Streamflow From the United States Into the Atlantic Ocean During 1931–60

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1899–I

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By CONRAD D. BUE

CONTRIBUTIONS TO THE HYDROLOGY OF THE UNITED STATES

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STREAMFLOW FROM THE UNITED STATES INTO THE ATLANTIC OCEAN DURING 1931–60

By Conrad D. Bue

ABSTRACT

Streamflow from the United States into the Atlantic Ocean, between the international stream St. Croix River, inclusive, and Cape Sable, Fla., averaged about 355,000 cfs (cubic feet per second) during the 30-year period 1931–60, or roughly 20 percent of the water that, on the average flows out of the conterminous United States. The area drained by streams flowing into the Atlantic Ocean is about 288,000 square miles, including the Canadian part of the St. Croix and Connecticut River basins, or a little less than 10 percent of the area of the conterminous United States. Hence, the average streamflow into the Atlantic Ocean, in terms of cubic feet per second per square mile, is about twice the national average of the flow that leaves the conterminous United States. Flow from about three-fourths of the area draining into the Atlantic Ocean is gaged at streamflow measuring stations of the U.S. Geological Survey. The remaining one-fourth of the drainage area consists mostly of low-lying coastal areas from which the flow was estimated, largely on the basis of nearby gaging stations.

Streamflow, in terms of cubic feet per second per square mile, decreases rather progressively from north to south. It averages nearly 2 cfs along the Maine coast, about 1 cfs along the North Carolina coast, and about 0.9 cfs along the Florida coast.

INTRODUCTION

PURPOSE AND SCOPE

The original purpose of this study was to furnish data on streamflow into the Atlantic Ocean as requested by the Woods Hole Oceanographic Institution. The data consisted of the following: Discharge by years from specified segments of coastline for a 10-year period (the period not specified), discharge of the Charles River at mouth for the period 1920–60, discharge of the Hudson River at mouth for the period 1890–1960, and mean monthly discharge of the Penobscot and James Rivers at mouth for a 10-year period (the period not specified). The 10-year period 1951–60 was selected, partly because more streamflow records were available for that period than for any earlier period and partly because it was presumed that data for a recent period would be more useful to the institution than those for an earlier period.

The coastline between the Canadian border and Cape Sable, Fla., was divided into 10 segments, as proposed by Dr. K. O. Emery of the Woods Hole Oceanographic Institution. For convenience, the segments of coastline were divided into reaches, some reaches consisting of the mouths of individual rivers or bays. The segments range, in size of contributing drainage area, from 10,808 square miles to 79,260 square miles. The total contributing drainage area is 288,339 square miles, of which about three-fourths is gaged. Flow from the remaining one-fourth, which consists mostly of coastal areas, was estimated on the basis of streamflow records from nearby gaging stations.

Figures of discharge into the ocean between Cape Kennedy and Cape Sable were furnished by the Tallahassee office of the U.S. Geological Survey. Much of the area along the coast from Cape Kennedy to St. Lucie Canal contains well-developed canal systems constructed by drainage districts. The major drainage canals were gaged during the entire 10-year period; flow in other canals having shorter records was estimated from the short-term records. From St. Lucie Canal southward to Cape Sable about 85 percent of the drainage to the ocean was gaged as of 1965.

After the original 10-year study was completed, the study was extended back to 1931 so as to coincide with the standard reference period 1931–60.

For the purpose of determining flow into the ocean, water wasted from cities along the coast was added to the observed streamflow where the waste was large enough to be of some significance. Cities for which the wastes were thus accounted are Boston, New York, Philadelphia, Baltimore, and Washington, D.C. Where figures of actual waste were not available, it was assumed that the waste was equivalent to the water consumption of the city. Streamflow records used herein are, with certain exceptions, the observed discharges as measured at gaging stations and do not include water diverted upstream from the gaging stations for municipal use by downstream cities. Hence, where these diversions are of significant size, it is appropriate that they be accounted for by adding the waste water to obtain the total inflow into the ocean.

For the purpose of estimating ungaged inflow to the Hudson River below Mechanicville, the 378 square miles of drainage area of the Croton River above the Croton Dam was withdrawn as being noncontributing, because all the water of the Croton River is diverted at the dam for municipal use by New York City, except for occasional spill at the dam. The spill, measured at a gaging station just below the dam, was added to the flow of the Hudson River. The water diverted to New York City is assumed to be wasted into the bay beyond the mouth of the Hudson River and was included in the outflow from reach 18. Figures of drainage area of the Hudson River, however, as well as those for reach 18, include the Croton River basin.

DRAINAGE AREAS

Streamflow reports of the U.S. Geological Survey give drainage areas at all gaging stations used in this study. Gaging stations are, however, almost invariably located some distance above the mouth of the stream and above tidewater, so that the lower reaches of rivers tributary to the ocean are ungaged, and many small coastal basins are wholly ungaged. For areas of ungaged drainages, the following various reports were consulted: Carter (1959), Maine State Water Storage Commission (1910 and 1913), Vermeule (1894), Virginia Department of Conservation and Economic Development (1960), and Walker (1962).

For the other coastal States, supplementary drainage area data were obtained from the district offices of the Geological Survey, mostly in mimeographed, unpublished form. Some supplemental drainage area data were also available in the Corps of Engineers' "308" reports—reports prepared under the provisions of House Document No. 308, 69th Congress, first session.

The areas of many small basins, or subbasins, were measured with a planimeter. As the maps used were small scale, the areas are subject to a fairly large percentage error, but as these areas constitute only a very small part of the total area, the overall error from this source is probably insignificant. In some basins, where the total drainage area had already been determined—by the Corps of Engineers or another agency—it was possible to adjust the planimetered areas so that the sum of all the subareas within the basin agreed with the total. Wherever possible, such adjustments were made to the planimetered areas to avoid inconsistencies with figures already published.

DIVISIONS OF COASTLINE

SEGMENT 1

St. Croix River to Penobscot Bay, inclusive

Reach 1: St. Croix River to the East Machias River, inclusive.
Reach 2: Machias River to Pleasant Bay, exclusive of the Narraguagus River.
Reach 3. Narraguagus River to but excluding Penobscot Bay.

Reach 4: Penobscot Bay, which includes the Penobscot River and contributing areas on the right and left banks of the bay.

SEGMENT 2

From Penobscot Bay to Orleans, Mass.

Reach 5: From Penobscot Bay to and including the outer exit of the Kennebec and Androscoggin Rivers.
Reach 6: From the Androscoggin River to and including the Saco River.
Reach 7: From the Saco River to and including the Piscataqua River.
Reach 8: From the Piscataqua River to Cape Ann, Mass.
Reach 9: Massachusetts Bay, extending from Cape Ann to the 42d parallel.
Reach 10: From the 42d parallel to Orleans, Mass. This reach consists mainly of Cape Cod Bay.

SEGMENT 3

From Orleans, Mass., to the Connecticut-New York State line

Reach 11: From Orleans to but exclusive of the Taunton River.
Reach 12: Narraganset Bay, including the Taunton River.
Reach 13: From Narraganset Bay to the Rhode Island-Connecticut State line.
Reach 14: From the Rhode Island-Connecticut State line to and including the Connecticut River.
Reach 15: From the Connecticut River to and including the Housatonic River.
Reach 16: From the Housatonic River to the Connecticut-New York State line.

SEGMENT 4

From the Connecticut-New York States line to Cape May, N.J.

Reach 17: Consists of Long Island and a contributing area lying between the East River and the Hudson River drainage divide.
Reach 18: Lower New York Bay, which includes the Hudson, Hackensack, Passaic, and Raritan Rivers, and the spill from Croton Reservoir.
Reach 19: From Lower New York Bay to but exclusive of the Mullica River.
Reach 20: Mullica River to Cape May.

SEGMENT 5

From Cape May to Cape Henry, Va.

Reach 21: Delaware Bay.
Reach 22: Coastal area in Delaware, Maryland, and Virginia, between Cape Henlopen, Del., and Cape Charles, Va.
Reach 23: Chesapeake Bay.

SEGMENT 6

From Cape Henry to a point on the outer bank east of Moorhead City, N.C., at lat 34°40′

Reach 24: From Cape Henry to lat 35°55′, which appears to be about the junction of Albemarle and Pamlico Sounds Because of the outer bank, however, the water from Albemarle Sound may have to flow south to the first break in the bank, which appears to be at lat 35°49′.
Reach 25: From lat 35°55′ to lat 34°40′. It includes Pamlico Sound and probably most of Core Sound.

SEGMENT 7

From lat 34°40′ (the vicinity of Moorhead City) to Georgetown, S.C., exclusive of the Pee Dee River

Reach 26: From lat 34°40′ to and including the Cape Fear River.
Reach 27: From the Cape Fear River to the Pee Dee River, but exclusive of both.

SEGMENT 8

Pee Dee River to but exclusive of the Altamaha River

Reach 28: Pee Dee River to the Edisto River, inclusive of both.
Reach 29: From the Edisto River to and including the Savannah River.
Reach 30: From the Savannah River to the Altamaha River, but exclusive of both.

SEGMENT 9

Altamaha River to Cape Kennedy

Reach 31: Altamaha River to the St. Marys River, inclusive of both.
Reach 32: From the St. Marys River to Cape Kennedy.

SEGMENT 10

From Cape Kennedy to Cape Sable, Fla.

Reach 33: From Cape Kennedy to and including the St. Lucie Canal and the St. Lucie River.
Reach 34: From the St. Lucie Canal to Cape Sable.

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ESTIMATING DISCHARGE FROM UNGAGED AREAS

PERIOD 1951–60

Discharge from ungaged areas was estimated, by years, on the basis of nearby gaged streams. Mean discharge for the year in a nearby gaged stream, or streams, expressed as cubic feet per second per square mile, was applied to the ungaged area. Insofar as possible, the gaged streams used were those having drainage areas of similar size as the ungaged area and at similar elevations, so that it could be inferred that the runoff characteristics of the gaged streams were somewhat similar to the ungaged area from which discharge was to be estimated.

In estimating the discharge from an ungaged area, as many streamflow records as available were used as a basis. The modal number of streamflow records available was three; for a very few areas only one streamflow record was available, or as many as five. With a very few exceptions, the mean discharges for the year from the gaged streams, expressed as cubic feet per second per square mile, were simply averaged and applied to the ungaged area. In the few exceptional areas, where there was great disparity in the discharge of the gaged streams, greater weight was given to streams that had drainage areas of comparable size.

It is recognized that this technique is subject to error, the error being variable from year to year and from place to place. The flow of small streams, particularly the monthly flow, tends to be erratic, even if their basins adjoin. For example, in any 1-month period the flow of one stream may be substantially less than in the preceding month, whereas in a nearby stream the flow may be greater than in the preceding month. However, the resulting errors introduced in the estimated yearly means of ungaged streams should be much smaller than in monthly means, and the errors in long-term means even smaller. During the period 1951–60 only about 25 percent of the total area of the Atlantic Coast drainage was ungaged; the corresponding estimated discharge was 24 percent of the total.

Extension of the study from 1950 back to 1931 required some modification of the procedures used in calculating the flow for the period 1951–60, owing to the fact that many streamflow records used in the 10-year study did not go back to 1931. Those modifications are discussed briefly in the following section of the report.

