SOME CRITERIA FOR DETERMINING UNIT AREA CONTROL IN WATERSHED MANAGEMENT ON MUNICIPAL AND INDUSTRIAL WATERSHEDS IN THE SOUTHERN APPALACHIANS

Thesis for the Degree of M. Sc.

MICHIGAN STATE UNIVERSITY

Glendon W. Smalley

1956

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By

Glendon W. Smalley

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department of Forestry

1956

Approved T. F. Stevens

GLENDON W. SMALLEY ABSTRACT

The ultimate goal of the Southern Appalachian regional watershed management research program is to discover and establish a sound and practical basis for a forest management program directed toward the maximum utilization of all forest resources. In this integrated practice the utilization of one forest product will be carried out without jeopardy to other forest products. This study (a pilot-study by nature) was undertaken in an effort to find a rational approach to this integrated management of water and timber resources.

The study is composed of two major parts: (1) development of criteria on which to base the integrated management, and (2) application of the criteria to determine their practicability.

The concept of unit area control as used in the management of California forests is thought to offer a rational approach to the integrated management of water and timber resources in the Southern Appalachians. The original concept (based on silvicultural factors) is broadened to include hydrologic factors expressed in terms of topography and soil characteristics.

A thorough review of literature and an intensive on-the-ground study of conditions existing within the Coweeta Hydrologic Laboratory is made in an effort to find suitable criteria whereby the "unit areas" could be delineated. The criteria selected are: aspect, slope, soil depth and vegetation. Each criterion is discussed from both hydrologic and silvicultural standpoints with particular reference to the Southern Appalachians.

The criteria are then applied to a small unit-watershed to determine their practicability. A survey is made of this small watershed to measure each of the criteria. The data are summarized in a series of maps and tables. The data are analyzed by using four overlays (one for each criterion) and the watershed is divided into unit areas, each one homogeneous with respect to aspect, slope, soil depth and vegetation.

Controls or management practices designed to achieve an optimum combination of water and timber production are prescribed for each unit area. In essence, these controls are silvicultural management practices modified by hydrologic factors in order to achieve the optimum combination of water and timber production.

The concept of variable levels of stocking is presented as a means of describing the intensity of vegetation manipulation. It is founded upon basal area and the recognition that there exists a wide range of basal area in which high rates of timber growth can be obtained.

The concept of unit area control provides a satisfactory approach to an integrated management of water and timber resources if hydrologic characteristics as well as silvicultural characteristics are considered.

Aspect, slope, soil depth and vegetation were selected as suitable criteria for describing the silvicultural and hydrologic characteristics of a watershed in the Southern Appalachians.

The criteria resulted in the delineation of many very small unit areas which were combined in the office to meet a minimum size of unit area requirement.

A knowledge of the fundamental relationships existing between plants, soil and water is essential before management practices can be prescribed for the unit areas. The characteristics of each unit area must be scrutinized and management practices prescribed based on this knowledge of fundamental relationships. In some cases similar treatments are prescribed for different unit areas because the watershed characteristics produce compensating influences.

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INTRODUCTION

Water is one of the most important of the natural resources basic to our national economy. Yet little thought was given this valuable resource until a few decades ago. Its prominence is the result of an ever-increasing demand for high quality water by municipalities, industries, and agriculture. The Southern Appalachian Mountain Region is a prime example of an area where great demands are being made upon the water resource.

This southern mountain region is the source of water supplies essential to the great aluminum and textile industries. An expanding paper and rayon industry is continually looking for additional water supplies. Municipal expansion has already led to rivalry for watershed areas. Hydroelectric power developments rank among the foremost of the Nation. Sportsmen from the great population centers of the East are making increasing and more exacting demands on the streams and lakes for recreation uses.

Within this region are numerous high unit-yield streams to furnish the needed water resource. This means that the amount of streamflow contributed from each acre of watershed is considerably above the average (Fig. 1). For many sections the local commodity value of water far exceeds the total value of harvested timber and other wood products.

Notwithstanding their importance in the economy of the region, the watersheds of the southern mountains have suffered much from mis-manage-

Fig. 1. A typical stream channel of the Southern Appalachian Mountain Region at approximately 3,000 feet elevation.

ment, from indiscriminate cutting and burning, from soil depleting types of mountain agriculture, and grazing. There has been a progressive deterioration of water resources as a result of land exploitation over a period of more than a century. Reduced water quality is evident in the sediment and pollution now carried by the streams. Floods are of frequent occurrence, with losses to crops and livestock and destruction of fertile valley land. Stream channel control is becoming increasingly necessary to prevent the cutting away of valuable land, loss of roads and bridges, and the debouchment of rubble debris into the valley land below (6).[1]

The ultimate goal of the regional watershed research program is to discover and establish a sound and practical basis for the management of forest land in the interest of water resources. Research problems in water resource management all relate directly to the use of the land. Practical application of research findings will come about through improvement or change in land use practices. Hence, the real problem in water resource management is to determine and understand the relation of different land use practices to water, and ultimately to apply this knowledge to land management designed to restore and maintain favorable supplies. As the facts of forest-streamflow relations become better known, they will be integrated into a forest management program directed toward the maximum utilization of all forest resources. In this integrated practice the utilization of one forest product will be carried out without jeopardy to other forest products (6).

[1]Numbers in parentheses refer to Literature Cited.

On areas where the water resource will receive primary consideration, the timber resource will be of secondary importance. Any utilization of the timber resource must be consistent with the maintenance of water yield, soil stability, and water quality.

INTENT AND SCOPE OF STUDY

The intent of this study is to devise some criteria for the application of the principle of unit area control to the integration of timber and water production in forests of the Southern Appalachians.

The silvicultural concept of unit area control (homogeneous stand units based on age class, species composition, stocking, and the presence or absence of seed trees) is broadened to include hydrologic unit areas as delineated in terms of source of streamflow, soil depth, slope, and aspect. Similarly the proposed treatments of unit areas incorporates silvicultural objectives of timber production and water resource management practices.

The study is composed of two major parts. The first concerns the development of the criteria. These criteria are based on past research and conditions existing within the Coweeta Hydrologic Laboratory, an area typical of the Southern Appalachian Region. The second deals with the application of these criteria to a watershed to determine their practicability. Unit areas are delineated on the basis of the criteria developed, and controls (management practices) prescribed for each unit area to achieve an optimum combination of water and timber production. The practices prescribed are broad in outline. They will be the basis for future development of stocking requirements, marking rules, and timber stand improvement instructions. Such detailed instructions will be the first step in the actual treatment of a watershed by unit areas to determine the effect of variable levels of stocking upon water yields and timber production. The actual application of treatments is not considered in this study.

The watershed used in this study is a "unit-watershed" of fifty acres within the Coweeta Laboratory. This small drainage basin can be considered a municipal or industrial watershed in miniature.

REVIEW OF LITERATURE

Lassen, Lull, and Frank (23) presented a thorough analysis of plant-soil-water relations in watershed management. The principles enumerated are essential for an understanding and appraisal of the effects of land conditions, treatments, and uses on streamflow behavior. Of particular help to the writer was the material in the section entitled "Application to Watershed Management."

Unit area control as discussed by Hallin (12) is the common sense application of silviculture to the individual unit areas of the forest stand. It is a silvicultural concept in which the essential characteristic is "detailed control of stocking on small areas." Forest stands are composed of unit areas and the forester controls his stand by applying silvicultural treatments to each unit area.

Kittredge (21) discussed the concepts of protection forest and watershed management. A protection forest, a term familiar in forestry literature, was defined as "an area wholly or partly covered with woody vegetation, managed primarily for its beneficial effects on water or soil movement rather than for wood or forage production." It implied that the vegetation was natural and the management consisted only of fire protection. Watershed management, suggested as a more suitable term, was defined as "the administration and regulation of the aggregate resources of a drainage basin for the production of water, and the control of erosion, streamflow and floods." This term permitted including the objective of production of a maximum yield of usable water and assumed that a manipulation of the vegetation would be necessary. The phases and objectives of watershed management, and methods to be employed in order to obtain the objectives were also discussed.

Kittredge (20) further pointed out that the need for increased water supplies may require forest management in which the objective would be to obtain a cover of trees with minimum foliage and transpiration, and to maintain the trees at minimum sizes and densities compatible with protection of the soil.

Toumey and Korstian (31) provided considerable information pertinent to this study. Soil depth is discussed in Chapter VI. The chapter on physiographic condition provided information regarding slope and aspect. Of particular importance was the classification of forest areas with reference to gradient. The material present in Chapter XI dealing with reaction of forest vegetation on its physical environment was of great value to the writer.

In Chapter III of their text, Wisler and Brater (35) considered the effects of physiographic factors upon the rainfall-runoff relation on any particular drainage basin. Among the factors discussed were: area of basin, shape, elevation, slope, orientation, and drainage net.

Hoover and Hursh (16) reported on the influence of topography and soil depth on runoff from forest land at the Coweeta Hydrologic Laboratory. Of particular interest was the classification of watersheds by elevation based on similar depth of soil-profiles. Hydrologic characteristics of each soil depth group were discussed.

Lutz and Chandler (27) in their discussion of soil depth presented a depth classification of soils presently used by foresters.

Fletcher (5) described soil reservoirs, presented the factors which influence opportunities for storing water in these reservoirs, and briefly discussed their significance from the standpoints of (a) decreasing the stage and frequency of peak stormflows for flood and sediment control, and (b) increasing watershed yields of high quality water for municipalities and industrial consumption.

Investigations were conducted jointly in the Wagon Wheel Gap area, in southern Colorado, by the United States Forest Service and the Weather Bureau, during the period June 1, 1910 to October 1, 1926 to determine the effects of deforestation on streamflow and erosion (2). The treatment increased total water yields 15 percent. The effect was not very pronounced because the area was originally thinly forested, and because the aspen sprouted after deforestation and rapidly restored the cover. The increase in flow was greatest in spring periods, but an excess was maintained throughout the drier summer months. The soil removed from the treated watershed by erosion averaged only 1.3 cubic yards per year.

Wilm and Dunford (34) investigated the effect of timber cutting on water available for streamflow from a lodgepole pine forest on the headwaters basin of the Colorado River near Fraser, Colorado. Four intensities of timber cutting were applied plus an additional treatment for timber stand improvement. Both winter snow, and spring and summer rain, reached the ground in greater quantities, owing to the progressively decreasing loss by interception as more trees were removed from the stand. On the average, the initial storage of snow was increased 26 percent by the heaviest timber cutting, and 5 percent by timber stand improvement. Regardless of the intensity of cutting, the snow disappeared from all plots at approximately the same time. It was apparent that melting was more rapid on the cut-over plots. During the spring periods (before July 1 each year) the average amount of net precipitation was increased 32 percent as a result of the heaviest timber cutting; and the corresponding figure for the summer periods was 35 percent. Autumnal soil moisture deficits were also affected by timber cutting. The influence of timber cutting on these deficits depended largely upon the amounts of net rainfall which reached the ground to replenish these losses. On the uncut plots the amount of water available for streamflow was 10.34 inches, or about 32 percent of the total precipitation. The heavily cut-over plots yielded 13.52 inches, an increase of 31 percent in the quantity of water available for streamflow. No visible erosion occurred on any of the plots aside from minor gullying of the steeper logging roads.

An experiment to determine the quantitative and qualitative effects of timber cutting in this same area was initiated in 1950 (8). Four different widths of cutting strips will be used. The most efficient strip will be the one which allows the greatest amounts of snow to accumulate and prolongs melting over the longest period. Streamflow, the net effect of the interaction of soil, water, and vegetation, will be measured and appraised. It will be several years before the results of this study are available.

Goodell (10) measured the effects of silvicultural thinning of second-growth lodgepole pine stands on hydrologic factors related to streamflow on the Fraser Experimental Forest in Colorado. Two different methods of thinning were applied: a mechanical thinning called the "single-tree" method and a modified crown thinning called the "crop-tree" method. The treatments applied caused an average increase of 20 percent in net snowfall and 15.5 percent in summer rainfall. The felled trees intercepted an appreciable portion of the summer rainfall; sufficient in fact, to reduce to zero the effect of the thinnings on rainfall reaching the ground. It is probable, however, that as the slash disintegrates, the rainfall reaching the soil will increase. If the felled trees had been removed for utilization, some immediate increase in net rainfall would have been realized. To be of practical value the trees removed must be large enough to be merchantable. Because the thinnings allowed more wind and sunlight to reach the snow-surface, it is likely that sublimation losses during cold weather and evaporation losses during periods of melt increased. Since there is no known technique for accurately measuring these vaporization losses on an areal basis, their influence could not be evaluated. This deficiency, however, did not weaken the conclusions. A more complete and definite answer must await watershed studies where the answer can be obtained in terms of streamflow, and vaporization losses from the snow surface can be more accurately determined. Accelerated erosion did not occur as a result of the thinning operations.

