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STREAM-FLOW FREQUENCY CHANGES ON COWEETA EXPERIMENTAL WATERSHEDS

J. A. Lieberman and M. D. Hoover

Abstract--Three land-use changes were made on small watersheds at the Coweeta Hydrologic Laboratory as follows: (1) removal of all major forest vegetation with repeated cutting of sprout growth; (2) removal of all major forest vegetation with natural regrowth allowed; (3) removal of all major forest vegetation and placement of the area under agriculture. The streamflow effects are demonstrated graphically by comparing frequency distribution curves of daily flow for periods before and after changes in land use. For the same periods comparisons are also made with similar curves for control watersheds on which no land-use changes were made. The ratios of the flows exceeded 16 per cent of the time to the flows exceeded 84 per cent of the time are presented as indexes of variability of streamflow. Each of the changes in land use resulted in increases in mean daily discharge when the rate of flow was below about three cubic feet per second per square mile. The higher base flow is attributed to the reduction in transpiration draft.

Introduction--Frequency distribution curves of mean daily discharge from treated experimental watersheds on the Coweeta Experimental Forest are compared for the prior and post treatment periods. In addition, similar comparisons are made between each treated watershed and an untreated, or control, watershed. From these comparisons conclusions are drawn as to the effect of the treatments on the regimen of daily stream flow and as to the practicability of frequency distribution curves in showing stream-flow changes brought about by experimental land use treatments.

The Coweeta Experimental Forest is a 5500-ac hydrologic research area operated by the Southeastern Forest Experiment Station of the U. S. Forest Service. Previous papers [see References] have given a description of the area and some results of watershed studies in progress. Table 1 gives a summary of rainfall, runoff, and temperature for one of the untreated experimental watersheds which is generally representative of the area.

Table 1--Average monthly precipitation, runoff, and air temperature for the period 1936 to 1945, Coweeta Watershed 18

Month	Precipitation	Runoff		Air temperature
	inch	inch	pct	°F
Nov.	4.32	1.10	25.5	43.9
Dec.	7.24	1.93	26.7	38.8
Jan.	5.79	3.37	58.2	38.1
Feb.	7.50	4.83	64.4	39.9
Mar.	7.64	5.41	70.8	47.3
Apr.	5.89	4.76	80.8	56.4
May	4.21	3.47	82.4	64.1
June	4.56	2.09	45.8	71.1
July	7.34	1.93	26.3	72.0
Aug.	5.76	1.66	28.8	71.5
Sep.	4.41	1.19	27.0	65.6
Oct.	3.08	0.94	30.5	55.8
Totals and mean	67.74	32.68	..	55.4

Experimental watershed treatments--One of the research objectives at Coweeta is to determine the effect of various land-use treatments on stream flow. To accomplish this, treatments are actually carried out on individual drainage areas, and the effects measured. The treatments under consideration in this paper are:

(1) All the vegetation on the 33-ac Watershed 17 was cut during January-March 1941 after a five-year calibration period. No material was removed. Trees were left where they fell and tops and limbs were lapped and scattered uniformly over the ground surface to form a loose mulch. This mulch protected the soil against excessive drying by sun and wind and maintained the forest soil. Sprout growth was cut back in the summers of 1941 and 1942, winter of 1946-1947, and summer of 1947. The adjacent 31-ac Watershed 18 which remained in natural forest cover serves as a control for this treatment.

(2) Watershed 13, an area of 40 ac, was cut over as described for Watershed 17 during the winter of 1939-1940. Natural re-growth has taken place since that time. Sprouts have developed rapidly and there are now 800 stems per acre

which are larger than two inches in diameter and average over 20 ft high. This watershed is compared with the nearby 31-ac Watershed 2 which has been undisturbed.

(3) The 23-ac Watershed 3 was cleared for agricultural use during the winter of 1939-1940. All vegetation was cut and stumps less than 17 inches were pulled. The logs were removed and the brush and tops were piled around the large stumps and burned. In 1941, 1942, 1943, 1946, and 1947 a six-acre portion of the area was cultivated for corn and the remainder was pastured by cattle. This watershed is also compared with the 31-ac Watershed 2.