PERIOD 1931–50

Insofar as possible, the same gaging-station records and the same procedures were used in calculating streamflow into the ocean for the 20-year period 1931–50 as for the 10-year period 1951–60. Along the New England coast most of the stations used in the 10-year study had records of the required length. For the comparatively few records that did not go back to 1931, it was possible to make extensions on the basis of nearby streams. South of New England, many records did not go back beyond 1951, or not far enough to warrant extension. Hence, for some areas along the coast south of New England it was found expedient to resort to graphical relations with long-record stations, rather than attempt to extend the records of many small streams. Graphical extensions were thus made for discharge from Long Island, Chesapeake Bay, Albemarle and Pamlico Sounds, reach 26 consisting mainly of the Cape Fear River, reach 27 consisting mainly of the Pee Dee River, reach 28 consisting mainly of the Santee River, and reach 29 consisting mainly of the Savannah River.

REACH 17 (LONG ISLAND)

Long Island and a 155 square-mile area in continental New York lying between the East and Hudson Rivers are designated as reach 17. A greater part of the streamflow from Long Island is southward directly into the ocean, and only a small part is northward into Long Island Sound, but as all the flow eventually discharges into the ocean, this study makes no attempt to separate the two components.

For the 10-year study, no streamflow records were available in Kings and Queens Counties. Streamflow from these counties was estimated largely on the basis of runoff rates in the Bronx River, although the high degree of urbanization has undoubtedly had a marked effect on the natural runoff rates. In addition to streamflow, water is wasted to the ocean in sewers. Some of this wasted water comes from the New York City municipal system and some is pumped from wells on Long Island. For the purpose of this study, no adjustment was made for either component of wastage. (All the water from the New York City system is assumed to be wasted into New York Bay. See "Municipal use" under the section "Adjustment for major diversions.")

For Nassau and Suffolk Counties, 18 gaging-station records were available in the 10-year study. Additional information, both quantitative and qualitative, was obtained from Brice (1951), Sawyer (1958), and from E. J. Pluhowski (oral commun., about Mar. 15, 1965) who had participated in a ground-water study in Suffolk County.

Very little of the information used in the 10-year study was available for the period 1931–50, so that period was estimated from a curve of relation between the Hudson River and the streamflow from Long Island for the period 1951–60. The points scatter considerably, but a relation was loosely defined. The mean of the 20 years estimated graphically is 1,014 cfs (cubic feet per second), which, when combined with the 10-year mean of 1,106 cfs, gives a 30-year mean of 1,045 cfs. The 30-year mean thus obtained is about 6 percent less than the 10-year mean, which is consistent with other streamflow records along this part of the coastline. (See also table 19.)

REACH 23 (CHESAPEAKE BAY)

In calculating the inflow to Chesapeake Bay for the 10-year period 1951–60, gaging-station records from 54 streams were used. These streamflow records accounted for about 80 percent of the drainage basin of the bay, ungaged areas constituting the remaining 20 percent. Streamflow from the ungaged areas was estimated on the basis of records at nearby gaged streams.

Many of the records used in the 10-year study did not go back beyond 1951, or at best only a few years. When the study was extended back to 1931, other procedures were necessary in lieu of the missing streamflow records. The best results were obtained from curves of relation between selected reference gaging stations and inflow to the bay for the 10-year period 1951–60. A requirement for a reference station was that its record go back to 1931 and hence could be used as a basis for estimating inflow to the bay during the period 1931–50. The stations used were Susquehanna River at Marietta, Pa.; Potomac River near Washington, D.C., adjusted for diversions; Rappahannock River near Fredericksburg, Va.; South Anna River near Ashland, Va.; Appomattox River near Petersburg, Va.; and James River near Richmond, Va., adjusted to include the flow of the James River and Kanawha Canal, which have a total drainage area of 47,634 square miles, or 73 percent of the drainage area of the bay.

The bay was divided into segments by cross sections across the bay. Cross section 1 was just above the mouth of the Potomac, cross section 2 was just below the Potomac, cross section 3 was just above the James, and cross section 4 was across the mouth of the bay between Capes Charles and Henry. Inflow above cross section 1 was estimated from Susquehanna River at Marietta. The increment of inflow between cross sections 1 and 2 was estimated from Potomac River near Washington, D.C. The increment of inflow between cross sections 2 and 3 was estimated from Rappahannock River near Fredericksburg and South Anna River near Ashland, the Rappahannock River being given a weight of 2 on the basis of comparative drainage areas. The increment of inflow between cross sections 3 and 4 was estimated from James River near Richmond and Appomattox River near Petersburg, the Appomattox River being given a weight of 2.6 on the basis of comparative drainage areas. The total inflow to the bay is then the sum of the four increments.

To check the probable reliability of the estimates obtained by this procedure, the inflow to the bay was estimated for the years 1951–60 and compared with the basic calculations in which all available streamflow records were used. Differences in the yearly means ranged from −8 percent to +7 percent, but the two 10-year means agreed within half a percent. It is assumed that the estimates for the 20-year period 1931–50 are within the same range of accuracy.

REACH 24 (ALBEMARLE SOUND)

The inflow to Albermarle Sound during the 20-year period 1931–50 was estimated from a curve of relation between the yearly inflow to the sound for the 10-year period 1951–60 and a weighted average of the flow at the gaging stations Nottoway River near Sebrell, Va., and Roanoke River at Roanoke Rapids, N.C. The Sebrell record was given a weight of 2.8 on the basis of the fact that its drainage area was more nearly comparable with that of the ungaged streams.

REACH 25 (PAMLICO SOUND)

The inflow to Pamlico Sound during the 20-year period of 1931–50 was estimated from a curve of relation between the flow at the gaging stations Tar River at Tarboro, N.C., and Neuse River at Kinston, N.C., and the total yearly inflow to the sound for the 10-year period 1951–60. Both stations were given equal weight.

REACH 26 (CAPE FEAR RIVER)

Reach 26 (10,521 sq mi) consists mainly of the Cape Fear River (9,136 sq mi at mouth). None of the gaging stations used in the 1951–60 study had records back to 1931. The principal station, Cape Fear River at lock 3 near Tarheel, N.C., which has records beginning in 1938, was extended back to 1931 on the basis of the upstream station at Fayetteville. A curve of relation was then drawn between the yearly flow at the Tarheel station and the yearly inflow to the reach during 1951–60, and from this relation curve, the inflow during 1931–50 was estimated on the basis of the Tarheel station.

REACH 27 (PEE DEE RIVER)

Reach 27 (18,562 sq mi) consists mainly of the Pee Dee River (16,310 sq mi at mouth). As few of the gaging stations used in the 1951–60 study have records back to 1931, the outflow from reach 27 during the 20-year period 1931–50 was estimated from a curve of relation between a weighted yearly flow at four gaging stations and the yearly outflow from reach 27 during the period 1951–60. The stations used were Pee Dee River at Pee Dee, S.C.; Lynches River at Effingham, S.C.; Lumber River at Boardman, S.C.; and Black River at Kingstree, S.C.; which have a combined drainage area of 12,340 square miles. On the basis of comparative drainage areas, the flow at the last three stations was given double weight.

REACH 28 (SANTEE RIVER)

Reach 28 (20,545 sq mi) consists mainly of the Santee River (15,700 sq mi at mouth). Owing to regulation and lack of streamflow records, it was not possible to calculate the outflow from reach 28 for 1931–50 by the some procedure as for 1951–60. The outflow was estimated from a curve of relation between yearly flow of Santee River near Pineville and of reach 28 for the period 1951–60.

In order to use the gaging station Santee River near Pineville as a reference, it was necessary to construct an adjusted record of unregulated flow for the entire period 1931–60. The Santee River is completely regulated by Lake Marion just upstream from the Pineville gaging station, and the greater part of the flow of the river is diverted from Lake Marion to Lake Moultrie through the Lakes Marion-Moultrie diversion canal. Only the water released down the Santee River, which in most years is a small part of the total flow, passes the Pineville station.

Unregulated streamflow records upstream at Ferguson were available for 1931–41. As the drainage area at Ferguson is only 100 square miles less than at Pineville, the two sites are considered equivalent when Pineville is adjusted for regulation. The Ferguson record ends with the 1941 water year. Storage in Lake Marion began in November 1941. The Pineville record begins in May 1942, but records of diversion in the Marion-Moultrie canal were not published until October 1943. Hence, for the purpose of this study, the water years 1942 and 1943 were cosidered as being missing at Pineville. An unregulated record at Pineville was then constructed as follows: for the period 1931–41, the observed flow at Ferguson was used; for the period 1944–60, the observed flow at Pineville was adjusted for diversion in the Marion-Moultrie canal and for change in contents in Lake Marion; and for the years 1942 and 1943, the flow was estimated from a curve of relation between Pineville, adjusted, and Saluda River near Columbia, S.C., adjusted, based on the periods 1936–41 and 1944–45. Beginning with 1944 the Pineville record was adjusted by adding to the observed flow at the Pineville station the flow of the Marion-Moultrie canal, adjusted for change in contents in Lake Marion converted to equivalent cubic feet per second. If storage in Lake Marion decreased during the year, the equivalent amount of the decrease was subtracted because it had come out of storage rather than down the Santee River; conversely, if storage in Lake Marion increased, the equivalent amount was added. The adjusted mean thus obtained at Pineville for the 10-year period 1951–60 is about 11 percent less than the adjusted mean for the 30-year period 1931–60, which is consistent with other streamflow records along this part of the coastline. (See also table 19.)

A curve of relation was drawn between the adjusted Pineville flow and the outflow from reach 28 for the 10-year period 1951–60, and this relation was used to estimate the outflow from reach 28 for the period 1931–50 on the basis of adjusted Pineville flow for that period.

REACH 29 (SAVANNAH RIVER)

Reach 29 (13,445 sq mi) consists mainly of the Savannah River (10,600 sq mi at mouth). Outflow from the reach for the period 1931–50 was estimated from a curve of relation between the station Savannah River near Clyo, Ga., and the yearly outflow from the reach for the period 1951–60. A gap of 4 years (1934–37) in the Clyo record was estimated on the basis of a curve of relation between the Clyo station (9,850 sq mi) and the Augusta station (7,508 sq mi).

ADJUSTMENT FOR MAJOR DIVERSIONS

MUNICIPAL USE

BOSTON

The figures showing the amount of waste from sewers that flowed into Boston Harbor were furnished by the Massachusetts Metropolitan District Commission. As nearly as can be ascertained, the waste is water that was diverted above measuring points on streams and hence is not included in the streamflow records. As actual, or historic, flow is used in this study, diversions were not traced to the stream or streams from which they originated, nor was any adjustment made to streamflow. The waste must, however, be added to obtain the flow of Massachusetts Bay into the ocean. Figures of waste were furnished for the years 1920–60; for the 10 years 1951–60 the waste averaged 537 cfs, and for the 30 years 1931–60 it averaged 466 cfs.

NEW YORK CITY

Water for the New York City municipal supply is diverted above measuring points on streams and hence is not included in the streamflow records. Except for spill at Croton Dam, all the Croton River is diverted at the dam to the municipal water system. (See p. I2).

Figures of water use and population for the years 1898–1951 were obtained from a report entitled "A Description of the Water-Supply System of the City of New York," by the New York Department of Water Supply, Gas and Electricity (1952). Figures of water use for the years 1952–60 were obtained from the New York Department of Water Supply; figures of population for those years were furnished by the Bureau of the Census. Although the figures of water use were used only for the period 1931–60 in calculating the flow into the bay (reach 18), earlier figures are available and they are shown in table 1. Figure 1 shows a graphical comparison between water use and population for the period 1900–60.