Studies in Utah showed that deep-rooted aspen trees require more soil moisture than shallow-rooted herbaceous plants (3). Cutting aspen trees and leaving only herbaceous plants increased the amount of water available for streamflow. The herbaceous cover thus far has been equal to aspen in preventing erosion. This suggests that replacement of deep-rooted plants by shallow-rooted ones may be a means of increasing streamflow.

The Michigan Hydrologic Project was established in 1940 in order to determine the effect of various types of land use on the hydrology of soils under northern conditions (9). Three watersheds were selected for the study. Two were handled under approved prevailing farming practices. The other watershed was forested. This watershed was considered typical of a good, well-stocked oak-hickory farm woodlot.

Smith and Crabb (29) reported on the progress of the wooded watershed study. The effectiveness of forest cover in increasing infiltration was demonstrated. Soil temperatures were generally more stable in the wooded watershed—lower in summer and higher in winter—than those at similar depths in the cultivated watersheds. During the winter of 1951-52, all timber from 5.45 inches up was removed from the watershed and a surrounding isolation strip by a commercial clear-cutting operation for sawlogs and cordwood. A young growth of oak, hickory, and cherry was left on the area, and it is suspected that natural regrowth will occur.

Several studies have been conducted at the Coweeta Hydrologic Laboratory to determine the effect of cutting forest vegetation on streamflow. All tree and shrub growth was cut on one watershed of 33 acres to find out what would be the maximum effect on streamflow (15). The cutting was done with a minimum disturbance to the soil; the logs and slashings were all left on the ground. Although there was no increase in storm peaks or stream turbidity, the yield of high quality water increased 65 percent in terms of annual runoff, during the first year after cutting. This is equivalent to 17 area inches or approximately 15 million gallons. During the late summer months when water is most valuable, the increase in usable base flow of the stream amounted to 100 percent.

On another watershed of 40 acres a quite similar cutting was carried out, but in this case the forest was permitted to come back through sprouting and natural regrowth (18). The increased water yield the first year following cutting was about 58 percent, but subsequent regrowth increased transpiration and interception each year and a relative decrease in water yield was experienced. After 11 years of regrowth the coppice forest is between 25 and 40 feet high, and the increase in yield for the watershed still amounts to about 15 percent above pre-treatment flow. No change in flood peaks, water quality or physical properties of the soil have been observed.

On still another watershed only the trees and shrubs close to the stream channel and its associated high water tables were cut and slashed to the ground (4). The cut was confined to woody vegetation within 15 vertical feet of the stream bed. The cutting was done during the course of a few days in mid-summer, at a time when the streamflow was exhibiting a very definite diurnal fluctuation caused by transpiration draft. About 12 percent of the total area of the watershed was cut. The maximum daily increase in yield was about 20 percent. The annual increase was less than 10 percent. No impairment of the water quality was observed since the soil was afforded cover by the slash resulting from the clearing.

In another study the laurel and rhododendron understory of a 70-acre watershed was completely cut to the ground (18). The average increased water yield for the first two years after cutting was 3.6 inches. More time is needed to fully evaluate the magnitude of this change.

For Coweeta climatic conditions these studies indicate that tree cutting affects the water balance throughout the year, with an effect depending on the amount of vegetative growth removed.

Chapter 5 of Westveld's (33) text provided a thorough and detailed description of the Southern Appalachian Region, its timber types, silviculture and management practices.

Jemison and Hepting (19) brought together in one publication the results of research and twenty years of experience of timber stand improvement practitioners. It is a compilation of published work, processed releases, and unpublished reports by many individuals. The material was presented by grouping the diverse forest types of the Southern Appalachians into four major groups and adding a fifth--plantations. The characteristics, problems and timber stand improvement measures are discussed for each group.

Wahlenberg (32) compared three methods of rehabilitating depleted Appalachian hardwood stands. The three methods were quality selection, flexible diameter-limit, and clearcutting. Only sound specimums of desirable species, particularly white oak, were left on the quality selection plot. The flexible diameter-limit plot was cut according to prevailing practices to an approximate diameter limit of 15 inches. On the clearcut plot everything was cut leaving the site bare. Quality selection proved to be the more desirable method of reclaiming decrepit stands.

Studies by Lieberman and Hoover (24, 25) at the Coweeta Hydrologic Laboratory showed that typical local logging practices caused serious disturbances to the soil. Steep access roads and skid trails eroded severely, and stream turbidity rose sharply. They concluded that the harvesting of wood products from areas of high watershed values will require the proper location and design of access roads and skid trails, and the continued maintenance of these roads and trails.

Four instances of municipalities managing their watersheds for timber as well as water are known to the writer. The Cedar River watershed of the City of Seattle, Washington has been subjected to logging on an extensive scale during the entire period over which it has served as the source of water for the city (11, 14, 30). Intensive forest fire protection has minimized the damage from fire. No deleterious influences to either the soil or water have stemmed from logging. The logging has been conducted on a sustained yield basis using advanced silvicultural methods.

Logging operations have been conducted on the Green River watershed of Tacoma, Washington for over 40 years (22). The city owns only a small percentage of the total drainage area. The sanitary problem resulting from many small logging and sawmill operations, and camps of woods workers presented almost an insurmountable obstacle to the city for many years. Through education, much has been accomplished in this respect. The watershed residents and miscellaneous crews are now complying with the state sanitary rules and regulations. The city authorities are considering the development of storage in the Green River watershed to overcome turbidity and to supplement low water periods.

The Pewuannock watershed of the City of Newark, New Jersey is being managed under a policy which stipulates that no forest work may be done that will be detrimental to the water supply, and that the net forest income is purely secondary to the primary object of water production (13). Fire prevention measures, particularly among the 1,500 permanent residents within the watershed boundaries, have markedly reduced the damage resulting from wild fires. Over 2,800 acres have been planted largely to conifers on old abandoned farm land and eroded areas. Cultural operations on 3,400 acres have produced considerable quantities of fuel wood for those residents on relief. A resident forester has been in charge of the 63.7 square mile catchment basin since 1931. In 1945 the income from forest products was $4,355.13. Live timber stumpage made up 74 percent of this value, dead timber stumpage—17 percent, laurel and evergreen boughs—6 percent, and sale of live spruce (Christmas trees)—3 percent. About 20 years hence, an annual cut of 4,000,000 board feet of lumber and 5,000 cords of wood does not appear overly optimistic.

An outstanding forest management plan designed to bring about perpetual land cover and at the same time a perpetual timber yield has been established on the City of Bremerton, Washington watershed (1). The city conducts its own log sales. The amount realized from the timber sold from the watershed will be many times the original cost of the timberlands. As a protection to the city, the water commissioner has written into the timber contract the authority to stop logging activities altogether or the right to increase the volume harvested. This flexibility allows for unforeseen factors that might arise in the future which would make altering of plans essential for the city's welfare.

COWEETA HYDROLOGIC LABORATORY

The Coweeta Hydrologic Laboratory was established in 1931 by the United States Forest Service in the high rainfall belt of the Southern Appalachian Mountains. The selection of this field laboratory was made following a meticulous search to find an area that would meet rigid specifications designated by hydrologists, engineers, and foresters interested in watershed research. In 1933 intensive research was begun at this 4,200-acre field laboratory in southwestern North Carolina (Fig. 2).

Here the Forest Service through fundamental hydrologic research is developing practical methods of forest land management for maximum timber, forage, and water production consistent with region-wide interest in flood control and the industrial, municipal, and recreational use of water.

Physiography and Soils

The steep slopes and sharp-crested ridges form natural boundaries for the many small drainage basins—each an independent hydrologic unit—ranging in size from 25 to 200 acres. The elevations vary from 2,200 to 5,200 feet within the Laboratory boundary (Fig. 3).

The entire area is underlain with deeply weathered Archean Carolina gneiss and schist. As a result of complex folding and the absence of open faults or fractures, there is little likelihood of continuous channels through the rock that would permit subterranean loss of water. The parent rocks weather to form a deep soil mantle, with rock outcrops oc-

LOCATION MAP

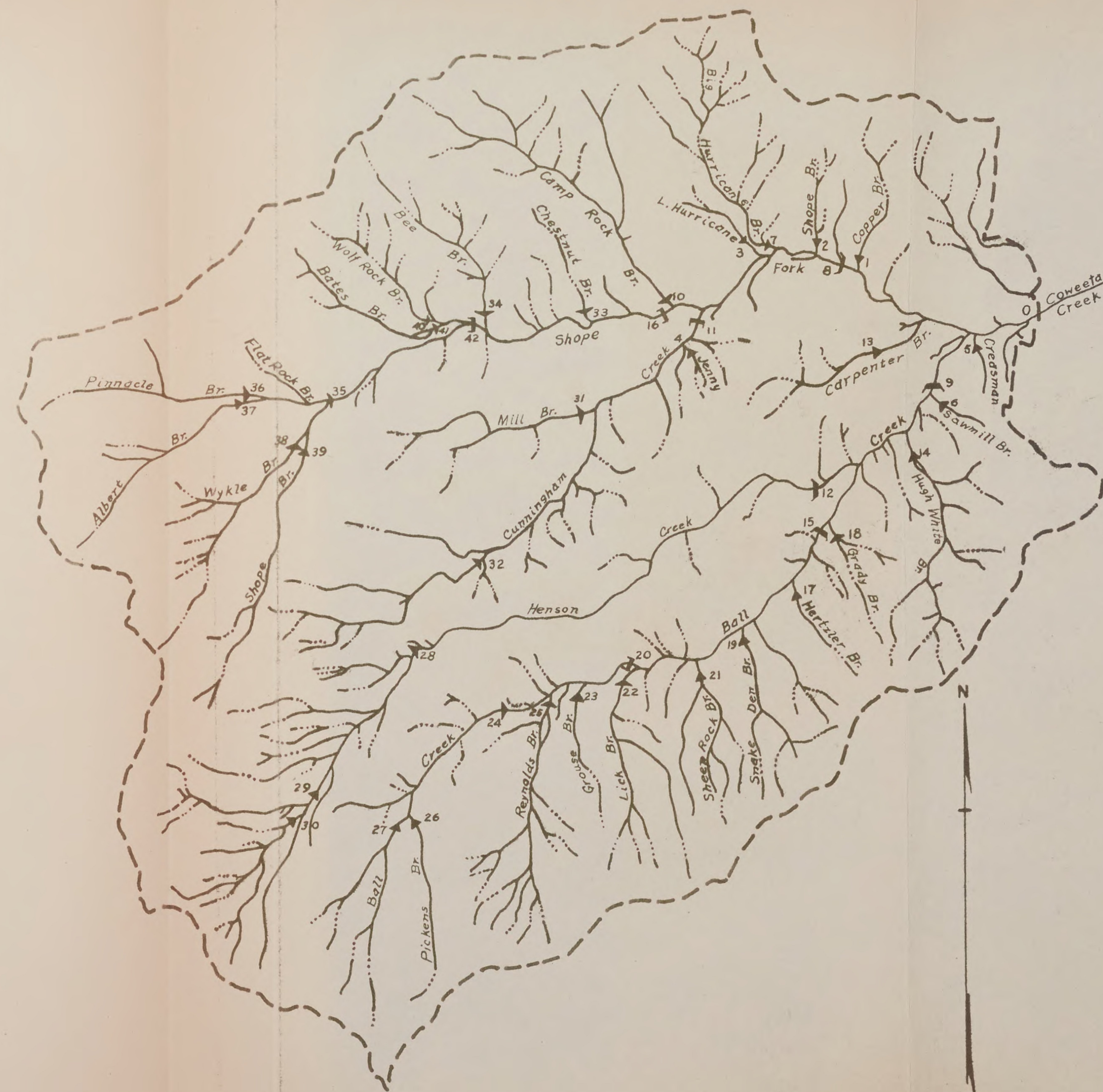
Fig. 2

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

COWEETA HYDROLOGIC LABORATORY

LOCATION MAP
FOR
STREAM GAGING INSTALLATIONS

SCALE OF FEET
1000 0 1000 2000 3000



LEGEND

90° V-NOTCH WEIRS
120° V-NOTCH WEIRS
RECTANGULAR WEIRS
CIPOLETTI WEIRS

Fig. 3. Steep slopes and sharp-crested ridges are typical of the terrain of the Southern Appalachians.

curring only on steep slopes at high elevations. The slopes are covered with a residual soil mantle from two to four feet thick, usually underlain to a considerable depth by partially decomposed rock. At the foot of the slopes and in the coves there is an accumulation of soil and rock from the slopes. These colluvial soils, often called "ravine-fill", are from four to eight feet in depth.

Climate and Precipitation

The annual precipitation averages about 72 inches per year and is fairly evenly distributed throughout the entire year. October is the driest month, and March is the wettest. The uniformity of storm patterns and the large number of storms per year permit the accumulation of significant experimental results in a relatively few years, as compared with regions having less rainfall. Approximately 98 percent of the total precipitation occurs as rain. The complications met in hydrologic analysis associated with larger percentages of snow are nonexistent at Coweeta.

The mean annual temperature is 55° F. and the normal frost-free season extends from April 17th to October 23rd. During the growing season the temperature averages 65° F. Temperatures above 90° F. are rare and the summer nights are cool, with minimum temperatures averaging 58° F. The average temperature of December, January, and February is 39° F. and periods of cold weather with temperatures less than 20° F. are short in duration.

