Snowfall, Accumulation, and Disposition As Related to the Northeast Drought[1]

William J. Schneider[2]
Washington, D.C.

The Northeastern United States recently experienced one of the most severe droughts in its history. Since September 1961, much of the area has suffered from below-normal hydrologic conditions. At the height of the drought in 1965, record low levels of streamflow and ground-water were observed over an 11-state area. Of 72 ground-water observation wells in the area, only 9 showed normal or near-normal water levels at this time. However, some relief was experienced during late spring and summer of 1966, and in the New England states, the drought is currently (February 1967) confined to a small pocket in the Massachusetts-Connecticut area.

One of the reasons for the persistence of the drought has been the subnormal winter precipitation and subsequent shortage of spring runoff and ground-water recharge. For example, at Concord, New Hampshire, measured precipitation during the December through April period ranged from 2.19 inches below normal during 1961-62 to 5.01 inches below normal in 1964-65. Normal precipitation for this period is 14.13 inches. Thus precipitation, the source of recharge for both surface water and ground water supplies in this area, ranged from 15.5 percent to 35.4 percent below normal during the recharge period of these drought years.

Although an overall precipitation deficiency is the prime cause of the drought, the amount, accumulation, and disposition of snow have been important factors in the persistence of the drought. Data available on runoff, ground-water levels, precipitation, temperature, snow depths and water content permit some evaluation of the relation between snow and the hydrologic regimen for the significant recharge period of the now-famous Northeast Drought.

The effect of winter precipitation on streamflow and ground-water levels can be shown by three illustrative examples selected to represent general areas of differing drought severity during the winter of 1965-66. At the beginning of the winter, the critical core of the drought centered in eastern Massachusetts. Conditions of below-normal streamflow and ground-water levels extended in the peripheral area from Maine to New Jersey. Much of New York State had shown sufficient recovery during the preceding spring and summer to be considered as having near-normal conditions. The areas selected are the Ware River at Coldbrook, Massachusetts, representative of the persistent drought area; the Carrabassett River near North Anson, Maine, representative of the peripheral area; the Deer River at Deer River, New York, representative of the area of near-normal hydrologic conditions.

1/ Publication approved by the Director, U.S. Geological Survey

2/ Staff Hydrologist, Water Resources Division, U.S. Geological Survey, Washington, D.C.

Although these areas represent general conditions of drought, they do not represent similar weather or climatic regimens within the given drought conditions. For example, the pattern of snow accumulation and melting as well as the total precipitation is certainly different in southern Massachusetts than in northern Maine; however, both are in the same relative hydrologic position with respect to the drought. Because this Conference is primarily interested in snow, the amount of snowfall as well as the availability of data was a factor in selection of the study areas. The general locations of the three areas are shown in figure 1.

Available hydrologic data for each site include daily streamflow records, observations of ground-water levels, and depth and water content of the snowpack. Available meteorological data include measurements of precipitation and temperature and daily snow depths. Because the data on water content of the snow are available only from periodic snow surveys which vary in frequency and timing between locations, much of the analyses of the data are based on the time intervals between snow surveys at each of the areas. Locations of the basins and sites at which data are available are shown in figure 1.

Available data for the Carabassett River basin consist of daily streamflow records near North Anson and twice-monthly observations of ground-water levels at Mercer collected by the U.S. Geological Survey; snow survey data at Highland and North Anson collected by the Geological Survey, and daily temperature and precipitation data for Madison and Long Falls Dam as well as daily measurements of snow depths at Long Falls Dam, collected by the Weather Bureau.

In the analyses of the data, precipitation data at Madison (elevation, 260 feet) and Long Falls Dam (elevation, 1,160 feet) were averaged and used as an index for the basin. Snow depths and water contents also were obtained by averaging data for the courses at Highland School and North Anson. A correlation between snow depths at Long Falls Dam and at North Anson (see figure 2) permitted estimation of daily snow depths for the basin from December 22 until March 15.

Available data for the Ware River basin include daily streamflow records at Coldbrook and month-end observations of ground water levels at Hardwick, collected by the U.S. Geological Survey; snow survey data for Princeton, Rutland, and Petersham collected at biweekly intervals and for Hubbardstown and Barre Falls Dam collected at weekly intervals by the Corps of Engineers during the snow season; and daily temperature and precipitation data and daily snow depth at Barre Falls Dam collected by the Weather Bureau.