Data analysis and results--As a routine compilation procedure, the mean daily stream flow in cubic feet per second per square mile (csm) from all watersheds is determined from continuously recorded stream hydrographs. In this analysis the mean daily stream-flow data from the treated

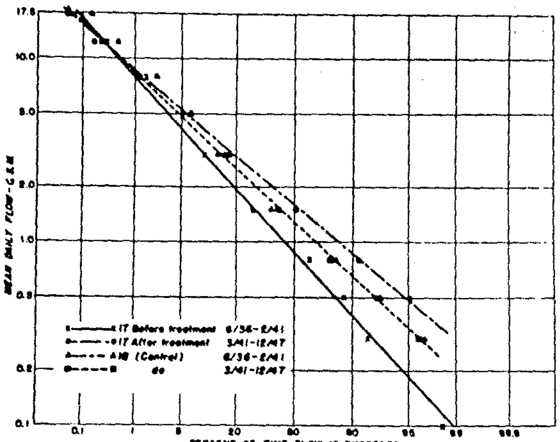

Fig. 1--Coweeta 17 and 18, flow frequency distribution

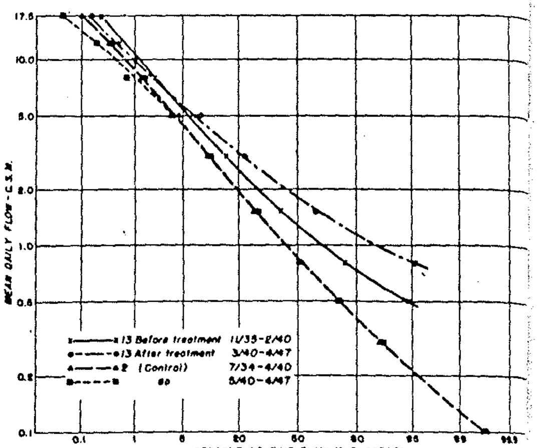

Fig. 2--Coweeta 13 and 2, flow frequency distribution

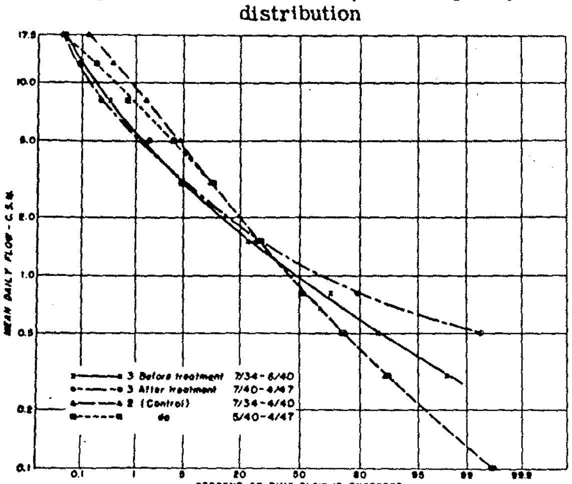

Fig. 3--Coweeta 3 and 2, flow frequency distribution

and control watersheds for the total prior and total post treatment periods are grouped and plotted on logarithmic probability paper to present a graphical picture of the frequency distribution (see Fig. 1-3). An inspection of these graphs indicates that the treatments described produced changes in this frequency distribution.

Besides the direct visual comparison of the logarithmic probability curves, the comparison of certain ratios and constants obtained from the curves offers a quick and useful means of describing or indicating the general level and variability of mean daily stream flow. The value of the 50 per cent ordinate is taken from the curve to indicate the general level of stream flow, and the ratio of the 16 per cent ordinate to the 84 per cent ordinate is arbitrarily used to describe the variability of the flow. Table 2 gives these values for the watersheds. The ratio of the 16 per cent ordinate to the 84 per cent ordinate is suggested as a more satisfactory indication of variability than the standard deviation because of the skewness of stream-flow data.

On Coweeta 17, where all vegetation was cut, and regrowth also cut, the general level of stream flow was raised, with the most noticeable increase occurring in the lower range of flows. The mean daily flow at the 84 per cent level was increased 124 per cent and at the 16 per cent ordinate, 45 per cent. The median value was increased 83 per cent. Changes in flows above five

Table 2--Comparison of flow frequency distribution curves

Coweeta Watershed	Mean discharge	50 pct ordinate	84 pct ordinate	16 pct ordinate	Ratio, 16 pct ÷ 84 pct ordinate
	csm	csm	csm	csm	
17[b]	1.94	0.88	0.34	2.28	6.71
17[a]	2.74	1.61	0.76	3.30	4.34
18[b]	2.42	1.30	0.58	2.90	5.00
18[a]	2.43	1.30	0.58	2.90	5.00
13[b]	2.51	1.28	0.67	3.00	4.48
13[a]	3.16	1.81	1.08	3.50	3.24
3[b]	1.73	0.97	0.55	1.80	3.27
3[a]	1.93	1.12	0.77	1.87	2.43
2[b]	1.92	0.86	0.36	2.30	6.39
2[a]	1.86	0.86	0.36	2.30	6.39