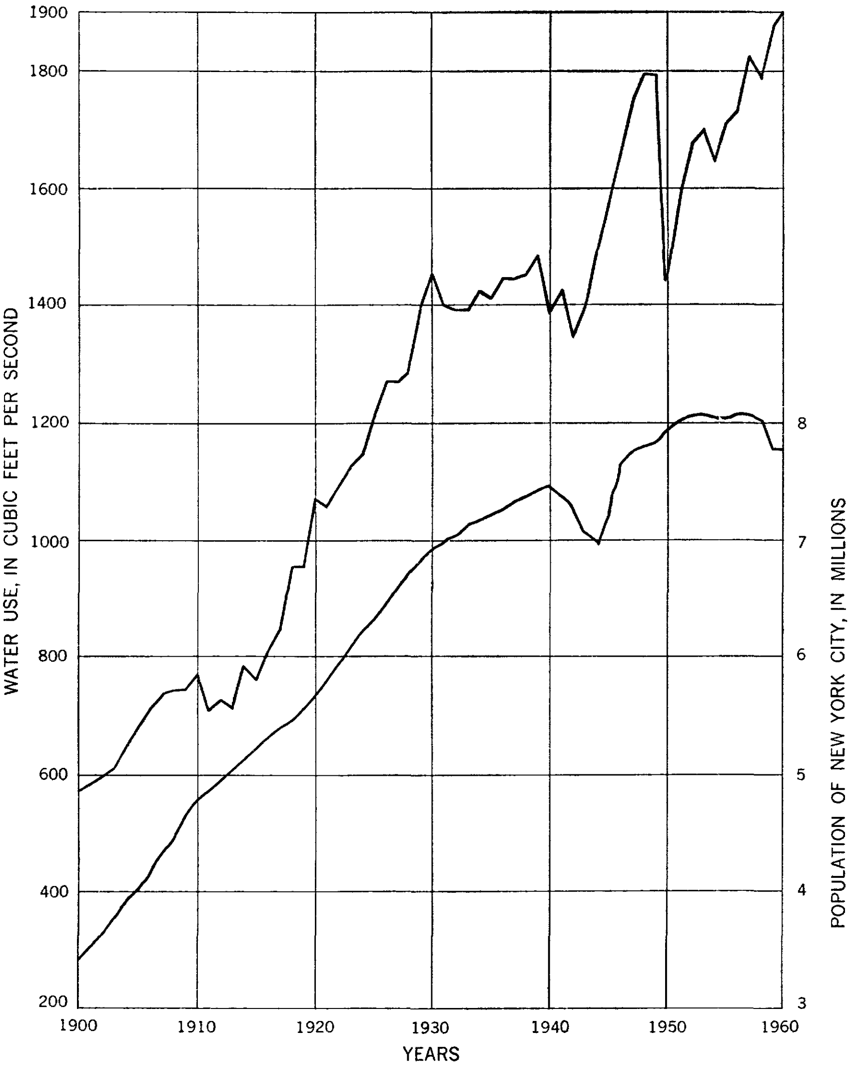

Figure 1.—Use of water by New York City.

TABLE 1.—*Use of water by New York City for calendar years 1898–1960*

[Figures for 1898–1951 obtained from a report "A Description of the Water-Supply System of New York City," 1952, by the New York Department of Water Supply, Gas, and Electricity; those for 1952–60 furnished by the New York Department of Water Supply]

Calendar year	Cubic feet per second	Calendar year	Cubic feet per second	Calendar year	Cubic feet per second	Calendar year	Cubic feet per second
1898	503	1915	766	1932	1, 391	1949	1, 796
1899	542	1916	816	1933	1, 389	1950	1, 458
1900	574	1917	845	1934	1, 422	1951	1, 596
1901	583	1918	958	1935	1, 410	1952	1, 676
1902	600	1919	958	1936	1, 443	1953	1, 698
1903	616	1920	1, 068	1937	1, 444	1954	1, 651
1904	652	1921	1, 060	1938	1, 452	1955	1, 716
1905	688	1922	1, 089	1939	1, 488	1956	1, 729
1906	715	1923	1, 125	1940	1, 368	1957	1, 822
1907	739	1924	1, 148	1941	1, 433	1958	1, 785
1908	743	1925	1, 239	1942	1, 344	1959	1, 876
1909	744	1926	1, 274	1943	1, 395	1960	1, 903
1910	767	1927	1, 276	1944	1, 494		
1911	714	1928	1, 293	1945	1, 567	Mean,	
1912	727	1929	1, 396	1946	1, 660	1931–60	1, 578
1913	718	1930	1, 458	1947	1, 753		
1914	786	1931	1, 399	1948	1, 795		

Water use by New York City (table 1) averaged 1,745 cfs during the 10-year period 1951–60 and 1,578 cfs during the 30-year period 1931–60. Waste water is discharged at several points, including the lower Hudson River, the East River, Long Island Sound, Rockaway Inlet, Jamaica Bay, Raritan Bay, and New York Bay. As no breakdown of the amounts wasted at each point is available, all the waste is assumed to be discharged, either directly or indirectly, into New York Bay beyond the mouth of the Hudson River. Thus, all the waste is included in the discharge of reach 18, segment 4 (table 7). This assumption as to point of discharge introduces a slight inaccuracy, but the figures of total outflow from reaches 17 and 18 are not affected.

PHILADELPHIA

The city of Philadelphia takes its water from the Delaware and Schuylkill Rivers. Water from the Schuylkill River is diverted at a point upstream from the measuring point, the gaging station Schuylkill River at Philadelphia, but the streamflow records are adjusted for this diversion. Water from the Delaware River is diverted at a point downstream from the Trenton gaging station. As Philadelphia wastes its water back into the Delaware River, no further adjustment for waste is applicable.

BALTIMORE

According to Water-Supply Paper 1812, the water use of Baltimore in 1962 was 211 mgd, (million gallons per day) and the population

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served was 1,387,000. According to the 1954 inventory by the U.S. Public Health Service, the water use was 199 mgd, and the population served was 1,261,000. Therefore, it was assumed that the average water use during the decade 1951–60 was 205 mgd, or 318 cfs.

Water from the Gunpowder River, supplemented from the Susquehanna River, constitutes about 55 percent of the total, and the Patapsco River furnishes the remaining 45 percent. Water is taken out of the Gunpowder and Patapsco Rivers above the measuring points, so that the streamflow records do not include the diversions. Water from the Susquehanna is taken out downstream from the measuring point, so that no adjustment would be required for this diversion. It was assumed, however, that the supplemental water from the Susquehanna is so small in comparison with the Gunpowder diversion that the entire diversion of 318 cfs can be added to the flow of Chesapeake Bay during the period 1951–60 without appreciable error. As the flow of Chesapeake Bay was calculated graphically for the period 1931–50 (see section on Chesapeake Bay), no separate adjustment was made for that period.

WASHINGTON, D.C.

The city of Washington takes its water from the Potomac River upstream from the gaging station near Washington D.C., and wastes its water back into the Potomac River downstream from the gaging station. The Potomac River streamflow records used in this report are adjusted for this diversion, so that no further adjustment for waste from Washington is applicable.

CHESAPEAKE AND DELAWARE CANAL

The Chesapeake and Delaware Canal is a sea-level navigation channel between the upper end of Chesapeake Bay and the Delaware River. Water in the canal may flow in either direction, depending upon the difference in the height of the tides at the ends of the canal.

A publication by the Corps of Engineers, Committee on Tidal Hydraulics, which is dated August 1965 and entitled "Inland Waterway Between Delaware River and Chesapeake Bay—Problem of Disposal of Material to Be Removed From a Portion of Channel in the Chesapeake Bay," states that "under present conditions (27×250-foot channel), the Chesapeake and Delaware Canal carries approximately 43,000,000 cubic feet more flow eastbound than it does westbound per tide cycle of 12.42 hours during normal tides." This net difference is equivalent to a little less than 1,000 cfs. A pamphlet issued by the Philadelphia District, Corps of Engineers, which is dated April 1967 and entitled "Inland Waterway, Delaware River to Chesapeake Bay—Historic Chesapeake and Delaware Canal," states that "the mean range (of tide) at the Delaware River end is approximately 5½ feet while at the western end of the canal proper it is about 2 feet * * *. The mean level of the water surface at the western end is about 0.3 foot higher than mean river level in the Delaware at the eastern end."

Prior to 1935 the canal was 12 feet deep and the width ranged from 90 to 150 feet. Between 1935 and 1938 the dimensions were increased to 27 feet deep and 250 feet wide. In 1954, work began on deepening the canal to 35 feet and widening it to 450 feet; as of January 1, 1967, the work was about 51 percent complete. As the canal is a sea-level channel, it would seem reasonable to believe that the slope of the water surface is little affected by change in dimensions, and that the flow in the canal is somewhat proportional to the controlling, or minimum, cross section. Accordingly, the net eastward flow in the canal is estimated to be about as follows: 1931–35, 200 cfs; 1936, 500 cfs; 1937, 800 cfs; and 1938–60, 1,000 cfs. When the enlargement now in progress is completed, the canal will likely carry proportionally more water than it does now.

As far as total flow into the ocean is concerned, it makes no difference whether or not adjustment is made for diversion of water by the canal. Delaware Bay and Chesapeake Bay are both in segment 5 of the coastline (see table 8); both unadjusted and adjusted figures are shown for both bays (reaches 21 and 23). The total outflow from segment 5 is the same, regardless of which set of figures is used.

DIVERSION FROM THE SANTEE RIVER TO THE COOPER RIVER

Water is stored in Lake Marion (storage began in November 1941), 2.4 miles upstream from the gaging station Santee River near Pineville and diverted through the Lakes Marion-Moultrie diversion canal to Lake Moultrie (storage began in November 1941), from whence it is released into the West Branch Cooper River. Records of discharge in the canal began in October 1944.

The Cooper River basin occupies roughly half of an ungaged area of 1,800 square miles of coastal area lying between the basins of the Santee and Edisto Rivers. The discharge of the Santee and Edisto Rivers, the diversion from the Santee to the Cooper River, and the discharge originating within the 1,800-square-mile area are included in reach 28, a breakdown of which is shown in table 2 for the 10-year period 1951–60. About half of the discharge from the 1,800-square-mile area is assumed to originate in the Cooper River basin.

The amount of water released into the Cooper River basin is equal to the discharge of the Marion-Moultrie canal adjusted for change in contents in Lake Moultrie. If storage in Lake Moultrie increased during the year, the equivalent amount in cubic feet per second was subtracted from the discharge of the Marion-Moultrie canal; conversely, if storage decreased, the equivalent amount was added. Records of release to the Cooper River basin are available since 1944. During the 17-year period 1944–60 the release ranged from 7,377 cfs in 1955 to 19,920 cfs in 1960 and averaged 13,770 cfs. Releases during 1951–60 are shown in table 2.

TABLE 2.—*Components of discharge, in cubic feet per second, from reach 28*

Water year	Santee River at mouth	Edisto River at mouth	Ungaged area including Cooper River basin [1]	Release from Santee River to Cooper River	Total for reach 28
1951	1, 305	1, 910	1, 116	11, 920	16, 250
1952	2, 937	2, 322	1, 332	12, 570	19, 160
1953	1, 357	2, 214	1, 242	13, 410	18, 220
1954	1, 298	1, 621	1, 008	11, 530	15, 460
1955	1, 303	1, 311	684	7, 377	10, 680
1956	1, 288	1, 667	810	9, 003	12, 770
1957	1, 289	1, 401	774	9, 817	13, 280
1958	4, 658	3, 104	1, 710	18, 130	27, 600
1959	1, 615	2, 998	1, 566	13, 890	20, 070
1960	9, 217	5, 748	2, 988	19, 920	37, 880
Mean	2, 627	2, 430	1, 323	12, 760	19, 140
Drainage area in square miles	15, 700	3, 045	1, 800	----------	20, 545

[1] Approximately half of this discharge is assumed to originate in the Cooper River basin

STREAMFLOW

SUMMARY OF STREAMFLOW INTO THE ATLANTIC OCEAN

Streamflow from the United States into the Atlantic Ocean, between the St. Croix River, inclusive, and Cape Sable, Fla., averaged about 363,000 cfs during the 10-year period 1951–60 and about 355,000 cfs during the 30-year period 1931–60. Streamflow from the conterminous United States into the oceans and across the international boundaries was computed by Langbein (1949) as about 1,800,000 cfs for the period 1921–45, and the Water Resources Council (1968) gives 1,860,000 cfs as the annual natural runoff for the period 1931–60 from the same area. Hence, the flow into the Atlantic Ocean is roughly 20 percent of the flow from the conterminous United States.