In the analyses of these data, the precipitation data for Barre Falls Dam (elevation, 910 feet) were used as an index of precipitation for the basin. When available, snow course data for the 5 courses, ranging in elevation from 820 feet to 1,400 feet were averaged as an index for the basin. A correlation between snow data for Hubbardstown and the average of the 5 snow courses (see figure 3) was used to obtain the indexes for times when data were not available for all 5 courses.

Available data for the Deer River basin consist of daily streamflow records at Deer River, and observations of ground-water levels at Woodgate and Boonville, collected by the U.S. Geological Survey; snow survey data for Sears Pond and Copenhagen, collected by Mr. Livingston Lansing of Boonville; and temperature and precipitation data at Lowville, Boonville, and Hooker, collected by the U.S. Weather Bureau.

In the analyses of these data, the precipitation data for Hooker were used as an index for the basin. Snow course data for Sears Pond (elevation 1,740 feet) and Copenhagen (elevation 1,210 feet) were averaged and also used as an index for the basin. Attempts to correlate snow data for the basin with daily records of snow accumulations at Boonville, Lowville, or Watertown were not satisfactory.

The pattern of snow accumulation and disposition and its effect on the hydrology of the Carrabassett River basin is shown in figure 4 and summarized in table 1. Streamflow and ground-water levels in November responded to near-normal precipitation with a seasonal upturn. No appreciable snow was reported until November 22, when a 2-inch accumulation was noted in the daily record for Long Falls Dam. During the winter months, a general accumulation, as shown in figure 4, continued.

Ground-water levels continued their seasonal upward trend through mid-December in response to the continued percolation of soil moisture to the ground-water reservoir and additional recharge from minor amounts of snowmelt. No appreciable snowmelt then occurred until early March, when in response to above-normal precipitation, streamflow and ground-water levels both rose to normal or above-normal levels. The seasonal increase in temperatures through March and April continued to deplete the snowpack, and runoff and ground-water levels for the spring were slightly above normal despite much-below-normal precipitation for April.

During the winter months of December through February, streamflow remained below normal although the base flow for the period was near normal or above. This apparent anomaly was caused by the absence of surface runoff resulting from lack of snowmelt during the period. The average, of course, includes those years when brief thaws released water from the snowpack to the streams during this period, and thus increased streamflow.

Although precipitation was below normal for the November through May period (18.45 inches as compared with 23.13 inches average at Madison), an adequate spring runoff coupled with a near-normal ground-water reservoir provided an alleviation of drought conditions and a promising outlook for the following growing season.

The pattern of snow accumulation and disposition and its effect on the hydrology of the Ware River basin are shown in figure 5 and summarized in table 2. Note first that runoff at the beginning of the winter period 1965-66 was extremely deficient and ground-water levels were very low. Runoff in November was only 17 percent of median, the second lowest for November since 1928, and ground-water levels in Massachusetts ranged from 1 to 7 feet below normal.

Runoff continued much below normal through February as a result of below-normal precipitation. The first appreciable snow accumulation resulted from precipitation on December 26, but above-freezing temperatures through early January coupled with two moderate storm periods resulted in surface runoff totalling just under one-quarter inch. Ground-water levels remained at record lows during this period as the resultant infiltration of about 1.6 inches went toward replenishment of the soil moisture deficiency. Precipitation between mid-January and mid-February mainly accumulated as snow, as moderately cold temperatures prevailed. Heavy precipitation on February 14, accompanied by a period of above-freezing temperatures resulted in about one-half inch of surface runoff and a rise in ground-water levels, the first significant upturn in the ground-water levels for the season. Additional snow on February 25 and 26 again increased the snowpack to its maximum for the year, with the water content probably slightly more than the 4.6 inches determined on February 28. Continued melting through March then depleted the snowpack, and 1.56 inches of surface runoff occurred. Ground-water levels continued to rise through April, although streamflow receded sharply to much below normal as a result of extremely deficient precipitation.

At the beginning of the depletion season drought conditions still persisted in the basin. Both streamflow and ground-water levels were below normal as a result of below normal precipitation during the November through April period estimated at about 70 percent of normal for the basin.

