EFFECT OF FOREST COVER ON SNOWMELT RUNOFF

By

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The effect of forest cover on runoff resulting from snowmelt has been a matter of concern throughout the world for many years. Considerable has been written on the subject; the most recent discussion before the Eastern Snow Conference was presented by Baldwin (1956). The topic is presented again in this paper as it has turned out to be one of the most significant factors in a twenty-five year study of the effect of reforestation on stream-flow in central New York. Some of the preliminary results of the study will be given since they add strength to certain conclusions reached by other investigators during the past three decades.

It has been recognized for many years that coniferous trees modify to a considerable extent the amount and distribution of snow reaching the ground under these trees. In a dense stand of conifers, particularly spruce, balsam, and fir, with stiff branches, a large part of a moderate snowfall may be caught by the tree crowns and never reach the ground. Some pine trees are not as effective in intercepting snow because their branches tend to sag and thus permit the snow to slide off onto the ground below. This accumulation of intercepted or trapped snow frequently disappears directly into the atmosphere, often during periods when the temperature remains considerably below freezing so that no melting takes place. It is not uncommon, therefore, to find practically all of a 6-inch snowfall suspended in the coniferous tree crowns, never to reach the ground, thus decreasing by as much as half an inch the effective precipitation under such a tree canopy.

This reduction in effective precipitation suggests a decrease in runoff potential and a consequent decrease in the $\frac{P}{R}$ ratio where R is actual runoff and P the measured precipitation outside the coniferous covered areas. The intercepted and subsequently sublimated snow is actually removed from any consideration as far as runoff production is concerned. Interception of snow several times during a single winter can add up to a sizeable reduction in the runoff potential for a given area.

On the areas considered in the report previously mentioned, planting of conifers over as much as 50 percent of three drainage areas of 0.7 to 3.1 square miles took place in the early 1930's. Since that time these trees have grown without interference by man. No grazing has been permitted. No fires have occurred which might have damaged the trees or litter and no thinning or release cutting has been done. The replanted areas were formerly sub-marginal land bearing a cover of scrub brush, grasses and weeds. The lands were

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abandoned, probably because the farms of which they were part could no longer be operated at a profit by their owners.

Hydrologic data collected on these areas have been the basis of several studies (Ayer, 1949; Outlaw, 1953; Barkow, 1957). The most recent analysis of the data was started a little more than a year ago. The final report on this analysis will be presented as a publication of the U. S. Geological Survey.

Although previous reports on the project detected no significant changes in runoff regimen as the result of the growing trees, some preliminary results of the present study indicate that there have been a highly significant reduction in streamflow for the winter months. 1/ Not only is the net water yield progressively less in relation to measured precipitation, but there is indicated a reduction in winter peak flows and a redistribution of runoff during the winter.

In order to study these apparent changes in detail, analysis was made of comparable peak flows during the winter months from one of the reforested areas, Shackham Brook near Truxton (drainage area 3.1 square miles), and from Albright Creek at East Homer (7.1 square miles), a non-reforested area used as a control. The principal differences between the two areas are in size and shape. The distance between centers of gravity of the basins is about 5 1/2 miles. The study was made on the basis of two 5-year periods, an early period 1939-43 and a later period 1953-57, these periods being selected to obtain the greatest growth difference possible.

The basis for selecting the peak discharges used in this analysis was established on Albright Creek as 10 cfs per square mile. Because snow is a factor in these basins from November until April, the period November 1 to April 30 was used for the study. None of the peaks selected had to be eliminated on the basis of precipitation differences; comparison of precipitation data indicated good agreement between areas in precipitation for each peak used. This agreement is attributable to the general movement of frontal activity during the winter which causes a very similar pattern of precipitation over relatively large areas. A precipitation difference of over 10 percent would have resulted in disqualification of a particular peak.

Correlations were computed for the peaks during the winter for the two 5-year periods 1939-43 and 1953-57. The linear regressions are shown in figure 1. Differences between regressions for the early period and the late period were tested for significance by analysis of covariance. A decrease in peak discharge on the reforested area, Shackham Brook, for the winter period peaks for 1953-57 ranged from 20 percent at the lower peaks to more than 40 percent at the higher peaks, which was determined highly significant.

1/ Since this paper was presented, the data have been reanalyzed by more rigorous statistical methods. The results based on the more rigorous approach have been presented in a final report (Schneider, W.J., and Ayer, G.R., 1960; Effect of reforestation on streamflow in central New York, U.S. Geological Survey water-supply paper, in preparation).