The area drained by streams flowing into the Atlantic Ocean is 288,339 square miles, including 625 square miles of the St. Croix River basin in New Brunswick and 114 square miles of the Connecticut River basin in Quebec, a little less than 10 percent of the area of the conterminous United States. Thus in terms of cubic feet per second per square mile, the flow into the Atlantic Ocean is about twice the national average of the flow that leaves the conterminous United States. Table 3 summarizes, by segments, streamflow into the Atlantic Ocean for each year of the 30-year period 1931–60. The table shows also the 30-year mean for each segment, and the segment means and yearly totals expressed in terms of cubic feet per second per square mile. Flow is not uniformly high or low along the entire coastline. In some segments the flow may be below average in any 1-year period and above average in other segments. However, in 1931, the year of lowest total flow, the flow in all segments was well below average, and in 1960, the year of highest total flow, the flow in all segments was well above average.

Total discharge to the ocean, in terms of cubic feet per second (from table 3), is plotted in figure 2. Although there apparently is a very slight upward trend during the 30-year period, this trend is probably due to the fact that the period begins in a sequence of low years and ends in a sequence of high years. If the graph were extended both ways so as to include some higher years before 1931 and some lower years after 1960, the apparent upward trend would no doubt be nullified.

In terms of cubic feet per second per square mile, streamflow decreases rather progressively from north to south. It averages nearly 2 cfs along the Maine coast, about 1 cfs along the North Carolina coast, and about 0.9 cfs along the Florida coast.

In contrast to streamflow, precipitation increases from north to south. The normal statewide precipitation is about 42 inches in Maine, 49 inches in North Carolina, and 55 inches in Florida. Accordingly, the precipitation-runoff ratio decreases from about 0.6 in Maine to about 0.3 in North Carolina and to about 0.2 in Florida. This decrease in runoff from north to south may be explained in part by the corresponding increase in evaporation. According to U.S. Weather Bureau Technical Paper No. 37 (pl. 1) average annual Class A pan evaporation averages about 25–30 inches in Maine, 50–55 inches in North Carolina, and 60–65 inches in Florida.

As pointed out by Hidore (1966), one cause of the decreasing runoff per unit area from north to south is the greater seepage into the coastal plain sediments (the coastal plain widens progressively from New Jersey southward to North Carolina). Proof of this is found in the existence of fresh water in the extension of the coastal plain aquifiers under the continental shelf (Manheim, 1967).

Tables 4–13 show the breakdown of discharge by reaches for each of the 10 segments.

Many streams that discharge from the mainland empty into a bay or a sound, instead of directly into the ocean. As the outflow from bays and sounds is not measured directly, the outflow from such bodies of water to the ocean is considered as being equivalent to the total inflow

TABLE 3.—*Streamflow in cubic feet per second into the Atlantic Ocean, by segments between the St. Croix River, inclusive, and Cape Sable, Fla., 1931–60*

Water year	Segment 1[1]	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8	Segment 9	Segment 10	Total	Mean per square mile
1931	17,030	27,210	23,430	21,070	57,370	19,050	23,050	32,140	21,780	7,200	249,300	0.86
1932	23,070	29,530	22,470	24,240	68,560	15,950	21,470	37,300	17,290	7,900	267,800	.93
1933	23,230	38,720	34,710	34,630	119,300	27,220	32,340	49,300	31,150	12,400	403,000	1.40
1934	24,430	32,480	30,140	26,590	71,680	22,270	16,800	31,960	23,500	14,800	294,600	1.02
1935	23,830	36,300	30,990	28,580	106,800	32,600	28,100	37,710	15,720	5,200	345,800	1.20
1936	28,440	43,220	33,130	33,110	117,900	42,140	47,110	68,000	33,070	17,200	463,300	1.61
1937	23,870	40,900	35,760	33,020	114,500	42,500	43,090	64,870	28,540	11,000	438,000	1.52
1938	23,750	40,640	42,200	35,070	94,540	33,170	22,590	36,200	21,100	4,000	353,300	1.23
1939	23,550	36,140	35,210	33,610	94,600	35,290	34,730	38,770	22,040	5,100	359,000	1.25
1940	23,560	33,390	30,790	29,590	97,780	29,790	18,050	29,290	18,930	13,100	324,300	1.12
1941	17,570	21,900	20,830	23,100	75,010	18,960	18,890	29,600	20,030	11,700	257,600	.89
1942	20,870	26,790	24,080	23,690	79,990	15,180	23,500	39,100	34,670	10,300	298,200	1.03
1943	19,160	32,740	32,850	36,120	124,700	29,520	30,640	43,780	22,630	5,400	377,500	1.31
1944	21,220	33,120	23,710	26,280	82,600	25,820	33,040	44,830	33,520	4,600	328,700	1.14
1945	28,940	43,160	35,700	36,500	107,900	35,920	38,250	33,290	26,650	6,500	392,800	1.36
1946	22,350	36,580	31,550	33,170	114,100	33,580	36,950	44,130	32,120	10,000	394,500	1.37
1947	26,140	38,060	29,010	31,840	89,450	20,930	25,090	36,570	30,090	22,900	350,100	1.21
1948	16,920	27,310	30,670	31,580	103,800	34,220	41,590	65,140	57,930	18,000	427,200	1.48
1949	18,710	26,280	25,460	28,850	112,200	39,260	44,610	63,830	39,750	7,300	406,200	1.41
1950	19,700	26,670	23,270	26,810	97,060	23,100	23,120	33,810	18,970	5,400	297,900	1.03
1951	32,550	44,130	32,770	34,320	116,500	16,680	16,090	29,360	20,010	6,450	348,900	1.21
1952	27,760	48,040	40,530	43,070	128,000	27,600	24,650	35,620	23,970	7,370	406,600	1.41
1953	23,480	42,330	36,560	34,970	111,900	21,400	24,590	33,360	28,930	10,120	367,600	1.27
1954	33,910	48,780	32,740	26,820	65,040	20,110	19,360	28,850	26,730	15,790	318,100	1.10
1955	32,110	43,480	38,110	30,080	87,600	25,560	24,390	20,930	12,610	6,510	321,400	1.11
1956	18,170	37,530	40,740	36,590	97,900	21,120	20,830	24,420	14,610	2,990	315,000	1.09
1957	15,330	23,270	21,520	23,170	88,850	25,720	21,680	25,670	23,710	7,170	276,100	.96
1958	28,300	43,390	34,750	33,360	122,000	42,720	43,960	51,600	33,300	10,930	444,300	1.54
1959	24,430	31,070	27,520	27,650	73,850	28,360	34,760	35,660	32,770	9,590	325,700	1.13
1960	32,510	48,270	39,630	37,760	119,300	45,740	54,250	68,830	41,800	13,700	501,800	1.74
Mean	23,830	36,050	31,360	30,840	98,030	28,380	29,590	40,460	26,930	9,687	355,200	1.23
Mean per square mile	1.80	1.72	1.75	1.59	1.24	1.00	1.02	1.02	.90	.90	1.23	
Drainage area in square miles	13,236	20,901	17,968	19,456	79,260	28,262	29,083	39,585	29,780	10,808	288,339	

[1] Includes 625 square miles of St. Croix River basin in New Brunswick and 114 square miles of Connecticut River basin in Quebec.

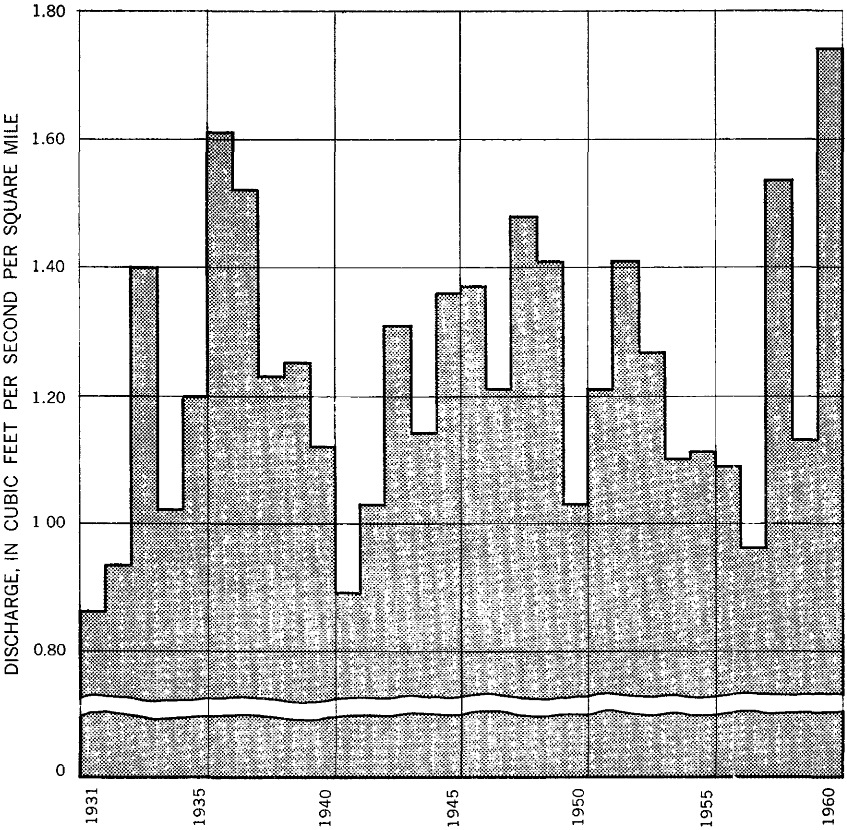

FIGURE 2.—Pattern of streamflow into the Atlantic Ocean, 1931–60.

to those bodies. The inflow to a bay or a sound and the outflow to the ocean are theoretically equivalent if adjustments were made for rainfall on and evaporation from the water surface of that body and for ground-water inflow. These items are probably relatively small, on the average, and probably constitute only a small percentage of the total inflow to that body of water. Hence, in this study no adjustments are attempted.

Chesapeake Bay is the largest bay discharging into the ocean, so that it is discussed briefly as an example of the probable magnitude of the adjustments that would be applicable for rainfall, evaporation, and ground-water inflow. The average annual rainfall on Chesapeake Bay is in the range of 32–48 inches (U.S. Weather Bureau, 1955), and the average annual evaporation is in the range of 36–40 inches (U.S. Weather Bureau, 1959, pl. 2). If the average annual rainfall is assumed to be 40 inches and the average annual evaporation, 38 inches, the net rainfall is only 2 inches, which on the 2,800 square miles of water surface of the bay is equivalent to about 400 cfs, or about one-half of 1 percent of the average inflow to the bay. The U.S. Geological Survey has estimated the upward leakage into the bay from artesian aquifers lying beneath it to be about 250 cfs and has qualified the estimate as possibly being in error by an order of magnitude, but the Survey has made no estimate of direct seepage along the shore (E. G. Otten, written commun., Aug. 17, 1967). Thus it appears that, on the average, the net effect of rainfall, evaporation, and groundwater inflow is small, percentagewise, although if a month of low streamflow were also a month of low rainfall and high evaporation, the net effect might constitute a large percentage of the total inflow.