Vegetation[2]

A dense mixed hardwood forest is dominant, with scattered pines occurring occasionally on the ridges. Some scattered hemlock is found along the streams. Although about 60 percent of the area had been cut over a quarter century or more before the Federal Government acquired ownership, this part of Coweeta now supports a second-growth forest, with the remainder still in old-growth. Before being killed out by the blight, chestnut was the major species. Now about 80 percent of the Laboratory supports oak-hickory stands. Fifteen percent is in cove hardwoods: tulip poplar and northern red oak. Hemlock occurs with this type along the streams. Five percent is in northern hardwoods: sugar maple; yellow birch; beech. Pitch pine is also among this five percent but occurs only at lower elevations.

The forest is typically three-storied with large trees forming the upper layer, small trees and large shrubs a second layer, and shrubs and/or herbs covering the ground. A dense understory of laurel and rhododendron is present on some slopes.

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[2]See Appendix A for a list of all vegetation and scientific names.

DEVELOPMENT OF CRITERIA

Unit Area Control

Original Concept

Unit area control is a term selected by Duncan Dunning to name a silvicultural concept in which the essential characteristic is "detailed control of stocking on small areas." Hallin (12) recently revived the term for use in California forests. Its application in that region is believed to offer the most realistic approach to forest management.

To fully understand the concept it is necessary to seperate the term into its two components, unit area and control. Unit area refers to homogeneous stand units characterized by age class, species composition, stocking, and presence or absence of seed trees. Control describes the aim of the silvicultural treatments to be applied to the unit areas.

Unit area control is in sharp contrast to the narrower concepts of treatment based on those reproduction methods which are applied on a tree by tree basis. Under the unit area control concept, silviculture is applied according to the needs and condition of each unit area of the forest rather than tree by tree.

Application to Watershed Management

Every unit of land, however small, is part of a watershed. Hence, the manner in which the land is managed will inevitably exert some influence on streamflow. And streamflow is the end product of the interaction of soil, water, and vegetation. The logical conclusion is that in the management of municipal and industrial watersheds there exists a particular opportunity for integrating high quality, long-rotation timber crops with the production of high-yield, high quality water. The unit area control concept provides a rational means of approach to this integration of timber and water production of forested watersheds.

For use in watershed management the characteristics determining stand unit homogeneity must be broadened to include hydrologic unit areas delineated in terms of topography and soils characteristics. Such characteristics are slope, soil depth and aspect.

In like manner the treatment in terms of water values must be incorporated into the "control" phase of the concept. Therefore, principles of protection forests and other water resource management practices must be considered in the proposed treatments in addition to intermediate and harvest cutting practices designed primarily for timber production.

Criteria

The management of a watershed requires specific information pertaining to the conditions affecting plant-soil-water relations for the watershed in question. In the first place, broad regional differences such as climate must be considered. Secondly, consideration must be given to local variations in climate, vegetation and soil characteristics. It is apparent that the effect of these regional differences and local variations holds constant over a wide area, and often transcends individual watershed divides. These characteristics are not readily adaptable for use as criteria in determining unit area control.

Irrespective of the regional and local variations there are fundamental relations between plants, soil and water which apply in all instances. These relations or characteristics are ones whose effects frequently change within a single watershed and, consequently, are better adapted as possible criteria. In addition, consideration should be given to the ease by which these characteristics can be recognized and measured in the field. Still another consideration is the cost of obtaining the field measurements. These considerations are necessary in selecting criteria if unit area control is to be successfully practiced on municipal and industrial watersheds.

The final selection of criteria followed an extensive review of literature and an intensive on-the-ground survey of conditions existing within the Coweeta Hydrologic Laboratory. The criteria selected are (a) aspect, (b) soil depth, (c) slope, and (d) vegetation. A discussion of each criterion from both hydrologic and silvicultural standpoints follows with particular reference to the Southern Appalachian Mountains.

Aspect

The aspect of a slope determines the amount of heat received from the sun. This, in turn, affects the transpiration and evaporation losses. Aspect influences forest growth primarily through its effect upon temperature and soil moisture. It aids in determining the kind of vegetation present. The amount of heat absorbed by the soil depends largely upon how near to the vertical the sun's rays strike it. In the northern latitudes, the rays strike the ground much more obliquely on north-facing slopes than on south-facing slopes; hence, the former receive less heat than the latter where the rays are nearer to the vertical. Greater heat increases soil moisture evaporation and, hence, the south-facing slopes are drier.

The effect of aspect is modified to a considerable extent by latitude, its effect increasing with distance from the equator. It is also modified by the steepness of slope. When the slope is such that the sun's rays strike the ground vertically, the effect is greatest.

East slopes receive the early sun and are in danger of thawing too rapidly after frost. These sites are protected from southwest and west winds, and from the sun during the hottest part of the day. It is a favorable slope for tree growth.

North slopes are protected from the sun during most of the day, and in most cases protected from winds. These slopes have a maximum amount both of atmospheric and soil moisture. There is usually an excellent growth of trees.

A south slope is warm and relatively dry. Humus disintegrates rapidly, and the soil dries out quickly. The vegetation starts its growth early, and is often exposed to late frosts. West slopes are also warm and dry.

Soil Depth

Watersheds in the Southern Appalachian Mountains may be roughly classified on the basis of elevation (16). Watersheds which lie mainly below an elevation of 3,000 feet are characterized by a soil profile common to the intermountain areas of the Appalachian Region and Piedmont Plateau. The soil profile has deep sub-soil horizons. The shallowest soils occur on the upper slopes, but even here soil depths of four to six feet are common.

Watersheds above 3,000 feet in elevation are typically steeper. On the slopes soil profiles are generally two feet or less in depth. At the foot of these slopes, and along stream courses, in these high-elevation watersheds, there is an accumulation of colluvial material composed of angular rock-talus and finer material commonly called "ravine-fill".

Runoff characteristics vary widely between low elevation and high elevation watersheds. These variances are due mainly to differences in storage of the respective soil profiles. Deep soil profiles of low elevation watersheds are capable of storing large quantities of water both as retained soil moisture and as ground water.

The shallow soils of high elevation watersheds have a lower total storage-capacity. This is compensated for in part by the high unit-storage of the talus-deposits which contribute considerable storage-capacity even though they cover only a small portion of any drainage basin. Outflow from this storage occurs at rapid rates because of the steep slopes and large voids in the fill-material. This outflow represents a dynamic form of sub-surface storm-water and contributes appreciably to the hydrograph during the period of the storm. It is this form of water that accounts for the high unit-rates of storm-discharge that frequently have been reported from mountain forest land.

However, the amount of rainfall exerts considerable influence upon storage and flow from the respective soil groups. Deep soils have more storage-capacity and exhibit a higher base flow during drought periods.

Shallow soils have less storage and exhibit a lower base flow during real droughts. With normal or above normal rainfall these shallow soils have a higher total flow. It is also important to note that the amount of rainfall increases with elevation. Consequently, the high elevation watersheds generally operate at higher soil moisture levels and unit-yields are greater for all but drought periods.

There is a greater opportunity for practicing "root depth management" (23) on low elevation drainages. On these areas of deep soil profiles timber cutting can affect increases in streamflow. A similar opportunity exists on the deep soil profiles of coves in high elevation drainages.

Timber cutting on medium-depth soils common to the upper slopes of low elevation drainages and the lower slopes of high elevation drainages also offers some possibility of increasing streamflow.

On areas characterized by shallow soils the maintenance of soil stability should be the primary objective of management. Harvesting of timber on these areas can be done, but only if the greatest care is exercised in logging so that a minimum of soil disturbance results. Cultural work such as deadening wolf trees and large culls is possible and desirable. No harvesting of timber should be attempted on very shallow soils. Or if necessary, instigate management practices which will increase the density of deep rooted vegetation to insure complete soil stability. Areas of rock outcrops should be treated in a similar manner.

Occasionally semi- or impervious hardpans are present. When they do occur it is the physiological depth (depth to hardpan) not the absolute depth that is important. Hydrologically these soils are similar to a shallow profile soil. Hardpans also hinder root development to the extent that trees have a shallow root system which is not windfirm.

Classifications of soils from the standpoint of depth have been suggested by various foresters. The classification which is most widely used has five depth designations ranging from very shallow to very deep, and respective depths of less than 6 inches to more than 48 inches (27). Hydrologically soils with depths less than 24 inches function similarly. They are considered shallow in depth. Soils more than 48 inches in depth are also hydrologically similar. Consequently, it appears that a three-category classification of soil depth will provide adequate description of forest soils for unit area control purposes (Table I).

TABLE I

SOIL DEPTH CLASSIFICATION
FOR WATERSHED MANAGEMENT

Designation	Depth in Inches
Shallow	Less than 24
Medium	24 to 48
Deep	More than 48

Because of the deep-rooted nature of most trees, it is convenient to consider soil depth as the combined A, B and C horizons. From observations made at the Coweeta Hydrologic Laboratory a considerable depth of parent material is permeated by tree roots and consequently should be included in a measurement of soil depth. This C horizon also provides considerable soil moisture storage.

Slope

The slope of a drainage basin has an important but rather complex relation to infiltration, surface runoff, soil moisture, and ground water contributions to streamflow. It is one of the major factors controlling the time of overland flow and the concentration of rainfall in stream channels. Slope also has an indirect influence on vegetation through its effect on soil formation processes and the intensity of insolation.

No classification of slope by elevation similar to that of soil depth has been made. Generally, slope increases with an increase in elevation.

In the Southern Appalachians level to gentle terrain occurs primarily in the valleys and foothills. Such land is usually cultivated or pastured. At higher elevations the gradient becomes steeper, agriculture is not feasible, and trees are the common vegetative cover. Coves are the only places at higher elevations where gentle to medium slopes may be found. The ridges are commonly sharp-crested.

Soils of this mountainous region are subject to two types of mass movement: frost creep and slides. Both phenomena are abetted by steep slopes and result in deep soils at the foot of these slopes. Frost creep is the result of the alternate freezing and thawing of soil moisture and is quite a common occurrence, but scarcely perceptible because the movement is so slow. Slides occur on areas further characterized by a thin soil mantle. Heavy rains saturate the soil greatly increasing its weight and also serving as a lubricant between the soil and the underlying bed rock. Such a rapid mass movement exposes large areas of bed rock and destroys the vegetation.

Slope affects the rainfall-runoff relation principally by increasing the velocity of overland stormflow. However, the magnitude of this effect is dependent upon the condition of the watershed. Overland stormflow has never been observed in the Southern Appalachians on forested watersheds with no degrading land use history. Such is not the case on grazed woodlands, mountain farming areas, and areas denuded by fire. Here the increased velocities of overland stormflow result in shortening the period of infiltration and producing a greater concentration of surface runoff in the stream channels. Greater velocities of overland stormflow will also increase erosion. Such erosion soon impairs the quality of water making expensive purification processes necessary. It is evident that the maintenance of an adequate plant and litter cover will hold this deleterious effect to a minimum even on the steeper slopes.

Toumey and Korstian (31) cite Grebe's classification of gradient for use on forested areas as follows: gentle, 5 to 10°; medium, 11 to 20°; steep, 21 to 30°; very steep, 30 to 45°; and precipitous, over 45°. A slight modification of this classification was made in order to change the unit of measurement from degrees to percent, since the Abney level percent scale is used more frequently, especially for measuring merchantable tree height. The modified classification appears in Table II.

TABLE II

SLOPE CLASSIFICATION

Class	Percent	Degrees*
Level to Gentle	0- 20	0-11
Medium	21- 40	11-22
Steep	41- 60	22-31
Very Steep	61-100	31-45
Precipitous	Over 100	Over 45

*To show comparison with original classification.

Logging on level to gentle terrain can be conducted quite easily with only a minimum of precaution necessary in locating access roads and skid trails. Considerably more care should be exercised in logging slopes of medium gradient. The majority of the higher elevation watersheds are steep to very steep in gradient and will require the utmost care in their logging. Precipitous slopes support only a scattered tree cover which clings precariously to the thin soil mantle helping it to remain in place. The importance of soil stability is paramount and no harvesting on precipitous slopes should be undertaken.

Vegetation

The relationship existing between forests and water is extremely complex. This relationship varies with the season, topography, soil, climate and the type and character of the forest itself.

Forests probably do not affect precipitation greatly. However, there has been and still is considerable controversy regarding the effect of forests upon precipitation. Zon (36) was an early advocate of the positive effect of the forests. On the other side Moore (28) concluded that timber cutting and reforestation had little or no effect on precipitation. Kittredge (21) points out that it is extremely difficult if not impossible to obtain satisfactory proof for a decision between these conflicting viewpoints. He feels that attempts to analyze the influence of the forest should be limited to a single geographic climatic region, rather than deal with broad generalizations for a large area. The conclusion of his discussion of later studies is that forests have no appreciable effect on precipitation. The one striking example to the contrary is the Copper Basin in eastern Tennessee (17).

