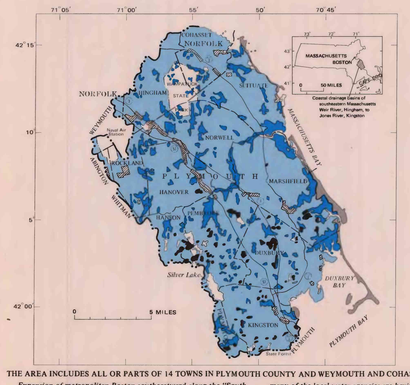
PREPARED IN COOPERATION WITH THE
COMMONWEALTH OF MASSACHUSETTS WATER RESOURCES COMMISSION
BOSTON, MASSACHUSETTS

INTRODUCTION



EXPLANATION

- Largely residential land, increasingly rural southward
- Recreational land, chiefly beaches and summer colonies
- Business and light industrial centers
- Coastal and inland wetlands
- Federal and State reservations
- Agricultural areas, principally cranberry bogs
- Basin boundary

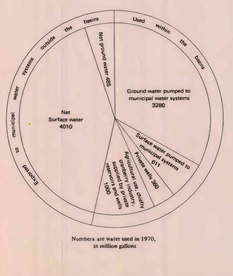
THE AREA INCLUDES ALL OR PARTS OF 14 TOWNS IN PLYMOUTH COUNTY AND WEYMOUTH AND COHASSET IN NORFOLK COUNTY

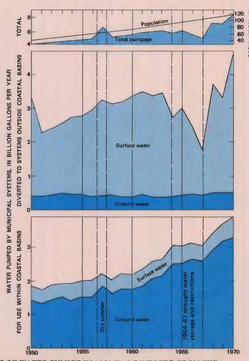
Expansion of metropolitan Boston southeastward along the "South Shore" has been rapid since 1940, when towns consisted of small centers with a business zone along the principal road network. Although some large housing projects have been built, most of the development has been on frontage lots along primary and secondary roads, leaving vacant the relatively inaccessible land on hills, in swamps, and behind the frontage lots. Some parts of south Kingston and Plympton are still sparsely populated.

Increased population has increased the demand for water, and development has decreased the amount of land available to the point where many of the local water agencies are having difficulty in locating and developing additional supplies. The large summer population of the coastal towns has added to demand at a time when demands are already high and supplies low. In addition, the area exports an amount of water even greater than its own demands to satisfy the needs of Hull, Abington, and Brockton, all outside the area.

This report describes the availability of ground water, streamflow characteristics, and quality of water in a way that may be useful to local officials in their search for additional supplies and to planners of regional water systems. It is based on fieldwork from 1969 to 1971.