[a]After treatment period.
[b]Before treatment period.

csm do not seem to be significant. The frequency distribution for control watershed 18 is essentially the same for both the before and after treatment periods, indicating that the changes on watershed 17 are due primarily to treatment and not to climatological changes. A more detailed analysis of the increase in water yield brought about by this treatment has already been made [LIEBERMAN, 1947].

Where natural regrowth was allowed to take place (Watershed 13), the influence of vegetation removal is still evident, although to a lesser degree. The median value shows an average increase of 41 per cent since treatment, with the 84 per cent ordinate increased 62 per cent and the 16 per cent ordinate increased 17 per cent. There is apparently no change in the higher flows. For both this treatment and that on Watershed 17, the values given are the separate averages for the entire prior and post treatment periods. Because of rapid re-establishment of vegetation, greater increases in stream flow occur in the first years after cutting than in later years. An analysis of mean daily discharge on an annual basis would show how the maximum effect of treatment is influenced by regrowth of vegetation.

On Watershed 3, which was cleared for mountain agriculture, a smaller increase in flow was observed than where the forest soil was protected by a mulch. The median value was increased 15 per cent. The value of the 84 per cent ordinate was increased 40 per cent and that of the 16 per cent ordinate shows no significant increase. The reason for the smaller increase in this experiment is believed due to the greater evaporation from the bare soil as compared to the cutting experiments where the brush mulch and the undisturbed forest floor protect the soil.

It must be emphasized that, in this agricultural watershed, the analysis based on mean daily discharge does not give the complete picture of the results of treatment. An important treatment effect has been that runoff peaks from summer thunderstorms have been greatly increased because of the reduction of infiltration rates on this watershed. The time base of the storm hydrographs from this particular watershed is so short that the cognizance of this effect is greatly reduced when the analysis is made on the 24-hr basis of mean daily stream flow. An analysis of peak runoff rates is required to completely evaluate all the results of this treatment.

Discussion and conclusion--In each watershed study in which the major vegetation was cut, the mean daily flows in the range up to four or five csm were increased. These increases can be attributed to the elimination of the transpiration draft of the vegetation and the resulting increased recharge to ground water, which in turn has contributed to high base flows towards the end of the growing season.

Several factors of hydrological importance should be emphasized in connection with the vegetation cutting experiments. First, the fact that none of the cut vegetation was actually removed from the individual experimental area insured minimum soil disturbance. Also, since the cut vegetation formed a mulch over the entire area, the favorable original forest soil characteristics of high infiltration capacities and storage capacities within the soil mass were maintained, and no surface runoff occurred. Second, the rather uniform distribution of precipitation throughout the year is an important factor contributing to the indicated increase in stream flow. Because all the moisture supplied by summer rainfall is not drawn on for current transpiration requirements, a larger amount of water becomes available for increased base flow. The higher mean daily flows (above five csm) are unaffected because they generally occur in late winter or early spring when storage of soil moisture is at a maximum and approximately the same on all watersheds regardless of the vegetative cover. Thus both treated and untreated watersheds react similarly to precipitation at these times.

The extreme importance of the role played by the soil in the hydrologic picture should also be stressed in connection with the experiment on mountain agriculture. In this experiment increases in water yield are noted, but, in contrast to the areas where the vegetation was not removed, there was also an increase in instantaneous flood peaks and soil movement. The latter may be attributed to a breakdown of soil structure and subsequent decrease in infiltration capacity, pore space, and moisture storage capacity.

The comparison fo flow frequency distribution curves as plotted on logarithmic probability paper and arbitrary values obtained from them afford a useful means of comparing sets of streamflow data and determining some of the influences of land management on the flow of small streams. Although the use of mean daily flow limits the ability to describe hydrologic processes connected with individual storms, these curves represent an additional tool for demonstrating more completely the effects of land use changes on stream flow.

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1016 Tod Street (J.A.L.),
Falls Church, Virginia

Southeastern Forest Experiment Station (M.D.H.),
P. O. Box 257,
Union, South Carolina

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