the West River in Uxbridge reduces major flood flows.

Probability curves of the maximum annual peak discharges and highest average discharges for indicated number of consecutive days are shown for various stream-gaging stations (fig. 6). These flood-frequency curves are used for flood inundation and flood control reservoir-capacity studies. They apply to a specific site, and should not be used at other stream locations.

Information on floods in ungaged streams is essential to designing flood control and riverine structures. Equations have been developed by Wandle (1980) for estimation magnitude and frequency of floods in the central region of Massachusetts. The equations apply to ungaged sites where floodflows are basically natural. They do not apply to sites where floodflows are significantly affected by diversion, urbanization, or regulation, where the usable manmade storage is 4.5 million ft^3/mi^2 of drainage area above the site.

The equations that follow are the product of multiple-regression techniques that provide estimates of annual peak discharges corresponding to the 0.1, 0.04, 0.02, and 0.01 annual exceedance probabilities.

$$Q_{0.1} = 84.98A^{0.760}St^{-0.166}$$
$$Q_{0.04} = 114.9A^{0.775}St^{-0.195}$$
$$Q_{0.02} = 141.9A^{0.785}St^{-0.217}$$
$$Q_{0.01} = 172.7A^{0.797}St^{-0.237}$$

where,

Q_t is the peak discharge, in cubic feet per second, for the specified exceedence probability, t (0.1,0.04, 0.02, 0.01);

A is the drainage area, in square miles; and

St is a storage index which is the combined area of lakes, ponds, and swamps expressed as a percentage of the drainage area plus 0.5.

Additional explanation and examples of how to determine estimates are given in Wandle (1980).

The preceding equations are applicable to sites where drainage area is between 0.49 mi^2 and 199 mi^2 and storage index is less than 23 percent.