WATER USE

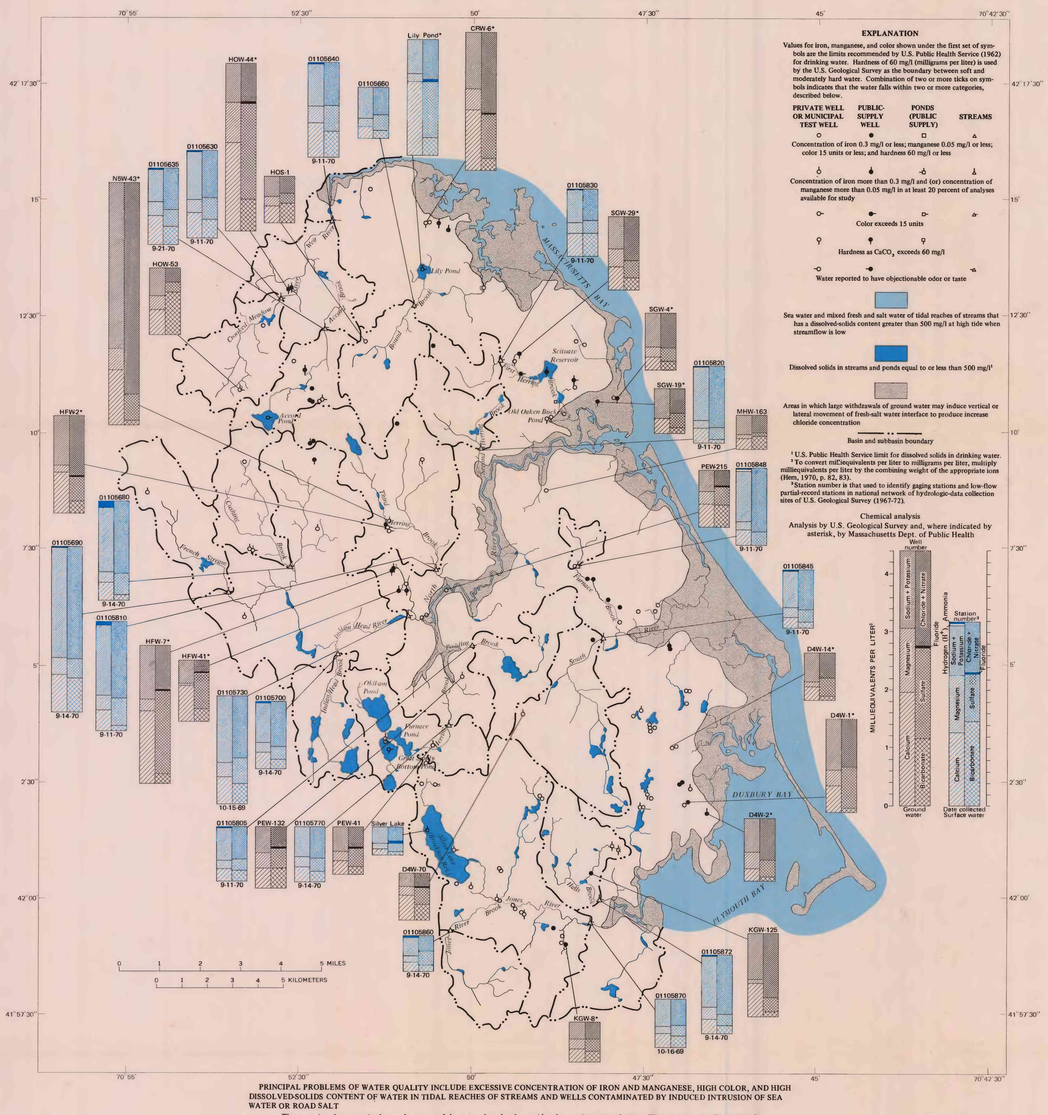




ALMOST HALF THE NEARLY 10 BILLION GALLONS OF WATER PUMPED IN 1970 WAS DIVERTED FROM THE AREA BY THE BROCKTON WATER SYSTEM TO SUPPLY BROCKTON, WHITMAN, AND PART OF HANSON AND BY THE HINGHAM WATER COMPANY TO SUPPLY HULL AND PART OF HINGHAM. – *The increase in water pumped to public-supply systems from 1950 to 1970 has paralleled the increase in population.*

QUALITY OF WATER

GENERAL CHARACTER AND PROBLEMS



EXPLANATION

Values for iron, manganese, and color shown under the first set of symbols are the limits recommended by U.S. Public Health Service (1962) for drinking water. Hardness of 60 mg/l (milligrams per liter) is used by the U.S. Geological Survey as the boundary between soft and moderately hard water. Combination of two or more ticks on symbols indicates that the water falls within two or more categories, described below.

PRIVATE WELL OR MUNICIPAL TEST WELL — PUBLIC-SUPPLY WELL — PONDS (PUBLIC SUPPLY) — STREAMS

Concentration of iron 0.3 mg/l or less; manganese 0.05 mg/l or less; color 15 units or less; and hardness 60 mg/l or less

Concentration of iron more than 0.3 mg/l and (or) concentration of manganese more than 0.05 mg/l in at least 20 percent of analyses available for study

Color exceeds 15 units

Hardness as $CaCO_3$ exceeds 60 mg/l

Water reported to have objectionable odor or taste

Sea water and mixed fresh and salt water of tidal reaches of streams that has a dissolved-solids content greater than 500 mg/l at high tide when streamflow is low

Dissolved solids in streams and ponds equal to or less than 500 mg/l[1]

Areas in which large withdrawals of ground water may induce vertical or lateral movement of fresh-salt water interface to produce increase chloride concentration

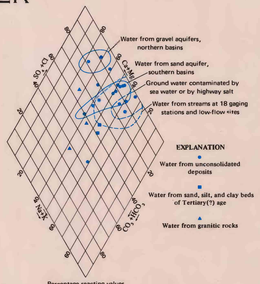
Basin and subbasin boundary

[1] U.S. Public Health Service limit for dissolved solids in drinking water.
[2] To convert milliequivalents per liter to milligrams per liter, multiply milliequivalents per liter by the combining weight of the appropriate ions (Hem, 1970, p. 82, 83).
[3] Station number is that used to identify gaging stations and low-flow partial-record stations in national network of hydrologic-data collection sites of U.S. Geological Survey (1967-72).