Trees cause a loss in available water through interception of precipitation on the surfaces of branches and foliage much of which is promptly evaporated into the air. The loss of water through interception depends not only upon the intensity and amount of rainfall, but upon the kind of trees, their size, stand density and the season. The percentage of total precipitation lost decreases as the amount and intensity of precipitation per shower increases. Well-stocked stands intercept more precipitation than understocked stands. Stands of middle age intercept more than mature or young stands. Tolerant species intercept more than intolerant, climax more than preclimax, and mesophytic more than xerophytic. Interception is greatest for deciduous trees when they are in full leaf. Interception of rain by conifers is about the same in all seasons (21).

Forests build soil. The soil is enriched by the decay of the foliage, and a humus develops which aids the soil physically, chemically and biologically. As a result the infiltration capacity of the soil and its water-storage capacity are increased. The development of an organic layer over the soil is extremely important on areas of steep slope and thin profile. Without this protective organic layer no soil would remain on steep slopes in the Southern Appalachians and the talus-fills would lose a great portion of their detention-storage ability.

Trees require water to carry on their physiological functions. Most transpiration occurs during the period of growth and only a small proportion during the dormant period. Transpiration is greater on dry, windy days than on quiet, humid ones, and on bright days than on cloudy ones or at night. Transpiration is greatest for the climax types and progressively less as the types are further removed from the climax. It is also believed that small trees transpire less than large trees. In general, hardwood trees with soft-textured leaves are thought to transpire a greater amount of water than those with coarser textured foliage (21, 31).

One of the most recognized benefits of the forests is the protection of the soil from erosion. The tree crowns minimize the force with which rain strikes the ground and the litter prevents the disturbance of surface soil particles by raindrop splash. The forest so holds the soil in place that even when surface runoff occurs, it causes very little soil displacement.

Streamflow is the residual difference between precipitation and losses due to interception, transpiration, evaporation, and deep seepage. Since precipitation and deep seepage vary only to a negligible extent with changes in cover, streamflow varies inversely as the sum of interception, transpiration and evaporation. Hence, streamflow can be increased by reducing the amount of interception and transpiration while holding evaporation relatively constant. Insofar as vegetation reduces surface runoff, promotes infiltration and offers mechanical obstructions, it delays the movement of water to the stream channels and in turn retards and lessens flood peaks, and prolongs the flow into the summer season.

No mention of snow was made in the above discussion because it constitutes only a very small percentage of the total precipitation in the Southern Appalachians.

The Southern Appalachian forests are the most diversified in the United States. There are approximately 140 different species of trees, about sixty of which are commercially important. These occur in various combinations to make the forests of this region extremely complex in composition. In an effort to simplify discussion, the forest types are grouped into six type-groups as follows: (a) cove hardwoods; (b) oak-chestnut; (c) yellow pine-hardwoods; (d) white pine-hardwoods; (e) northern hardwoods; and (f) spruce-fir. A brief discussion of the composition and character of each type-group follows. For a more detailed discussion of individual forest types consult Westveld (33), and Jemison and Hepting (19).

Cove hardwoods are composed of ten individual types. In the aggregate they constitute 10 to 15 percent of the forest land area of the Region. The cove hardwood types occur as relatively small contiguous areas mostly restricted to coves and moist sites except some components of the northern hardwoods. See Appendix B, for a list of moist site species. There is no distinct range of elevation. Potentially cove hardwood types have high commercial value. The residual stands for the most part are now composed of low-value species as a result of heavy culling in past years. This low-value residual stand condition is typical of most of the Southern Appalachian forests.

Nine types comprise the oak-chestnut group which covers a large aggregate area. The scarlet oak-black oak and chestnut oak types occupy most of this area. This group occurs on dry ridges and slopes and displays a wide range in elevation. See Appendix C, for a list of dry site species. The present stands are of low commercial value. This is the result of past culling and the chestnut blight. Prior to the blight chestnut constituted about thirty percent of the stand composition.

The yellow pine-hardwoods are the predominant timber stands of the Piedmont Plateau and the foothills of the mountains. They also occur at higher elevations on dry ridges with a southern aspect. The eight types making up this group resemble the pine-hardwood types to the north and south of this Region. The commercial value of this group is determined largely by the amount of shortleaf pine, white oak, and red oak present in the stands.

Eastern white pine reaches its southern limit in the Southern Appalachians. Here in association with hardwoods it occurs on predominantly sandy loams of abandoned farms at lower elevations. It also occurs at higher elevations on north slopes. The three types comprising this group occupy a small area. However, these types possess potential high commercial value.

Northern hardwoods occupy a large area between 3,000 to 4,000 feet elevation. This group is composed of high-value species. The two types represented by this group occur on well-drained fertile soils with north or east aspect.

The last group, spruce-fir, is made up of three types. It once was of major areal and commercial importance at high elevations. The decline of this group was caused by extensive cutting and replacement by other types, notably pin cherry and northern hardwoods.

The cumulative adverse effects of fire, disease, and bad cutting practices have turned the original fine forests of the Southern Appalachian Mountains into one vast depleted forest. The Region has benefitted in the past few years by greatly improved fire protection. Progressive improvement of stand composition and quality is possible through a series of partial cuttings. Wahlenberg (32) working with depleted hardwood stands in the Southern Appalachians states that, "Quality selection has proved to be a suitable method of preparing typically decrepit stands for continuous systematic management."

APPLICATION OF CRITERIA

Brief History of Watershed No. 40

Prior to 1837 the entire Coweeta Creek drainage basin was inhabited by Cherokee Indians who used the area primarily for livestock grazing. The Indians practiced spring and fall burning to improve the woods for grazing. Burning eliminated the undergrowth and litter and facilitated both the livestock and Indians in obtaining nuts and acorns. The Indians also believed that their burning would eliminate the milk-sickness, a disease which killed livestock and human beings as well. The disease still persists today.

In 1837 the Indians were removed from the area and placed on the Qualla Indian Reservation. Settlement by white man started in 1842 and continued until the turn of the century. During this period the principal land use was grazing and the white settlers practiced spring and fall burning for practically the same reasons that the Indians burned the woodlands. The effect of burning on the soil resource is not definitely known, but it probably had a detrimental effect in the long run. There are no records or signs of cultivation on this portion of the Coweeta Creek drainage basin.

In 1901 the Nantahala Company, a land speculation group, purchased practically all of the Coweeta drainage including watershed No. 40 or Wolf Rock Branch. In 1924 the merchantable timber was removed from the lower portion of the area. It has restocked satisfactorily, but is in the need of an improvement cutting. Old residuals are for the most part defective and of little value. Chestnut has ceased to be a major constituent of the forest because of the blight.

Iron, mica, and copper were mined in the area, but the operations were on a small scale and, therefore, did not affect the condition of the land to any appreciable extent.

The United States Forest Service acquired the area in 1923, and it became part of the Natahala National Forest. In 1934 the drainage was part of the land set aside as the Coweeta Experimental Forest. The name was officially changed to Coweeta Hydrologic Laboratory in 1949.

Field Methods

During the summer of 1952 a complete survey of watershed #40 was undertaken. A base map with a scale of one-inch equals five-chains was prepared from the Laboratory base map showing drainage, roads and trails, and elevation. Cutting across the watershed was a portion of one of the permanent cruise lines which transect the entire Coweeta drainage basin. Wooden stakes with appropriate notation were spaced at two-chain intervals along this transect line. Using these points as an origin, a two-chain square grid system was constructed over the entire watershed; a total of 133 survey points.

At each one of these survey points data were obtained concerning each criterion. Two separate surveys were made. The following data were obtained in the first survey.

The percent of slope was determined by use of the Abney hand level. Two separate readings were taken; one up-slope and the other down-slope, both for a distance of one-chain. The average of these two readings was recorded.

The aspect of the slope was recorded by use of a hand compass. The eight major points of the compass were used.

The depth of soil to bed rock or to a four-foot maximum depth was measured by use of a soil auger. The hole was bored at a three-foot distance in a southwest direction along the transect line. If any obstruction prevented drilling at this point another location was selected at a three-foot distance in a northwest direction perpendicular to the transect line. This procedure was followed in a clockwise direction if further obstructions were present. The measurement of soil depth was prevented at only one survey point; in this case by a large rock outcrop. While boring each hole any peculiar profile characteristics were noted. Rock outcrops were also noted and mapped.

The dominant vegetation in a one-chain radius circle was identified. This particular item was for the purpose of checking against the Laboratory's cover-type map. Two changes resulted; first, extension of the cove hardwood type further up the main stream channel, and second, extension of the north boundary of the scarlet oak-black oak-white oak type to a slightly higher elevation. Both of these changes reduced the area of the red oak-chestnut oak-hickory type.

Such items as presence and degree of erosion, and location of streams, roads and trails were listed under remarks for each survey point.

The second survey consisted of a timber cruise. A systematic type of sampling in the form of line-plots was made at two-chain intervals at right-angles to the even-numbered permanent cruise line stakes. The only exception was made in forest type #4 where three additional plots were taken on an odd-numbered cruise line to insure adequate sampling. A total of sixty plots comprised the sample. The number of plots sampled and the percent of sample by forest types and the entire watershed is shown in Table III.

TABLE III

PERCENT CRUISE
1952 CRUISE—WATERSHED NO. 40*

Type	Number 1/5 Acre Plots	Percent Sample
1	3	24
2	22	22
4	9	39
10	13	21
16	13	26
Watershed	60	24

*Based on sawtimber sized trees.

Using a common center all reproduction and saplings 1.0 to 5.5 inches d.b.h. were recorded on a one-fortieth acre plot (18.5 feet in radius), all pole-size trees 5.6 to 12.5 inches d.b.h. were recorded on a one-tenth acre plot (37.2 feet in radius), and all sawtimber 12.6 inches d.b.h. and up were recorded on a one-fifth acre plot (52.7 feet in radius). The standard RS-AP Inventory of Experimental Forest tally form (Appendix D) was used. Only the number of stems by species was tallied for the 1 to 5-inch d.b.h. class. No volume was calculated. The number of stems by species and d.b.h. classes were tallied for the 6 to 12-inch classes and volumes calculated in cubic feet from a local volume table. Sawtimber was tallied by number of stems, by species, d.b.h. classes, and merchantable log lengths to an eight-inch minimum top diameter. The volume was calculated in board feet Scribner (7).

The individual species were grouped into three categories based upon Westveld's classification (33): desirable timber species, less desirable timber species, and minor species which seldom attain sawlog size (Appendices B and C).

The data were summarized by forest types in the form of a combined stand and stock table listing the number of stems, basal area, and volume by species group and d.b.h. classes on a plot area basis. The data were converted to a per acre basis by the proper multiplicative factor.

All diameters were measured with a diameter tape and merchantable heights with an Abney hand level.

Discussion of Criteria

Slope

The topography of watershed #40 is steep and rugged (Fig. 4). The mean sea level elevations range from 2,860 feet at the base to 4,190 feet at the summit. Fig. 5 is a hypsometric curve of the watershed showing the percent of area above various elevations. The graph was obtained by plotting column 4 against the lower elevations in column 1 of Appendix E.