In calculating the flow to the ocean for the period 1951–60, the most downstream gaging-station records of required length were used. These records were about 240 in number and accounted for about three-fourths of the drainage area between the Canadian border and Cape Kennedy. Flow from the ungaged areas between the Canadian border and Cape Kennedy was estimated on the basis of nearby gaging stations. Between Cape Kennedy and Cape Sable the streamflow to the ocean is so complicated by canals and drainage facilities that the author made no attempt to calculate flow to the ocean on the basis of streamflow records; for this part of the coastline, flow records were furnished by the Tallahassee office of the U.S. Geological Survey.

DISCHARGE OF THE HUDSON RIVER AT MOUTH, 1890–1960

Discharge of the Hudson River at mouth was computed for the years 1890–1960. Streamflow records available were as follows: Hudson River at Mechanicville, 1890–1955; Mohawk River at Cohoes (at Vischer Ferry Dam prior to 1919), 1899–1960; Hudson River at Green Island, 1947–60; and records from seven small streams below Green Island, 1929–60. The gaging stations on these seven streams were as follows: Poesten Kill near Troy, 89 square miles; Kinderhook Creek at Rossman, 329 square miles; Catskill Creek at Oakhill, 98 square miles; Esopus Creek at Coldbrook, 192 square miles; Rondout Creek at Rosendale, 386 square miles; Wallkill River at Gardiner, 711 square miles; and Wappinger Creek near Wappinger Falls, 182 square miles.

These seven records were used as a basis for estimating the ungaged flow below the Mohawk River prior to 1947 and below Green Island thereafter for the period 1929–60. A graphical relation between the flow at Mechanicville and the flow at mouth for the period 1929–55 was used to estimate the flow at mouth for the period 1890–1928. Discharge of the Hudson River is shown in table 14.

TABLE 4.—*Discharge, in cubic feet per second, from reaches 1–4, segment 1*

Water year	Reach 1 [1]	Reach 2	Reach 3	Reach 4 [2]	Segment 1
1931	2, 645	1, 156	1, 552	11, 680	17, 030
1932	3, 947	1, 434	2, 003	15, 690	23, 070
1933	4, 090	1, 519	2, 024	15, 600	23, 230
1934	4, 721	1, 779	2, 086	15, 840	24, 430
1935	4, 538	1, 680	2, 252	15, 360	23, 830
1936	5, 220	1, 791	2, 543	18, 890	28, 440
1937	4, 161	1, 571	2, 106	16, 030	23, 870
1938	3, 796	1, 650	2, 127	16, 180	23, 750
1939	4, 556	1, 607	2, 045	15, 340	23, 550
1940	3, 835	1, 547	2, 179	16, 000	23, 560
1941	3, 340	1, 022	1, 459	11, 750	17, 570
1942	3, 782	1, 486	1, 829	13, 770	20, 870
1943	3, 454	1, 385	1, 561	12, 760	19, 160
1944	3, 803	1, 519	2, 086	13, 810	21, 220
1945	5, 245	1, 951	2, 585	19, 160	28, 940
1946	4, 097	1, 451	1, 828	14, 970	22, 350
1947	4, 087	1, 636	2, 293	18, 120	26, 140
1948	3, 475	1, 013	1, 275	11, 160	16, 920
1949	3, 166	1, 232	1, 633	12, 680	18, 710
1950	3, 705	1, 323	1, 613	13, 060	19, 700
1951	6, 278	2, 276	2, 725	21, 270	32, 550
1952	5, 403	2, 046	2, 560	17, 750	27, 760
1953	4, 333	1, 633	2, 169	15, 350	23, 480
1954	5, 840	2, 341	2, 966	22, 760	33, 910
1955	6, 167	2, 012	2, 342	21, 590	32, 110
1956	3, 477	1, 159	1, 510	12, 020	18, 170
1957	2, 844	999	1, 310	10, 180	15, 330
1958	4, 738	1, 788	2, 294	19, 480	28, 300
1959	4, 754	1, 569	2, 201	15, 910	24, 430
1960	6, 368	2, 120	2, 928	21, 090	32, 510
Mean	4, 330	1, 590	2, 069	15, 840	23, 830
Drainage area in square miles	2, 358	797	1, 034	9, 047	13, 236

[1] Includes 625 square miles of St. Croix River basin in New Brunswick and 114 square miles of Connecticut River basin in Quebec.
[2] Penobscot Bay.

TABLE 5.—*Discharge, in cubic feet per second, from reaches 5–10, segment 2*

Water year	Reach 5	Reach 6	Reach 7	Reach 8	Reach 9 [1]	Reach 10 [2]	Segment 2
1931	13, 570	4, 135	1, 094	6, 714	1, 292	406	27, 210
1932	15, 920	3, 983	1, 176	7, 159	988	302	29, 530
1933	18, 370	5, 190	1, 776	11, 280	1, 560	547	38, 720
1934	16, 570	4, 367	1, 248	8, 630	1, 251	413	32, 480
1935	18, 180	5, 310	1, 601	9, 559	1, 267	384	36, 300
1936	22, 170	6, 678	1, 930	10, 640	1, 377	422	43, 220
1937	20, 630	6, 265	1, 816	10, 430	1, 309	449	40, 900
1938	18, 680	5, 426	1, 693	12, 550	1, 760	535	40, 640
1939	17, 050	5, 172	1, 572	10, 590	1, 311	442	36, 140
1940	16, 720	5, 082	1, 445	8, 554	1, 178	413	33, 390
1941	10, 920	3, 241	932	5, 550	917	341	21, 900
1942	14, 390	3, 700	958	6, 448	1, 008	286	26, 790
1943	16, 300	4, 707	1, 327	8, 796	1, 233	374	32, 740
1944	17, 660	5, 168	1, 279	7, 844	956	216	33, 120
1945	22, 090	6, 398	1, 910	10, 860	1, 490	413	43, 160
1946	17, 540	5, 408	1, 589	9, 918	1, 566	554	36, 580
1947	20, 600	5, 617	1, 530	8, 849	1, 125	334	38, 060
1948	12, 620	3, 712	1, 036	7, 922	1, 480	542	27, 310
1949	13, 370	4, 117	1, 160	6, 255	1, 010	365	26, 280
1950	13, 980	4, 151	995	6, 373	954	221	26, 670
1951	23, 030	6, 645	1, 880	10, 880	1, 357	336	44, 130
1952	22, 170	8, 068	2, 552	13, 320	1, 501	425	48, 040
1953	19, 880	6, 857	2, 165	11, 450	1, 513	466	42, 330
1954	25, 800	7, 029	2, 096	11, 560	1, 758	535	48, 780
1955	22, 750	6, 030	1, 700	10, 620	1, 877	499	43, 480
1956	16, 110	5, 263	1, 771	11, 840	1, 967	576	37, 530
1957	11, 520	3, 483	1, 080	5, 710	1, 147	331	23, 270
1958	22, 500	5, 962	1, 823	10, 830	1, 718	557	43, 390
1959	16, 840	3, 898	1, 114	7, 236	1, 515	466	31, 070
1960	24, 590	7, 154	2, 092	12, 310	1, 660	461	48, 270
Mean	18, 080	5, 274	1, 544	9, 356	1, 368	420	36, 050
Drainage area in square miles	10, 492	2, 763	925	5, 807	674	240	20, 901

[1] Massachusetts Bay Includes sewage waste from Boston, averaging 466 cfs during 1931–60. (See table 16).
[2] Cape Cod Bay.

TABLE 6.—*Discharge, in cubic feet per second, from reaches 11–16, segment 3*

Water year	Reach 11	Reach 12	Reach 13	Reach 14	Reach 15	Reach 16	Segment 3
1931	1, 102	2, 448	493	16, 130	2, 928	327	23, 430
1932	821	1, 689	412	16, 840	2, 461	247	22, 470
1933	1, 485	3, 457	733	24, 130	4, 388	517	34, 710
1934	1, 122	2, 660	659	20, 990	4, 055	651	30, 140
1935	1, 044	2, 789	659	22, 040	3, 949	505	30, 990
1936	1, 148	2, 847	716	24, 120	3, 770	533	33, 130
1937	1, 219	2, 926	762	25, 610	4, 600	644	35, 760
1938	1, 455	3, 897	1, 111	28, 760	6, 105	870	42, 200
1939	1, 199	2, 953	733	24, 910	4, 763	654	35, 210
1940	1, 122	2, 553	768	21, 400	4, 284	664	30, 790
1941	927	1, 882	516	14, 430	2, 689	388	20, 830
1942	777	1, 825	453	17, 370	3, 147	504	24, 080
1943	1, 019	2, 437	596	23, 520	4, 604	671	32, 850
1944	588	1, 441	423	17, 900	2, 933	423	23, 710
1945	1, 122	2, 801	687	25, 360	5, 140	594	35, 700
1946	1, 507	3, 155	720	21, 620	3, 982	562	31, 550
1947	906	2, 076	498	21, 820	3, 280	433	29, 210
1948	1, 473	3, 182	789	20, 250	4, 321	651	30, 670
1949	991	2, 100	530	17, 440	3, 890	507	25, 460
1950	600	1, 556	445	17, 400	2, 981	284	23, 270
1951	912	2, 537	555	23, 620	4, 548	594	32, 770
1952	1, 154	3, 095	720	28, 710	6, 013	837	40, 530
1953	1, 265	3, 049	763	25, 470	5, 305	705	36, 560
1954	1, 454	3, 205	792	23, 520	3, 423	347	32, 740
1955	1, 346	3, 549	806	26, 500	5, 285	628	38, 110
1956	1, 564	3, 938	892	27, 610	5, 853	878	40, 740
1957	899	1, 958	487	15, 240	2, 595	344	21, 520
1958	1, 514	3, 330	880	24, 120	4, 228	677	34, 750
1959	1, 264	2, 832	719	18, 620	3, 638	442	27, 520
1960	1, 251	3, 108	629	29, 140	4, 949	553	39, 630
Mean	1, 142	2, 709	665	22, 150	4, 137	554	31, 360
Drainage area in square miles	653	1, 505	**338**	**12, 825**	**2, 329**	**318**	**17, 968**

TABLE 7.—*Discharge, in cubic feet per second, from reaches 17–20, segment 4*

Water year	Reach 17	Reach 18 [1]	Reach 19	Reach 20	Segment 4
1931	770	18, 390	823	1, 089	21, 070
1932	910	21, 160	866	1, 305	24, 240
1933	1, 140	29, 700	1, 359	2, 433	34, 630
1934	910	22, 520	1, 142	2, 019	26, 590
1935	990	24, 190	1, 165	2, 234	28, 580
1936	1, 090	27, 870	1, 405	2, 744	33, 110
1937	1, 120	28, 200	1, 462	2, 233	33, 020
1938	1, 150	29, 960	1, 763	2, 199	35, 070
1939	1, 070	27, 600	1, 759	3, 177	33, 610
1940	990	24, 850	1, 317	2, 434	29, 590
1941	780	19, 130	1, 208	1, 978	23, 100
1942	830	20, 550	988	1, 320	23, 690
1943	1, 270	31, 990	1, 160	1, 701	36, 120
1944	870	21, 990	1, 485	1, 939	26, 280
1945	1, 230	31, 800	1, 495	1, 970	36, 500
1946	1, 090	28, 240	1, 471	2, 372	33, 170
1947	1, 120	28, 060	1, 077	1, 588	31, 840
1948	1, 010	26, 550	1, 588	2, 434	31, 580
1949	960	23, 860	1, 459	2, 569	28, 850
1950	980	23, 400	959	1, 474	26, 810
1951	993	30, 530	1, 118	1, 682	34, 320
1952	1, 340	37, 150	1, 739	2, 841	43, 070
1953	1, 226	29, 560	1, 541	2, 643	34, 920
1954	879	23, 180	1, 060	1, 700	26, 820
1955	1, 035	26, 470	1, 085	1, 492	30, 080
1956	1, 307	32, 340	1, 217	1, 727	36, 590
1957	889	19, 480	1, 040	1, 757	23, 170
1958	1, 279	27, 410	1, 838	2, 838	33, 360
1959	1, 001	22, 870	1, 370	2, 408	27, 650
1960	1, 112	33, 120	1, 412	2, 121	37, 760
Mean	1, 045	26, 400	1, 312	2, 081	30, 840
Drainage area in square miles	1, 556	15, 816	793	1, 291	19, 456

[1] Includes water used by New York City (see table 1) averaging 1,578 cfs during 1931–60.

