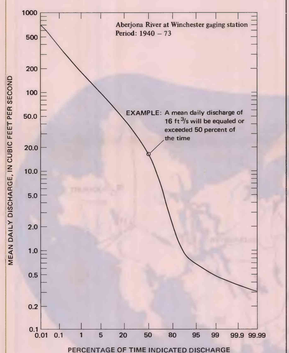
PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS WATER RESOURCES COMMISSION
BOSTON, MASSACHUSETTS

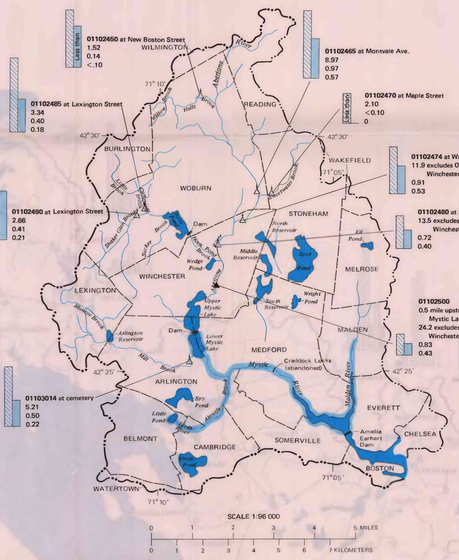
SURFACE WATER AVAILABILITY

FLOW DURATION

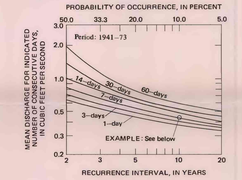


THE PERCENTAGE OF TIME FUTURE FLOWS WILL BE EQUALED OR EXCEEDED AT WINCHESTER CAN BE ESTIMATED IF CONDITIONS THAT GOVERN RUNOFF DO NOT CHANGE. – *The moderately sloping straight line at the upper end of the flow-duration curve for the Aberjona River indicates that ponds and swamps provide natural storage to absorb peak flows and to sustain high flows. However, the flat slope at the low end of the curve indicates that the stream is sustained by ground-water discharge during periods of high evapotranspiration and little or no overland runoff. Ground-water discharge is largely from storage in glacial sand and gravel deposits. The steeper slope near the center of the curve probably reflects the retention of runoff in Horn Pond. Horn Pond is regulated to maintain storage for Woburn's public-supply wells, whose flows are partly sustained by infiltration from the pond.*

LOW STREAMFLOW



Low-flow frequency curves computed from continuous record of streamflow for gaging station number **01102500**, Aberjona River at Winchester.



EXAMPLE: The annual minimum 7-day mean flow will be less than 0.43 ft³/s at intervals averaging 10 years in length, and the associated probability that the annual minimum 7-day mean flow will be less than 0.43 ft³/s in any 1 year is 10 percent.

EXPLANATION

- Low-flow measurement station
- Continuous-record gaging station
- 01102500 – Station number, in downstream order. Number from U.S. Geological Survey's data-collection network.
- 0.5 mile upstream from head of Mystic Lakes – Location along river course
- 24.2 includes 0.6 mi² drained by Winchester's North Reservoir – Drainage area, in square miles
- Annual minimum 7-day mean flow, in cubic feet per second
- 0.83 – 2-year recurrence interval
- 0.43 – 10-year recurrence interval
- ANNUAL MINIMUM 7-DAY MEAN FLOW, IN CUBIC FEET PER SECOND PER SQUARE MILE – 2-yr recurrence interval; 10-yr recurrence interval
- Extent of backwater caused by Amelia Earhart Dam
- Basin boundary
- Subbasin boundary

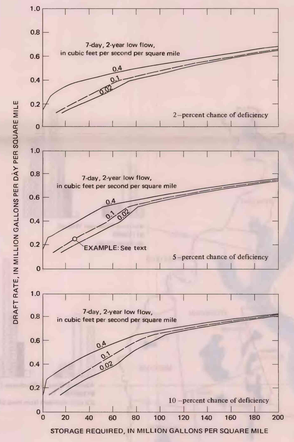
A DETERMINATION OF LOW-STREAMFLOW POTENTIAL IS NEEDED FOR THE EVALUATION OF RIVER-BASIN RESOURCES FOR WATER SUPPLY, WASTE DISPOSAL, AND RECREATION. – *The annual minimum 7-day mean flow at the 10-year recurrence interval is used by designers of waste-treatment facilities as an index of the dilution capacity of streams. Low-flow values at locations other than the continuous-record gaging station were obtained by correlating base-flow measurements with the long-term record for the Aberjona River at the Winchester gaging station.*