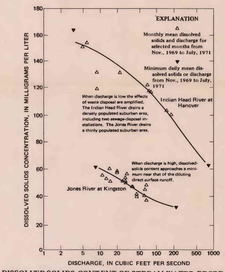
Chemical analysis
Analysis by U.S. Geological Survey and, where indicated by asterisk, by Massachusetts Dept. of Public Health

PRINCIPAL PROBLEMS OF WATER QUALITY INCLUDE EXCESSIVE CONCENTRATION OF IRON AND MANGANESE, HIGH COLOR, AND HIGH DISSOLVED-SOLIDS CONTENT OF WATER IN TIDAL REACHES OF STREAMS AND WELLS CONTAMINATED BY INDUCED INTRUSION OF SEA WATER OR ROAD SALT

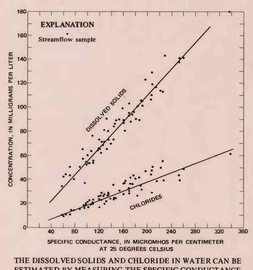
The water is soft, except in the northern part of the area, where locally it is moderately hard (greater than 60 milligrams per liter as calcium carbonate). It is very acid (pH 4.4 on Sept. 11, 1970, at gaging station 01105848, Furnace Brook at School Street near Marshfield) to slightly acid and corrosive to metal pipes. The water is generally suitable for public supplies and industrial use, but may require treatment for iron, manganese, color, and pH correction. Water samples from streams were taken during periods of low flow.



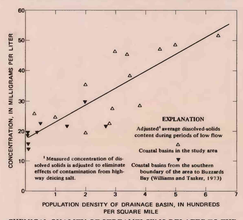
WATER FROM GRAVEL AQUIFERS AND STREAMS IN THE NORTHERN BASINS IS HIGHER IN CALCIUM AND MAGNESIUM AND LOWER IN SODIUM AND POTASSIUM THAN THAT FROM SAND AQUIFERS AND STREAMS IN THE SOUTHERN BASINS. – *The water from sand aquifers (in deltas) in the southern basins increases in chloride and sodium nearer the shore, but the relation is partly masked by local chloride contamination. Ground water that is contaminated by sea water intrusion or road salt is clearly higher in sodium and chloride than other ground water.*



DISSOLVED-SOLIDS CONTENT OF STREAM WATER DECREASES AS THE RATE OF DISCHARGE INCREASES



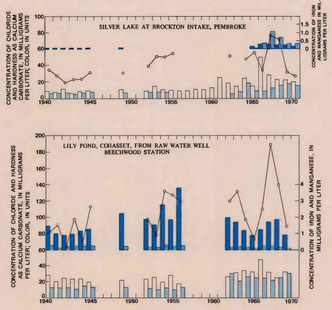
THE DISSOLVED SOLIDS AND CHLORIDE IN WATER CAN BE ESTIMATED BY MEASURING THE SPECIFIC CONDUCTANCE



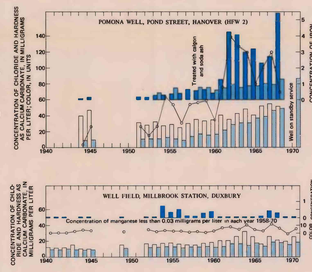
CHEMICAL QUALITY OF STREAMFLOW IS RELATED TO THE POPULATION DENSITY OF THE DRAINAGE BASIN

