MAPS OF RUNOFF IN THE NORTHEASTERN REGION AND THE SOUTHERN BLUE RIDGE PROVINCE OF THE UNITED STATES DURING SELECTED PERIODS IN 1983–85

By
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CONVERSION FACTORS

Factors for converting inch-pound units to the International System (SI) units are given below:

Multiply	By	To obtain
inch (in.)	25.40	millimeter (mm)
square mile (mi^2)	2.590	square kilometer (km^2)

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ABSTRACT

Maps of annual runoff for two regions in the eastern United States were prepared by the U.S. Geological Survey for the Direct/Delayed Response Project being conducted by the U.S. Environmental Protection Agency. These maps show annual runoff during water year 1984 in the northeastern region and in the Southern Blue Ridge Province and annual runoff for March 1, 1984, to February 28, 1985, for the Southern Blue Ridge Province.

Runoff from the northeastern region during the 1984 water year ranged from 12 to 55 inches; this was 25 to 55 percent greater than the average runoff for the 1951–80 period. Runoff from the Southern Blue Ridge Province during the 1984 water year ranged from 14 to 60 inches; this was 10 to 30 percent greater than the average runoff for the 1951–80 period.

A split-sample analysis of the data for New York was conducted to evaluate the accuracy of the runoff-mapping procedure used in this report. A runoff map was prepared using one-half of the data base. The map was then used to estimate runoff at the gaging stations that were not used to develop the map. The values estimated from the split-sample map were found to differ from the actual recorded values by 9.9 percent.

The runoff maps are most accurate in areas with a relatively large concentration of gaging stations and little topographic variability. Conversely, the maps are least accurate in areas with few gaging stations and high topographic variability. Based on these criteria, those parts of the maps covering Connecticut, Massachusetts, New Jersey, and Rhode Island, are the most reliable. The least reliable parts of the maps are those along the North Carolina-Tennessee border and in parts of Maine.

INTRODUCTION

Background

The runoff maps in this report were prepared by the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency (EPA), for the Direct/Delayed Response Project being conducted by the EPA. The EPA project personnel are studying the long-term response of surface waters to acidic deposition (Direct/Delayed Response Project or DDRP). A major goal of the DDRP study is to determine sulfur-retention patterns in the northeastern region and Southern Blue Ridge Province (SBRP) of the United States (U.S. Environmental Protection Agency, written commun. 1986). Budgets of inputs and outputs for 1,007 watersheds in the two regions will be computed to estimate sulfur retention. An estimate of runoff for the period prior to when water samples were collected is needed for these budget calculations. The runoff maps in this report will be used by the EPA to estimate the runoff in these watersheds.

The States in the EPA study include all of New Hampshire, Vermont, Connecticut, Rhode Island, Maine and Massachusetts and parts of New York, Pennsylvania, New Jersey, (the northeastern region) and parts of North Carolina, Tennessee, Georgia and South Carolina (the Southern Blue Ridge Province). The study areas are shown in figure 1.

Purpose and Scope

This report presents maps of runoff for the northeastern region and Southern Blue Ridge Province. The runoff maps were prepared by the U.S. Geological Survey for the 1984 water year (October 1, 1983, to September 30, 1984) for the entire study area. Runoff maps also were prepared by the U.S. Geological Survey for the period March 1, 1984, to February 28, 1985, for the SBRP. The report also compares runoff during 1951–80 to runoff during the 1984 water year.

SELECTION OF STREAMFLOW RECORDS

The primary sources of data used to compute runoff were streamflow records from U.S. Geological Survey streamflow-gaging stations. Secondary sources were a previous runoff map (Gebert and others, 1986) and various U.S. Geological Survey topographic maps.

The preferred sources of information for computing average runoff and preparing the runoff map were gaging stations operated during the 1984 and 1985 water years in small-to medium-size drainage basins with little or no diversions or regulation. Generally, gaging stations with drainage areas in the 500- to 1,000-mi² range or greater were not used for preparing the runoff maps. Runoff values from such stations are a composite of several upstream watersheds and may not adequately illustrate the variability in smaller watersheds. These large stations reflect the cumulative runoff from several sources rather than the amount of runoff from individual sources.