Streamflow per unit drainage area varies from stream to stream during low-flow periods as the result of both natural and manmade causes. Natural causes include noninformity of storage, geology, evaporation, transpiration, water-table slope, and precipitation. Some manmade causes include diversion of water from streams, ground-water pumping, waste-water discharge into streams, and changes in land use.

Annual minimum 7-day mean streamflows per unit drainage area at the 2- and 10-year recurrence intervals along the Aberjona River decrease with increased drainage area, in part because of diversion of water pumped from wells adjacent to the river. Ground-water withdrawal and subsequent diversion out of the basin by way of the MDC sewerage system is most noticeable during low base-flow periods, when streamflow is derived almost entirely from natural ground-water discharge. Discharge measurements along the Aberjona River during a base-flow period in October 1973 showed a loss of flow between Washington and Swanton Streets in Winchester. (See time-of-travel discharge profiles.) Comparison with nearby river basins, such as the Ipswich, Charles, and Shawsheen, indicates that the annual minimum 7-day mean flow at the 10-year recurrence interval for the Aberjona River gaging station at Winchester is one-half to one-third of its expected flow.

A reconnaissance of flows in other streams in the northeast coastal river basins was made during August 14-15, 1974. These data were used to estimate the annual minimum 7-day mean flow at the 10-year recurrence interval. Most streams were flowing less than 0.10 ft³/s or had no flow at all. Streams with flows greater than 0.10 ft³/s were: the entire Saugus River and three tributaries to it, Mill River, Bennetts Pond Brook, and Shute Brook; the lower half of Proctor Brook, a tributary to the North River; and Chebacco Lake's outlet stream, a tributary to the Essex River. (See transmissivity map on sheet 2 for stream locations.) For the previous 7 consecutive days (August 8-14), streamflow at the Aberjona River at Winchester gaging station averaged 1.4 ft³/s, with a corresponding recurrence interval of less than 2 years. Because the annual minimum 7-day mean flow at the 10-year recurrence interval is approximately one-third of that (0.43 ft³/s), it is assumed the annual minimum 7-day mean flow at the 10-year recurrence interval will be essentially zero for all streams except those named. This determination seems justified because most of the low flow of streams in this area is derived from ground-water discharge from unconsolidated deposits with scant storage capacity.

REGIONAL STORAGE ANALYSIS



REGIONAL DRAFT-STORAGE-FREQUENCY ANALYSIS USED IN CONJUNCTION WITH ANNUAL MINIMUM 7-DAY MEAN FLOWS AT THE 2-YEAR RECURRENCE INTERVAL DETERMINED FROM THE LOW-STREAM-FLOW MAP CAN PROVIDE INFORMATION USEFUL TO WATER MANAGERS AND PLANNERS IN COMPARATIVE STUDIES OR IN PRELIMINARY DESIGNS FOR RESERVOIR SITES. – *These regional draft-storage-analysis curves were prepared by Tasker (1977). They are based on a regional analysis of streamflow records for 12 gaging stations in eastern Massachusetts and Rhode Island, using the methods recommended by Riggs and Hardison (1973) to account for seasonal as well as year to year variations in streamflow.*

Draft rate is given reservoir outflow occurring at a uniform rate and is uncorrected for water losses resulting from changing land area to water area. Storage required is the usable volume of a reservoir required to maintain the indicated draft rate. When applying these curves to the evaluation of a specific reservoir site, the user should adjust the draft rates to account for expected evaporation and seepage losses; nonuniform draft rates, and low-flow augmentation requirements. Storage requirements should be adjusted for expected losses in reservoir capacity because of sedimentation.