SURFACE WATER

LOW STREAMFLOW

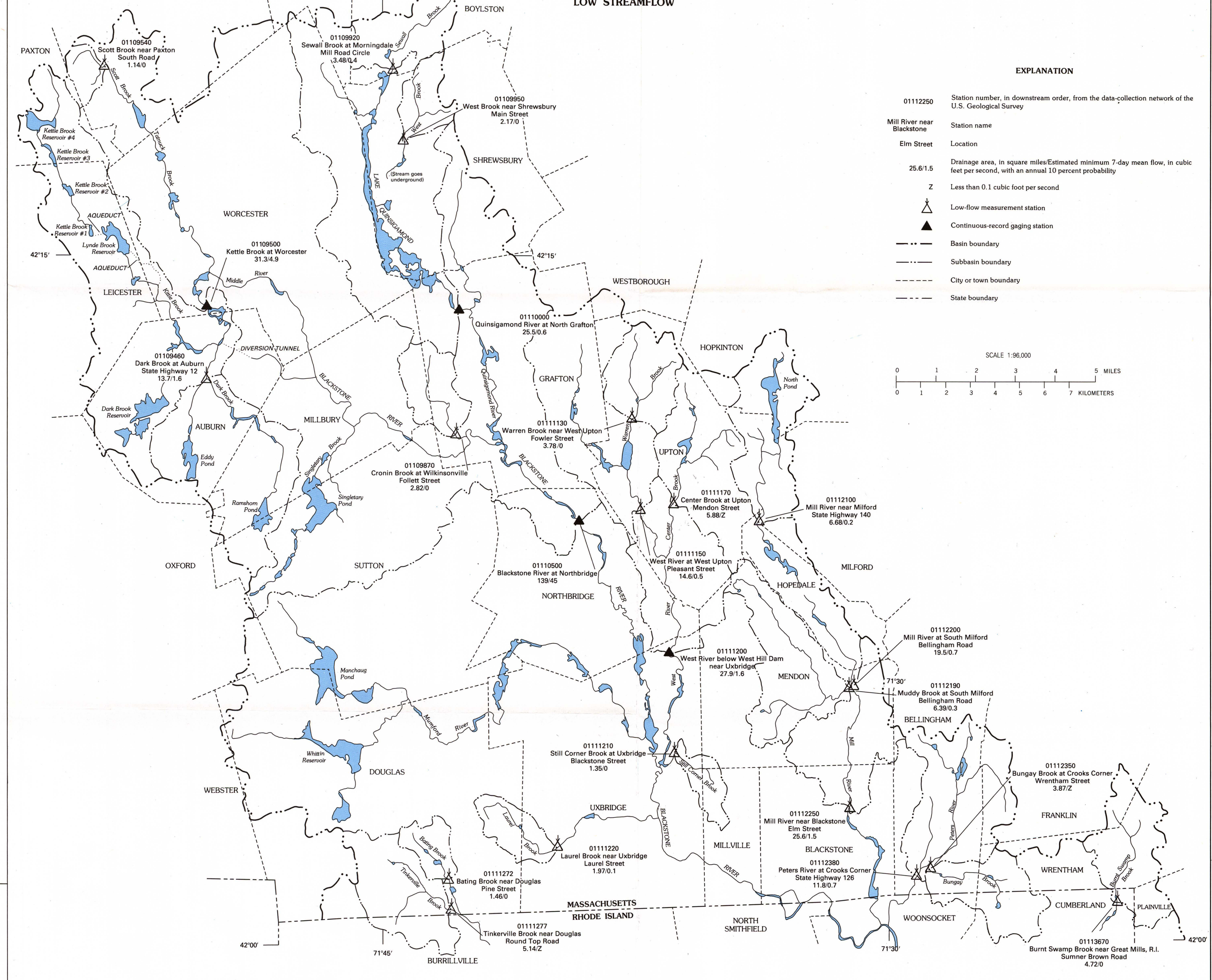


FIGURE 8—LOW STREAMFLOW OF DISCHARGE—MEASUREMENT SITES.