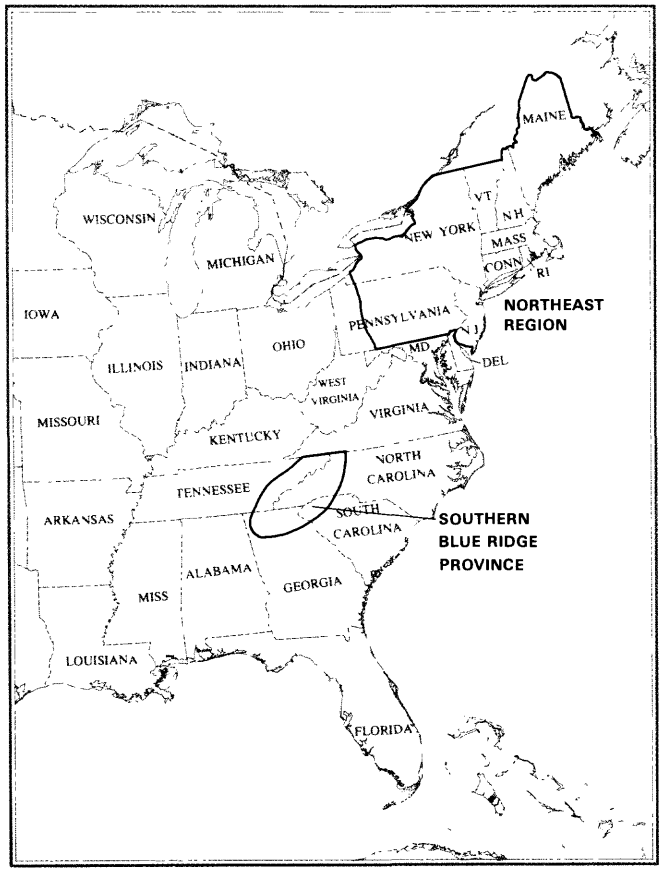

FIGURE 1. Location of the study area.

Stations with records influenced by diversions were used if the amount of the diversions for the 1984 water year was known or if the amount of the diversions was known to be insignificant. The annual mean discharge was adjusted to eliminate the effects of known diversions and corresponding changes also were applied to runoff for the water year. Stations with large amounts of diversion were not used. These stations were usually on streams or rivers that large cities in the Northeast used for municipal and industrial water supplies.

Records for regulated streams were used where information on annual change in storage permitted adjustment for the change. No adjustment was made if a reservoir was small and the regulatory pattern did not affect annual mean discharge.

The difference in annual mean discharge at two stations on a large river was used to estimate the runoff in some areas. This method calculates the contributing runoff for the area between gages. Runoff was computed as the difference in average discharge divided by the difference in drainage area and multiplied by a conversion factor to convert to inches of runoff. This method was used with caution because small errors in the measurement of discharge at the two stations could cause large errors in the difference. This method was applied only when the percentage increase in drainage area between the stations was large and data for the intervening area was not available.

In some areas, information was not sufficient to compute runoff. In such areas, estimates were based on knowledge of runoff in adjacent areas, a previous runoff map (Gebert and others, 1986), land elevation and/or hydrologic judgment.

Streamflow records were obtained by 1,098 U.S. Geological Survey gaging stations in the study area during the 1984 water year. This study used records from 774 of the stations to prepare the runoff maps. The size of drainage areas for the gaging stations used ranged from 0.8 to 3,356 mi², with an average size of 210 mi².

Table 1 lists the State, area of the study, number of gages with records retrieved, number of gages used in the study area, and square miles per gage used.

Data Processing

Data were retrieved from the National Water Data Storage and Retrieval System (WATSTORE) (Hutchison, 1975) on a State-by-State basis for all

TABLE 1.—Number of gaging stations available and used, by State
[mi^2 = square miles]

State	Area of study area (mi^2)	Total number of gages in State	Number of gages used in study area	Square miles per gages used
Connecticut	4,870	44	40	122
Georgia	48,520	97	67	724
Maine	31,000	45	43	721
Massachusetts	7,830	72	64	109
New Hampshire	8,990	35	33	272
New Jersey	7,470	100	87	86
New York	47,400	158	104	456
North Carolina	18,100	141	63	287
Pennsylvania	33,100	231	130	255
Rhode Island	1,050	15	15	70
South Carolina	21,000	50	39	540
Tennessee	18,820	80	60	313
Vermont	9,270	30	29	320
Totals		1,098	774	

stations that had any recorded streamflow data for the 1984 water year. The annual mean discharge for 1984 was retrieved for each station; the mean discharge for March 1, 1984, to February 28, 1985, for the SBRP also was retrieved. An additional retrieval was made from the header file to obtain the name, latitude, longitude, drainage area, and hydrologic code for each of the stations. The three retrievals for each State were stored in separate files.