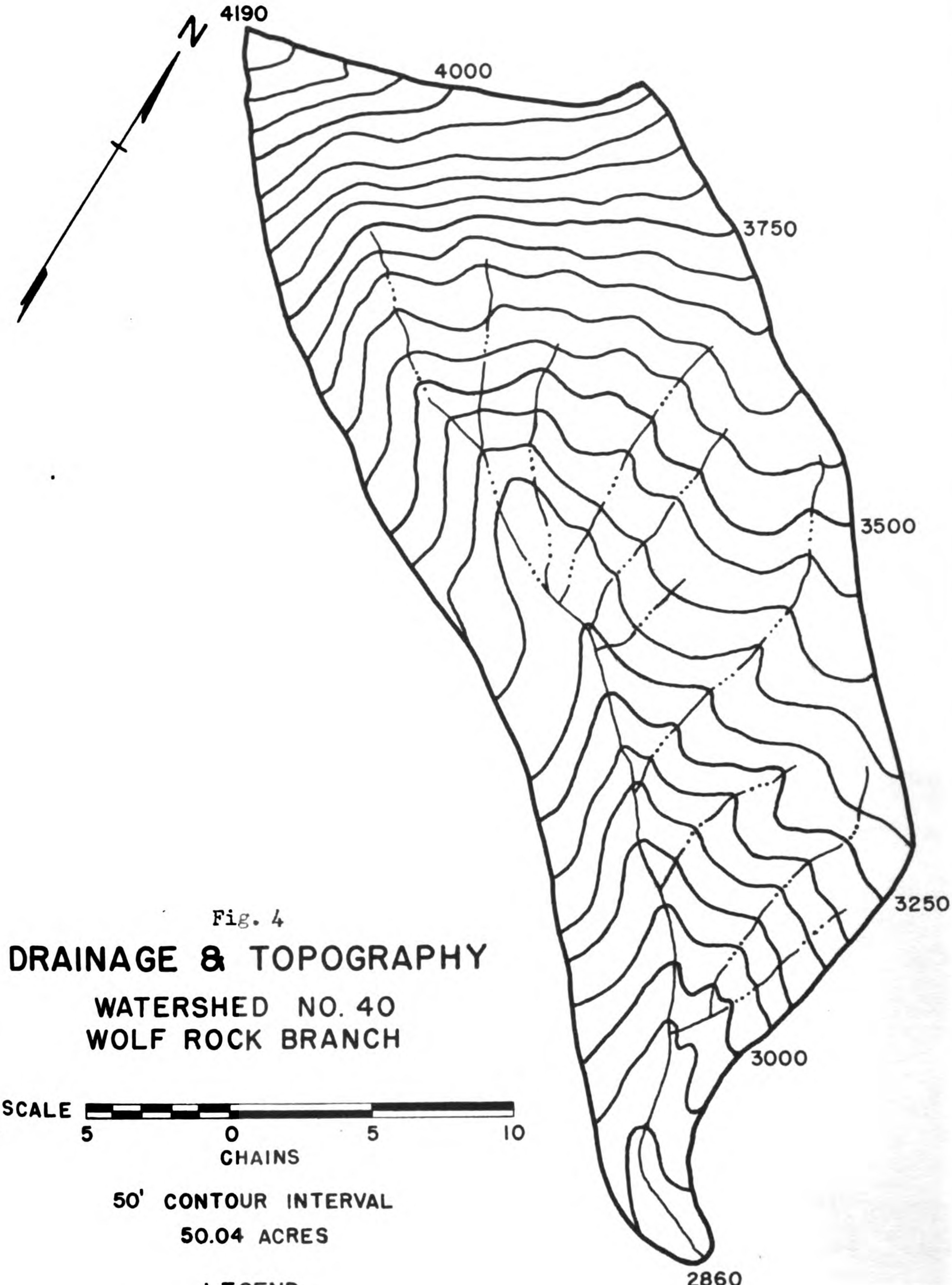

Fig. 4

DRAINAGE & TOPOGRAPHY

WATERSHED NO. 40
WOLF ROCK BRANCH

SCALE
5 0 5 10
CHAINS

50' CONTOUR INTERVAL
50.04 ACRES

LEGEND

CONTOUR LINES
PERMANENT STREAM
INTERMITTENT STREAM

The median elevation is 3,430 feet. The distance from the base to the summit is 0.55 miles and the mean slope is 60.6 percent.[3]

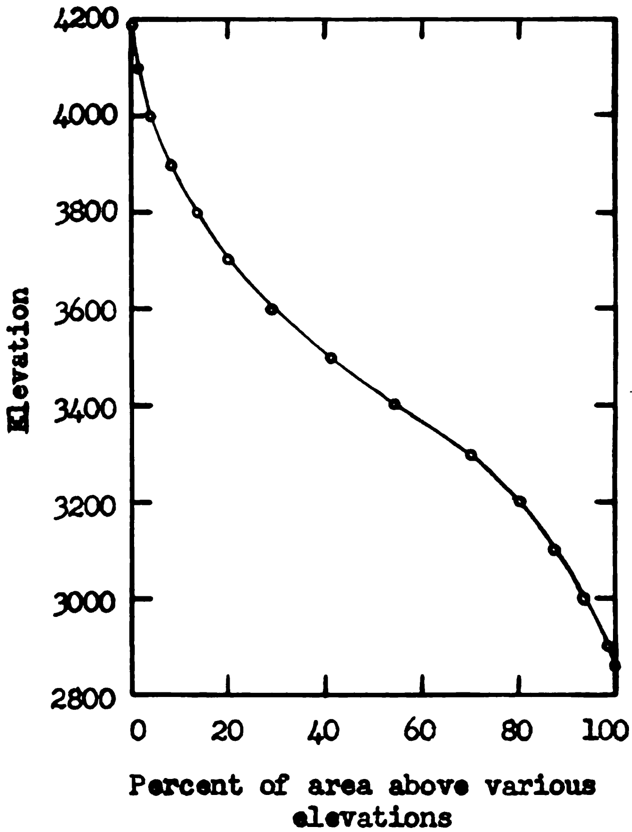

Fig. 5. Hypsometric curve for Watershed No. 40.

The drainage pattern of Wolf Rock Branch is dendritic, the stream channel V-shaped and the slopes steep, all indicating a youthful stage of stream development. The permanent stream channel is 1,670 feet long with a drop of 465 feet. The average stream gradient is 27.8 percent. Fig. 6 shows the distribution of slopes by classes for the entire watershed. There were no areas having slopes less than twenty percent. The

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[3]Mean slope calculated by use of formula given in Wisler, C. O. and E. F. Brater, Hydrology. John Wiley & Sons, Inc. pp 48 and 49, 1949.

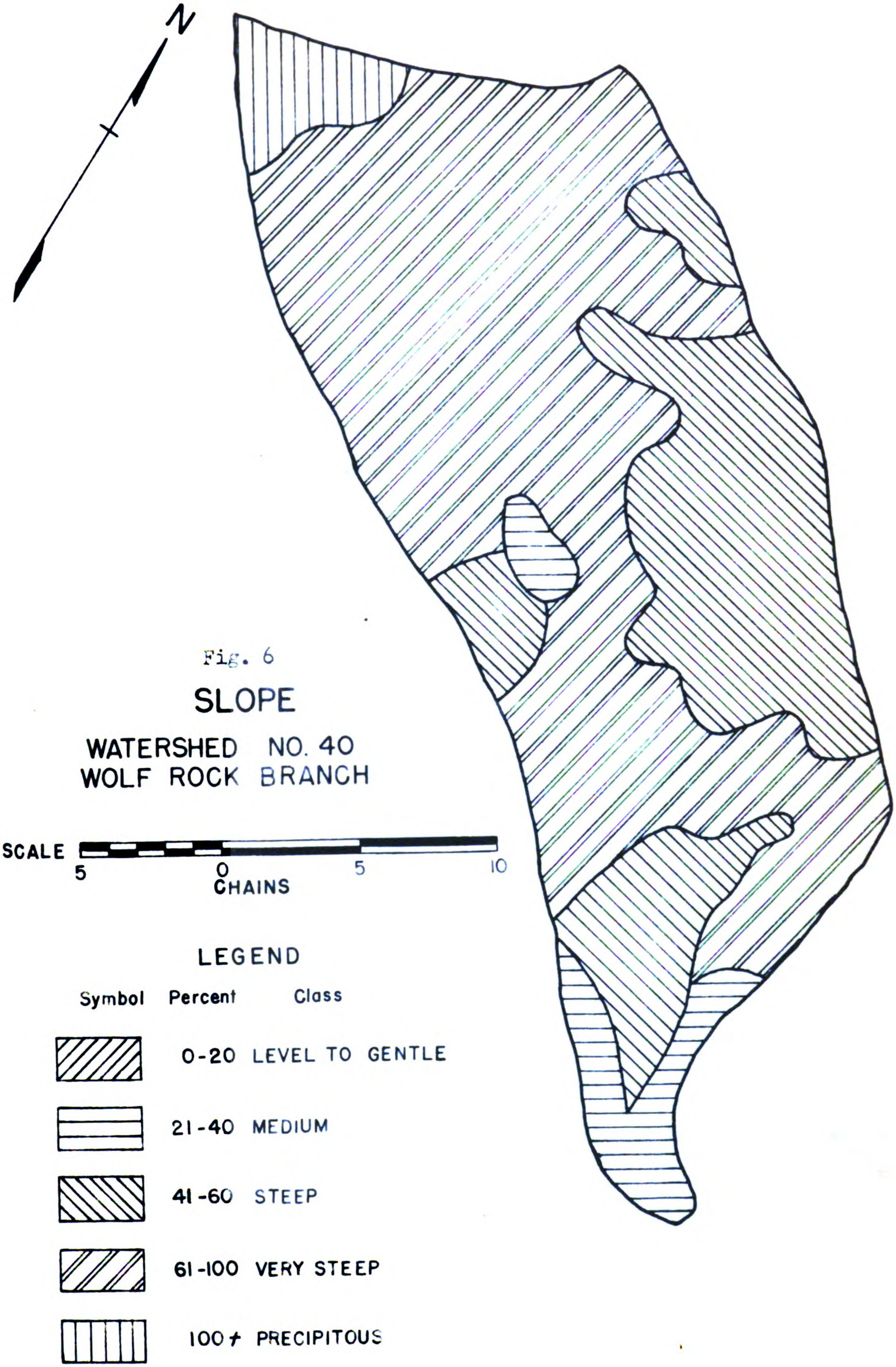

Fig. 6

SLOPE

WATERSHED NO. 40
WOLF ROCK BRANCH

area immediately above the weir at the base of the watershed has slopes ranging from 21 to 40 percent. The small cove situated between the 3,300 and 3,350-foot elevations on the main stream channel is also in this category. These two areas occupy six percent of the total drainage basin area. The major portion of the 41 to 60 percent class lies on the east slope of the basin. Thirty percent of the watershed has slopes ranging from 41 to 60 percent. The largest portion of the watershed (sixty percent) has slopes in the 61 to 100 percent class. The majority of this area is located above the median elevation. A small area in the northwest corner of the drainage basin is extremely steep; having a slope greater than 100 percent. This area constitutes the remaining four percent of the watershed area.

Aspect

The entire Wolf Rock Branch drainage is aligned in a northwest-southeast direction (Fig. 7). More than half of the watershed (fifty-eight percent) is oriented in a southerly direction from the stream channel to the east ridge. The slope from the stream channel to the west ridge has an easterly aspect and constitutes twenty-three percent of the total area. The remaining nineteen percent of the watershed situated above an elevation of 3,700 feet has a southeasterly aspect.

The combination of a primarily southern aspect and steep slopes result in relatively dry sites over most of the watershed except the cove area immediately adjacent to the main stream channel.

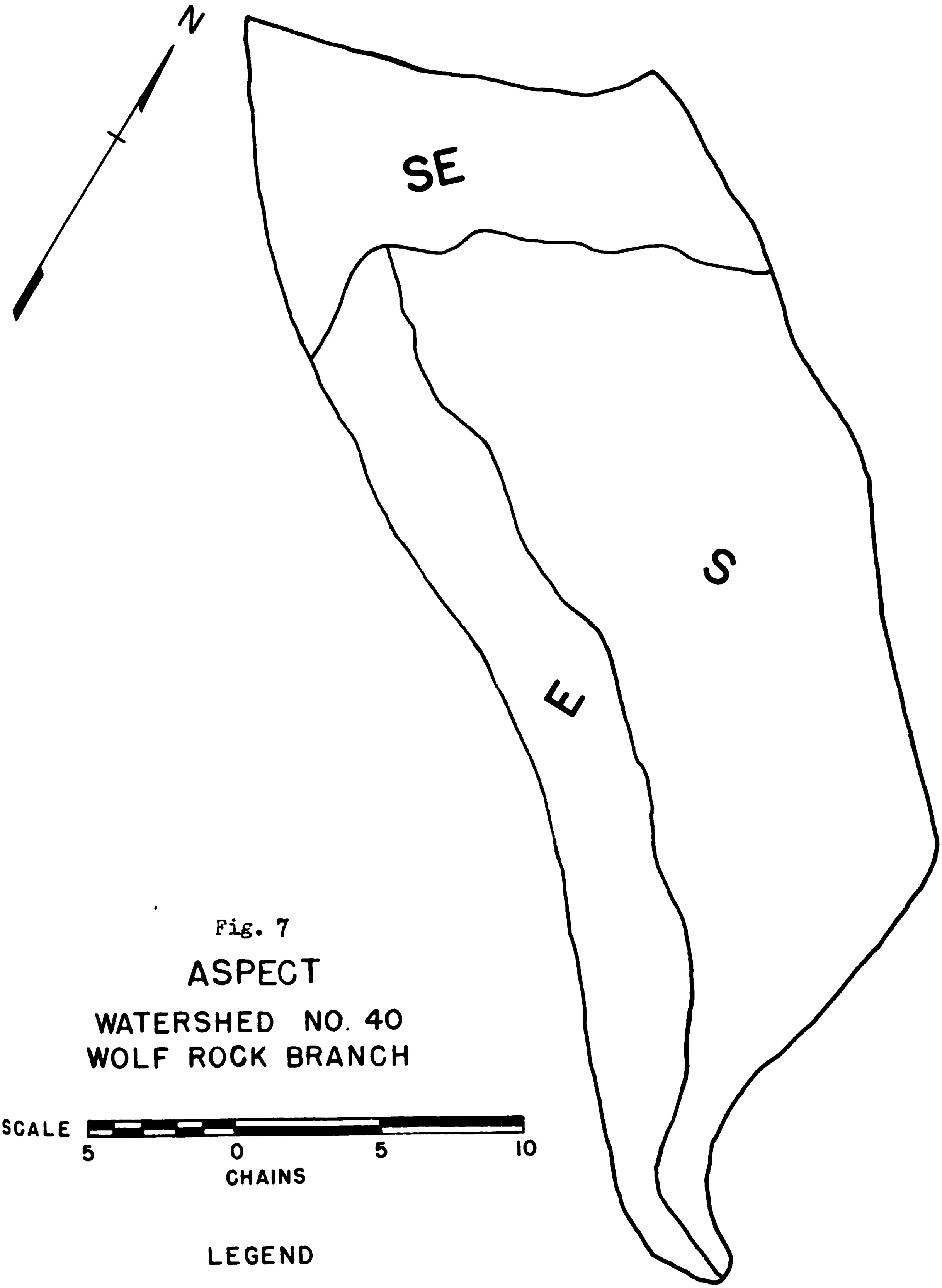

Fig. 7

ASPECT

WATERSHED NO. 40
WOLF ROCK BRANCH

SCALE 5 0 5 10
CHAINS

LEGEND

E EAST-FACING SLOPE
S SOUTH-FACING SLOPE
SE SOUTHEAST-FACING SLOPE

Soil Depth

A wide range of soil depth was found on watershed #40 (Fig. 8). The east ridge and slopes immediately below it, and southeasterly facing slope above 3,700-foot elevation exhibited soil profiles four feet and less in depth. The remainder of the watershed had soil depths in excess of four feet.

