SNOWMELT STUDIES

ON THE TULLY FOREST IN CENTRAL NEW YORK[1]

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Hydrologists working in areas of substantial snowfall have long been aware that melting snow may contribute a large portion of annual water yield, and that most of the annual runoff appears during periods of melt. Since the beginnings of scientific hydrology, the effects of vegetative cover on snowmelt have been a matter of much interest. The publication of the early paper by Chittenden (1909) aroused much controversy; but somewhat surprisingly, it was followed in the Northeast by very little research into the subject.

Later work emphasized the snowpack itself, rather than the runoff from it. Maule (1934) indicated that near New Haven, Connecticut, snow remained longest under white pine, and for shorter periods under red pine, Norway spruce, hemlock, hardwood forests, and open fields, respectively. He indicated that interception was less under white pine than other conifers, and that the shade of the trees slowed snowmelt.

Horton (1945), working in Pennsylvania, found melt to be higher per degree-day above 32° F. in heavily cutover and burned stands than in good stands of northern hardwood and hemlock. Lull and Rushmore (1960), found melt rates per degree-day above 32° F. nearly twice as great under hardwoods as under conifers in the northern Adirondacks.

Schneider and Ayer (1960) reported that, following reforestation of Shackham Brook watershed in central New York, reductions in peak discharge averaging 41 percent were due to interception and the shading of snow by the developing conifer forest. They also noticed that flood peaks from Shackham Brook did not occur at the same time as those from a nearby open watershed, because of retarded snowmelt in the forest. However, some of the snowmelt flood peaks that came late in the season were higher after reforestation in the latter years of their study.

The Study

Accordingly, we decided to study snow deposition and melt on Tully Forest to test the thesis of Schneider and Ayer (1960), that the effect of vegetation on snowmelt could account for the changed relationship of dormant-season flow of reforested Shackham Brook, and that of Albright Creek, which remained largely under agricultural use.

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Tully Forest, owned by the New York State University College of Forestry at Syracuse University, lies partially in and adjacent to the Albright Creek watershed, between Albright Creek and Shackham Brook. Snow courses were established within 1 mile of each other at elevations between 1,900 and 2,000 feet on less than 10 percent slopes, traversing 5 cover types typical of the area: unimproved pasture (open), open-brushy hardwoods, northern hardwoods, red pine plantations, and Norway spruce plantations. The plantations, similar to those on Shackham Brook, were represented by dense and thinned stands.

Snow depth and water equivalent were measured over 23 weekly intervals with a Mount Rose snow tube on each of 7 snow courses, from the beginning of snowfall in the autumn until final disappearance of the snowpack in the spring.

The results of the study on the snowpack have been reported by Eschner and Satterlund (1963), but the opportunity to relate these studies to actual runoff from the two nearby watersheds had to await publication of the streamflow data. Our study attempts to relate the snowmelt from Tully Forest to the observed runoff patterns of Albright Creek and Shackham Brook.

Complete descriptions of the cover of Albright Creek and Shackham Brook are given in Schneider and Ayer (1960). The cover conditions in 1958 are summarized in table 1. A reconnaissance of the watershed revealed that about 90 percent of the open land was completely open, and about 10 percent was similar to the brushy-open hardwoods sampled on the Tully Forest. The hardwoods were similar to those on Tully, but the conifers had dense and patchy spots that were similar to the unthinned and thinned areas, respectively, on Tully Forest.

Table 1.--Type of cover of Albright Creek and Shackham Brook watershed*

Area	Open land	Hardwoods	Conifers	Total
	%	%	%	%
Shackham Brook	16	27	57	100
Albright Creek	80	20	0	100

* From Schneider and Ayer (1960).

Therefore quantities of snow melted from open and brushy hardwoods were weighted 9 and 1 respectively, and were averaged to represent the quantities of snow melted from the open land. The amount of snow melted under hardwoods was used unchanged. A simple average of the quantity of snow melted on the four snow courses under dense and thinned red pines and Norway spruces was used to indicate the melt under coniferous cover. These figures were then weighted by the percentage of the open, hardwood, and conifer cover types in each watershed to serve as an index of the amount of snowmelt runoff generated for any given period.