TRENDS IN WATER QUALITY

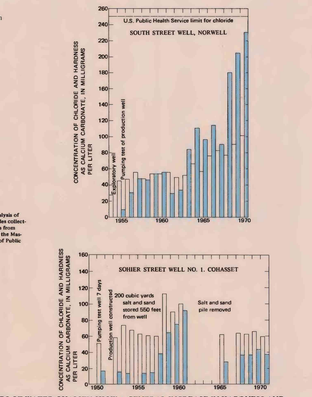
Silver Lake, fed largely by ground-water discharge through sandy banks, has had slight increases in hardness and concentration of chloride. The increase in iron and manganese was caused by diversion in 1966 and 1967 of water from Monponsett Pond (Taunton River basin) to restore lake level after the 1964-67 drought (Higgins and Heney, 1971, p. 131). By contrast, Lily Pond in Cohasset is bordered by extensive swamps, and most of the inflow is from small brooks draining swamps; high iron concentration and color are characteristic of many of the similar stream-fed ponds in the areas of till and bedrock in the northern part of the basins.



Several municipal wells in narrow aquifers along swampy stream valleys, like the Pomona well at Hanover, have been retired from service because of a sudden influx of iron, manganese, and high color after many years of pumping. Others, like the Millbrook well field in Duxbury, in broad sandy plains, have experienced temporary increases in iron concentration to levels above those recommended by the U.S. Public Health Service for drinking water, but have otherwise remained consistent from year to year. Increases in chloride in the rural Duxbury well field are consistent with the regional increase noted by Motts and Saines (1969, p. 23–38), and the more spectacular increase in the Hanover well is apparently caused by highway salt applied to nearby roads and to a salt storage pile upstream, as well as to the regional increases.



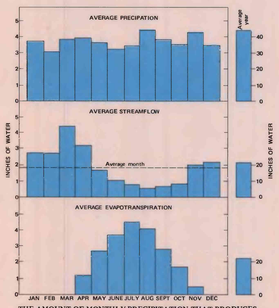
Chloride contamination apparently caused by heavily salted arterial highways and salt storage piles is continuing in the South Street well, Norwell, but was arrested in Sohier Street well No. 1, Cohasset, by removal of the salt storage pile.



LONG-TERM RECORDS OF WATER QUALITY SHOW A GENERAL INCREASE IN HARDNESS AND CHLORIDE IN LAKES AND GROUND WATER THAT IS ACCENTUATED BY PROXIMITY TO SOURCES OF CONTAMINATION BY SALT IN ROADSIDE STORAGE PILES OR APPLIED TO HIGHWAYS FOR ICE CONTROL. – *A high concentration of iron and manganese and high color appear commonly in ponds fed by streams draining swamps and in wells into which water from swamps and swamp-bordered streams is infiltrated by pumping.*

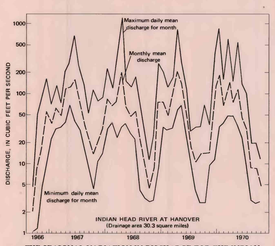
SURFACE WATER

AVERAGE PRECIPITATION, STREAMFLOW, AND EVAPOTRANSPIRATION



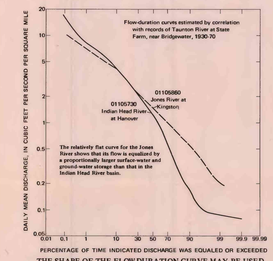
THE AMOUNT OF MONTHLY PRECIPITATION THAT PRODUCES ABOVE-AVERAGE STREAMFLOW DURING THE NONGROWING SEASON (LATE AUTUMN TO EARLY SPRING) WILL RESULT IN BELOW-AVERAGE STREAMFLOW DURING THE GROWING SEASON (EARLY SPRING TO LATE AUTUMN) WHEN EVAPOTRANSPIRATION IS HIGH.