This reduction in peak flows during the later years is believed to be attributable to an ameliorating effect of the conifers on snowmelt. Baldwin (1956) describes this ameliorating effect as follows:

> " A striking example of the influence of forests in conserving snow and thus reducing flood runoff from forest-covered land was afforded by the March 1936 flood in New England. Prior to the flood a deep snow blanket covered both forest and open but, after the torrential rains and thaw, snow remained only in the woods. Open fields were completely bare even in northern-most New Hampshire and on the summit of Mt. Washington all but one inch of the 20.5 in. of dense snow and ice melted. In the forest on the other hand, while the snow sank to less than one-half the original depth, this snow layer absorbed and held not only much of the melt water but some of the rain that fell."

Although no physical observations were made on the reforested areas to corroborate the effect described by Baldwin, corroboration may be inferred from the correlation of peak discharges of Shackham Brook and Albright Creek for the 6-month period ending April 30. The data as shown in figure 1 indicate a strong relationship for the years 1939-43, with a coefficient of correlation of 0.93. During these years, almost no coniferous woodland existed on either area, and the similarity in peaks associated with comparable meteorologic conditions indicates a potentially strong relationship in the respective contributions of snowmelt to these peaks. Conversely, in the years 1953-57, the relationship between comparable peaks as shown in figure 1 diminished with a resultant decrease to 0.60 in the coefficient of correlation. Since the meteorologic conditions affecting comparable peaks in this latter period are similar to those in the 1939-43 period, it can be inferred that the relative contributions to runoff from snowmelt from the two areas vary considerably.

The magnitude of reduction of peak flows on Shackham Brook during the latter years is noteworthy. It represents a major reduction in peak flows for a condition in which snowmelt from the area is retarded in the coniferous woodlands, but not in the open fields. Therefore, it is interesting to hypothesize the reduction of peak flows for a condition of complete coniferous cover on the Shackham Brook area. The relationship between comparable peak flows on Shackham Brook and Albright Creek might be lessened because of the potentially maximum adverse effect of snowmelt which frequently would occur on one area but not on the other. Under complete coniferous cover, the release of runoff from snowmelt probably would occur over the entire area at about the same time. This is in contrast to a partial coniferous cover which permits snowmelt first from open areas and at a later time from the coniferous woodland, and could alter materially the mitigating effect of partial coniferous cover. Therefore, the maximum reduction of peak flows might result from a partial coniferous cover of an area.

The effect of forest cover on peak flows was further studied to see if any trend existed within the winter period itself. Figure 2 was prepared wherein the percentage of deviation of each Shackham Brook peak from its regression line in Figure 1 was plotted against time in days of the occurrence of the peak subsequent to Nov. 1.

The two lines of best fit indicate that during the early period 1939-43 little change in deviation or scatter occurred as the winter season progressed. During the later period 1953-57, a definite trend is indicated suggesting that during this latter period a considerable and variable effect resulted from snowmelt contribution to the peak discharges of the two basins. The difference between the two trend lines in figure 2 was analyzed for significance by comparing the covariance of the departures and time. The ratio of covariance was 5.00, indicating a significant difference in the trends above the 5-percent level of confidence. The trend lines indicate a progressive increase chronologically during the 6-month period, of peak flows on Shackham Brook for the period 1953-57 when compared with the peaks computed from the period regression with Albright Creek.

The total yield from the Shackham Brook area for the period November 1 to April 30 also was studied using regression and covariance analyses. It was assumed that changes in ground-water storage between November 1 and April 30 were relatively constant for all winter periods both in the Shackham Brook area and in the Albright Creek area. In both areas, there is little ground-water storage on November 1 to affect streamflow, and on April 30 the ground water table is at or near the land surface in both areas. This relatively constant change in storage each year has no effect on the results of the analyses.

The first step was to compute average runoff for the 6-month periods Nov. 1 to Apr. 30 for the years 1940-48 and 1949-57. These data appear in columns 4 and 5 below.

Period	Ending	Years	Average runoff inches	Average precip. inches	Adjusted runoff inches	% change in adj. runoff	Covariance ratio F
6 month	Apr.30	1940-48	19.58	18.49	20.82		
		1949-57	18.12	20.81	17.25	-17.1	9.36**

Before a comparison of runoff for the 2 periods could be made, however, adjustments were made to the Shackham Brook averages to take into account the differences in precipitation for these periods. In other words the two periods of runoff were adjusted on the basis of the regressions, giving the computed runoff for each period, based on the same average precipitation for each period. Figure 3 shows the relationship between runoff and precipitation for the two 9-year periods. Entering these curves with an average value of 19.65 inches for precipitation gives adjusted runoff of 20.82 inches for 1940-48 and 17.25 inches for 1949-57, a reduction of 17.1%. Covariance analysis indicates that this reduction is significant at the 1% level. In other words, there is only one chance in a hundred that this was a random occurrence and 99 chances in a hundred that it was the result of some cause. Nothing but reforestation happened to the areas. We attribute the 17 percent decrease to the reforestation.