These indices were compared during the snow season, with emphasis upon two critical periods: (1) the shortest half-flow interval (i.e., the shortest interval during which one-half of the annual streamflow is discharged past the stream gage) and (2) the shortest one-quarter-flow interval, from Shackham Brook and Albright Creek. These measures have been found useful in analyzing the degree of concentration and the timing of runoff during the snowmelt season in central New York (Satterlund and Eschner, 1963).

Results and Discussion

Accumulated snow melt, at Tully Forest during the winter of 1961-62 is shown in figure 1, by cover types, along with the accumulated degree-days above 32° F. Snow was essentially continuous through March 23, April 6, and April 14 in the open, hardwoods, and conifers, respectively. During the period of snow cover, their degree-day melt rates were 0.11, 0.06, and 0.03 inches. These figures agree well with those of Lull and Rushmore (1960), who found degree-day melt rates of 0.06 and 0.03 inches under hardwoods and conifers respectively, in northern New York, and with Horton's (1945) degree-day melt rates of 0.08, 0.09, and 0.06 inches in heavily cutover hardwoods, burned areas, and hardwood-hemlock mixtures in northern Pennsylvania.

Our figures of melt are probably conservative for all types, but relatively more for the open and hardwoods than under coniferous cover. In some instances both melt and deposition occurred between sampling intervals, but the accumulated melt was based only on the differences between successive measurements.

The Tully Forest figures were applied to the cover types existing in the watersheds of Albright Creek and Shackham Brook, and were weighted by area of cover (fig. 2). It is clear that the quantity of winter melt on Albright Creek greatly exceeded that of Shackham Brook. In fact, one-half of the total snowfall on Albright Creek had melted by March 24 under relatively low temperature conditions, whereas on Shackham Brook less than one-third had melted by the same date.

By March 28, when the first warm period was ushering in spring, little snow remained in the open. Thereafter, the rate at which snowmelt was generated increased much more rapidly on Shackham Brook than Albright Creek, despite the lower degree-day melt rate under forested conditions. Most of the snowmelt reaching Albright Creek occurred in the hardwoods that covered only 20 percent of the watershed, while under both the hardwoods and conifers, which covered 84 percent of the Shackham Brook watershed, snow melted rapidly.

How well is this pattern of snowmelt, determined on Tully Forest, related to actual runoff from the two nearby watersheds of Albright Creek and Shackham Brook? The mean daily hydrographs of the two watersheds for the period December 1, 1961 - April 30, 1962, are shown in figure 3. It can be clearly seen that relative runoff from Albright Creek exceeded that from Shackham Brook until March 27, 1962. Thereafter the flow relationship was reversed.

The ratios of estimated snowmelt plus rainfall for each watershed were compared with the ratios of actual runoff during each snow-survey sampling interval. A "t" test of the differences (estimated minus actual runoff ratios) showed no statistical significance (calculated sample $t = 1.369$; tabular $t_{.05} = \pm 2.074$).