FLOW VARIABILITY



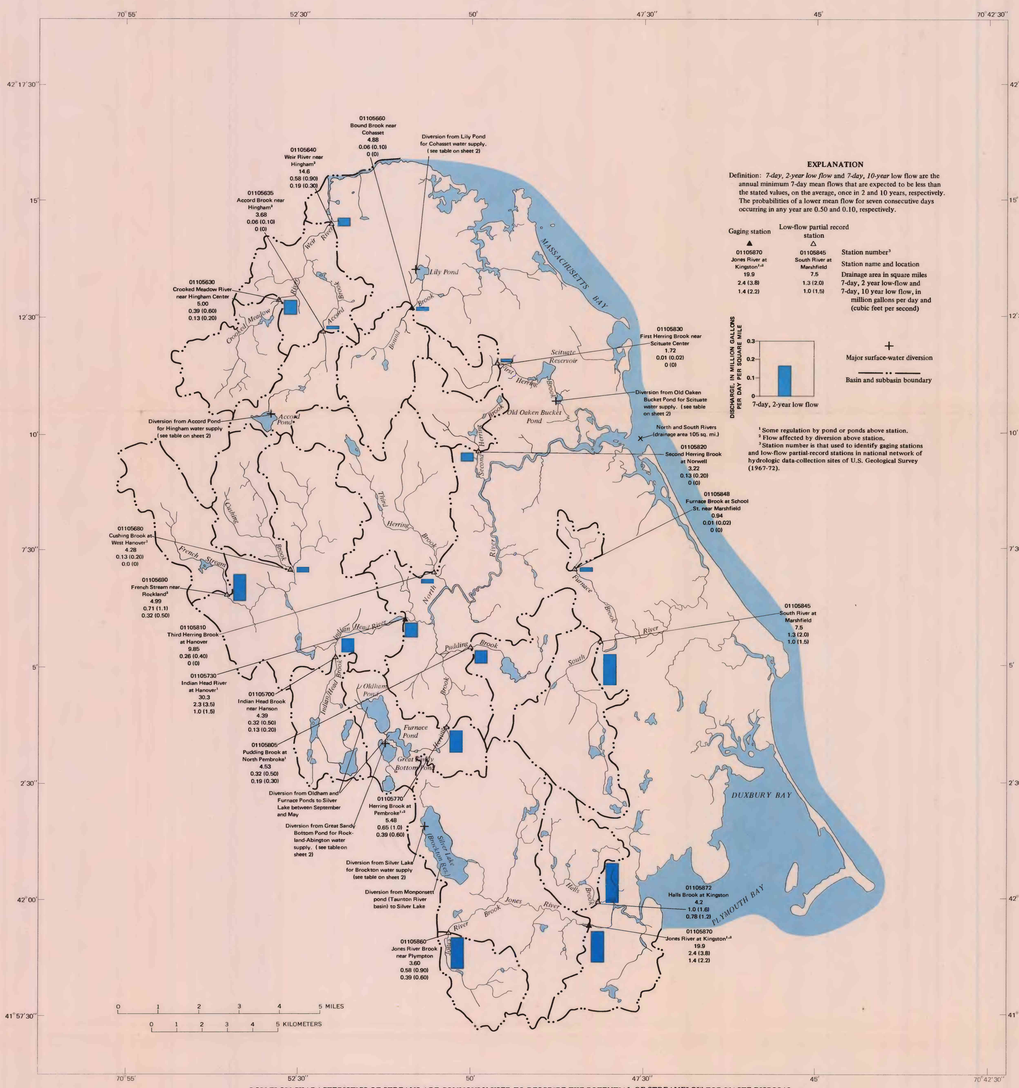
THE SEASONAL VARIATION IN DISCHARGE FOR THE INDIAN HEAD RIVER AT HANOVER IS TYPICAL OF THE RIVERS IN THE AREA.

FLOW DURATION



THE SHAPE OF THE FLOW-DURATION CURVE MAY BE USED TO COMPARE CHARACTERISTICS OF ONE BASIN WITH THOSE OF ANOTHER.

LOW FLOW



EXPLANATION

Definition: *7-day, 2-year low flow* and *7-day, 10-year* low flow are the annual minimum 7-day mean flows that are expected to be less than the stated values, on the average, once in 2 and 10 years, respectively. The probabilities of a lower mean flow for seven consecutive days occurring in any year are 0.50 and 0.10, respectively.

Gaging station ▲ 01105870 Jones River at Kingston[1,4] 19.9 2.4 (3.8) 1.4 (2.3)

Low-flow partial record station △ 01105845 South River at Marshfield 7.5 1.3 (2.0) 1.0 (1.5)

Station number[3]
Station name and location
Drainage area in square miles
7-day, 2 year low-flow and 7-day, 10 year low flow, in million gallons per day and (cubic feet per second)

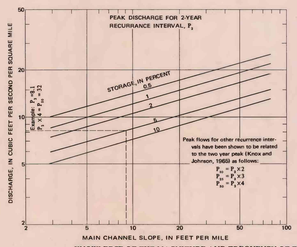
+ Major surface-water diversion

Basin and subbasin boundary

[1] Some regulation by pond or ponds above station.
[2] Flow affected by diversion above station.
[3] Station number is that used to identify gaging stations and low-flow partial-record stations in national network of hydrologic data-collection sites of U.S. Geological Survey (1967-72).