The first step in data processing was to combine the data retrieved into a single file. This involved computing the average runoff, and sorting the station by hydrologic cataloging units. Most of the computation was performed using the P-STAT[1] statistical package (Buhler and others, 1983).

A file was printed to be used as a worksheet. This file was sorted by cataloging unit. This worksheet listed downstream order number, station name, drainage area, and runoff in inches.

Preliminary Determination of Runoff Contours

Preparation of the runoff maps started with plotting representative runoff amounts for the 1984 water year and from March 1, 1984, to February 28, 1985, on the map of each State (U.S. Geological Survey State base maps, scale 1:500,000). Representative stations were determined from inspection of the remark section in the Water Resources Data reports for each State. Annual runoff at each of the representative stations was plotted at the approximate centroid of the drainage areas by visual inspection. These values were used in conjunction with topographic maps to draw the contour lines.

[1]Use of brand names in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

In the Northeast, contour intervals were 2 in., if runoff was less than 40 in., and additional contour lines indicating 5, 15, 25, and 35 in. of runoff were added. Contour intervals of 5 in. were used where runoff was greater than 40 in. The contour intervals used in the SBRP were 2 in. where runoff was less than 30 in., and 5 in. where it was greater than 30 in.

The relief of the area and the general distribution of rainfall and topographic affects were considered and used to guide the shape of the contour lines where streamflow information was sparse. The contour lines were matched and adjusted at the boundaries of adjoining States that had been plotted previously. An average runoff map of the United States for the period 1951–80 (Gebert and others, 1986) was used as a guide to the general pattern for drawing the contour lines. The runoff map for that study was based on more stations and, therefore, runoff patterns have better definition.

Digitization of Runoff Contours

Contours were digitized using the ARC/INFO system (Environmental System Research Institute, 1985); an edit plot was then created. The edit plot was overlaid on the original map to check the accuracy of the digitizing. Any discrepancies were adjusted so that all plotted lines were within the original manuscript lines. The ARC/INFO system was used to combine the State map into maps for the region. Contour lines were checked at the State boundaries for consistency and smoothed where necessary.

Review of Runoff Contours

Contours were independently reviewed by a hydrologist in the Wisconsin District office of the U.S. Geological Survey, Water Resources Division. The

map and the runoff data used also were submitted to the respective U.S. Geological Survey State offices for their reviews. The comments from the State offices were checked for conformance to the purpose and goals of the project and were used to revise the State maps where necessary. The local knowledge of the hydrology of the separate States was valuable in refining the final map.

All of the State maps were again edge-matched with adjoining maps. The contours on the maps were digitized again if there were any changes and these digital data were used to prepare the final maps.

RUNOFF DURING SELECTED PERIODS IN 1983–85

Runoff in the northeastern region ranged from 12 in. in western New York to greater than 55 in. in the White Mountains in New Hampshire. Annual runoff in the SBRP during the 1984 water year ranged from 14 in. in eastern Georgia and southern South Carolina to greater than 60 in. in the Smoky Mountains of North Carolina. A map showing average annual runoff for the period March 1, 1984, to February 28, 1985 also was prepared for the SBRP. The annual runoff for this period ranged from 12 to 50 in.. The runoff map for the northeastern region and for the SBRP can be found on plates 1, 2 and 3.

Quality Control and Assurance

The accuracy of the runoff maps depends on several factors. Some of these factors are the accuracy of the streamflow records, how closely the runoff values at the gaging stations represent the variation of runoff within the monitored watershed, the accuracy of the isopleths that represent runoff and the error associated with digitizing the maps, and the number of gaging stations in an area.

The accuracy of the streamflow data depends on the reliability of the stage-discharge relation, which, in turn, depends on the number of measurements, stability of the control, and the effects of ice and aquatic macrophyte growth on discharge. The stage-discharge relation or rating curve is developed and checked by making discharge measurements at various stages during the year. Quality control of the measurements is based on a subjective rating by the hydrographer for each measurement. The measurement ratings range from; "poor" to "excellent" and depend on the condition of the stream cross sections and flow conditions. If the discharge measurements plot more than 5 percent from an established rating curve, then the curve is shifted to the measurement or a new rating curve is developed if the shift is substantiated by additional measurements.

