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Transactions, American Geophysical Union Volume 28, Number 1 February 1947

EFFECT OF REMOVAL OF STREAM-BANK VEGETATION UPON WATER YIELD

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Abstract--This is a preliminary report of results of a study wherein vegetation has been cut along the stream bank of a 22-acre watershed on the Coweeta Experimental Forest. Previous measurements on this forest have shown that complete removal of vegetation results in notable gains in water yield because of a reduction in transpiration. The cutting of riparian growth has also resulted in an increase in yield of sufficient magnitude to be significant in water-resource management.

Preliminary examination of the data immediately following cutting shows a virtual elimination of the diurnal fluctuation during the growing season. This indicates that the vegetation immediately adjacent to the stream is making appreciable demands upon groundwater supplies contributing directly to streamflow.

It can be concluded, therefore, that important gains in water yield during the growing season in the southern Appalachian region may be realized with relatively little effort by eliminating the transpiration draft of riparian vegetation. This procedure can be of much practical value during drought years for municipal and industrial watersheds, when even small increases in yield are of unusual importance.

Diurnal variations in runoff have long been associated with the combined draft of evaporation and transpiration upon water in streams and the adjacent groundwater aquifer. This evapotranspiration factor has been termed "consumptive use" by BLANEY, TAYLOR, and YOUNG [see "References" at end of paper, 1930]. Except for water losses through deep seepage, it is almost entirely responsible for the difference between precipitation and runoff within the water year.

The importance of water losses through transpiration and evaporation has been emphasized repeatedly by investigators, particularly in semi-arid regions [BLANEY, TAYLOR, and YOUNG, 1930; BLANEY, TAYLOR, YOUNG, and NICKLE, 1933; TROXELL, 1936; WHITE, 1932; WICHT, 1941; and YOUNG and BLANEY, 1942]. In the southern Appalachian region water resources have been drawn upon heavily to meet the constantly increasing demands of industries and municipalities. In numerous instances supplies have become critically low. This situation has led to an active interest on the part of industrial and municipal watershed managers in the possibilities for augmenting existing supplies during summer drought periods.

On the Coweeta Experimental Forest, studies have already demonstrated that cutting vegetation over the entire surface of an experimental watershed will increase water yield as much as 17 area inches a year [HOOVER, 1944]. This increase, it was concluded, was derived almost entirely from the complete elimination of transpiration. The net effect of evaporation was unchanged because increased soil evaporation was offset by decreased interception. This study [HOOVER, 1944] has afforded an estimate of the maximum effect achieved by reducing transpiration in a superhumid climate.

Following this line of investigation, it was assumed that vegetation having continuous access to the water table is responsible for losses relatively greater in proportion than the area it occupies. Use of water in such locations continues at a high rate throughout the growing season and reaches a maximum during rainless periods when transpiration by plants in drier areas is limited by lowered groundwater tables. Therefore, it was concluded that an important measure of the transpiration draft by vegetation growing in zones of high water tables can be gained by studying the effect of its removal on streamflow in a small experimental watershed.

Transpiration and evaporation of water by stream-bank vegetation have been estimated with some success in the past by measuring the flow of water entering and leaving a given section of stream channel [TROXELL, 1936, and YOUNG and BLANEY, 1942]. It has been pointed out that determinations made in this manner may be subject to non-measurable movements of inflow and outflow. Studies of this nature have been conducted in Temescal Creek, Coldwater Canyon, and the Santa Ana River in Southern California. Daily losses in flow attributed to transpiration and evaporation in Coldwater Canyon varied in amounts from 0.12 to 0.50 acre inches per 1000 feet of canyon bottom. In Temescal Creek losses per day from 12.8 acres increased gradually from 0.02 to 0.64 acre inches from April 16 to May 27, 1929.

The present paper describes the methods of arriving at evapotranspirational losses by a comparison of streamflow before and after cutting of the stream-bank vegetation. It is believed that such a comparison will yield more direct information than the methods employed heretofore. One advantage of the direct treatment method is the fact that non-measurable inflow and outflow seepage do not affect the relative differences in flow due to treatment. On the basis of observations previously made at Coweeta Experimental Forest, it was concluded that measured effects of cutting stream-bank vegetation do not reflect any substantial change in evaporation rates [HOOVER, 1944].