LOW-FLOW CHARACTERISTICS OF STREAMS ARE COMMONLY USED TO DESCRIBE THE POTENTIAL OF STREAMFLOW FOR WASTE DISPOSAL, MUNICIPAL OR INDUSTRIAL WATER SUPPLIES, IRRIGATION, AND FISH HABITAT. – *The 7-day, 10-year low flow is a legal index for pollution control in Massachusetts. Low flows are generally higher in the southern basins than in the northern basins because of the higher basin-storage capacities in the southern basins.*

FLOOD FREQUENCY



LIMITATIONS

This analysis is limited to unregulated rural basins in the study area.

DEFINITIONS

Main channel slope is the difference in elevation at points 10 and 85 percent of the distance along the channel from the site to the drainage divide, divided by the distance along the channel between the points.

Q_2 is the peak discharge for the 2-year recurrence interval.

Recurrence interval is the average interval of time within which the given flood will be exceeded once.

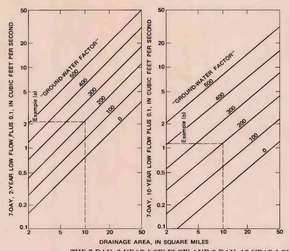
Storage is the area of lakes and ponds expressed as a percentage of the drainage area and increased by 0.5 percent.

EXAMPLE

The peak discharge that may be exceeded, on the average, once in 50 years from a basin that is 4.5 percent lakes and ponds and has a main channel slope of 9 feet per mile is 32 cubic feet per second per square mile.

KNOWLEDGE OF THE MAGNITUDE AND FREQUENCY OF FLOODS IS USEFUL FOR FLOOD-PLAIN ZONING AND IN THE DESIGN OF BRIDGE OPENINGS, ROADBED ELEVATIONS, AND FLOOD-PROTECTION WORKS. – *Estimates of the magnitude of peak flows for a given recurrence interval for gaged sites with predominantly rural drainage basins can be made from the above graph (Johnson, 1970; and C. G. Johnson and G. A. Laraway, written commun., 1971).*

LOW-FLOW GENERALIZATION



DEFINITION

"Ground-water factor" of a basin is determined from the map of the availability of ground water on sheet 2 by dividing the sum of 500 times the dark blue area within the basin, 300 times the medium blue area within the basin, and 100 times the light blue area within the basin by the total area of the basin.

EQUATIONS OF CURVES

$\log (Q_{2,7} + 0.1)^{*} = 1.101 + \log A + 0.0022G$

$\log (Q_{10,7} + 0.1)^{*} = 1.340 + 0.83 \log A + 0.0028G$

where $Q_{2,7}$ is the 7-day, 2-year low flow, in cfs

$Q_{10,7}$ is the 7-day, 10-year low flow, in cfs

A is the drainage area of the basin, in sq mi

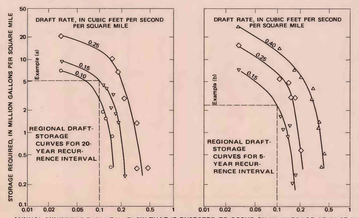
and G is the "ground-water factor".

EXAMPLE

The 7-day, 2-year and 7-day, 10-year low flows for an unregulated stream draining 10 square miles and having a ground-water factor, determined from the map of availability of ground water on sheet 2, of 200 is estimated as example (a), 2.0 cfs, and example (b), 1.0 cfs, respectively.

THE 7-DAY, 2-YEAR LOW FLOW AND 7-DAY, 10-YEAR LOW FLOW CAN BE ESTIMATED FROM THE SIZE OF THE DRAINAGE AREA AND MAPS OF THE AVAILABILITY OF GROUND WATER (TASKER, 1972a).