The pattern of snow accumulation and disposition and its effect on the hydrology of the Deer River basin is shown in figure 6 and summarized in table 3. Based upon Weather Bureau records at Boonville, minor amounts of snow occurred in the area on November 17-18 and November 28-29. However, periods of generally above-freezing temperatures accompanied by rainfall resulted in no appreciable snow accumulation and several significant periods of surface runoff. Ground-water levels rose significantly to above-normal levels as the result of infiltration of the rainfall into the unfrozen ground. Streamflow and ground-water levels continued to respond to generally above-freezing temperatures and rainfall during December, with the first appreciable snow accumulating in the latter part of the month. Precipitation in January, mainly as snow, was moderate until the latter part of the month when below freezing temperatures and moderate to heavy snowfall rapidly increased the depth of the snowpack to its maximum for the season in early February. Ground-water levels, responding to frozen ground which inhibited infiltration, reflected a gradual decline through February and streamflow dropped to low base-flow levels until a warming trend occurred on February 10. This warming trend resulted in considerable reduction of the snowpack and about 1.2 inches of surface runoff. Ground-water levels showed little response as the frozen ground continued to prevent infiltration.

Additional snowfall in the latter part of February, particularly on February 16-20 and February 25 again increased the snowpack which then remained relatively constant through March. However, intermittent periods of rain and snow accompanied by periods of warm temperatures resulted in a steady rise of ground-water levels and two significant periods of surface runoff in March.

Continued seasonal increases in temperature accompanied by rainfall intermittently mixed with periods of snow resulted in a steady decrease of the snowpack from early to mid-April with a subsequent rise in streamflow. However, in the latter part of April, ground-water levels abruptly stopped their normal seasonal rise and streamflow rapidly decreased to low base-flow levels as the result of much below normal precipitation during this period as well as the complete and rapid depletion of the snowpack in early April.

Several interesting comparisons can be made in the reactions of the 3 basins to the hydrologic conditions which existed during this period. The pattern of snow accumulation differed among the basins, because of geographic and climatic factors. In the Carrabassett River basin, the accumulation under conditions of generally below-freezing temperature continued from late November until early March, with the water content of the snow exceeding 10 inches at its peak. Although melting started late in March, snowmelt continued to affect runoff and recharge into May.

In the Ware River basin, snow did not accumulate until early January, and major periods of above-freezing temperatures in both January and February resulted in a fluctuating water content of the snowpack and consequent releases of water to streamflow. In the Deer Creek basin, no major accumulation of snow occurred until late January, although streamflow receded sharply in early January as a result of below-normal precipitation and below-freezing temperatures. Snow accumulation reached its maximum in early February. However, snow surveys indicate a water content of the snowpack of almost 11 inches through mid-March.

Ground-water levels in the three basins also responded differently. In the Carrabassett River basin, water levels rose sharply in the late fall, held steady in the winter, and rose only slightly in the spring. In the Deer River basin, ground-water levels rose sharply in December to well above normal levels, receded in January and February when frozen ground prevented infiltration, and rose again in March and April. However, in the Ware River basin, no recharge of the ground-water reservoir occurred until mid-February.

A third observation from the water balances is that the snow surveys frequently showed greater increases in the water content of the snowpack than were indicated by measured precipitation for the same period. Because of this, detailed quantitative comparison of factors in the water balance is precluded, and the data on precipitation and water content of the snow must be used only as indexes of the hydrologic behavior of the basin.

The anomalies in the data on precipitation and water content of the snowpack are apparent in the data for all 3 basins. However, there appears to be a pattern in the anomalies. For 10 of 12 periods of significant increase in water content of the snowpack, the increase in water content exceeded the measured precipitation for the same period. This strongly suggests that further research is needed into the relative accuracies of measurement of these data and their relative applicabilities as areal indexes.

Because of this anomalous data, the water balances for the three basins must be considered in terms of patterns of runoff rather than in terms of precise changes in amounts of water. However, the data, when used as indexes, are useful, and provide insight into the reactions of the climatic and meteorologic stimuli on the water regimens of the basins.

Table 1

Water Balance, 1965-66
Carrabassett River Basin
(Drainage area, 354 sq. mi.)