The Committee on Rainfall and Yield of Drainage Areas of the New England Water Works Association (1969, p. 168-169) considers it economically unsound to develop storage capabilities much beyond 200 Mgal/mi² in New England watersheds. The rationale for this decision can be seen from inspection of the draft-storage curves. Increases of draft rates require disproportionately large increases of storage for rates exceeding about 0.5 (Mgal/d)/mi².

Example: A stream has a 10.0 mi² drainage area and an annual minimum 7-day mean flow at the 2-year recurrence interval of 1.0 ft³/s or 0.1 (ft³/s)/mi² at a given site. To maintain a draft rate of 2.5 Mgal/d or 0.25 (Mgal/d)/mi², a storage capacity of 38 Mgal/mi² or 200 Mgal would be enough for an average of 95 out of 100 years (5 percent chance of deficiency), exclusive of losses.

SELECTED REFERENCES

Committee on Rainfall and Yield of Drainage Areas of the New England Water Works Association, 1969, Progress report of Committee on Rainfall and Yield of Drainage Areas: New England Water Works Assoc. Jour., v. 83, no. 2, p. 168-169.

Johnson, C. G., and Tasker, G. D., 1974, Progress report on flood magnitude and frequency of Massachusetts streams: U.S. Geol. Survey Open-File Rept. 74-131, 41 p.

Knox, C. E., and Nordenson, T. J., 1955, Average annual runoff and precipitation in the New England-New York area: U.S. Geol. Survey Hydrol. Inv. Atlas HA-7.

Massachusetts Department of Public Works, Geodetic Survey, 1936, High water data--Flood of March 1936 in Massachusetts: Massachusetts Dept. Public Works, Geodetic Survey, 210 p.

Riggs, H. C., and Hardison, C. H., 1973, Storage analyses for water supply: U.S. Geol. Survey Techniques Water-Resources Inv., book 4, chap. B2, 20 p.

Tasker, G. D., 1977, A regional reservoir storage analysis for eastern Massachusetts and Rhode Island: Boston Soc. Civil Engineers Sec., Am. Soc. Civil Engineers Jour., v. 64, no. 1, p. 13-26.

U.S. Army Corps of Engineers, 1970, Water resources development report on flood control and navigation, Saugus and Pines Rivers basin and adjacent coastal areas, Massachusetts: U.S. Army Corps Engineers, 37 p., 9 pl.

_____ 1975, Flood plain information Saugus and Mill Rivers, Wakefield, Massachusetts: U.S. Army Corps Engineers, 37 p., 7 pl.

U.S. Department of Agriculture, Soil Conservation Service, 1971, Inventory of potential and existing upstream reservoir sites in the Parker and North Shore study areas: U.S. Dept. Agriculture, Soil Conservation Service, 95 p.

_____ 1974, Map of flood-prone areas of the Lexington quadrangle, Massachusetts: U.S. Dept. Agriculture, Soil Conservation Service.

_____ 1974, Map of flood-prone areas of the Salem quadrangle, Massachusetts: U.S. Dept. Agriculture, Soil Conservation Service.

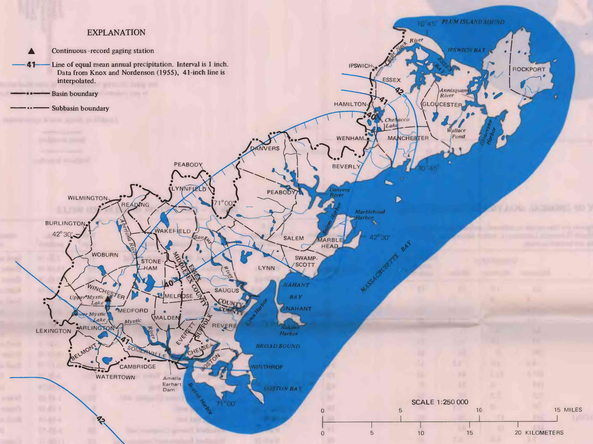
U.S. Geological Survey, 1975a, Map of flood-prone areas of the Boston North quadrangle, Massachusetts: U.S. Geol. Survey.