The hydrologist who develops the annual streamflow record assigns an accuracy rating based on an appraisal of the measurements and the stability of the rating curve and other factors such as the amount of missing record. For example, if the daily streamflow data are judged to be within 5 percent of the actual streamflow 95 percent of the time, the records are assigned a rating of "excellent." A "good" rating is within 10 percent and "fair" within 15 percent of the actual streamflow, "poor" means that daily discharges have less than "fair" accuracy. The accuracy rating may be further subdivided to rate winter periods and/or periods of no record, such as "record good except for winter period, which is fair." The reliability of streamflow records is based on the reliability of daily discharge; but the annual runoff should be as reliable or more reliable than the daily discharge unless there is a bias in one direction throughout the year.

Of the 43 stations used to define runoff in Maine for the 1984 water year, 11 were rated "good," 23 were rated "good/fair," 7 were rated "fair," and 1 station each had ratings of "excellent" and "poor." The remaining stations from the 12 other States studied typically would have the same accuracy as those in Maine.

To develop a general indicator of the accuracy of the runoff maps, the data base for New York was split in half and a runoff map was drawn with half of the data. New York was chosen for the test because it was felt it best represented average conditions of the other 13 States. Factors that were considered include adequacy of data base, variety of topographic conditions, size of the test area, and location of the State with respect to other States.

To split the sample in half, 52 stations were drawn at random from the entire set of 104 stations (by sampling without replacement from a uniform distribution). The runoff from the 52 gaging stations was then plotted at the centroids of the respective basins. A runoff map was drawn using the data set of 52 gaging stations. The remaining 52 station-centroid points were marked with x's on the map. A hydrologist estimated the runoff of these points from the partial map (drawn with one-half of data) and compared the values to the actual runoff recorded at the gaging stations. The difference between estimated values and the actual values ranged from -8.4 to $+7.1$ in. The absolute average difference, in inches, of the partial map was 2.8 in., 25 percent of the values were less than -3.3 in. and 25 percent of the values were greater than 0.6 in. (table 2).

Eight data points were not used in this analysis. These points were in urban areas or areas where runoff was undefined, such as Long Island, and in western New York, where data were sparse.

The percentage difference from the actual value also was calculated. The maximum difference was 20

TABLE 2.—Comparison of actual runoff for half of streamflow-gaging stations with runoff for the same stations estimated from runoff map prepared from the other half of the streamflow-gaging stations

Station number	Actual runoff, in inches	Estimated runoff, in inches	Difference, in inches	Percent difference from actual
4218518	27.1	20.5	−6.6	−24
4216500	25.3	20.5	−4.8	−19
4216200	24.2	21.0	−3.2	−13
4214500	28.0	25.5	−2.5	−9
4230380	22.1	22.0	−.1	−0
4231000	16.4	14.0	−2.4	−15
4230500	20.6	16.0	−4.6	−22
4232482	15.0	16.0	1.0	7
4234000	25.8	20.5	−5.3	−21
4240120	21.3	21.0	−.3	−1
4245200	21.2	21.5	.3	1
4245000	23.8	22.0	−1.8	−8
1509000	25.5	24.5	−1.0	−4
1510000	26.3	23.0	−3.3	−13
1505000	22.3	23.7	1.4	6
1521500	23.1	19.5	−3.6	−16
1523500	23.9	21.0	−2.9	−12
1528000	19.6	17.5	−2.1	−11
1529500	19.7	19.0	−.7	− 4
1530500	24.2	22.5	−1.7	−7
4270510	24.3	20.5	−3.8	−16
4275000	29.5	24.5	−5.0	−17
4273500	23.3	24.0	.7	3
4257000	39.8	32.0	−7.8	−20
4262500	33.8	30.5	−3.3	−10
4266500	29.8	32.0	2.2	7
1312000	32.7	30.4	−2.3	−7
1321000	36.9	28.5	−8.4	−23
1330500	28.2	27.0	−1.2	−4
1334500	35.0	33.5	−1.5	−4
1333500	32.0	30.0	−2.0	−6
1350000	35.8	34.0	−1.8	−5
1350140	22.6	21.0	−1.6	−7
1350200	24.7	22.0	−2.7	−11
1362198	38.7	42.0	3.3	9
1434025	44.0	42.5	−1.5	−3
1415000	27.5	29.5	2.0	7
1502000	23.2	23.5	.3	1
1500000	24.5	27.0	2.5	10
1387400	44.5	48.0	3.5	8
1372500	27.5	29.9	2.4	9
1371500	33.2	29.5	−3.7	−11
1376800	35.4	42.5	7.1	20
1200000	30.8	32.5	1.7	6
		Maximum	7.1	Maximum 20
		Minimum	−8.4	Minimum −24
		Median	−1.8	Median −6.5
		Absolute average	2.8	Absolute average 9.9
		25 percent quartile	−3.3	25 percent quartile −13
		75 percent quartile	.6	75 percent quartile 2.5

percent and the minimum was −24 percent. The absolute average difference was 9.9 percent; 25 percent of the values were less than −13 percent and 25 percent of the values were greater than 2.5 percent (table 2).