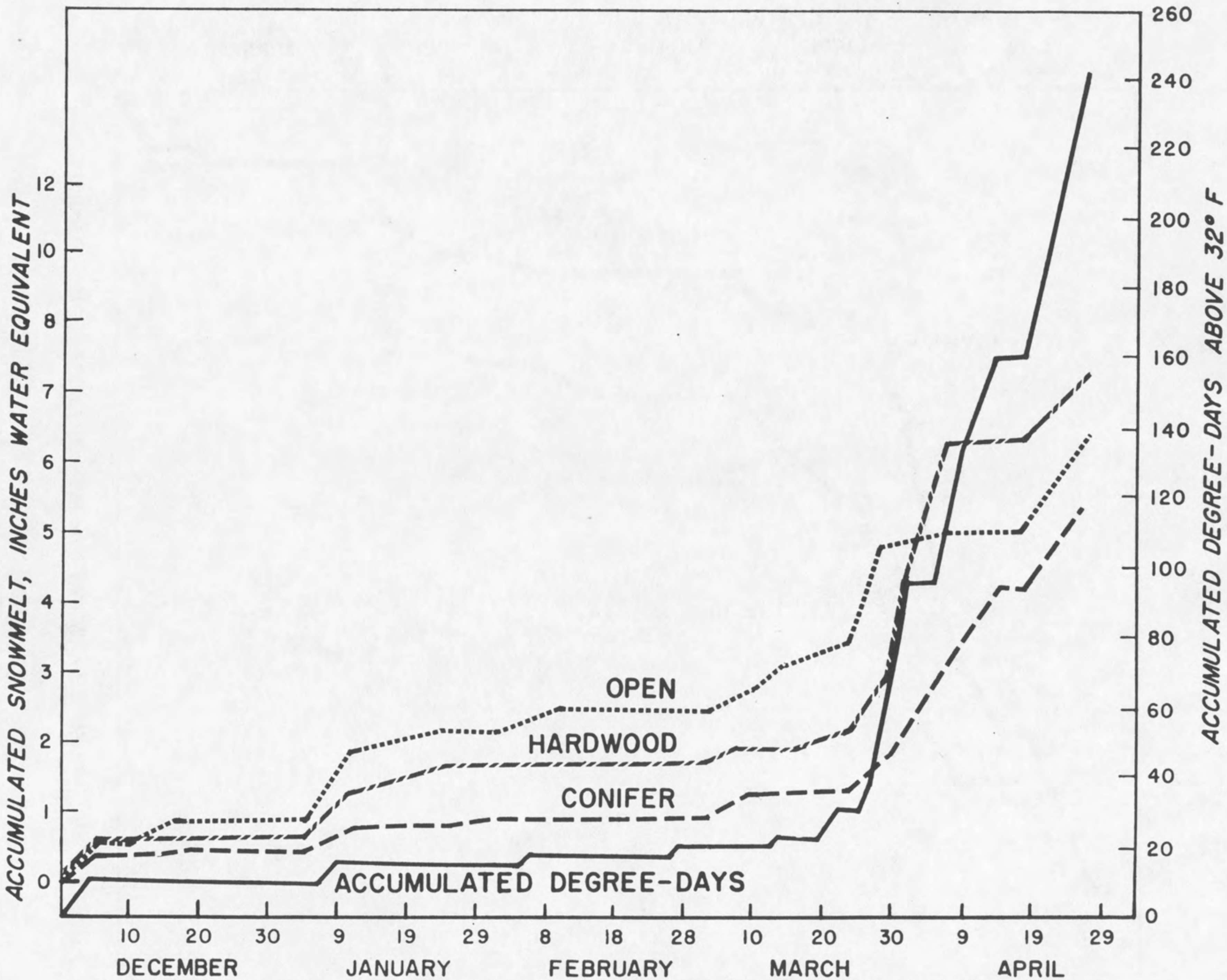

Figure 1. --Accumulated snowmelt and accumulated degree-days on the Tully Forest, New York, December 1961 through April 1962, by cover types.