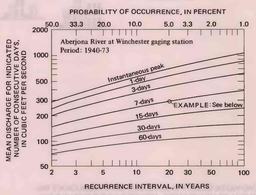
_____ 1975b, Water resources data for Massachusetts, New Hampshire, Rhode Island, and Vermont, 1973--Part 1, Surface water records, part 2, Water quality records: U.S. Geol. Survey, 433 p., 1 pl.

_____ 1975c, Water Resources data for Massachusetts, New Hampshire, Rhode Island, and Vermont, 1974--Part 1, Surface water records, part 2, Water quality records: U.S. Geol. Survey, 429 p., 1 pl.

_____ 1976, Water resources data for Massachusetts and Rhode Island, water year 1975: U.S. Geol. Survey Water-Data Rept. MA-RI-75-1, 288 p.

HIGH STREAMFLOW





EXAMPLE: The annual maximum 7-day mean flow will exceed 300 ft³/s at intervals averaging 20 years in length, and the associated probability of the annual maximum 7-day mean flow exceeding 300 ft³/s in any 1 year is 5 percent.

REGIONAL FLOOD-FREQUENCY FORMULAS CAN BE USED TO ESTIMATE THE MAGNITUDE OF A FLOOD AT UNGAGED SITES, PROVIDED FLOOD PEAKS ARE NOT SIGNIFICANTLY AFFECTED BY MANMADE REGULATION. THE FORMULAS SHOULD NOT BE APPLIED TO THE MYSTIC RIVER BECAUSE IT IS AFFECTED BY REGULATION. – *Major floods in the northeast coastal river basins occurred in March 1936, August 1955, October 1962, and March 1968. All except the March 1936 flood were recorded at the Aberjona River gaging station at Winchester. High-water marks and flood profiles for the Aberjona and Mystic Rivers and selected tributaries, as well as high-water marks for the Saugus River and selected tributaries, have been published for the March 1936 flood (Massachusetts Department of Public Works, Geodetic Survey, 1936). Other flood profiles for the Saugus River and two tributaries, Mill River and Bennetts Pond Brook, have also been published (U.S. Army Corps of Engineers, 1970; 1975). There was no widespread or severe flooding from these events except locally along tributary streams, where residential, commercial, and industrial complexes are close to the stream. The many lakes, ponds, and swamps, as well as flat stream gradients and topography of the area, provide temporary storage for overland runoff and reduce instantaneous peak discharges.*

The Amelia Earhart Dam, completed in 1966 and located near the mouth of the Mystic River, prevents storm-high tides in Boston Harbor from entering the Mystic River, Malden River, Alewife Brook, and the Lower Mystic Lake. (See low-streamflow map for stream locations.) However, there remains a potential flood threat for these streams and lake because overland runoff received by them can leave the basin by way of the Amelia Earhart Dam only during low tide in Boston Harbor. This flood threat should be greatly reduced when the pumping station under construction at the dam is completed in late 1976 or early 1977.

Flow data from the long-term continuous-record gaging station in Winchester provided information for the flood-frequency curves shown. Flood-frequency curves for other than instantaneous peak values are used to determine volume requirements of flood-control dams but are site specific and should not be transferred to other stream sites. Instantaneous peak discharges at ungaged sites in the northeast coastal river basins can be estimated from instantaneous peak discharge equations developed from long-term streamflow data collected in Massachusetts (Johnson and Tasker, 1974).

In the equations listed below, instantaneous peak discharges at selected frequencies are related to drainage area, mean annual precipitation, and main-channel slope. These equations are valid if the drainage area is between 0.25 mi² and 500 mi², is largely rural and is not significantly affected by manmade regulation.

A large part of the study area is urbanized, and care should be exercised when applying instantaneous peak-discharge values determined from these formulas. Flow estimates based on these formulas are likely to be too low if a large part of the stream's drainage area is urbanized.