A similar analysis using runoff of Albright Creek instead of precipitation for Shackham Brook area revealed a net decrease of 9.3 percent in runoff for Shackham Brook between the early and late periods. The decrease was found significant at the 5-percent confidence level. The magnitude of the decrease was of the same order as that obtained from the precipitation-runoff relationship.

It is evident from these studies that forest cover has a significant effect on peak flows, total runoff, and distribution of runoff during the winter months in northeastern United States. We should also recognize that management of forest areas can vary the effects on runoff. A recent paper presented before the Western Snow Conference (Anderson, et al, 1958) discusses the effect of forest management on snow disposition in relation to streamflow at the California Forest and Range Experiment Station. Although the water problems in the eastern part of our country differ from those of the western part, the manipulation of forest cover to influence both snowpack accumulation and disposition may well be useful in the eastern United States under certain conditions.

References

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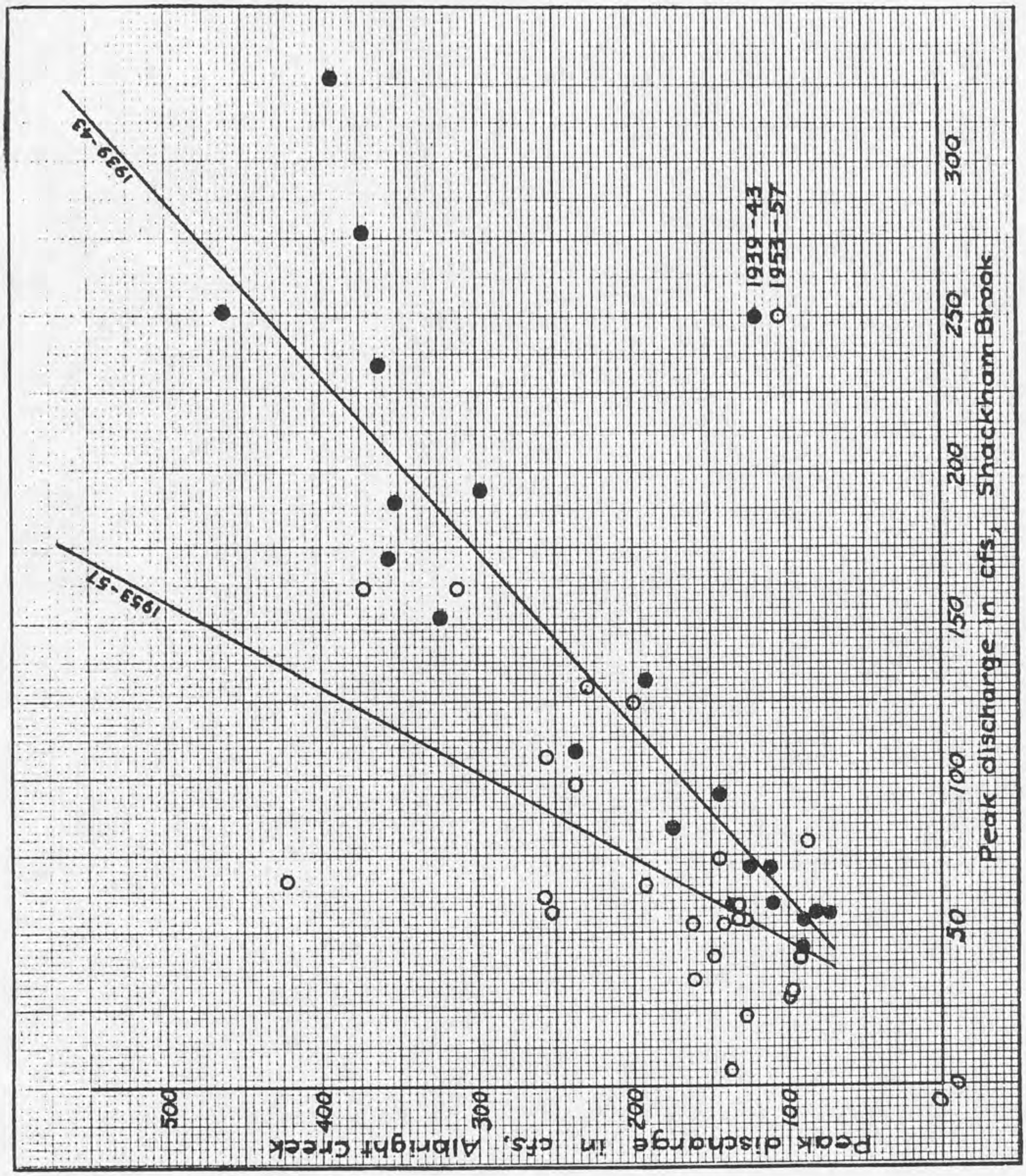