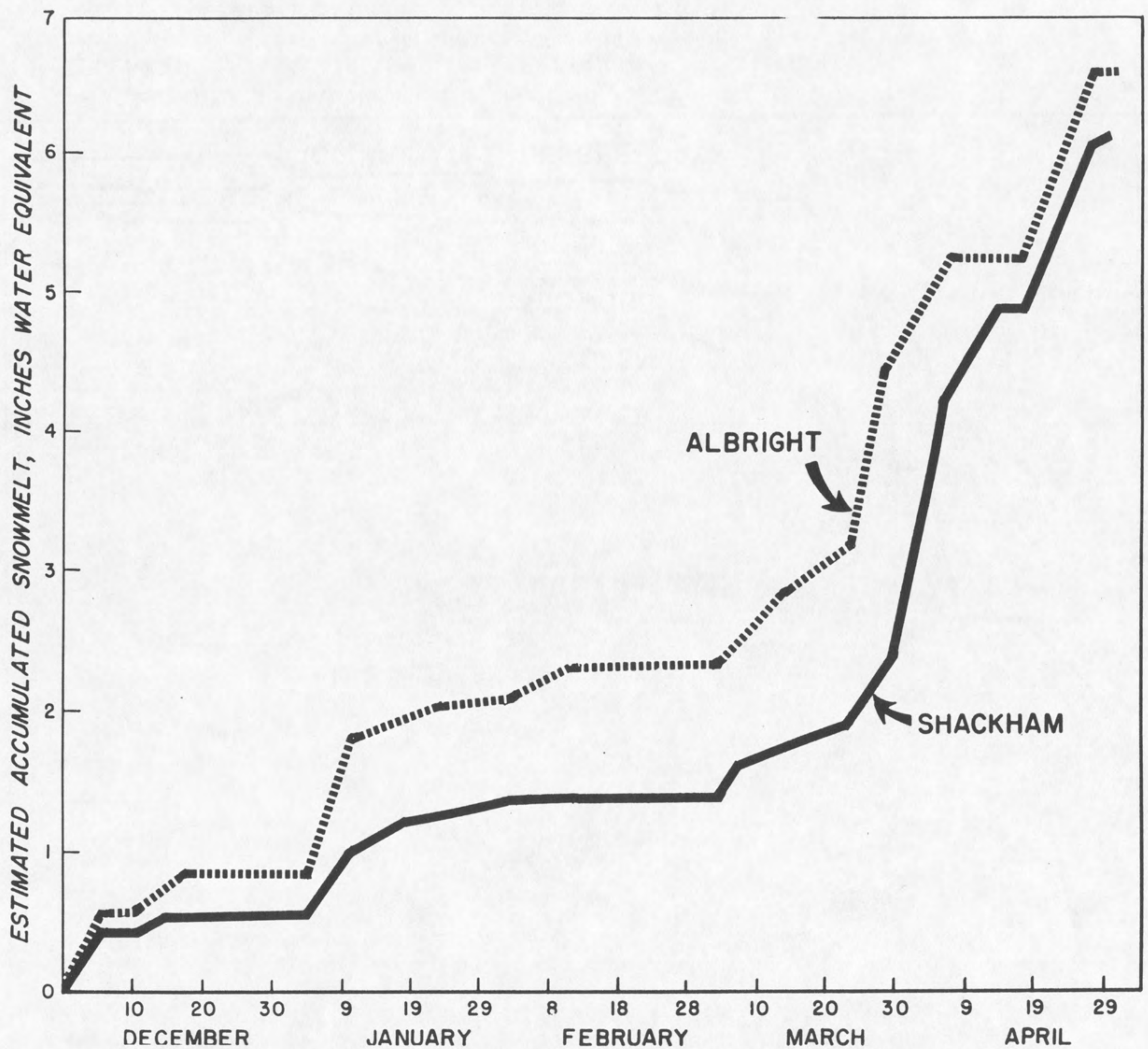

Figure 2. --Accumulated snowmelt (estimated) on the Albright Creek and Shackham Brook watersheds, December 1961 through April 1962.