Soil profiles less than four feet in depth were similar in character regardless of their location. In general the depth of individual horizons was proportional to the total profile depth, except for very shallow profiles. Very thin soils consisted of partially decomposed bedrock and an organic layer, and in some instances only the organic layer existed over the solid bedrock. It was observed that the tree roots penetrated partially decomposed bedrock quite extensively. An excellent hardwood litter covered the entire watershed. There were just a few instances where litter wash was observed, particularly on the steepest slopes. The litter had decomposed to form a deep organic layer.

Soil profiles in excess of four feet were characterized by deep surface and subsurface horizons; the depth increasing down slope to a maximum adjacent to the stream channel. Considerable colluvial material consisting of rock fragments and finer material had accumulated at the foot of the steep slopes and along the stream course, and greatly added to the depth of soil. In most instances very little difference was noted between the A and B horizons of these colluvial soils. Adjacent to the stream channel where the site was moist the organic content of the soil was very high and extended to a considerable depth.

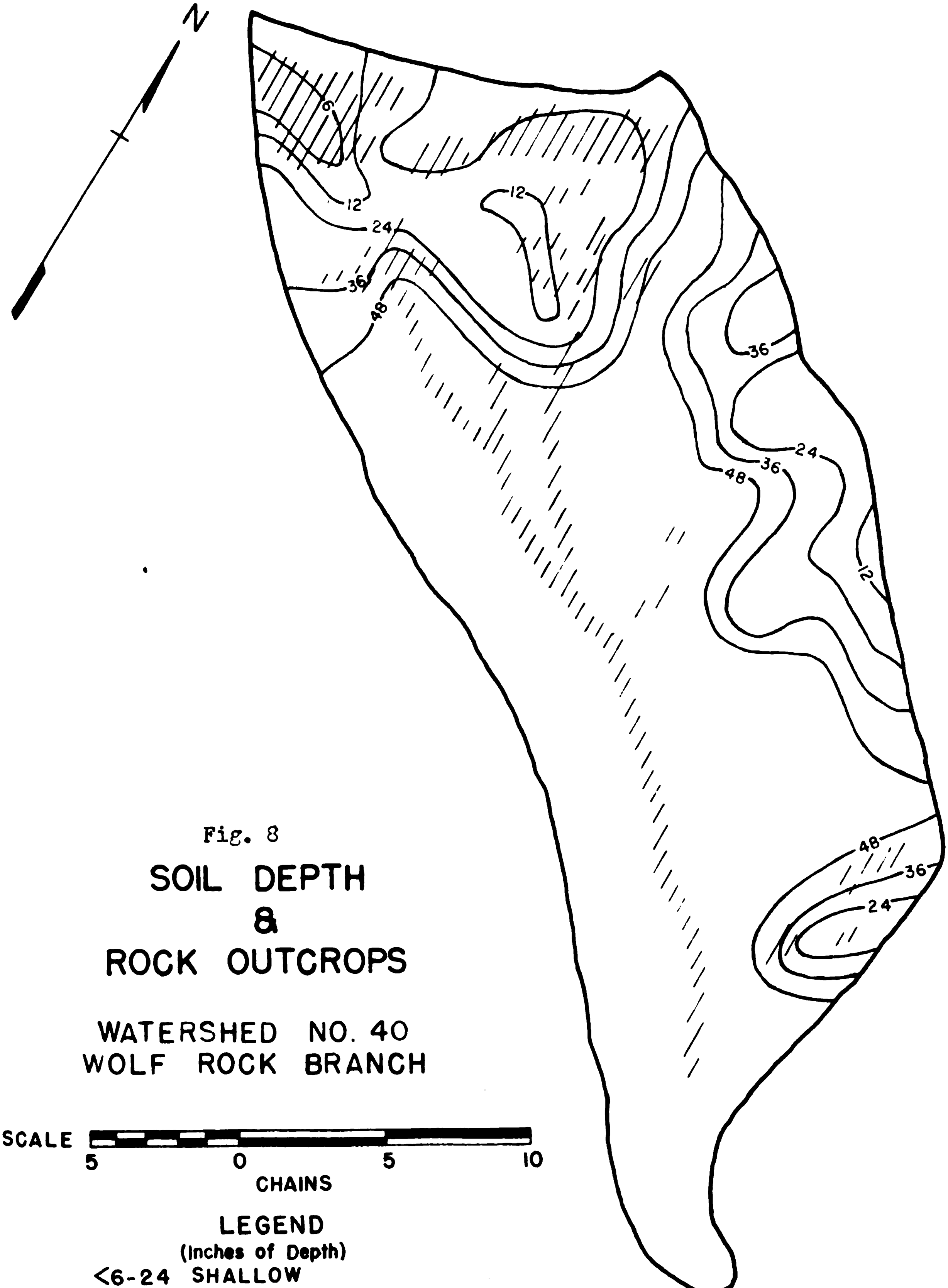

Fig. 8

SOIL DEPTH
&
ROCK OUTCROPS

WATERSHED NO. 40
WOLF ROCK BRANCH

SCALE
5 0 5 10
CHAINS

LEGEND
(Inches of Depth)
<6-24 SHALLOW
24-48 MEDIUM
>48 DEEP
//// ROCK OUTCROPS

The soils in general exhibited a loamy textured surface and a clay-loam subsurface. The parent material is composed of weathered gneiss and schist.

The occurrence and distribution of soil depths on Wolf Rock Branch are typical of a high-elevation watershed and hydrologically operate as such.

Vegetation

Forest cover types found on watershed #40 are five in number (Fig. 9). One (type 1) belongs to the yellow pine-hardwood group; three (types 2, 4 and 10) belong to the oak-chestnut group; and one (type 16) belongs to the cove hardwood group. Types in the oak-chestnut group will probably be treated alike from a silvicultural standpoint when marking and cutting begins. However, for this study these types will be discussed separately. Stand composition, diameter distribution, merchantable volumes, site characteristics, and usual management practices are presented for each type. These management practices are strictly silvicultural in nature with no regard being given to hydrologic factors. The modification of silvicultural management practices by hydrologic factors is discussed in a later section.

Appendix F is a summary of volume by types and species groups for the entire watershed. Appendix G is individual type stand and stock tables listing number of stems, basal area, and volume by diameter classes and species groups on a per acre basis.

Type 1. The pitch pine-scarlet oak-chestnut oak type has a volume of 406 cubic feet per acre in the 6 to 12-inch d.b.h. classes and 3,213 board feet per acre in trees 13 inches d.b.h. and larger. Seventy-six percent of the cubic foot volume and 94 percent of the board foot volume is in group I or desirable species trees.

Only 5 percent of the stems in the 1 to 5-inch d.b.h. classes are desirable species. A dense growth of laurel which comprises 90 percent of the stems will greatly hinder the establishment of desirable species.

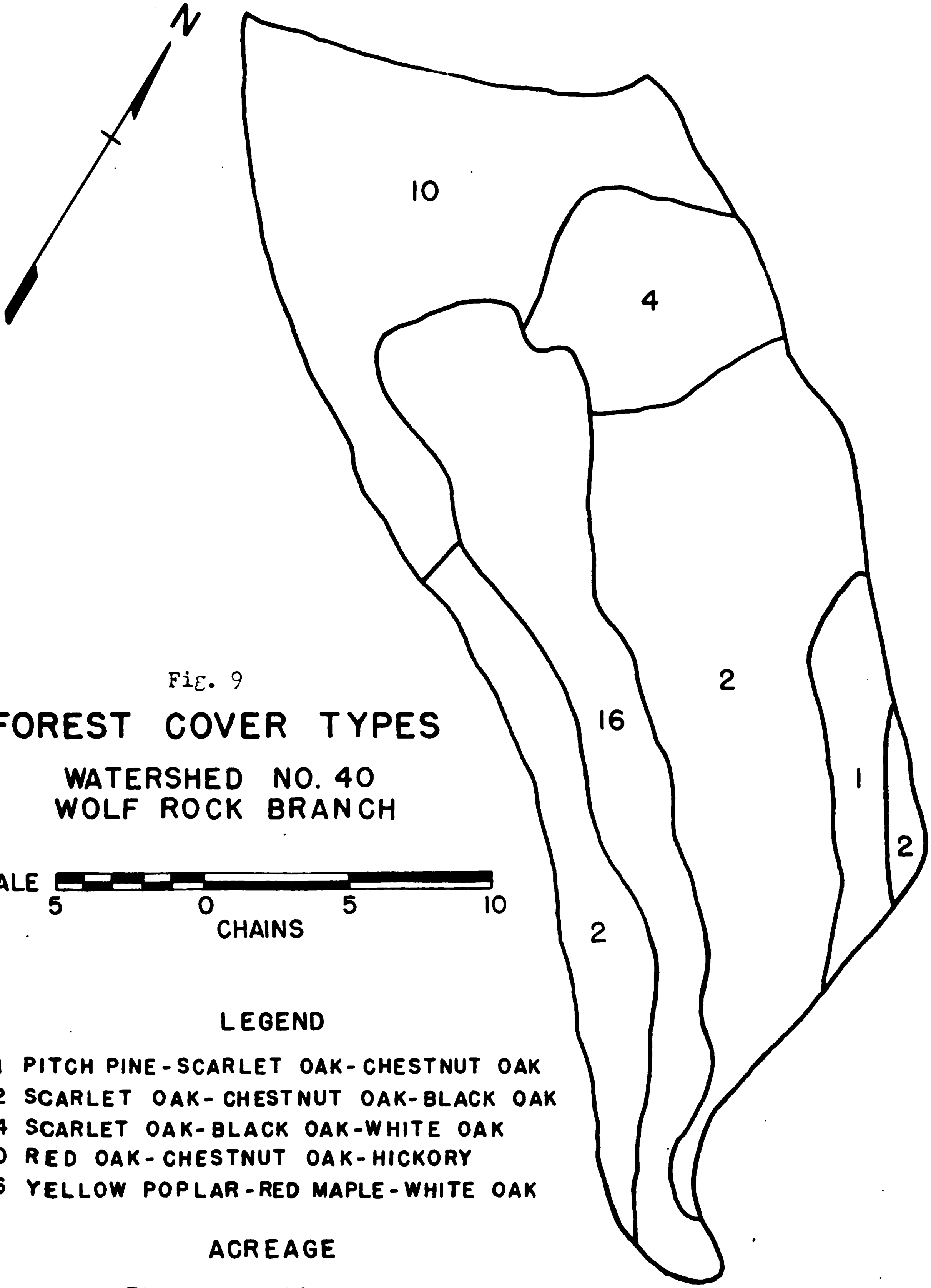

Fig. 9

FOREST COVER TYPES

WATERSHED NO. 40
WOLF ROCK BRANCH

LEGEND

1 PITCH PINE-SCARLET OAK-CHESTNUT OAK
2 SCARLET OAK-CHESTNUT OAK-BLACK OAK
4 SCARLET OAK-BLACK OAK-WHITE OAK
10 RED OAK-CHESTNUT OAK-HICKORY
16 YELLOW POPLAR-RED MAPLE-WHITE OAK

ACREAGE

TYPE	1	2.50	ACRES
"	2	20.32	"
"	4	4.65	"
"	10	12.56	"
"	16	10.01	"

This type occurs on a dry, exposed, and generally poor site. The stands are uneven-aged and commonly sparsely stocked. They are composed of a scattered overstory of mature and defective pine and hardwoods. The understory is composed of second-growth trees, medium stocked, and poor in quality (Fig. 10).

The type needs intensive improvement work to increase its productivity. Every effort should be made to favor pine on this poor hardwood site. Available pine trees should be reserved as sources of seed. Harvest the large, mature hardwoods. Stand improvement measures should result in killing by girdling or poisoning all defective or otherwise unmerchantable trees interfering with the development or establishment of desirable species.