Period	Hydrologic Data in Inches							
	Average Precipitation	Snow Accumulation		Water Content		Total Runoff	Est. Base Flow	Surface Runoff
		Average	Change	Average	Change			
11/1-11/22	2.14	0.		0.		1.38	0.80	0.58
11/23-12/15	1.72	13.5	+13.5	2.49	+2.49	0.67	0.65	.02
12/16-1/11	1.10	18.4	+ 5.9	3.95	+1.46	0.56	0.55	.01
1/12-2/8	2.56	30.2	+11.8	6.08	+2.13	0.50	0.50	0.
2/8-3/14	4.15	29.2	- 1.0	10.0	+3.9	1.49	0.75	.74
3/14-4/5	2.24	14.	-15.	5.6	-4.4	3.37	0.70	2.67
4/5-5/15		0.	-14.	0.	-5.6	7.42	1.20	6.22

Table 2

Water Balance, 1965-66
Ware River Basin, Mass.
(Drainage area, 96.8 sq. mi.)

Period	Hydrologic Data in Inches							
	Average Precipitation	Snow Accumulation Average	Snow Accumulation Change	Water Content Average	Water Content Change	Total Runoff	Est. Base Flow	Surface Runoff
12/1-1/17	3.30	7.9		1.0		0.62	0.35	0.27
1/18-1/24	.61	20.0	+12.1	2.7	+1.7	.05	.05	0.
1/25-1/31	.47	21.5	+ 1.5	3.7	+1.0	.05	.05	0.
2/1-2/7	.23	19.5	- 7.0	4.1	+ .4	.05	.05	0.
2/8-2/14	1.47	11.6	- 7.9	3.2	- .9	.16	.05	.11
2/15-2/21	.27	13.3	+ 1.7	3.5	+ .3	.58	.12	.46
2/22-2/28	.47	18.5	+ 5.2	4.6	+1.1	.13	.12	.01
3/1-3/7	.68	11.7	- 6.8	3.7	- .9	.26	.20	.06
3/8-3/14	.35	14.4	+ 2.7	4.1	+ .4	.76	.32	.44
3/15-3/21	.10	9.5	- 4.9	2.9	-1.2	.54	.38	.16
3/22-3/28	1.02	1.2	- 8.3	.4	-2.5	1.33	.43	.90
3/28-4/11	.23	0.	- 1.2	0.	- .4	1.19	.86	.33

Table 3
Water Balance, 1965-66
Deer River Basin, N. Y.
(Drainage area, 98.1 sq. mi.)

	Hydrologic Data in Inches							
Period	Average Precipitation	Snow Accumulation Average	Snow Accumulation Change	Water Content Average	Water Content Change	Total Runoff	Est. Base Flow	Surface Runoff
11/1-11/31	7.06	0.	0.	0.	0.	4.97	2.12	2.85
12/1-1/5	5.35	7.6	+7.6	2.6	+2.6	4.94	2.45	2.49
1/6-2/2	4.22	54.5	+46.9	10.2	+7.6	1.13	1.10	0.08
2/3-3/2	3.83	32.8	-11.7	10.7	+0.5	2.45	1.22	1.23
3/3-3/15	1.68	29.9	-1.9	10.8	+0.1	2.54	1.28	1.26
3/16-4/30	3.29	0.	-29.9	0.	-10.8	13.50	5.10	8.40