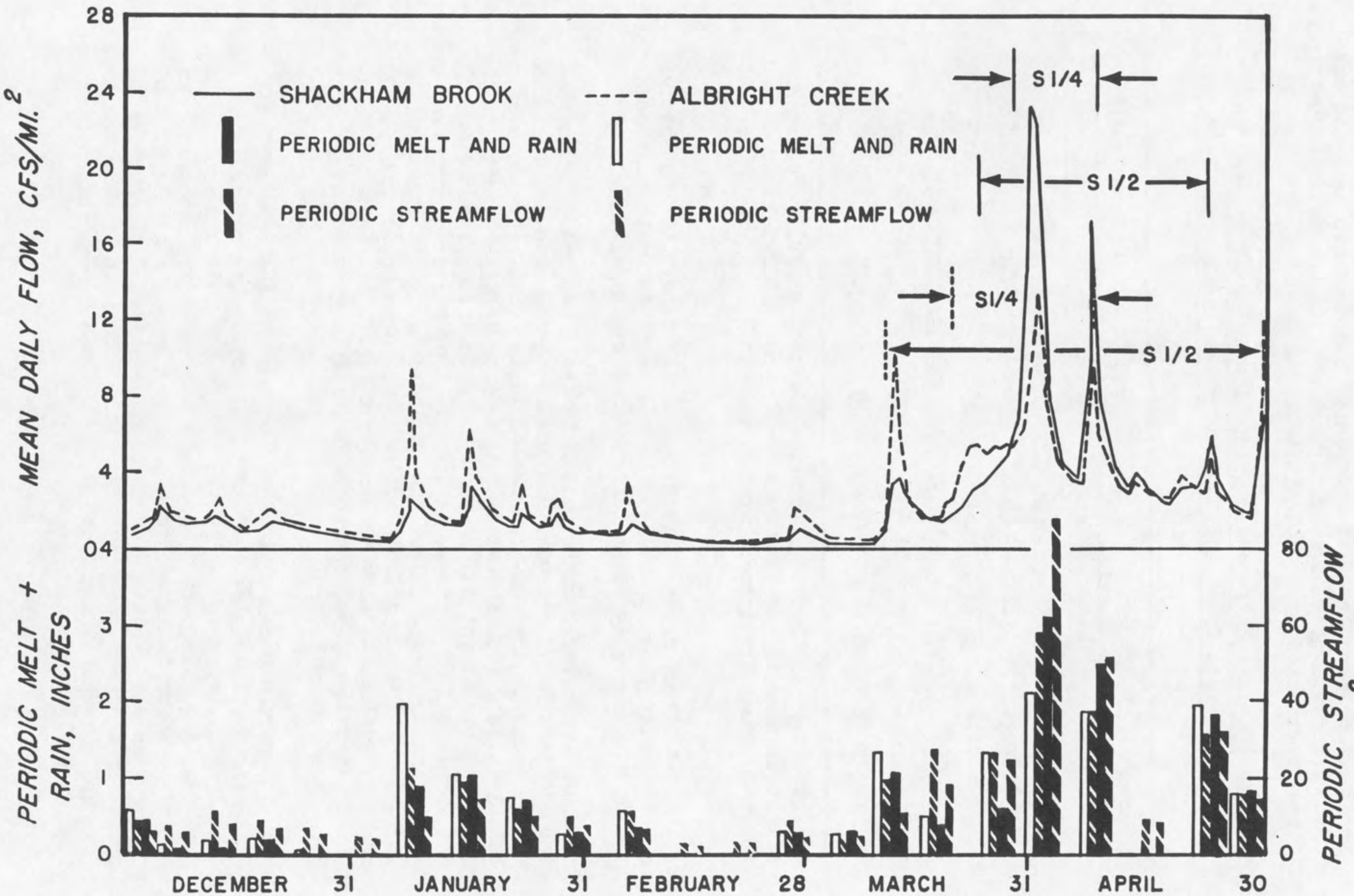

Figure 3. -- Hydrograph, periodic snowmelt and rain, and periodic streamflow for Albright Creek and Shackham Brook, December 1961 through April 1962.

In regulation of storage, or in snowmelt floods routed downstream, the large amounts of runoff generated during relatively short periods can be of major importance. Therefore, let us examine the shortest half and one-quarter flow intervals more closely. These periods are outlined in figure 3. Quantitative descriptions are shown in table 2.

Table 2.--Shortest half- and quarter-flow interval values for Albright Creek and Shackham Brook, water-year 1962

Stream	Start	End	Length	Runoff	Snowmelt*
	Date	Date	Days	Inches	Inches
		SHORTEST HALF-FLOW INTERVAL			
Albright Creek	3/12	4/30	50	7.86	4.45
Shackham Brook	3/23	4/24	33	7.49	4.29
		SHORTEST QUARTER-FLOW INTERVAL			
Albright Creek	3/20	4/7	18	3.93	2.37
Shackham Brook	3/29	4/7	10	3.75	1.90

* Calculated on the basis of amounts measured on Tully Forest and weighted according to type of plant cover on Albright Creek and Shackham Brook watersheds.

Despite the rather great differences in the length of the shortest half and one-quarter flow intervals, the amount of snowmelt that occurred from corresponding cover types on Tully Forest was similar.