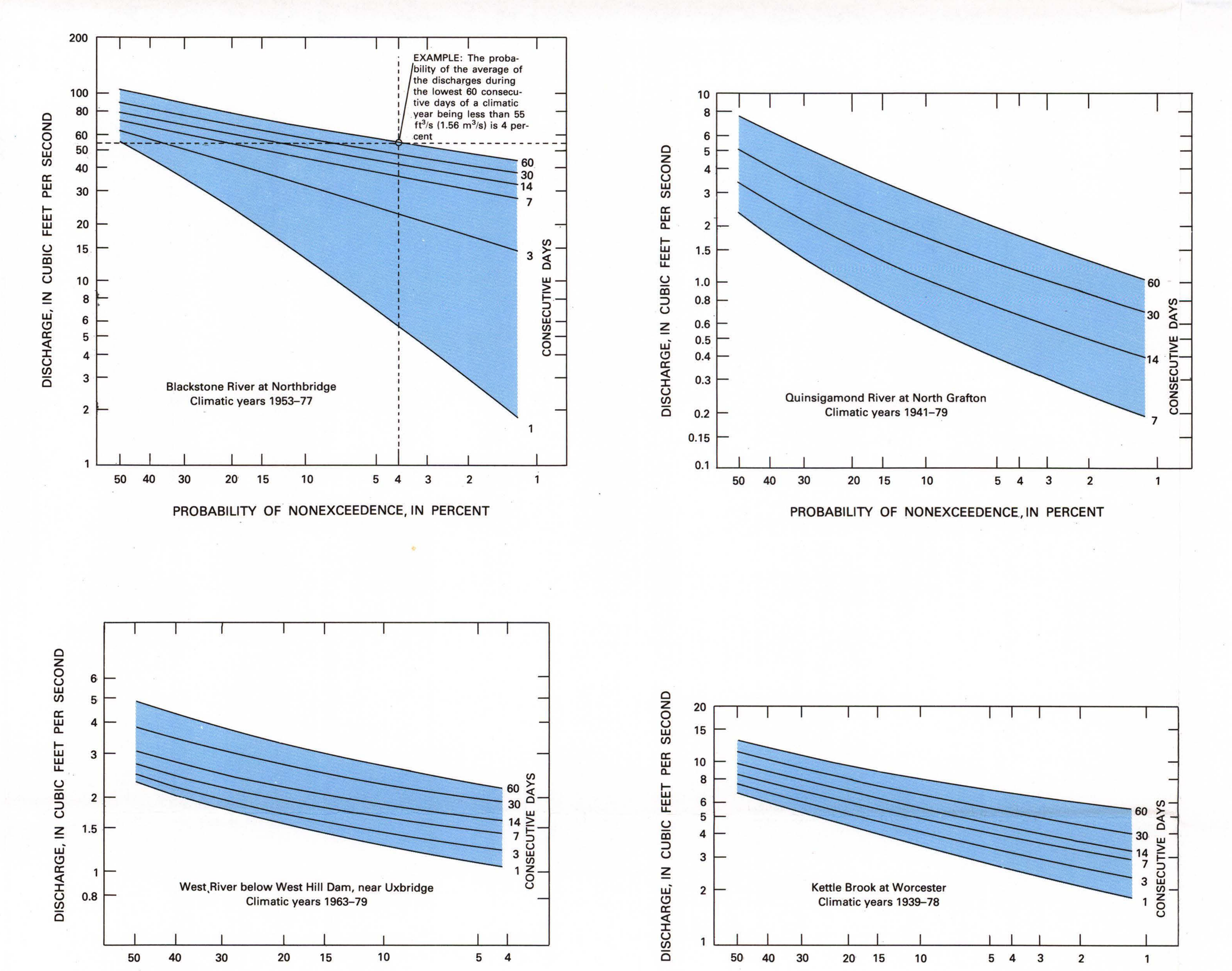


FIGURE 7—LOW-FLOW FREQUENCY CURVES.

The annual probability that the average of the daily discharges during the indicated number of consecutive days of lowest flow during a year will be less than a specified value is shown for selected gaging stations in figure 7.

Estimated annual minimum 7-day low flows having a 10 percent annual probability for various sites are shown in figure 8. They were obtained by correlating baseflow measurements with long-term gaging-station records. The 7-day, 10 percent probability low flow is used as an index of dilution capabilities of streams and in water-quality standards. These characteristics are representative of the hydrologic conditions at the time of data collection (1978). The annual period used in the analysis of low flows is the climatic year, the 12-month period ending March 31 of the designated year.

The relation between low streamflow and drainage area varies from one stream to another and between sites on a stream. Consequently, the data on the map should not be used to estimate the 7-day, 10 percent probability low flow for other sites in the basin. The major cause of nonuniformity between natural-flowing streams during low-flow periods is differences of ground-water storage. Other causes include variances of surface storage, evaporation, transpiration, and precipitation. Activities of man, such as ground-water pumping, and regulation and diversion of streamflow, can also result in nonuniformity.

Specific conductance was measured twice in September 1978 at all the streams in the low-flow network. Specific conductance ranged from less than 100 µmho/cm at 25°C in the rural areas of Paxton, Holden, and Douglas to more than 250 µmho/cm in the urban areas of Auburn and towns of Grafton, Mendon, and Upton.

STREAM-GAGING STATIONS

Kettle Brook at Worcester

Drainage area: 31.3 mi^2.
Period of record: August 1923 to September 1978.
Maximum instantaneous discharge for period of record: 3,970 ft^3/s August 19, 1955.
Average discharge for water years 1924–77:53.4 ft^3/s, (adjusted for diversion).

Quinsigamond River at North Grafton

Drainage area: 25.5 mi^2.
Period of record: October 1939 to 1979.
Maximum instantaneous discharge for water years 1940–79: 820 ft^3/s August 20, 1955.
Average discharge for water years 1940–79: 41.4 ft^3/s.

West River below West Hill Dam, near Uxbridge

Drainage: 27.9 mi^2.
Period of record: March 1962 to 1979.
Maximum instantaneous discharge for water years 1963–79: 435 ft^3/s February 1, 1979.
Average discharge for water years 1963–79: 46.2 ft^3/s, (adjusted for change in storage in West Hill Reservoir).

Blackstone River at Northbridge

Drainage: 139 mi^2.
Period of record: October 1939 to September 1977.
Maximum instantaneous discharge for period of record: 16,900 ft^3/s August 20, 1955 (greatest since at least 1900).
Average discharge for water years 1940–77: 266 ft^3/s.

Mumford River at East Douglas

Drainage: 27.8 mi^2.
Period of record: July 1939 to September 1951.
Maximum instantaneous discharge for period of record: 420 ft^3/s March 22, 1948.
Average discharge for water years 1940–51: 44.8 ft^3/s.

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WATER RESOURCES OF THE BLACKSTONE RIVER BASIN, MASSACHUSETTS

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