Figure 1

PEAK DISCHARGE RELATIONSHIP
6-MONTH PERIOD ENDING APRIL 30

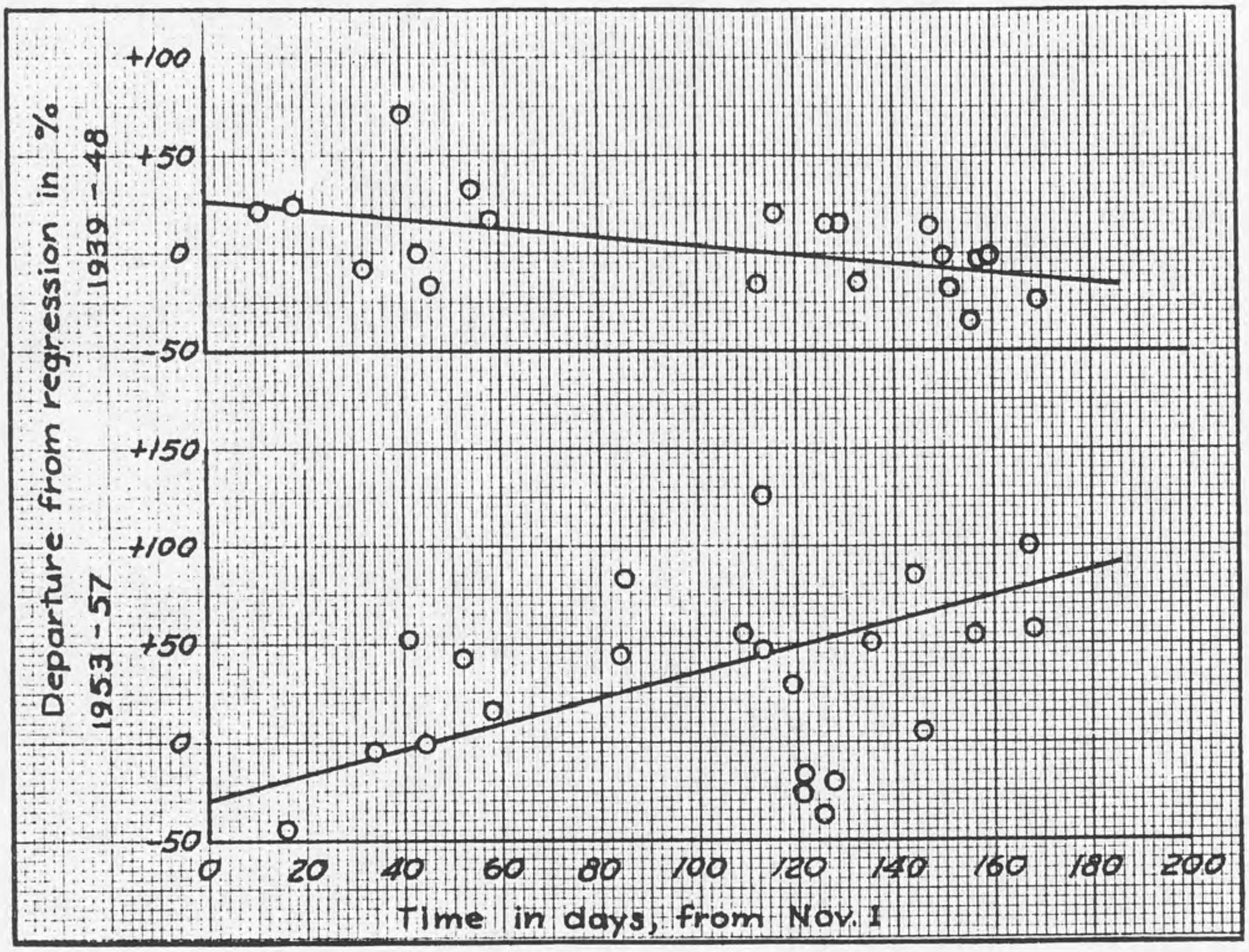

Figure 2

TREND IN PEAK DISCHARGES

ON