The use of the New York runoff map based on all the 104 stations to estimate runoff for the DDRP should provide better estimates than this split-sample map analysis indicates.

A grid overlay was made to evaluate the accuracy of the partial map (one-half the data) as compared to the map based on 104 stations. A grid of 4-in.-square blocks was drawn on the partial map. Runoff from the partial map was estimated at the intersection of 48 points. The complete map was overlaid and runoff was estimated from the same 48 points. Two grid points were not used in the analysis, because both points were in areas in western New York where there were little or no data. The accuracy of runoff contours from this area would have been improved if runoff maps from Ohio and Pennsylvania had been used.

The results from the grid analysis are summarized in table 3. The difference in runoff between estimates based on half the data base and the entire data base ranged from −8.5 in. to +4.5 in.; with the absolute average of difference of 3.0 in. Twenty-five percent of the values of the partial map were less than −4.0 in., and 25 percent of the values were greater than 0.50 in.

The percentage difference between the partial map and the complete map ranged from −45.9 percent to +20.0 percent and the absolute average was 10 percent. Twenty-five percent of the values were less than −15 percent and 25 percent of the values were greater than 1.4 percent.

Although the runoff map using all 104 gaging stations should be more accurate in representing actual runoff, it is not possible to assign an overall accuracy to this map. The analyses should only be used as a general guide to the accuracy that might be associated with the runoff maps.

The accuracy of the maps also varies for the remainder of the States studied. The accuracy of the maps is generally better for States that have greater densities of gaging stations—that is, lower values of square miles per gages (see table 1)—and smaller amounts of topographic variability. Conversely, accuracy of the maps is lower for those States that have fewer gaging stations and more topographic variability.

Based on station density and topographic variability, New York represents average conditions for the 13 States for which runoff maps were prepared. The runoff maps are probably the most accurate for Massachusetts, Connecticut, New Jersey, and Rhode Island, and the least accurate for the mountainous area along the Tennessee-North Carolina border and in parts of Maine.

Another factor not included in the accuracy analyses is the comparability of streams monitored by the gaging stations to those where the runoff will be estimated for the DDRP study. The watersheds analyzed by EPA may generally be smaller than those monitored by the gaging stations used to prepare the runoff maps. Runoff is usually more variable in small watersheds and, therefore, estimates of runoff may be less accurate than those for larger watersheds. An analysis of the New York results showed no relation between the size of the watershed and variation of estimated to actual runoff in the split-sample test. The percent difference from actual was plotted on both the split-sample map and the grid-overlay map. On both maps, the highest percent difference was found in the northwestern part of New York and along the Canadian border where data for drawing the contours are sparse.

Comparison of Runoff During 1951–80 and 1984 Water Years

Runoff from the 1984 water year was compared to the long-term runoff for the period 1951–80. This was done to illustrate the necessity of using the runoff from 1984 instead of a long-term average period.

A runoff map for the period 1951–80 was prepared by Gebert and others (1986). Some of the stations used to prepare that map were also used to prepare the 1984 water year runoff map. The runoff values for stations for 1951–80 (Krug and others, written commun., 1986) were compared to runoff values for the same stations used to prepare the 1984 map. Percent change in runoff for the 1984 water year as compared to 1951-80 runoff for the 13 States is listed in table 4.

Runoff for the 1984 water year as compared to the 1951–80 period was more extreme in the Northeast. On the average, the percentage by which runoff for the 1984 water year exceeded the mean for the 1951–80 period ranged from 25 percent for gaging stations evaluated in New York to 55 percent for gaging stations evaluated in New Jersey and Massachusetts. The runoff for 1984 was nearly 10 to 15 percent greater than the mean for the 1951–80 period at gaging stations evaluated in South Carolina and Tennessee and 30 percent greater than the mean at gaging stations evaluated in Georgia and North Carolina.