Regional flood-frequency formulas

$$P_2 = 0.0645A^{0.816}S^{0.091}p^{1.59}$$
$$P_5 = 0.0795A^{0.831}S^{0.116}p^{1.67}$$
$$P_{10} = 0.102A^{0.852}S^{0.132}p^{1.60}$$
$$P_{25} = 0.144A^{0.885}S^{0.155}p^{1.43}$$
$$P_{50} = 0.193A^{0.911}S^{0.171}p^{1.27}$$
$$P_{100} = 0.266A^{0.940}S^{0.187}p^{1.08}$$

in which,

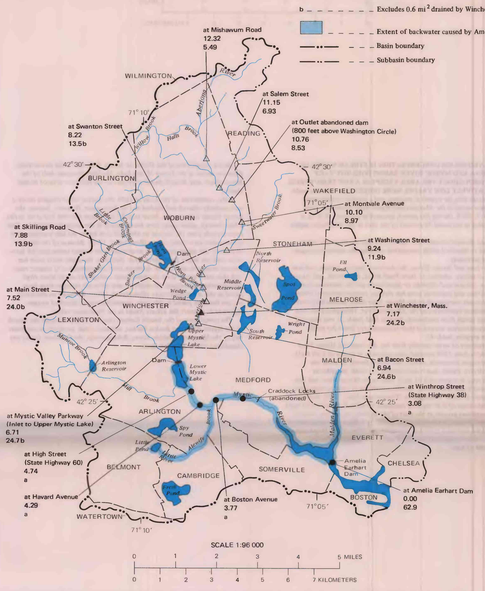
$P_2, P_5, P_{10}, P_{25}, P_{50}, P_{100}$ = *peak discharge for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence intervals*

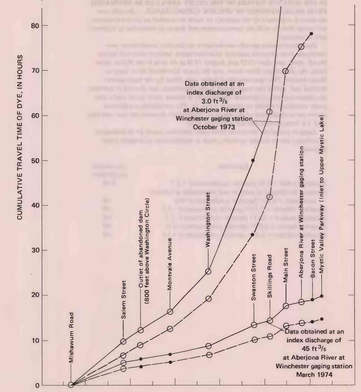
A = *drainage area, in square miles*

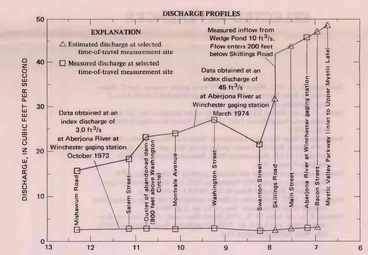
S = *main-channel slope, in feet per mile. To determine main-channel slope, choose upstream from each stream junction point on a topographic quadrangle map the stream that drains the most area. At the last junction point, continue the main channel to the surface-water drainage divide by drawing an imaginary stream channel, as indicated by the contour lines. Measure the total length of the stream channel upstream from the site of interest to the drainage divide, and then locate points on the stream channel that are 85 and 10 percent upstream from the site. Determine the altitude at these points and divide the difference in altitude, in feet, by the stream length between the two points, in miles.*

p = *mean annual precipitation, in inches, from map. Convert inches to feet before using in formula.*

TIME OF TRAVEL







THE TIME REQUIRED FOR A SOLUBLE MATERIAL TO TRAVEL A GIVEN DISTANCE ALONG THE ABERJONA RIVER IS INVERSELY RELATED TO STREAM DISCHARGE. – *Time-of-travel data were obtained in October 1973 and March 1974 by injecting a fluorescent dye, rhodamine WT-20 percent, into the stream at selected sites and monitoring concentration of the dye at selected sites downstream. Streamflow at the Winchester gaging station during the March study was in the medium-flow range, which is equaled or exceeded about 20 percent of the time; whereas, during the October study it was in the low-flow range, which is equaled or exceeded about 75 percent of the time.*

These data can be used to determine the time required for the leading edge and maximum concentration of a soluble material (for example, a pollutant) to travel from one point to another along the stream. They can also be used to determine stream velocity.

The marked increase in traveltime below Washington Street during the low-streamflow period was caused by several small impoundments; however, during the medium-streamflow period, these impoundments did not decrease traveltime.

Interior – Geological Survey, Reston, Va.--1980--W78239

HYDROLOGY AND WATER RESOURCES OF THE COASTAL DRAINAGE BASINS OF NORTHEASTERN MASSACHUSETTS, FROM CASTLE NECK RIVER, IPSWICH, TO MYSTIC RIVER, BOSTON

By
David F. Delaney and Frederick B. Gay

1980