Because of the limited scope of this investigation, the results obtained must be regarded as only indicative of the water volumes utilized by vegetation growing in zones of high water tables. Cutting was confined to a strip of vegetation adjacent to an active stream in a small watershed. No attempt was made to include other possible zones of high water tables existing within the area. This preliminary test will be followed by a more comprehensive study which will include the measure of cutting effects upon water temperatures and aquatic biology.

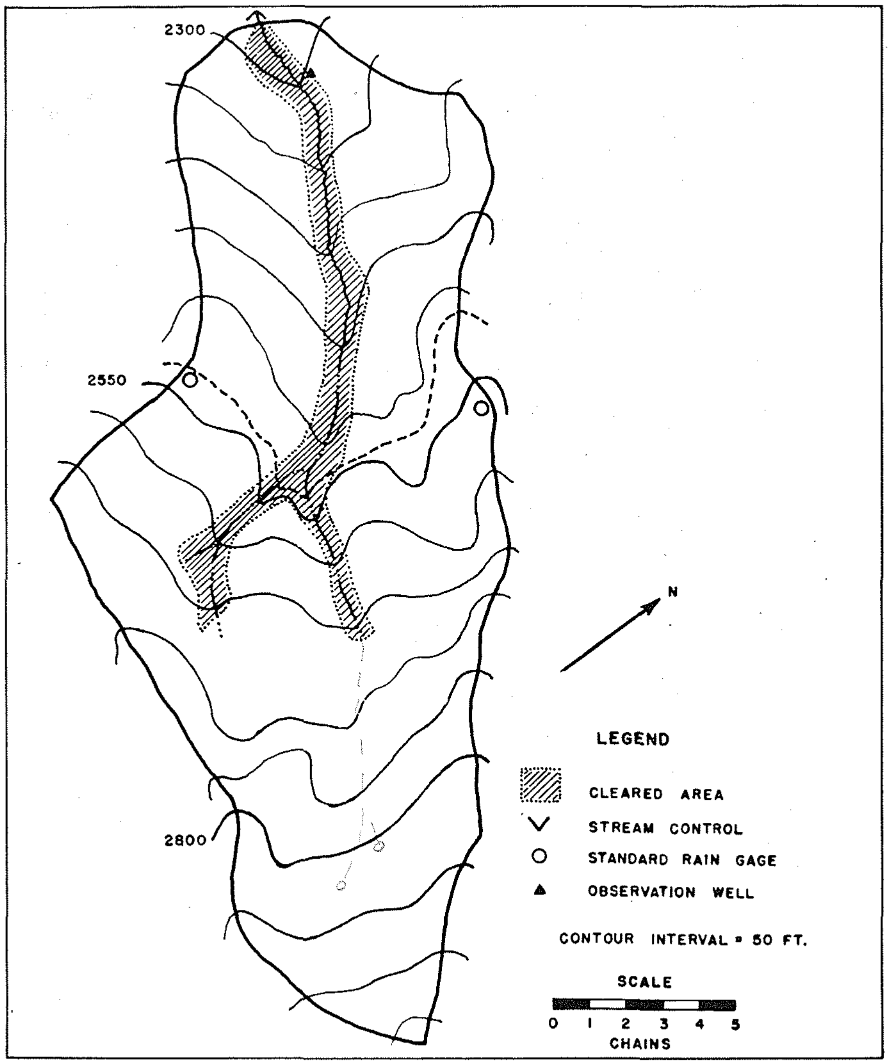

Fig. 1--Topographic map of Area Number 6, Coweeta Experimental Forest, showing area cleared of stream-bank vegetation

The experiment is being conducted on the Coweeta Experimental Forest in the Appalachian Mountains of western North Carolina. The region is one of high rainfall, averaging about 70 inches a year, distributed rather uniformly throughout the year. The growing season extends from April 15 to October 15, with a mean temperature of 65°F. Natural vegetation is abundant and primarily deciduous. For the purposes of investigation a 22-acre watershed designated as Area Number 6 was selected (see Fig. 1). The aspect is northwest and elevations range from 2282 to 2955 feet. Continuous records of streamflow from a sharp crested V-notch weir have been obtained since July 1934.