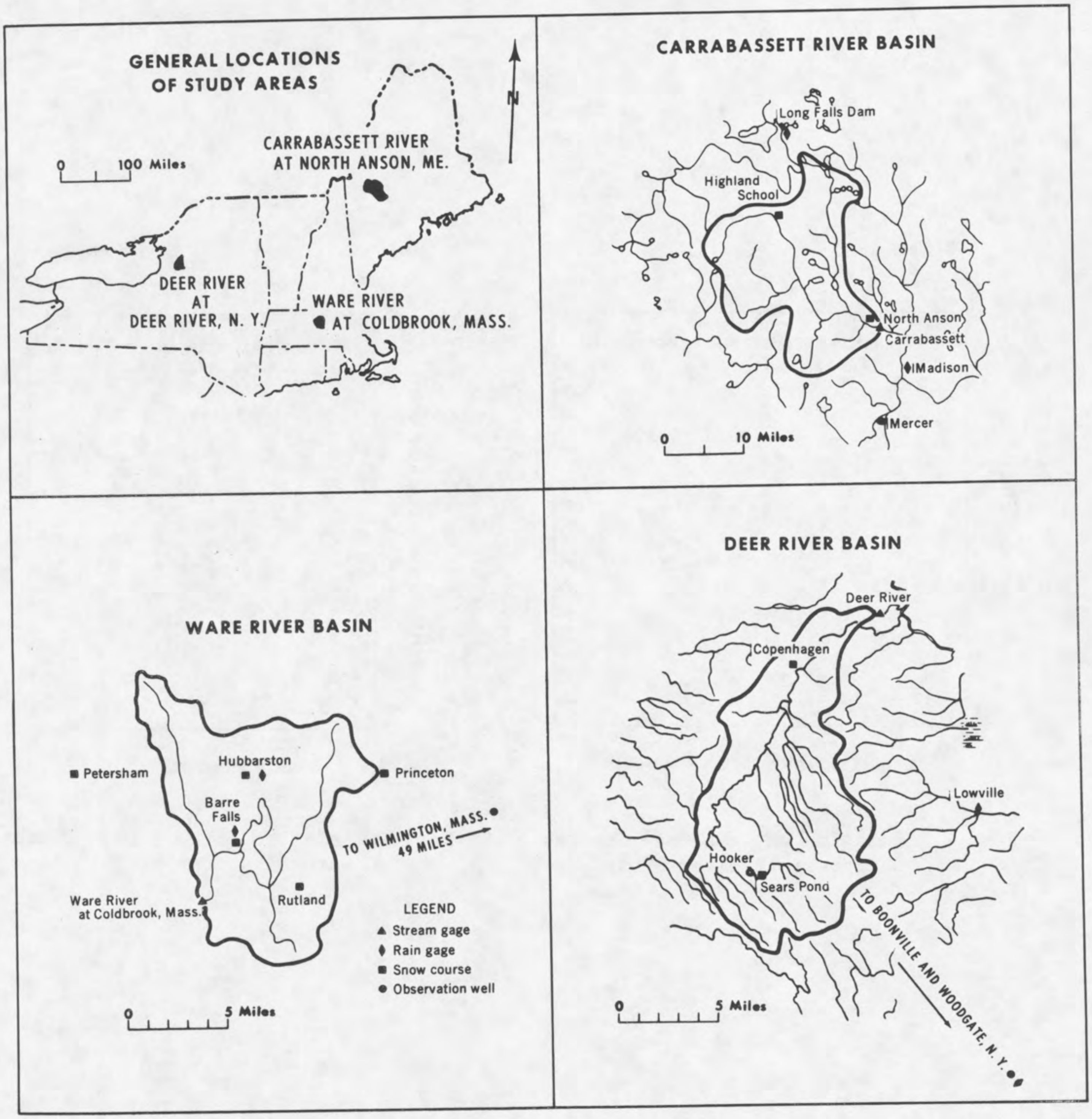

Fig. 1 Map of Northeastern United States showing location of Hydrologic Data Sites