Type 2. The scarlet oak-chestnut oak-black oak type has a volume of 408 cubic feet per acre in the 6 to 12-inch d.b.h. classes and 2,546 board feet per acre in trees 13 inches d.b.h. and larger. Sixty-four percent of the cubic foot volume and 77 percent of the board foot volume is in group I.

Only 17 percent of the stems in the 1 to 5-inch d.b.h. classes are desirable species. Sixty percent of this size class is composed of group III species. This dense undergrowth of laurel and rhododendron will hinder future regeneration of the more valuable species.

This type occupies the slopes between the ridges and the cove. It is a relatively dry site. The stands are uneven-aged and sparsely stocked. The overstory is composed of overmature and defective trees. The second-growth understory is generally of poor form and quality (Fig. 11).

Fig. 10. Yellow pine-hardwoods group; type 1 composed primarily of pitch pine, scarlet oak and chestnut oak. It occurs on dry ridges with southern aspect. All ages of pine are present from saplings to sawtimber.

Fig. 11. Oak-chestnut group; type 2 composed primarily of scarlet, chestnut and black oaks. Stands consist of scattered, defective, mature residuals, and a sparse stocking of desirable species in poles and sawtimber.

Considerable improvement work is needed in this type to bring it into full productivity. An attempt should be made to harvest the mature trees. Merchantable thinnings and stand improvement work should favor the black and chestnut oaks and trees of better quality.

Type 4. The scarlet oak-black oak-white oak type has a volume of 275 cubic feet per acre in the 6 to 12-inch d.b.h. classes and 6,022 board feet per acre in trees 13 inches d.b.h. and larger. Ninety-five percent of the cubic foot volume and 90 percent of the board foot volume is in group I.

Almost 70 percent of the stems in the 1 to 5-inch d.b.h. classes are desirable species. Rhododendron and laurel constitute only a small percentage of the undesirable species. No problem of regeneration due to dense rhododendron or laurel exists.

Type 4 also occupies a relatively dry site with a south to southeasterly aspect. This type, however, occurs at higher elevations than types 1 or 2. Consequently, it receives more moisture which accounts for the white oak component. The stands are uneven-aged and medium stocked. The overstory is composed of scattered, defective residuals. A good stand of saplings and poles of desirable species, good form and quality occurs in the understory throughout the type (Fig. 12).

Marking should aim for the removal of mature, defective residuals and thinning of the younger sawlog-size stands where necessary. Merchantable thinnings should be made in existing dense pole stands. A small amount of stand improvement will bring this type into excellent condition. All cultural work should favor the black and white oaks and trees of better quality.

Fig. 12. Oak-chestnut group; type 4 composed primarily of scarlet, black, and white oaks. A few residuals remain; these are defective. A medium stocked, good quality stand of desirable species in all size classes occurs throughout this type.

Type 10. The red oak-chestnut oak-hickory type has a volume of 433 cubic feet per acre in the 6 to 12-inch d.b.h. classes and 6,601 board feet per acre in trees 13 inches d.b.h. and larger. Ninety-seven percent of the cubic foot volume and 94 percent of the board foot volume is in group I.

Slightly more than one-half of the stems in the 1 to 5-inch d.b.h. classes are desirable species. As was the case in type 4, rhododendron and laurel do not occur extensively and present no regeneration problem. in this type.

Type 10 occurs at the highest elevations of the watershed and, therefore, receives more moisture than any of the aforementioned types. It is still a relatively dry site, but of fairly good quality as evidenced by the vegetation. The stands are uneven-aged with medium to dense stocking. The overstory is composed of a good stand of sawlog size trees possessing average or better quality. Only the oldest have extensive defect. The understory is a dense stand of saplings and poles of desirable species, good form and quality (Fig. 13).

Logging should result in the removal of the mature trees and thinning of the younger sawlog size stands where necessary. Merchantable thinnings should be made in existing dense pole stands. A small expenditure for stand improvement will bring this type into excellent condition. The oaks should be favored along with good quality hickory in all cultural work.

Type 16. The yellow poplar-red maple-white oak type has a volume of 379 cubic feet per acre in the 6 to 12-inch d.b.h. classes and 5,915

Fig. 13. Oak-chestnut group; type 10 composed primarily of red oak, chestnut oak and hickory. A fair quantity of sawtimber is present. A dense stocking of desirable species in saplings and poles constitute the second-growth stands. The quality is average and better.

board feet per acre in trees 13 inches d.b.h. and larger. Eighty-four percent of the cubic foot volume and only fifty percent of the board foot volume is in group I. The reason for the low percentage in group I is probably one of past logging history. The largest and best quality trees grew in the coves and were first choice of the logging companies which cut this area. However, the higher percentage of cubic foot volume in group I suggest that these species are more aggressive than those in group II, and with proper cultural work will eventually result in a desirable species composition.

In the 1 to 5-inch d.b.h. classes only 32 percent of the stems are desirable species while 57 percent are in group III. The majority of the group III stems are rhododendron which grow in dense thickets along the stream channel (Fig. 14). These thickets present a regeneration problem. They also are the cause for considerable soil moisture loss due to high transpiration rates in the riparian zone.

Type 16 occurs along the main stream channel over a wide range of elevation. It is, therefore, a moist site of high site index capable of producing trees at a rapid rate of growth and of excellent quality. The stands are composed of scattered old-growth trees of poor form and quality. These are the remnant of the virgin stand which were left by the loggers. The second-growth understory is even-aged, medium stocked, and high in quality (Fig. 15).

Cutting should remove the old-growth trees which are merchantable. The unmerchantable trees should be girdled to aid in the establishment and growth of the second-growth stand. Considerable stand improvement work is necessary to bring this type into high productivity. Yellow

Fig. 14. A typical rhododendron thicket in the riparian zone. It hinders regeneration of desirable species and constitutes a considerable loss of soil moisture due to high transpiration rates.

Fig. 15. Cove hardwood group; type 16 composed primarily of yellow poplar, red maple and white oak. Other than a few scattered residuals, the stands are second-growth, even-aged, medium stocked, sapling and pole sizes. Only 50 percent of the stems 13 inches d.b.h. and larger are desirable species.

poplar and white oak, and other desirable species of good form should be favored during silvicultural treatments.

Delineation of Unit Areas

The next step in the study was to combine all criteria. The combination resulted in the establishment of unit areas—silviculturally and hydrologically homogeneous. This step was closely akin to a jigsaw puzzle.

The combination was made by using overlays of each criterion (Figs. 6, 7, 8 and 9). The initial combination was made with no regard given to size and resulted in forty-four distinct unit areas ranging in size from 0.1 to 4.3 acres. From the overlays it was evident that the criteria of slope and soil depth were primarily responsible for the many small unit areas.

It was immediately apparent that a minimum size of unit area had to be established. It would be next to impossible to delineate such small areas on the ground. After giving due consideration to the problem, a minimum size of 2.0 acres was established.

But a minimum size meant combining unit areas which were not homogeneous with respect to all criteria. A small unit area would be made a part of a larger unit area or several small unit areas would be combined to form one. A thorough analysis of the characteristics of each unit area was made in an effort to find some one method by which the small unit areas could be combined to meet the minimum size requirement. Also the characteristics of the combined areas would have to accurately describe the existing conditions so that ultimately it would be accorded sound silvicultural and watershed management practices. The method used was as follows: at least three of the four characteristics must be similar for units to be combined to meet the minimum size requirement. In every case the criteria of vegetation and aspect remained constant; either the slope or soil depth criteria were dissimilar. Where several less than minimum size unit areas were combined to form one, the characteristics of the whole were an average of the characteristics of each unit area comprising the whole. A less than minimum size unit area combined with a unit area larger than the minimum took on the characteristics of the unit area of which it was made a part.

This combination to make every unit area at least 2.0 acres in size resulted in the delineation of fourteen distinct unit areas (Fig. 16). A summary of the characteristics of each unit area appears in Table III. A discussion of each follows.

Unit Area A

Unit area A includes all of forest type 1 (pitch pine-scarlet oak-chestnut oak) and a small portion of type 2 on the east ridge. Since the extent of type 2 is so small, it will be disregarded; unit area A will be considered as consisting entirely of type 1. The vegetation consists of a scattered overstory of pine and hardwoods and a medium stocked, uneven-aged, poor quality second-growth stand of desirable species in the pole and sawtimber size classes. The soil is medium in depth. The slope is steep with a southern aspect. This unit area occupies a poor site and does not offer much in the way of timber production.

TABLE III

CHARACTERISTICS AND CORRELATED TREATMENT PRACTICES ON WATERSHED NO. 40*

Watershed Characteristics					Treatment and Management Practices
Unit Area	Aspect	Slope	Soil Depth	Vegetation	
A	South	Steep	Medium	Mixed pine-hardwood: pitch pine-scarlet oak-chestnut oak.	Apply improvement cut to remove mature hardwoods and defective or poor-risk pines. Favor pine and the better chestnut oak.
				Scattered overstory of defective pine and hardwood. Medium stocked, uneven-aged poor quality second-growth stands of desirable species in poles and sawtimber.	Treat culls and undesirable species interfering with the development of desirable species. Cut lanes in dense growth of laurel and plant white pine. Blister rust is no problem above 3,000 feet elevation.
				Dense growth of laurel.	Maintain a good litter cover to prevent excessive soil moisture evaporation and protect soil from erosion.
					Maintain stocking at a high level.
B	South	Steep	Deep	Oak-hickory: scarlet oak-chestnut oak-black oak.	Harvest scattered merchantable residuals. Second-growth will not support a merchantable cut.
				Scattered mature residuals. Sparse stocked, uneven-aged poor quality second-growth stand of desirable species in poles and sawtimber.	Deaden cull trees and release all desirable species trees of good form to improve quality and species composition and to stimulate further regeneration of desirable species.

TABLE III (Continued)

Watershed Characteristics					Treatment and Management Practices
Unit Area	Aspect	Slope	Soil Depth	Vegetation	
				Dense clumps of rhododendron scattered throughout understory.	Cup and poison or spray rhododendron. Favor black and chestnut oaks. Maintain stands at a medium level of stocking.
C	South	Steep	Medium	(do)	Same as Unit Area B, except maintain stands between a medium and high level of stocking.
D	South	Steep	Shallow	(do)	Same as Unit Area B, except maintain stands at a high level of stocking.
E	South	Very Steep	Deep	(do)	Same as Unit Area C.
F	East	Steep	Deep	(do)	Same as Unit Area B. Although site is somewhat more moist than B, steep slopes prevent reduction of stocking below a medium level.
G	East	Very Steep	Deep	(do)	Same as Unit Area C. Although site is somewhat more moist than C, very steep slopes prevent reduction of stocking below a medium to high level.
H	South	Very Steep	Medium	Oak-hickory: scarlet oak-black oak-white oak.	Apply improvement cut to remove mature residuals and thin second-growth stands where necessary. Favor black and white oaks.

TABLE III (Continued)

Watershed Characteristics					Treatment and Management Practices
Unit Area	Aspect	Slope Depth	Soil	Vegetation	
				Scattered defective residuals. Medium stocked, uneven-aged, good quality second-growth stands of desirable species in all size classes.	Treat culls and undesirable species interfering with the development of desirable species of good form and quality. Maintain stands at a high level of stocking.
I	East	Very Steep	Deep	Oak-hickory: red oak-chestnut oak-hickory.	Harvest the mature trees on a group selection basis. Thin pole-size second-growth stands.
				Medium stocked overstory of sawtimber; desirable species, average quality, some defect.	Timber stand improvement should consist of a combined liberation and improvement cut in an effort to release existing desirable second-growth and improve species and quality composition.
				Dense stocked, uneven-aged, good quality second-growth stands of desirable species in saplings and poles.	Maintain stands between a medium to high level of stocking.
J	South-east	Very Steep	Medium	(do)	Harvest only the mature trees on a group-selection basis. Timber stand improvement measures should be restricted to a minimum treatment of release of existing desirable species.

TABLE III (Continued)

Watershed Characteristics					Treatment and Management Practices
Unit Area	Aspect	Slope	Soil Depth	Vegetation	
					Maintain stands at a medium to high level of stocking.
K	South-east	Very Steep	Shallow	(do)	Same as Unit Area J. Maintain a high level of stocking to insure soil stability and protection. Fell culls to reduce landslides.
L	South-east	Precip-itous	Shallow (numerous rock out-crops)	(do)	Maintain optimum stocking to hold shallow soil in place. Fell culls to reduce landslide possibilities. No attempt should be made to conduct commercial logging. Maintain as a "protection forest".
M	East	Very Steep	Deep (Colluvial)	Cove hardwoods: yellow poplar-red maple-white oak. Scattered mature residuals. Medium stocked, even-aged, second-growth stands of desirable and undesirable species (about 50-50) in saplings and poles.	Harvest scattered merchantable residuals and thin dense stands of pole-size second-growth favoring yellow poplar, white oak, basswood, northern red oak and black walnut. Deaden cull trees and weed species by girdling and/or poisoning. Cup and poison or spray rhododendron particularly in riparian zone.