TABLE 8.—*Discharge, in cubic feet per second, from reaches 21–23, segment 5*

Water year	Reach 21, Delaware Bay		Reach 22	Reach 23, Chesapeake Bay [1]		Segment 5
	Unadjusted [2]	Adjusted [2]		Unadjusted [2]	Adjusted [2]	
1931	12, 570	12, 770	497	44, 300	44, 100	57, 370
1932	13, 320	13, 520	543	54, 700	54, 500	68, 560
1933	26, 200	26, 400	1, 877	91, 200	91, 000	119, 300
1934	17, 790	17, 990	1, 194	52, 700	52, 500	71, 680
1935	20, 880	21, 080	1, 510	84, 400	84, 200	106, 800
1936	25, 100	25, 600	1, 923	90, 900	90, 400	117, 900
1937	19, 940	20, 740	994	93, 600	92, 800	114, 500
1938	23, 290	24, 290	1, 445	69, 800	68, 800	94, 540
1939	23, 210	24, 210	1, 793	69, 600	68, 600	94, 600
1940	20, 330	21, 330	1, 352	76, 100	75, 100	97, 780
1941	16, 310	17, 310	999	57, 700	56, 700	75, 010
1942	16, 980	17, 980	706	62, 300	61, 300	79, 990
1943	23, 500	24, 500	1, 398	99, 800	98, 800	124, 700
1944	17, 000	18, 000	799	64, 800	63, 800	82, 600
1945	23, 950	24, 950	1, 343	82, 600	81, 600	107, 900
1946	22, 980	23, 980	1, 561	89, 600	88, 600	114, 100
1947	20, 440	21, 440	813	68, 200	67, 200	89, 450
1948	22, 820	23, 820	1, 589	79, 400	78, 400	103, 800
1949	20, 340	21, 340	1, 695	90, 200	89, 200	112, 200
1950	17, 980	18, 980	883	78, 200	77, 200	97, 060
1951	23, 550	24, 550	683	92, 220	91, 220	116, 500
1952	31, 440	32, 440	1, 580	95, 010	94, 010	128, 000
1953	25, 880	26, 880	1, 134	84, 850	83, 850	111, 900
1954	15, 040	16, 040	715	49, 290	48, 290	65, 040
1955	18, 050	19, 050	855	68, 690	67, 690	87, 600
1956	22, 540	23, 540	984	74, 380	73, 380	97, 900
1957	16, 390	17, 390	1, 296	71, 160	70, 160	88, 850
1958	23, 730	24, 730	2, 053	96, 250	95, 250	122, 000
1959	16, 370	17, 370	1, 167	56, 310	55, 310	73, 850
1960	23, 860	24, 860	1, 463	93, 930	92, 930	119, 300
Mean	20, 730	21, 570	1, 228	76, 070	75, 230	98, 030
Drainage area in square miles	12, 855		929	65, 476		79, 260

[1] Includes water diverted from Gunpowder and Patapsco Rivers above gaging stations by city of Baltimore and wasted into Bay, estimated at 318 cfs during 1951–60; discharge into bay determined graphically for 1931–50, so no separate estimate of wastage made for that period.

[2] Adjustment is for water carried from Chesapeake Bay to Delaware River by Chesapeake and Delaware Canal, estimated at 200 cfs in 1931–35, 500 cfs in 1936, 800 cfs in 1937, and 1,000 cfs in 1938–60. Adjustment not applicable to total for segment.

TABLE 9.—*Discharge, in cubic feet per second, from reaches 24 and 25, segment 6*

Water year	Reach 24 [1]	Reach 25 [2]	Segment 6	Water year	Reach 24 [1]	Reach 25 [2]	Segment 6
1931	10,900	8,150	19,050	1950	16,260	6,840	23,100
1932	10,510	5,440	15,950	1951	12,080	4,597	16,680
1933	17,970	9,250	27,220	1952	18,380	9,215	27,600
1934	14,580	7,690	22,270	1953	12,540	8,856	21,400
1935	21,150	11,450	32,600	1954	11,160	8,950	20,110
1936	25,060	17,080	42,140	1955	14,440	11,120	25,560
1937	24,140	18,360	42,500	1956	12,570	8,549	21,120
1938	23,540	9,630	33,170	1957	17,130	8,587	25,720
1939	20,470	14,820	35,290	1958	25,790	16,930	42,720
1940	21,200	8,590	29,790	1959	14,010	14,350	28,360
1941	12,580	6,380	18,960	1960	25,640	20,100	45,740
1942	10,210	4,970	15,180				
1943	17,660	11,860	29,520	Mean	17,550	10,830	28,380
1944	16,040	9,780	25,820				
1945	21,750	14,170	35,920				
1946	20,510	13,070	33,580				
1947	13,520	7,410	20,930				
1948	20,570	13,650	34,220	Drainage area in square miles	17,651	10,611	28,262
1949	24,060	15,200	39,260				

[1] Albemarle Sound.
[2] Pamlico Sound.

TABLE 10.—*Discharge, in cubic feet per second, from reaches 26 and 27, segment 7*

Water year	Reach 26	Reach 27	Segment 7	Water year	Reach 26	Reach 27	Segment 7
1931	8,880	14,170	23,050	1950	9,020	14,100	23,120
1932	7,960	13,510	21,470	1951	5,867	10,220	16,090
1933	10,600	21,740	32,340	1952	9,368	15,280	24,650
1934	6,900	9,900	16,800	1953	8,810	15,780	24,590
1935	11,250	16,850	28,100	1954	7,309	12,050	19,360
1936	18,580	28,530	47,110	1955	11,800	12,590	24,390
1937	17,180	25,910	43,090	1956	8,797	12,030	20,830
1938	7,360	15,230	22,590	1957	9,164	12,520	21,680
1939	14,390	20,340	34,730	1958	16,010	27,950	43,960
1940	7,140	10,910	18,050	1959	14,390	20,370	34,760
1941	6,500	12,390	18,890	1960	18,860	35,390	54,250
1942	6,600	16,900	23,500				
1943	12,050	13,590	30,640	Mean	11,290	18,280	29,590
1944	13,420	19,620	33,040				
1945	15,690	22,560	38,250				
1946	14,770	22,180	36,950				
1947	9,380	15,710	25,090				
1948	13,880	27,710	41,590	Drainage area in square miles	10,521	18,562	29,083
1949	16,900	27,710	44,610				

TABLE 11.—*Discharge, in cubic feet per second, from reaches 28–30, segment 8*

Water year	Reach 28	Reach 29	Reach 30	Segment 8
1931	18, 470	10, 400	3, 273	32, 140
1932	20, 700	13, 110	3, 489	37, 300
1933	28, 920	15, 730	4, 651	49, 300
1934	17, 850	11, 000	3, 111	31, 960
1935	22, 100	12, 200	3, 410	37, 710
1936	35, 310	23, 250	9, 436	68, 000
1937	35, 060	21, 040	8, 768	64, 870
1938	20, 600	12, 690	2, 907	36, 200
1939	21, 900	13, 180	3, 686	38, 770
1940	13, 650	12, 270	3, 367	29, 290
1941	15, 850	10, 430	3, 323	29, 600
1942	20, 420	13, 180	5, 496	39, 100
1943	24, 100	15, 770	3, 906	43, 780
1944	22, 850	15, 590	6, 391	44, 830
1945	20, 560	10, 050	2, 684	33, 290
1946	24, 790	15, 430	3, 911	44, 130
1947	18, 140	13, 410	5, 024	36, 570
1948	30, 440	22, 860	11, 840	65, 140
1949	33, 520	23, 000	7, 309	63, 830
1950	19, 680	12, 250	1, 881	33, 810
1951	16, 250	10, 060	3, 049	29, 360
1952	19, 160	12, 750	3, 709	35, 620
1953	18, 220	10, 740	4, 403	33, 360
1954	15, 460	10, 290	3, 101	28, 850
1955	10, 680	8, 006	2, 248	20, 930
1956	12, 770	8, 648	2, 997	24, 420
1957	13, 280	9, 515	2, 873	25, 670
1958	27, 600	16, 860	7, 141	51, 600
1959	20, 070	11, 290	4, 305	35, 660
1960	37, 880	22, 340	8, 610	68, 830
Mean	21, 880	13, 910	4, 677	40, 460
Drainage area in square miles	20, 545	13, 445	5, 595	39, 585

TABLE 12.—*Discharge, in cubic feet per second, from reaches 31 and 32, segment 9*

Water year	Reach 31	Reach 32	Segment 9	Water year	Reach 31	Reach 32	Segment 9
1931	12, 110	9, 665	21, 780	1950	10, 570	8, 399	18, 970
1932	12, 740	4, 554	17, 290	1951	11, 930	8, 081	20, 010
1933	22, 120	9, 033	31, 150	1952	15, 920	8, 052	23, 970
1934	11, 740	11, 760	23, 500	1953	16, 470	12, 460	28, 930
1935	9, 994	5, 721	15, 720	1954	13, 920	12, 810	26, 730
1936	23, 480	9, 594	33, 070	1955	6, 949	5, 661	12, 610
1937	21, 810	6, 725	28, 540	1956	9, 973	4, 634	14, 610
1938	12, 750	8, 348	21, 100	1957	14, 210	9, 500	23, 710
1939	15, 340	6, 698	22, 040	1958	24, 340	8, 959	33, 300
1940	12, 290	6, 641	18, 930	1959	19, 040	13, 730	32, 770
1941	10, 050	9, 984	20, 030	1960	23, 890	17, 910	41, 800
1942	20, 840	13, 830	34, 670				
1943	16, 310	6, 318	22, 630	Mean	17, 210	9, 717	26, 930
1944	23, 930	9, 595	33, 520				
1945	15, 390	11, 260	26, 650	Drainage area in square miles	19, 625	10, 155	29, 780
1946	20, 040	12, 080	32, 120				
1947	18, 970	11, 120	30, 090				
1948	41, 320	16, 610	57, 930				
1949	27, 960	11, 790	39, 750				

TABLE 13.—*Discharge, in cubic feet per second, from reaches 33 and 34, segment 10*

[Records furnished by Tallahassee Office, U.S. Geol. Survey]