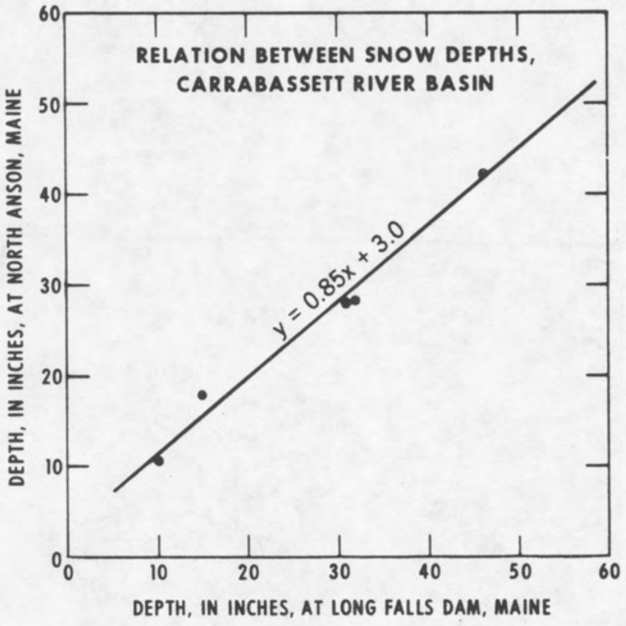

Fig. 2 Relation between Snow Depths, Carrabassett River basin

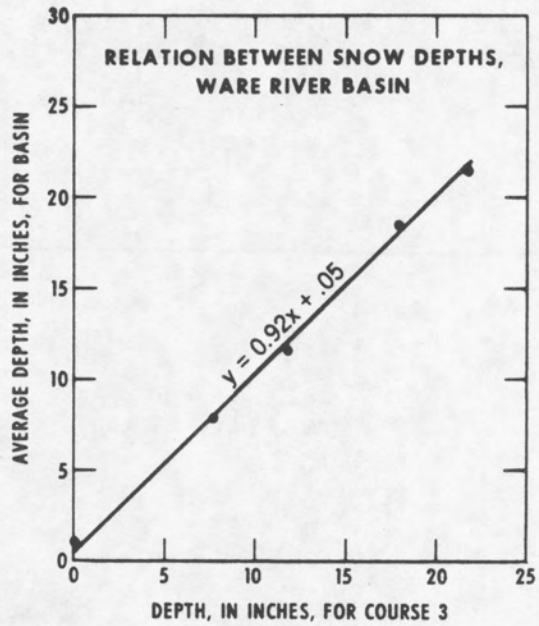

Fig. 3 Relation between Snow Depths, Ware River basin