A treatment area was delineated by assuming that all vegetation at a ground level within 15 feet in elevation above the stream channel had access to the continuous water table. Within those limits was an area of 2.62 acres or 12 per cent of the total watershed area. The length is 1600 feet and the width varies from 60 to 250 feet. During the period of July 21 to 25, 1941, all woody vegetation within this zone was cut, lopped, and scattered (see Fig. 2). The soil surface was disturbed as little as possible and all debris due to cutting was removed from the channel.

Fig. 2--View of Area Number 6 after cutting stream-bank vegetation
[photo by U. S. Forest Service]

A complete tally of the vegetation on the cutting area showed a total of 3563 stems larger than 0.5 inch in diameter. The greater portion of this number was represented by an understory of rhododendron, mountain laurel, azalea, witch hazel, black birch, and associated species. The principal tree species in the overstory were chestnut oak, yellow poplar, red maple, and hickory. Sprout growth was quite rapid during the 1942 growing season, one year following treatment. Species such as yellow poplar, red maple, and hickory made an early appearance and grew vigorously. Rhododendron still remains the most abundant species. No further cutting was done following the original treatment.

In the analysis of the effects of cutting, two approaches have been considered. The first of these is based on a comparison of data obtained from the treated watershed alone. The second, introduced as supplementary evidence, employs data from an adjoining watershed serving as an untreated check. Treatment effects derived from either method are subject to variables which cannot be controlled other than by statistical procedures. In view of the preliminary nature of the present study, the possibilities of increasing the accuracy of the estimates by use of statistics were not explored.

A fairly reliable expression of streamflow during rainless periods following cutting can be depicted by a smoothed groundwater depletion curve. Such a curve was developed from data obtained during August and September of 1941, and June to September 1942. A close approximation of the average daily flow is maintained throughout, since it is based on a series of instantaneous midnight readings from the hydrographs. The curve has been synthesized from a group of individual segments of post-treatment hydrographs adjusted horizontally to positions providing the best fit of midnight points. Average readings on a vertical scale at each of these reference points were then obtained, from which the smoothed curve was drawn.

Having an expression of post-treatment stream behavior depicted by the synthesized depletion curve, a measure of treatment effect may then be estimated. In Figure 3 is shown a curve, B, representing the observed flow for a ten-day period just prior to treatment. This period represents the groundwater depletion following a storm producing a peak flow of 7.023 csm. The diurnal fluctuations shown are characteristic of the flow of Area Number 6 prior to treatment. If it can be imagined that the ten-day period shown in Figure 3 occurs immediately following the cutting of stream-bank vegetation, one can assume that the flow from Area Number 6 will be represented by a portion of the synthesized depletion curve, A. After inspection of the hydrograph of the storm preceding curve B, it was estimated that the initial point on the groundwater depletion curve was at a discharge of 1.0225 csm occurring at $08^{h}00^{m}$, June 12, 1942. This can be assumed to represent a point of time immediately following treatment. Post-treatment stream-flow behavior will then follow the pattern shown by a portion of the synthesized depletion curve, A, beginning at a discharge rate of 1.0225 csm.