The amount of snowmelt contribution to the flow of Albright Creek during the shortest half- and quarter-flow interval, however, is inflated by an unknown amount. The snow courses on Tully Forest were located near 2,000 feet elevation, representative of the extreme upper limits of the watersheds. At this elevation, snow in the open disappeared before the first real warm spell of spring. At lower elevations it disappeared even earlier; hence at the beginning of the shortest half- and quarter-flow intervals, less snow was available in the open to generate runoff. On the other hand, sufficient snow remained under both conifers and hardwoods, even at lower elevations, to contribute considerably to runoff generated during both flow intervals.

During the period March 23 to 28, when snow in the open at Tully Forest disappeared completely, calculated snowmelt plus rainfall was 1.30 inches for Albright Creek and only 0.59 inches for Shackham Brook. Yet actual runoff during this period was 26.38 csm-days for Albright Creek and 24.33 csm-days for Shackham Brook. These figures indicate that bias from sampling high elevations leads to an overestimate of snowmelt contribution for Albright Creek in comparison with that of Shackham Brook, an overestimate somewhere in the order of 0.5 inch during the shortest half and quarter flow intervals.

Spring rainfall, which contributed substantially to runoff from both basins, was fairly well synchronized in time and quantity and tended to offset the disparity in flow intervals that would have resulted if they were due solely to the differences in quantity and timing of snowmelt under the various cover types.

While the effect of rainfall was to decrease disparities in runoff over those due to snowmelt alone with respect to length and timing of shortest half- and quarter-flow intervals, the storm runoff during individual storms showed increased disparities, depending on the presence or absence of snow and its melt during storms (fig. 3).

Before March 24, runoff from all rainstorms was bulked considerably by runoff generated from snowmelt in the open. Snowmelt in the forest during winter rainfall was slight; and, in at least one instance, rainfall was definitely stored in the snowpack. On January 6 and 7, 1962, approximately 1 inch of rain fell. Air temperatures in a standard weather shelter were slightly above freezing. In the open, snowmelt accompanied the rain. Under the conifer forest, the falling rain froze in the snowpack, resulting in a layer of ice that persisted a variable length of time, until April 27 under dense Norway spruce (Eschner and Satterlund, 1963).

On the other hand, during a heavy storm of March 30 and 31, large quantities of snow remained and melted rapidly under forest cover, where the aforementioned ice layer was still present in some stands. Ground in the open was unfrozen, had been bare and draining for several days, and stored a small part of the rainfall. Runoff was much greater from forested than open lands (fig. 3). Shackham Brook discharged twice as much runoff per square mile as Albright Creek on those 2 days. Runoff during rainfall was greater from forests than from open throughout the period March 30 - April 27.

One might well question whether or not this single season study is typical of conditions on the Allegheny Plateau. With reference to specific results, the answer is a qualified "yes". A study of the relation of runoff of Albright Creek to Shackham Brook indicates that reforestation usually increases the degree of concentration of spring snowmelt runoff as measured by length of the shortest half- and one-quarter flow interval, and that desynchronization of runoff generally occurs. However, individual exceptions to this pattern occur (Satterlund and Eschner, 1963).

With properly located snow courses to sample elevation, slope, aspect, and vegetation, we see no reason why the relative timing of snowmelt runoff could not be determined for any small watershed on the northern Allegheny Plateau.

Conclusions

Several conclusions can be drawn from this study of snowmelt on the Tully Forest. Primary among these is that snowmelt rates, as considered in terms of melt per degree-day alone, can be quite misleading in interpreting the effect of vegetative cover on snowmelt runoff. Emphasis must be placed upon the potential runoff generated, a function of melt rate, available energy, and available snow, rather than on the snowpack alone. The good relationship of observed runoff of Albright Creek to Shackham Brook in relation to snowmelt under various cover types points out the value of such interpretation.

Further, this study points out that differences in snowmelt timing, involving large quantities of water, exist between different cover types on the northern Allegheny Plateau.

Finally, it appears that this study confirms the opinion of Ayer (1959) that a desirable pattern of land use on the northern Allegheny Plateau would be a combination of open and reforested lands, for purposes of improved streamflow regimen during periods of melting snow.

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