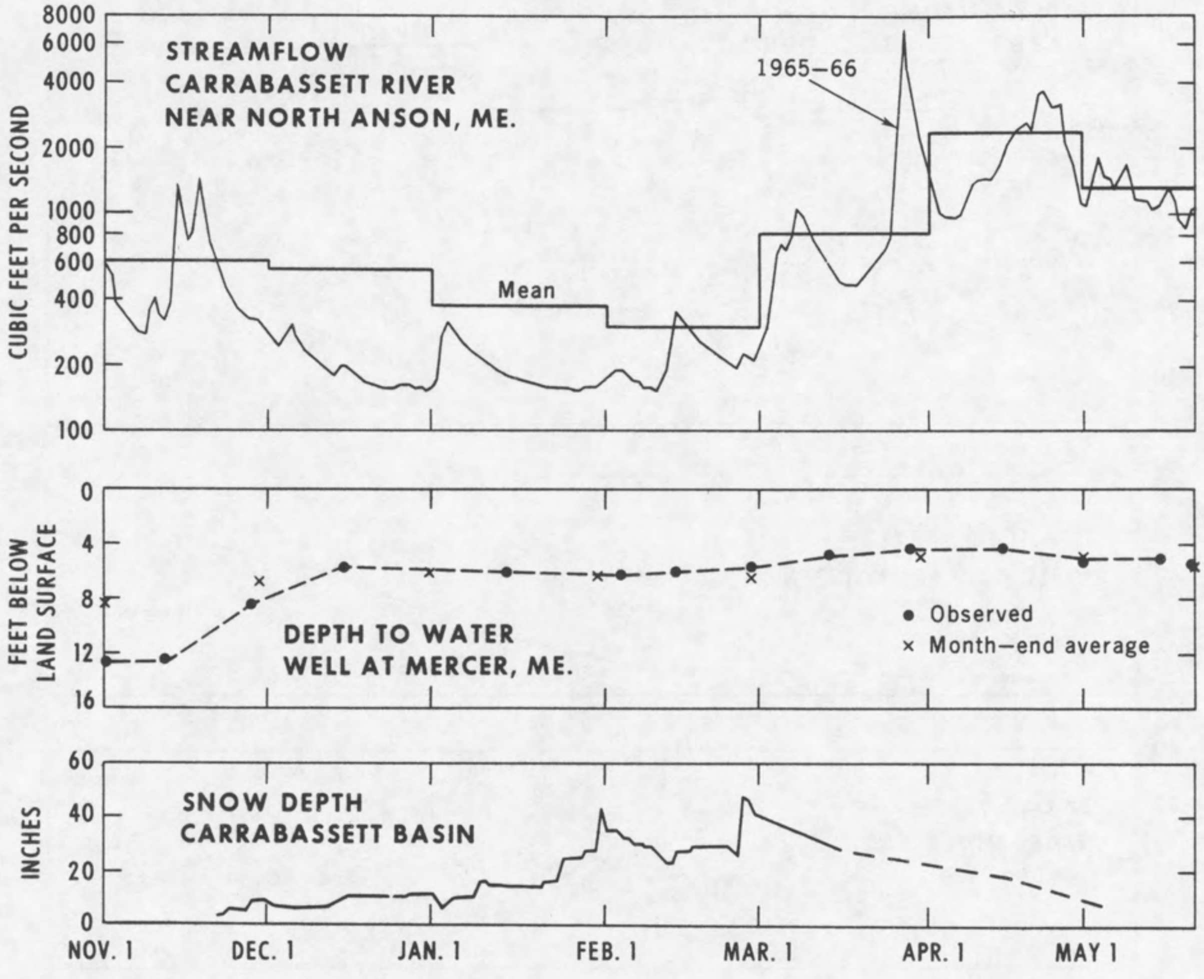

Fig. 4 Hydrologic Regimen of Carrabassett River basin
November 1965 to May 1966

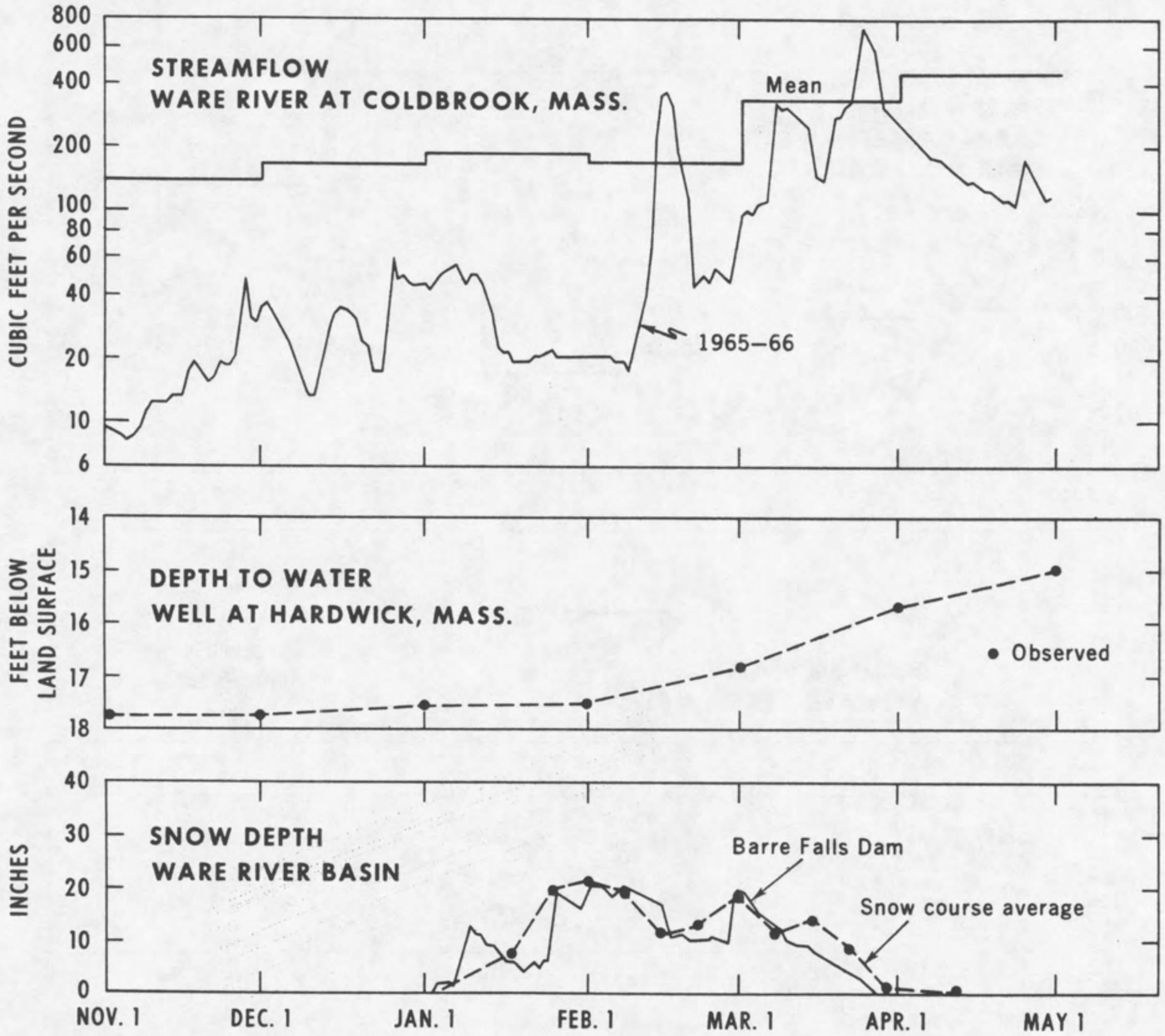