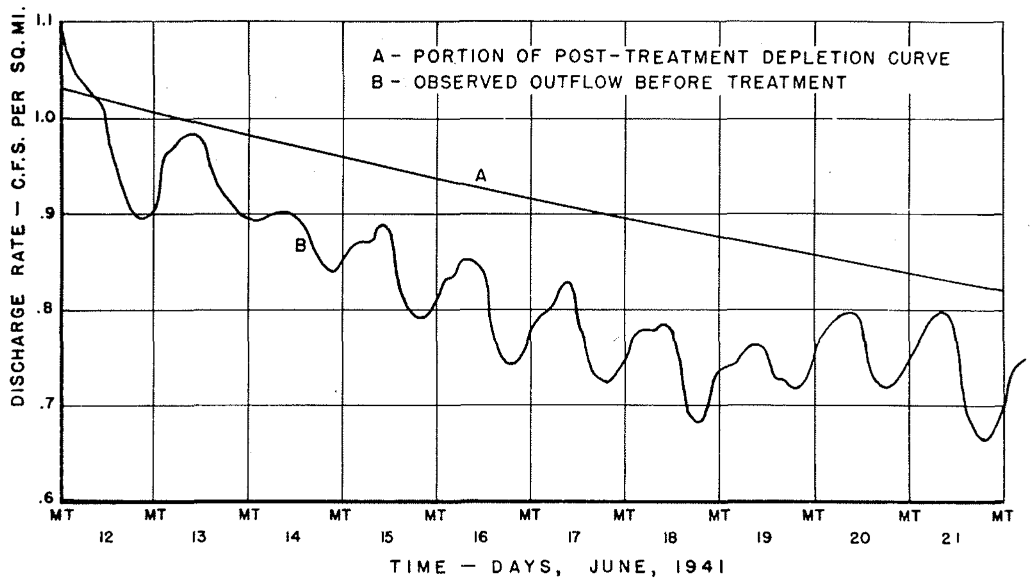

Fig. 3--Estimated effect of cutting stream-bank vegetation, Area Number 6, Coweeta Experimental Forest

Estimated daily increases attributed to cutting vary from 3.8 per cent to 19.0 per cent or a ten-day average of 12 per cent above the measured flow taken from the lower curve. Although some diurnal fluctuation remains after cutting, curve A represents a mean of these daily fluctuations, a fact which does not alter the differences obtained from Figure 3. Indicated treatment differences are shown in Table 1.

An interesting interpretation may be derived from the characteristics of the post-treatment depletion curve A. Its position with respect to pre-treatment depletion curve B in Figure 3 indicates that the transpiration losses are not represented by the daily fluctuations alone. This would tend to bear out some conclusions reached by TROXELL [1936] in his discussion of diurnal fluctuations in the Santa Ana River. He states that the practice of connecting the periods of maximum discharge of diurnal fluctuations and assuming that the difference between the curve thus obtained and the actual flow represents transpiration loss will give results which are too conservative. The interpretation gained from Figure 3 is that transpiration by stream-bank vegetation is not only responsible for a daily depression in the hydrograph but also for a progressive drain on the groundwater reservoir in excess of that which would normally occur if there were no transpiration.

A second approach to the problem of estimating the effects of removal of stream-bank vegetation was investigated. This method involves the use of data from a check watershed to aid in the