SHACKHAM BROOK NEAR TRUXTON

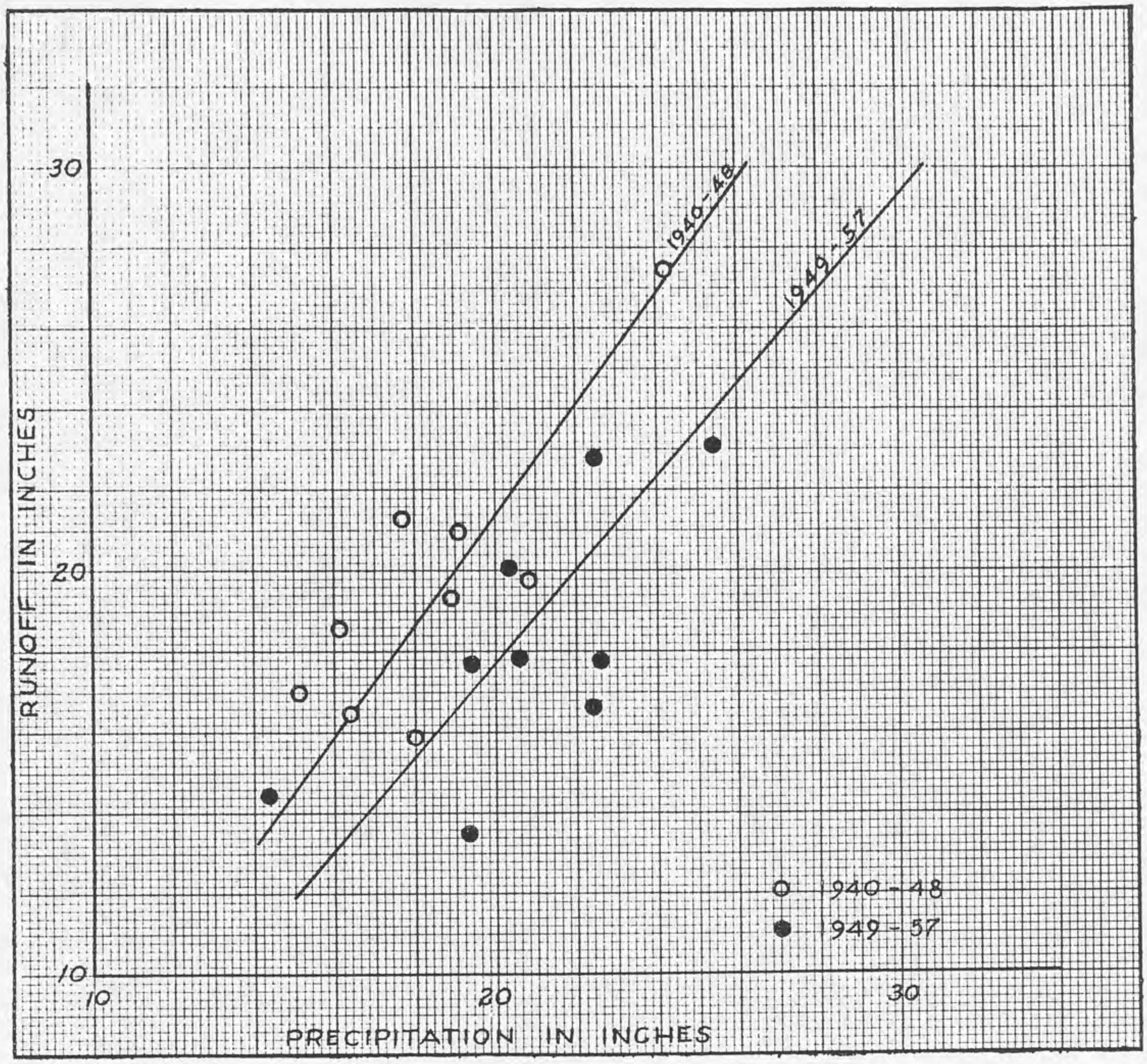

Figure 3

RELATIONSHIP BETWEEN RUNOFF AND PRECIPITATION
SHACKHAM BROOK AREA
6-MONTH PERIOD ENDING APRIL 30