Fig. 5 Hydrologic Regimen of Ware River basin
November 1965 to May 1966

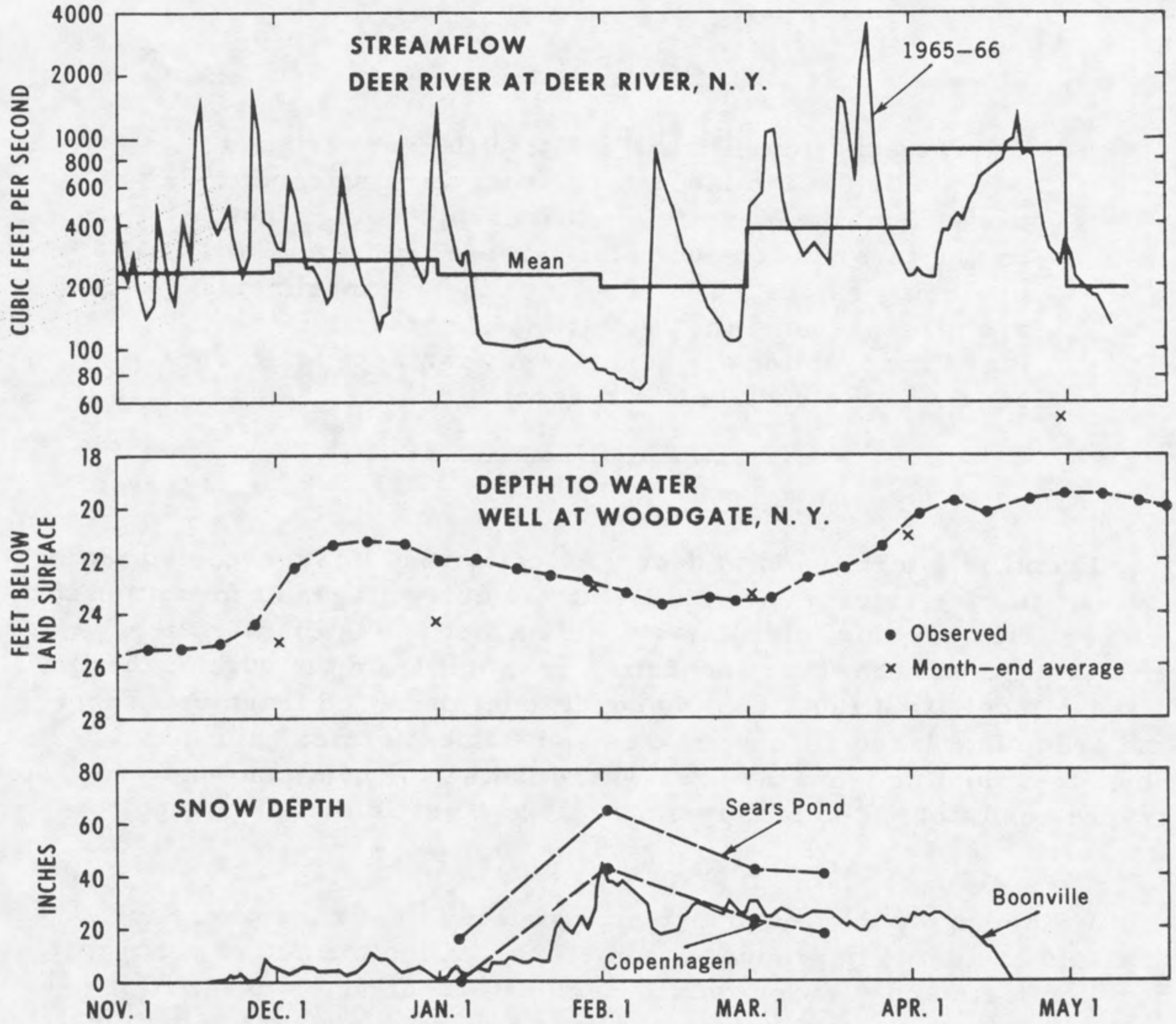

Fig. 6 Hydrologic Regimen of Deer River basin
November 1965 to May 1966