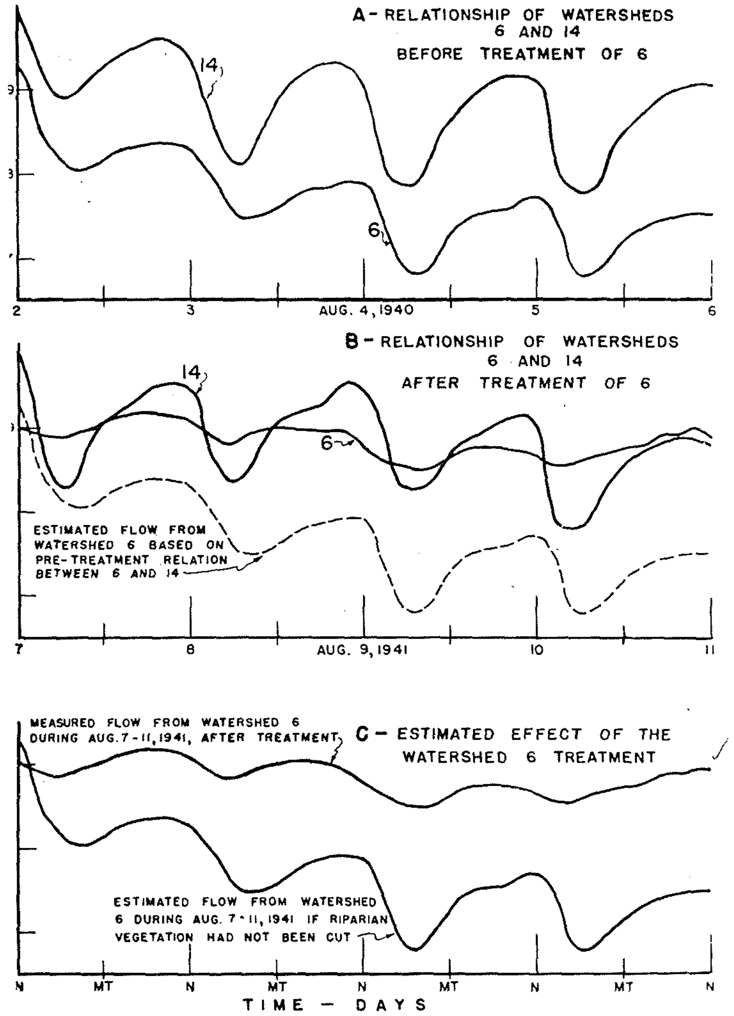

Fig. 4--Estimated increase in water yield due to cutting of stream-bank vegetation, Coweeta Experimental Forest

interpretation of results before and after treatment in Area Number 6. The advantages of this comparison lie in the fact that climatic factors affecting transpiration before and after treatment can be controlled statistically. The following discussion does not fully exploit the advantages of this method, but a more comprehensive investigation will be made of its possibilities in subsequent analyses planned for this study. The graphical representation in Figure 4, however, is indicative of the results which may be found.

The check watershed, Area Number 14, employed in this comparison, is 152 acres in area and lies adjacent to Area Number 6. The general aspect is north and the vegetation along the stream banks is similar to that existing in Area Number 6 prior to cutting. Preliminary investigation indicates that a well-defined relationship exists between the discharge rates of both watersheds. For the purposes of graphical demonstration, two four-day periods were selected, one before and one after treatment. Hourly discharge rates in csm were plotted as shown in Figures 4A and 4B. The discharge rate in Area Number 14 is substantially the same before and after treatment. For Area Number 6, however, treatment appears to have accomplished two things: (1) Raised the average level of discharge rates; and (2) eliminated much of the diurnal fluctuation in flow. The residual fluctuation indicates that there was not a complete removal of the vegetation affecting the groundwater supplies adjacent to the stream.

Table 1--Estimated effect of cutting stream-bank vegetation on water yield from Area Number 6

Day	Estimated discharge curve A		Measured discharge curve B		Treatment effect (A - B)		
	av. csm	ft^3	av. csm	ft^3	ft^3	area inches	pct
1	1.0190	3011	0.9820	2902	109	0.012	3.8
2	0.9950	2940	0.9482	2802	138	0.015	4.9
3	0.9720	2872	0.8822	2607	265	0.028	10.2
4	0.9495	2806	0.8419	2488	318	0.034	12.8
5	0.9280	2742	0.8034	2374	368	0.039	15.5
6	0.9070	2680	0.7753	2291	389	0.041	17.0
7	0.8870	2621	0.7452	2202	419	0.044	19.0
8	0.8670	2562	0.7411	2190	372	0.039	17.0
9	0.8485	2507	0.7597	2245	262	0.028	11.7
10	0.8300	2453	0.7343	2170	283	0.030	13.0

A third step in the graphical comparison gives an estimate of the increase in yields due to treatment. This is accomplished by matching the flow in Area Number 14 before and after treatment as closely as possible and noting the difference between the pre-treatment and post-treatment flows in Area Number 6. This step is represented by the dashed line in Figure 4B and the final comparison in Figure 4C. Increases thus indicated have been computed at 13, 17, and 19 per cent for a three-day period. These compare favorably with those obtained by the depletion-curve method.

It can be concluded, therefore, that important gains in water yield during the growing season in the southern Appalachian region may be realized with relatively little effort by eliminating the transpiration draft of stream-bank vegetation. This procedure can be of much practical value during drought years for municipal and industrial watersheds, when even small increases in yield are of unusual importance.

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(Manuscript received June 3, 1946; presented at the Twenty-Seventh Annual Meeting, Washington, D. C., May 28, 1946; open for formal discussion until July 1, 1947.)