STORAGE ANALYSIS



ANNUAL MINIMUM 7-DAY MEAN FLOW THAT IS EXPECTED TO OCCUR ON AN AVERAGE OF ONCE IN 2 YEARS (7-DAY, 2-YEAR LOW FLOW), IN CUBIC FEET PER SECOND PER SQUARE MILE

EXPLANATION

SYMBOLS:

0.40 △ 0.25 ○ 0.15 ▽ 0.10 ○

Storage required for the indicated draft rate and 7-day, 2-year low flow for gaging stations in eastern Massachusetts and Rhode Island.

DEFINITIONS:

Draft rate is the rate at which water is withdrawn from the reservoir for use.

Recurrence interval is the average number of years within which the draft rate will be less than the given draft rate once.

Storage required is the usable volume of a reservoir required at the site to maintain the indicated draft rate.

EXAMPLE

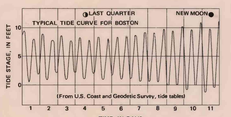
If a minimum flow of 1.5 cfs is desired on a stream that drains 10 square miles and has a 7-day, 2-year low flow of 1 cfs, then a reservoir of 50 mg, example (a), will suffice 19 of 20 years and a reservoir of 25 mg, example (b), will suffice 4 of 5 years.

SOME DEMANDS FOR WATER GREATER THAN MINIMUM STREAMFLOW CAN BE MET BY IMPOUNDING WATER DURING PERIODS OF HIGH FLOW FOR FUTURE USE. – *The storage required at a site to meet these demands can be estimated from the above graph if the drainage area and 7-day, 2-year low flow are known (Riggs, 1966). This analysis should be considered a first approximation to the amount of controlled flow available from storage because it does not consider losses from reservoir evaporation and seepage, nonuniform draft rates, probable reduction in capacity because of sedimentation, and possible modification of capacity for flood control and recreation.*

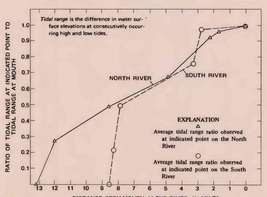
NORTH AND SOUTH RIVERS ESTUARY

The North and South Rivers flow through a drowned river valley estuary into Massachusetts Bay near the center of the study area. (See surface water map.) The estuary, which is the lower part of the rivers exposed to tidal fluctuations, extends from the mouth about 13 miles upstream along the North River and about 8 miles along the South River.

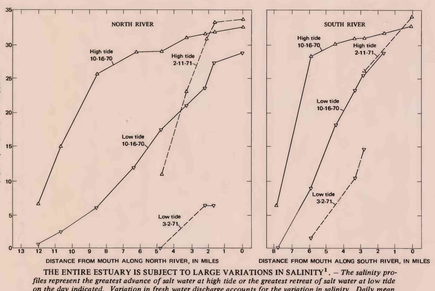
The estuary, bordered by tidal marsh for many miles above its mouth, is one of the few remaining and relatively unspoiled river systems in eastern Massachusetts. Some of the tidal and chemical characteristics of the estuary are shown in the graphs below.



THE PRINCIPAL VARIATIONS IN THE SEMIDIURNAL TIDES FOLLOW THE MOON'S DISTANCE AND PHASE. – *Because of the differential gravitational action of the moon and sun, the tidal range is greatest at the time of the new or full moon and smallest when the moon is in its first or last quarter.*



TIDAL RANGE DECREASES FROM THE MOUTH TO THE HEAD OF THE ESTUARY. – *Energy of the tidal wave is dissipated as it moves landward by the increasing resistance of the meandering channels. Mean tidal range at the mouth is 8.5 feet.*



THE ENTIRE ESTUARY IS SUBJECT TO LARGE VARIATIONS IN SALINITY[1]. – *The salinity profiles represent the greatest advance of salt water at high tide or the greatest retreat of salt water at low tide on the day indicated. Variation in fresh water discharge accounts for the variation in salinity. Daily mean discharge at Indian Head River at Hanover (North River basin) was for October 16, 9.6 cfs, for February 11,103 cfs, and for March 2, 134 cfs.*

[1] Salinity is a measure of the dissolved solids in water.

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WATER RESOURCES OF THE COASTAL DRAINAGE BASINS OF SOUTHEASTERN MASSACHUSETTS, WEIR RIVER, HINGHAM, TO JONES RIVER, KINGSTON

By
John R. Williams and Gary D. Tasker

1974

For sale by U.S. Geological Survey, price $1.25 per set