TABLE 3.—Comparison of runoff map for New York prepared from one-half of the data base with map prepared from entire data base

Grid point	Partial map, in inches	Complete map, in inches	Difference from actual map, in inches	Percent difference from actual map
1	***	***	***	***
2	***	***	***	***
3	19.5	18.0	1.5	8.3
4	13.5	18.0	−4.5	−25.0
5	21.5	22.2	−.7	−3.2
6	25.5	25.5	.0	.0
7	23.5	22.2	1.3	5.9
8	14.0	12.5	1.5	12.0
9	10.0	18.5	−8.5	−45.9
10	10.0	18.2	−8.2	−45.1
11	14.8	16.0	−1.2	−7.5
12	23.5	24.3	−.8	−3.3
13	24.5	25.4	−.9	−3.5
14	21.0	25.5	−4.5	−17.6
15	21.0	22.5	−1.5	−6.7
16	19.5	25.8	−6.3	−24.4
17	19.0	24.5	−5.5	−22.4
18	18.5	23.0	−4.5	−19.6
19	31.0	30.5	.5	1.6
20	42.0	41.5	.5	1.2
21	25.5	26.7	−1.2	−4.5
22	22.5	23.0	−.5	−2.2
23	24.8	24.9	−.1	−.4
24	29.0	27.0	2.0	7.4
25	23.0	21.8	1.2	5.5
26	25.5	31.5	−6.0	−19.0
27	37.0	36.5	.5	1.4
28	30.5	32.5	−2.0	−6.2
29	24.9	26.5	−1.6	−6.0
30	16.0	22.0	−6.0	−27.3
31	19.0	24.5	−5.5	−22.4
32	25.5	26.5	−1.0	−3.8
33	33.0	33.0	.0	.0
34	34.5	36.5	−2.0	−5.5
35	27.0	34.0	−7.0	−20.6
36	27.0	22.5	4.5	20.0
37	40.0	38.0	2.0	5.3
38	31.5	34.0	−2.5	−7.4
39	39.5	38.0	1.5	3.9
40	41.0	40.5	.5	1.2
41	30.0	31.0	−1.0	−3.2
42	31.0	30.5	.5	1.6
43	25.5	24.9	.6	2.4
44	25.5	25.5	.0	.0
45	25.5	25.2	.3	1.2
46	24.0	27.8	−3.8	−13.7
47	23.0	25.5	−2.5	−9.8
48	22.0	24.5	−2.5	−10.2
			Maximum 4.5	Maximum 20.0
			Minimum −8.5	Minimum −45.9
			Median −.95	Median −3.4
			Absolute average 3.0	Absolute average 10
			25 percent quartile −4.0	25 percent quartile −15
			75 percent quartile .5	75 percent quartile 1.4

TABLE 4.—Change in runoff at selected gages from 1951–80 to 1984
[Source: 1951–80 runoff data; Krug and others, U.S. Geological Survey, written commun., 1986]

	Minimum	Maximum	Mean
Connecticut	30	85	50
Georgia	−5	100	30
Maine	15	80	45
Massachusetts	15	100	55
New Hampshire	10	70	45
New Jersey	20	90	55
New York	−20	125	25
North Carolina	−20	65	30
Pennsylvania	10	105	40
Rhode Island	35	70	45
South Carolina	−15	65	15
Tennessee	−10	30	10
Vermont	15	70	35

SUMMARY

Surface-water-runoff maps were prepared for an area encompassing 13 eastern States, including New Hampshire, Vermont, Connecticut, Rhode Island, Maine and Massachusetts and portions of New York, Pennsylvania, New Jersey, North Carolina, Tennessee, Georgia and South Carolina. Maps were prepared for the 1984 water year for all 13 States and for the Southern Blue Ridge Province (North Carolina, Tennessee, Georgia and South Carolina) for the period March 1, 1984, to February 28, 1985.

Runoff from the northeastern region ranged from 12 in. to 55 in., whereas runoff from the Southern Blue Ridge Province ranged from 14 in. to 60 in.

The general accuracy of the runoff-mapping procedures was assessed for New York. A map prepared using only one-half of the stations was used to estimate runoff from the remaining stations. The absolute average percent difference was 9.9 percent; 25 percent of the values were less than −13 percent difference and 25 percent of the values were greater than 2.5 percent difference.

The runoff maps were considered to be more accurate in areas that have a higher concentration of gaging stations and little topographic variability, such as parts of the Northeast. Based on these criteria, the least-accurately mapped areas are in the Smoky Mountains along the North Carolina-Tennessee border.

Runoff for the 1984 water year was compared to mean runoff for the 1951–80 period. The average runoff for 1984 at gaging stations evaluated was 25 percent to 55 percent higher in the northeastern region and 10 to 30 percent higher in the Southern Blue Ridge Province.

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