Water year	Reach 33	Reach 34	Segment 10	Water year	Reach 33	Reach 34	Segment 10
1931	1,600	5,600	7,200	1950	1,800	3,600	5,400
1932	1,500	6,400	7,900	1951	1,850	4,600	6,450
1933	2,500	9,900	12,400	1952	1,670	5,700	7,370
1934	1,800	13,000	14,800	1953	1,920	8,200	10,120
1935	1,100	4,100	5,200	1954	2,790	13,000	15,790
1936	2,200	15,000	17,200	1955	1,610	4,900	6,510
1937	3,200	7,800	11,000	1956	1,190	1,800	2,990
1938	1,400	2,600	4,000	1957	2,670	4,500	7,170
1939	1,300	3,800	5,100	1958	1,730	9,200	10,930
1940	2,100	11,000	13,100	1959	2,290	7,300	9,590
1941	2,400	9,300	11,700	1960	3,700	10,000	13,700
1942	2,000	8,300	10,300				
1943	1,600	3,800	5,400	Mean	1,994	7,693	9,687
1944	1,300	3,300	4,600				
1945	1,600	4,900	6,500	Drainage area in square miles	1,357	9 451	10,808
1946	1,500	8,500	10,000				
1947	2,900	20,000	22,900				
1948	3,000	15,000	18,000				
1949	1,600	5,700	7,300				

TABLE 14.—*Annual discharge of Hudson River at mouth (13,366 sq mi), 1890–1960*

[Means for the following periods: 1890–1960 (71 yr) = 21,520 cfs; 1931–60 (30 yrs) = 21,300 cfs; 1921–45 (25 yr) = 20,660 cfs; 1951–60 (10 yr) = 22,790 cfs]

Water year	Cubic feet per second	Water year	Cubic feet per second	Water year	Cubic feet per second	Water year	Cubic feet per second
1890	25,970	1908	27,930	1926	22,300	1944	17,130
1891	22,770	1909	20,370	1927	18,120	1945	25,720
1892	30,210	1910	19,100	1928	28,620	1946	22,480
1893	21,570	1911	13,640	1929	21,020	1947	23,270
1894	17,790	1912	22,500	1930	16,550	1948	20,440
1895	16,400	1913	24,200	1931	14,570	1949	18,870
1896	21,410	1914	19,380	1932	18,020	1950	19,760
1897	25,800	1915	17,250	1933	23,650	1951	24,870
1898	24,180	1916	22,560	1934	17,960	1952	29,640
1899	20,420	1917	20,280	1935	19,900	1953	23,460
1900	20,270	1918	17,830	1936	22,420	1954	19,450
1901	20,720	1919	20,080	1937	23,160	1955	21,490
1902	24,380	1920	20,510	1938	23,880	1956	26,830
1903	26,810	1921	19,620	1939	21,990	1957	15,080
1904	24,390	1922	24,290	1940	20,070	1958	21,420
1905	24,840	1923	16,380	1941	14,770	1959	18,450
1906	24,440	1924	21,950	1942	16,020	1960	27,250
1907	20,600	1925	21,580	1943	26,840		

As explained on page I2, the Croton River basin above Croton Dam was considered as being noncontributing, because the entire flow of the Croton River, except for spill over Croton Dam, is diverted for the New York City water supply. The spill, which is measured at a gaging station a short distance below the dam, was added to the flow of the Hudson River. Table 15 gives the spill from Croton Reservoir. Gaging-station records are available since 1934. During the period 1934–60, the spill ranged from 1 cfs in 1942 to 849 cfs in 1956 and averaged 237 cfs for the 27 years. A flat estimate of 235 cfs was made for the years prior to 1934.

DISCHARGE OF THE CHARLES RIVER AT MOUTH, 1930–60

The discharge of the Charles River at mouth was estimated by the Boston district of the U.S. Geological Survey. Below the gaging station at Waltham, the discharge is complicated by storm sewers, some of which carry water into the basin and some out of the basin. The discharge was estimated by calendar years to be consistent with the figures of waste from Boston sewers, the figures being furnished by the Massachusetts Metropolitan District Commission by calendar years. The waste was not added to the Charles River but was included in the discharge of Boston Bay into the ocean. Discharge of the Charles River and the waste into Boston Harbor are shown in table 16.

TABLE 15.—*Spill from Croton Reservoir*

Water year	Cubic feet per second	Water year	Cubic feet per second	Water year	Cubic feet per second
1890–1933	[1] 235	1943	255	1953	452
1934	276	1944	16	1954	2
1935	206	1945	226	1955	289
1936	210	1946	232	1956	849
1937	255	1947	51	1957	184
1938	558	1948	137	1958	341
1939	434	1949	48	1959	223
1940	55	1950	2	1960	308
1941	34	1951	273		
1942	1	1952	476	Mean for 1934–60	237

[1] Estimated.

MEAN MONTHLY DISCHARGE OF PENOBSCOT AND JAMES RIVERS, 1951–60

The mean monthly discharge of the Penobscot and James Rivers at mouth for the period 1951–60 is shown in table 17. Mean monthly discharge is shown graphically in figure 3, expressed as a percentage of the mean, to give a better visual comparison of the monthly distribution of discharge of these two widely separated streams. The drainage area of the Penobscot River is 14 percent less than that of the James River, but mean annual discharge during the 10-year period was 67 percent greater; in other words, the mean discharge per square mile of the Penobscot River was nearly double that of the James River. (See also table 18.)

TABLE 16.—*Annual discharge, in cubic feet per second, of the Charles River at mouth (275 sq mi) and sewage waste into Boston Harbor, 1920–60*

Calendar year	Charles River	Waste	Total	Calendar year	Charles River	Waste	Total
1920	440	340	780	1941	140	410	550
1921	314	328	642	1942	215	419	634
1922	357	319	676	1943	226	498	724
1923	404	323	727	1944	191	455	646
1924	315	316	631	1945	307	554	861
1925	302	337	639	1946	278	525	803
1926	288	343	631	1947	215	460	675
1927	496	370	866	1948	286	511	797
1928	400	347	747	1949	163	415	578
1929	337	350	687	1950	179	456	635
1930	190	336	526	1951	314	478	792
1931	330	370	700	1952	273	495	768
1932	231	351	582	1953	334	529	863
1933	314	378	692	1954	391	562	953
1934	267	367	634	1955	497	579	1,076
1935	281	379	660	1956	392	605	997
1936	332	416	748	1957	182	518	700
1937	292	398	690	1958	390	549	939
1938	422	439	861	1959	355	518	873
1939	249	398	647	1960	479	534	1,013
1940	245	401	646				
				Mean for 1931–60	292	466	758

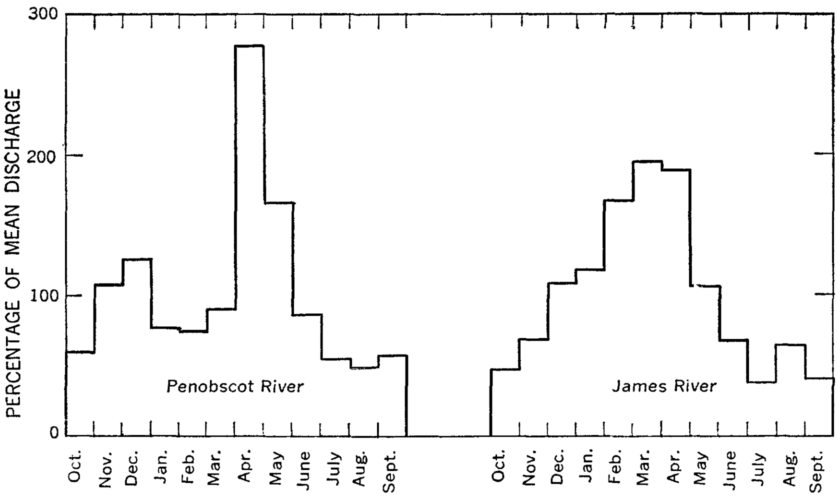

FIGURE 3.—Mean monthly discharge of Penobscot and James Rivers, 1951–60.

DISCHARGE OF PRINCIPAL RIVERS, 1951–60 AND 1931–60

Table 18 gives the average discharge at mouth of 33 selected rivers for the periods 1951–60 and 1931–60. The table also gives the drainage area of each and the discharge expressed in cubic feet per second per square mile. With the exception of the Schuylkill River, which is tributary to the Delaware, these rivers empty directly into the Atlantic Ocean, or into a sound or a bay. The list includes most of the coastal streams that have drainage areas greater than 1,000 square miles. Stream names are in the order from north to south, going counterclockwise around Chesapeake Bay. The State names shown are the States through or between which the rivers flow at their mouths, regardless of how much of their drainage basins may be in another State.

TABLE 17.—*Mean monthly discharge, in cubic feet per second, of the Penobscot and James Rivers, 1951–60*

Month	Penobscot River [1]	James River	Month	Penobscot River [1]	James River
October	9, 849	4, 774	June	14, 050	6, 678
November	17, 540	6, 933	July	8, 730	3, 832
December	20, 750	10, 940	August	8, 125	6, 305
January	12, 270	11, 760	September	9, 548	4, 051
February	12, 030	16, 660			
March	14, 850	19, 370	Drainage area in square miles	8, 570	10, 002
April	46, 160	18, 900			
May	27, 300	10, 550			

[1] Does not include two areas of about 223 and 254 square miles that contribute to the north and south shores of Penobscot Bay.

TABLE 18.—*Discharge of principal rivers, 1951–60 and 1931–60*

River	Drainage area (sq mi)	Mean discharge (cfs)		Cubic feet per second per square mile	
		1951–60	1931–60	10 year	30 year
Part 1-A					
St. Croix, Maine and New Brunswick	1, 635	3, 325	2, 840	2. 03	1. 74
Penobscot, Maine	8, 570	16, 750	14, 970	1. 95	1. 75
Kennebec, Maine	5, 970	11, 220	9, 871	1. 88	1. 65
Androscoggin, Maine	3, 470	7, 229	6, 440	2. 08	1. 85
Saco, Maine	1, 730	4, 040	3, 545	2. 34	2. 05
Merrimack, Massachusetts	[1] 4, 800	[2] 8, 901	[2] 7, 962	1. 85	1. 66
Thames, Connecticut	1, 473	2, 976	2, 645	2. 02	1. 80
Connecticut, Connecticut	11, 250	21, 070	19, 320	1. 87	1. 72
Housatonic, Connecticut	1, 949	3, 799	3, 422	1. 95	1. 76
Part 1-B					
Hudson, New York and New Jersey	[3] 13, 366	[4] 22, 790	[4] 21, 300	[5] 1. 73	[5] 1. 62
Raritan, New Jersey	1, 105	1, 625	1, 580	1. 47	1. 43
Schuylkill, Pennsylvania	1, 916	[6] 3, 145	[6] 2, 960	1. 64	1. 54
Delaware, Delaware and New Jersey	11, 415	[7] 19, 750	[7] 18, 870	1. 73	1. 65
Susquehanna, Maryland	27, 469	[8] 40, 290	[8] 38, 100	1. 47	1. 39
Potomac, Maryland and Virginia	13, 670	[9] 14, 040	[9] 14, 000	1. 03	1. 02
Rappahannock, Virginia	2, 718	2, 475	2, 705	. 91	1. 00
York, Virginia	2, 663	2, 423	----------	. 91	------

See footnotes at end of table.

TABLE 18.—*Discharge of principal rivers, 1951–60 and 1931–60*—Continued

River	Drainage area (sq mi)	Mean discharge (cfs)		Cubic feet per second per square mile	
		1951–60	1931–60	10 year	30 year
		Part 2–A			
James, Virginia	10, 002	[10] 10, 030	[10] 10, 690	1. 00	1. 07
Chowan, North Carolina	4, 929	4, 626	----------	. 94	------
Roanoke, North Carolina	9, 666	8, 620	9, 585	. 89	. 99
Pamlico, North Carolina	4, 302	4, 693	----------	1. 09	------
Neuse, North Carolina	5, 598	5, 703	5, 903	1. 02	1. 06
Cape Fear, North Carolina	9, 136	9, 475	----------	1. 04	------
Waccamaw, South Carolina	1, 580	1, 522	----------	. 96	------
Pee Dee, South Carolina	16, 310	15, 270	15, 830	. 94	. 97
Santee, South Carolina	15, 700	[11] 15, 400	[11] 17, 300	. 98	1. 10
Edisto, South Carolina	3, 045	2, 430	----------	. 80	------
Savannah, South Carolina and Georgia	10, 600	10, 280	12, 030	. 97	1. 13
		Part 2–B			
Ogeechee, Georgia	4, 625	3, 513	3, 878	0. 76	0. 84
Altamaha, Georgia	14, 200	12, 140	13, 140	. 85	. 93
Satilla, Georgia	3, 440	2, 146	2, 460	. 62	. 72
St. Marys, Georgia and Florida	1, 480	1, 064	1, 253	. 72	. 85
St. Johns, Florida	8, 740	8, 867	8, 404	1. 01	. 96

[1] Excludes 210 square miles set aside for municipal use by city of Boston. (See p. I33.)
[2] Adjusted for wastage; represents runoff from net area of 4,800 square miles. (See p. I33.)
[3] Includes 378 square miles in Croton River basin.
[4] Includes spill from Croton Reservoir. (See table 15.)
[5] Based on net drainage area of 12,988 square miles, and excluding spill from Croton Reservoir.
[6] Adjusted for diversion made by city of Philadelphia.
[7] Does not include diversion from Chesapeake Bay to Delaware River through Chesapeake and Delaware Canal, estimated at 1,000 cfs for period 1951–60 and 840 cfs for period 1931–60.
[8] Not adjusted for small diversions to Baltimore and Chester (which in 1967 averaged 73 cfs).
[9] Adjusted for diversions made above gaging station near District of Columbia and wasted back into river below station.
[10] Includes flow of James River and Kanawha Canal.
[11] Completely regulated; reconstructed record including diversion to Cooper River basin.

COMPARISON BETWEEN DIFFERENT PERIODS

Mean discharges for 1951–60, 1931–60, and period of record through 1966 is shown in table 19 for gaging stations on 26 principal rivers along the coast. The gaging stations are either the farthest downstream on the rivers or the stations with the longest record if the most downstream records were less than 30 years in length.

As the purpose of this study was to calculate actual streamflow into the Atlantic Ocean, the figures of mean discharge shown for 1931–60 and 1951–60 in table 19 are the observed discharge unless otherwise indicated, with the exception of the Schuylkill and Potomac Rivers, which were adjusted for water diverted above the gaging station and wasted back into the river below the gaging station. In the column showing mean discharge during the period of record, several means are qualified as being adjusted for storage or for diversions or both. These adjustments may be fairly large in some years, but over the period of record, the net effect is relatively small. Adjustments for storage may be either plus or minus in successive years, although if storage began during the period of record, the net adjustment to the period mean will always be plus. Adjustments for diversions are, of course, always in the same direction at any one gaging station.

In the Androscoggin River basin, a group of reservoirs upstream from the Auburn gaging station have a combined capacity of about 700,000 acre-feet (30.3 billion cubic feet). During the 38-year period of record 1929–66, the yearly adjustments ranged from minus 402 cfs to plus 460 cfs. However, the adjustment to the mean for the period of record was only minus 2 cfs; the adjustment applicable to the 10-year mean is plus 2 cfs; and no adjustment is applicable to the 30-year mean. At the end of the 1966 water year, the amount of water in storage was about 443,500 acre-feet. Had storage begun during the period of record at Auburn, the adjustment applicable to the 38-year mean would have been plus 16 cfs.

In the Roanoke River basin, facilities for a large amount of storage have been constructed since 1950, and in some years since then the adjustments applicable to the observed yearly mean have been large. In 1953, for example, 1,110 cfs was stored. However, the adjustment applicable to the observed mean for 1951–60 is only plus 215 cfs, and to the observed mean for 1931–60, only plus 71 cfs. The adjusted mean for the 54-year period of record 1913–66 includes an adjustment of only 47 cfs.

It is evident from the records on the Androscoggin and Roanoke Rivers that long-term means at gaging stations are little affected by storage unless storage begins during the period of record at the gaging station. If a large amount of water is stored during the period of record, a short-term mean can, of course, be affected considerably.

The means shown for the Savannah River at Augusta are all observed. There is considerable regulation by four reservoirs upstream from Augusta, and in the 1966 water year the monthly adjustment applicable ranged from minus 1,628 cfs to plus 3,765 cfs, but the net adjustment applicable to the yearly mean for 1966 was only plus 1 cfs.

In the published records of discharge for Merrimack River below Concord River, at Lowell, Mass., the average discharge shown for the period of record has been adjusted for wastage into the Merrimack River. The figures of daily discharge are the observed discharge; the monthly summaries show both the observed monthly means and the monthly means adjusted for wastage. The term "wastage" as used here bears explanation. A tributary area of 210 square miles in the

TABLE 19.—*Comparison between means for 10- and 30-year periods and period of record at selected gaging stations on principal rivers*

Part	River	Location	Drainage area (sq. mi.)	Tributary to—	Mean discharge (cfs)			Percentage ratio 10-year to 30-year mean
					10 years 1951–60	30 years 1931–60	Period of record through 1966[1]	
1-A	St. Croix	Near Baileyville, Me.	1,320	Passamaquoddy Bay	2,659	2,271	(47) 2,247	+17
	Penobscot	At West Enfield, Me.	6,600	Penobscot Bay	12,880	11,620	(64) 11,520	+11
	Androscoggin	Near Auburn, Me.	3,257	Ocean	6,798	6,053	(38) [2] 5,913	+12
	Merrimack	At Lowell, Mass.	[3] 4,425	do	[4] 8,247	[4] 7,393	(43) [4] 7,010	+11
	Connecticut	At Thompsonville, Conn.	9,661	Long Island Sound	17,960	16,590	(33) [5] 15,960	+8
	Housatonic	At Stevenson, Conn.	1,545	do	2,925	2,661	(38) [5] 2,476	+10
1-B	Mohawk	At Cohoes, N.Y.	3,456	Hudson River	5,751	5,613	(41) 5,452	+2
	Hudson	At Mechanicville, N.Y.	4,500	Lower Bay	[6] 7,766	[6] 7,245	(71) [7] 7,428	+7
	Passaic	At Little Falls, N.J.	762	do	1,160	1,140	(69) 1,150	+2
	Delaware	At Trenton, N.J.	6,780	Delaware Bay	[9] 12,680	[8] 12,200	(54) [8] 11,450	+4
	Schuylkill	At Philadelphia, Pa.	1,893	Delaware River	[9] 3,107	[10] 2,975	(35) [9] 2,811	+4
	Susquehanna	At Marietta, Pa.	25,990	Chesapeake Bay	38,400	36,130	(35) 35,110	+6
	Potomac	Near Washington, D.C.	11,560	do	[9] 11,210	[9] 11,100	(36) [9] 10,790	+1
	Rappahannock	Near Fredericksburg, Va.	1,599	do	1,480	1,624	(59) 1,615	−9
2-A	James	At Cartersville, Va.	6,242	do	6,499	6,798	(68) 6,961	−4
	Appomattox	Near Petersburg, Va.	1,335	James River	1,094	1,199	(40) 1,115	−9
	Roanoke	At Roanoke Rapids, N.C.	8,410	Albermarle Sound	7,473	8,301	(54) [2] 8,089	−10
	Neuse	At Kinston, N.C.	2,690	Pamlico Sound	2,810	2,884	(36) 2,951	−3
	Pee Dee	Near Rockingham, S.C.	6,870	Ocean	[8] 7,247	[8] 7,576	(44) [8] 7,864	−4
	Lynches	At Effingham, S.C.	1,030	Pee Dee River	876	933	(37) 987	−6
	Santee	At Pineville, S.C.	14,700	Ocean	[11] 14,510	[11] 16,400		−11
	South Fork Edisto	Near Denmark, S.C.	720	Edisto River	677	[10] 750	(35) 800	−10
	Savannah	At Augusta, Ga.	7,508	Ocean	7,761	9,235	(59) 10,260	−16
2-B	Altamaha	At Doctortown, Ga.	13,600	do	11,690	[10] 12,770	(35) 13,580	−8
	Satilla	At Atkinson, Ga.	2,790	do	1,739	1,994	(36) 2,141	−13
	St. Marys	Near Macclenny, Fla.	700	do	519	610	(40) 684	−15
	St. Johns	Near De Land, Fla.	3,120	do	3,582	[12] 3,318	(33) 3,298	+8
	Oklawaha	Near Ocala, Fla.	1,070	St. Johns River	402	437	(36) 421	+13

[1] Figures in parentheses are years of record. Some records prior to 1931 not continuous.
[2] Adjusted for storage.
[3] Net area, exclusive of 210 square mile set aside for Boston municipal use. (See p. I33.)
[4] Adjusted for wastage into Merrimack River from 210-square-mile area. (See p. I33.)
[5] Adjusted for storage and diversion.
[6] Years 1957–60 estimated from other Hudson River records.
[7] Through 1960.
[8] Unadjusted.
[9] Adjusted for diversions.
[10] 29-year mean; record began in 1932 water year.
[11] Reconstructed record; river completely regulated since 1942.
[12] 27-year mean; record began in 1934 water year.

basins of the Sudbury and South Branch Nashua Rivers and Lake Cohituate has been set aside for the municipal water supply of Boston, and theoretically only the flow from the remaining 4,425 square miles passes the Lowell gaging station. Not all the flow from the 210 square miles is diverted, however, and the remainder, termed "wastage," flows into the Merrimack River and passes the Lowell gaging station. In tables 18 and 19, the figures of drainage area shown are exclusive of the 210 square miles, and the figures of mean discharge have been adjusted for wastage, because in both these tables the purpose is to show the runoff of the Merrimack River from the net drainage area. (In table 5, however, the drainage area shown for reach 8 includes the 210 square miles, and the observed discharge of the Merrimack River was used; the water diverted from the 210 square miles to the city of Boston reappears as waste in Massachusetts Bay and is included in the outflow from reach 9. See also table 16 for waste from the city of Boston.)

Table 19 shows that mean discharge was greater during 1951–60 than during 1931–60 north of the Potomac River and less south of it; on the Potomac River itself there was very little difference between the two periods. Exceptions are the St. Johns River and its tributary, the Oklawaha River, in northern Florida where discharge was greater during 1951–60 than during 1931–60. Total streamflow to the ocean (table 3) followed a similar pattern. In segments 1–4, the discharge to the ocean was 10 percent greater during 1951–60 than during 1931–60; in segment 5, which includes Delaware Bay and Chesapeake Bay, discharge was 3 percent greater during 1951–60 than during 1931–60; in segments 6–10, discharge was 7 percent less during 1951–60 than during 1931–60; and total inflow to the ocean was 2 percent greater during 1951–60 than during 1931–60. This increase reflects the slight upward trend referred to in the section "Summary of streamflow into the Atlantic Ocean" and shown graphically in figure 2.

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