TABLE III (Continued)

Watershed Characteristics					Treatment and Management Practices
Unit Area	Aspect	Slope	Soil Depth	Vegetation	
				Dense rhododendron particularly along stream channel.	Maintain stocking at a medium level.
N	South	Very Steep	Deep (Colluvial)	(do)	South aspect exerts very little influence within cove area. Consequently, same treatment as described for Unit Area M can be applied.

*Taken after L. Lassen, H. W. Lull, and B. Frank. Some Fundamentals of Plant-Soil-Water Relations in Watershed Management. U.S.D.A., Forest Service, Washington, D. C. Multilithed, pp 68-70, July 1951.

Unit Area B

The following six unit areas are similar with respect to vegetation—forest type 2 (scarlet oak-chestnut oak-black oak). The type is composed of scattered mature residuals and a sparsely stocked, uneven-aged, poor quality second-growth stand of desirable species in the pole and sawtimber size classes. Dense clumps of rhododendron occur throughout this type. The slope in unit area B is steep with a southern aspect and the soils are deep.

Unit Area C

Unit area C is similar to B in all respects except the soil is medium in depth.

Unit Area D

Unit area D is similar to B in all respects except the soil is shallow in depth.

Unit Area E

Unit area E is similar to B in all respects except the slopes are very steep.

Unit Area F

Unit area F is similar to B in all respects except the aspect which is easterly.

Unit Area G

Unit area G is similar to E in all respects except the aspect which is easterly.

Unit Area H

Unit area H coincides with forest type 4 (scarlet oak-black oak-white oak). This type is composed of scattered defective residuals, and a medium stocked, uneven-aged, good quality second-growth stand of desirable species in sapling and sawtimber size classes. The average soil depth is medium. The slope is very steep with a southern aspect.

Unit Area I

Unit areas I, J, K and L are similar with respect to vegetation—forest type 10 (red oak-chestnut oak-hickory). This type is composed of a medium to dense stocked uneven-aged, good quality second-growth stand of desirable species in sapling to sawtimber size classes. A few mature residuals are scattered throughout the overstory. Unit area I is further characterized by very steep slopes with an easterly aspect and a deep soil profile.

Unit Area J

Unit area J is composed of two separate areas and is similar to K in all respects except that the soils are medium in depth.

Unit Area K

Unit area K is similar to I with respect to vegetation and slope. The aspect is southeast and the soils are shallow in depth.

Unit Area L

Unit area L is similar to K in all respects except that the slopes are precipitous and numerous rock outcrops occur.

Unit Area M

Unit area M is composed of that portion of the cove hardwood type having an easterly aspect. Forest type 16 (yellow poplar-red maple-white oak) is present. This type is composed of scattered old-growth residuals and a medium stocked, even-aged, high quality second-growth stand of desirable and undesirable species in the pole and sapling size classes. The soil is of colluvial origin and deep. The slope is very steep.

Unit Area N

Unit area N comprises the remainder of the cove hardwood type and has a southern aspect. Stand characteristics of type 16, soil depth and slope are the same as discussed above for unit area M.

Controls

The characteristics of each unit area have been determined. It is now possible to prescribe controls or management practices designed to achieve an optimum combination of water and timber production for the entire watershed by unit areas. The silvicultural management practices presented in the discussion of the vegetation criterion are modified by hydrologic factors in order to achieve this optimum combination. A good example of modification is Unit Area L where no cutting is prescribed because of precipitous slopes.

The concept of variable levels of stocking is presented as a means of describing the intensity of vegetation manipulation. This concept has not been fully developed fully by Coweeta Hydrologic Laboratory technicians. However, it will be founded upon basal area. It is recognized that there exists a wide range of basal area in which high rates of timber-growth can be obtained. Unit areas on which protection is critical will be managed at the high end of the basal area range. Where protection is not critical unit areas will be managed at the low level of the basal area range to favor water yields. It is also possible that there will be some instances where management will be undertaken at higher or lower levels than the high timber-growth-range of basal area. However, the level of stocking will never be reduced to a point where soil stability will be placed in jeopardy.

Another control concept which needs some explanation is the idea of compensating watershed characteristics. It can best be explained by citing an example. Unit areas C and E are similar with respect to aspect and vegetation. Unit area C has steep slopes and medium-depth soils. Unit area E has very steep slopes and deep soils. It is felt that the deep soils compensate for the very steep slopes to the extent that both unit areas will be managed at the same level of stocking.

A listing of management practices by unit areas appears in Table III opposite the characteristics of each unit area.

FUTURE SURVEYS

Since this study was made several ideas have occurred to the writer which may influence the conduct of future surveys. They are presented below as recommendations with short discussions as to their merits.

The use of aerial photographs has much to offer. Topographic divides, drainage patterns, slope, aspect, and vegetative types can be readily recognized from aerial photographs. The timber cruise can be made from photographs if the necessary volume tables are available. The ground check of an aerial cruise could be incorporated with the survey of soil depth and the smaller vegetation. The use of aerial photographs will result in considerable savings both in time and money, especially if the watershed is large.

If aerial photographs are not available all criteria will have to be measured entirely on the ground in one survey. Prior to field work, adequate planning should combine the sampling of all criteria.

The line-plot method of sampling appears to be the best for conducting the survey. Each plot center can be located on a map or aerial photograph prior to the field work, and adjustments made to achieve the minimum percentage of sampling. Adjustments will be necessary particularly for the cove hardwood type because of its narrow width characteristic.

The sampling interval will be dependent upon the percentage of cruise desired for the vegetation criterion and the intensity of survey desired for the other three criteria. The variability of aspect, slope and soil depth suggests the use of a short sampling interval in order to accurately sample them. It is likely that these three criteria will have to be sampled more intensively than the vegetation. The cost of obtaining the data will exert considerable influence and may even be the governing factor which determines the intensity of sampling.

There remains the question of how small a unit area should be recognized, which is intimately related to the sampling interval discussed above. Very small unit areas will unduly complicate the management and administration of the watershed. This study used four major criteria with the following breakdown: aspect - 8 classes; soil depth - 3 classes; slope - 5 classes; and vegetation - by forest types. Perhaps four classes (four major points of the compass) is a sufficient breakdown of aspect. Type-groups may be a satisfactory substitute for forest types as a breakdown of vegetation. Appalachian forests have been grouped into six type-groups (33) as previously discussed. There is considerable difference between six type-groups and an estimated thirty-five forest types. Both of these alternatives will greatly simplify the delineation of unit areas and result in larger sized areas. Nevertheless, the forty-four unit areas originally delineated in this study seem to justify later studies aimed at seeking a modification of existing complexity.

The last idea is concerned with the mechanics of application of unit area control on the ground. The unit areas could be outlined on aerial photographs for field men to use. It is felt that the unit areas outlined on the photographs could be traced on the ground. These photographs and unit-area treatment instructions will be basic tools in the application of the unit area control concept.

SUMMARY AND CONCLUSIONS

The ultimate goal of the Southern Appalachian regional watershed research program is to discover and establish a sound and practical basis for a forest management program directed toward the maximum utilization of all forest resources. In this integrated practice the utilization of one forest product will be carried out without jeopardy to other forest products.

The concept of unit area control as used in the management of California forests was thought to offer a rational approach to the integrated management of timber and water resources in the Southern Appalachians. The original concept (based on silvicultural factors) was broadened to include hydrologic factors expressed in terms of topography and soil characteristics.

A thorough review of literature and an intensive on-the-ground study of conditions existing within the Coweeta Hydrologic Laboratory was made in an effort to find suitable criteria whereby the "unit areas" could be delineated. The following criteria were selected: aspect, slope, soil depth and vegetation. Each criterion has been discussed from both hydrologic and silvicultural standpoints with particular reference to the Southern Appalachians. In the discussion will be found the basis for the management practices prescribed for each unit area.

The criteria were then applied to a small unit-watershed to determine their practicability. A survey was made of this small watershed to measure each of the criteria. The data were summarized in a series of maps and tables. The data were analyzed by using four overlays (one for each criterion) and the watershed divided into unit areas, each one homogeneous with respect to aspect, slope, soil depth and vegetation.

This analysis resulted in the delineation of forty-four distinct unit areas ranging in size from 0.1 to 4.3 acres. To reduce the number of working units, a minimum size of 2.0 acres was set. The method used to combine these small areas was as follows: at least three of the four characteristics must be similar for units to be combined to meet the minimum size requirement. The combining resulted in the delineation of fourteen distinct unit areas. This combining was done in the office. It is felt that there is justification for later studies aimed at seeking a modification of sampling interval and criteria classes as presented in this paper so that a minimum size of unit area can be met in the field without resorting to a combining procedure in the office. The characteristics of these unit areas is presented in tabular form.

Controls or management practices designed to achieve an optimum combination of water and timber production were prescribed for each unit area. In essence, these controls were silvicultural management practices modified by hydrologic factors in order to achieve the optimum combination of water and timber production. A knowledge of the fundamental relationships existing between plants, soil and water was essential before management practices could be prescribed for the unit areas. The characteristics of each unit area had to be scrutinized and management practices prescribed on this knowledge of fundamental relationships. In some cases similar treatments were prescribed for different unit areas because the watershed characteristics produced compensating influences. A tabular summary of management practices for each unit area has been presented.

The concept of variable levels of stocking was presented as a means of describing the intensity of vegetation manipulation. The concept has not been developed fully, but it will be founded upon basal area and the recognition that there exists a wide range of basal area in which high rates of timber growth can be obtained.

The idea of compensating watershed characteristics is explained. An unfavorable watershed characteristic and a favorable watershed characteristic existing on the same unit area may compensate each other to the extent that different unit areas may be given similar treatments.

A short chapter entitled "Future Surveys" includes ideas which have occurred to the writer since the study was made. These ideas may influence the conduct of future surveys. The ideas include: (a) use of aerial photographs, (b) measuring all criteria in one survey, (c) line-plot method of sampling, (d) sampling interval, (e) smallest size of unit area to be recognized, and (f) justification of future studies.

This study was by its nature a "pilot-study". Its purpose was to find out how water and timber might be managed together on the same area. The unit area control concept provided that answer. The next step will be the actual treatment on a watershed basis to learn more about the effect of variable levels of stocking upon water yields and timber production.

APPENDIX

APPENDIX A

COMMON NAMES OF TREES AND THEIR SCIENTIFIC EQUIVALENTS*

Common Name	Scientific Equivalent
Ashes	Fraxinus spp. L.
Basswood, American	Tilia americana L.
Beech, American	Fagus grandifolia Ehrh.
Birch, river	Betula nigra L.
Birch, yellow	Betula alleghaniensis Britton
Buckeye, yellow	Aesculus octandra Marsh.
Butternut	Jugland cinerea L.
Cherry, black	Prunus serotina Ehrh.
Cherry, pin	Prunus pennsylvanica L. f.
Chestnut, American	Castanea dentata (Marsh.) Borkh.
Chinquapin, allegheny	Castanea pumila Mill.
Coffeetree, Kentucky	Gymnocladus dioicus (L.) K. Koch
Cucumbertree	Magnolia acuminata L.
Dogwood, flowering	Cornus florida L.
Elms	Ulmus spp. L.
Fir, fraser	Abies fraseri (Pursh) Poir.
Hawthorns	Crataegus spp. L.
Hemlock, Carolina	Tsuga caroliniana Engelm.
Hemlock, eastern	Tsuga canadensis (L.) Carr.
Hickory, bitternut	Carya cordiformis (Wangenh.) K. Koch
Hickory, mockernut	Carya tomentosa Nutt.
Hickory, pignut	Carya glabra (Mill.) Sweet
Hickory, shagbark	Carya ovata (Mill.) K. Koch
Holly, American	Ilex opaca Ait.
Honeylocust	Gleditsia triacanthos L.
Hophornbeam, eastern	Ostrya virginiana (Mill.) K. Koch
Hornbeam, American	Carpinus caroliniana Walt.
Locust, black	Robinia pseudoacacia L.
Magnolia, fraser	Magnolia fraseri Walt.
Magnolia, umbrella	Magnolia tripetala L.

*Elbert L. Little, Jr. Check List of Native and Naturalized Trees of the United States (Including Alaska). U.S.D.A., Forest Service. Agr. Hndbk. No. 41, 1953.

APPENDIX A continued

Maple, red	Acer rubrum L.
Maple, silver	Acer saccharinum L.
Maple, striped	Acer pennsylvanica L.
Maple, sugar	Acer saccharum Marsh.
Mountain-laurel	Kalmia latifolia L.
Mountain-ash, American	Sorbus americana Marsh.
Mulberry, red	Morus rubra L.
Oak, black	Quercus velutina Lam.
Oak, blackjack	Quercus marilandica Muenchh.
Oak, chestnut	Quercus prinus L.
Oak, chinquapin	Quercus muehlenbergii Engelm.
Oak, northern red	Quercus rubra L.
Oak, pin	Quercus palustris Muenchh.
Oak, post	Quercus stellata Wangenh.
Oak, scarlet	Quercus coccinea Muenchh.
Oak, shingle	Quercus imbricaria Michx.
Oak, southern red	Quercus falcata Michx.
Oak, water	Quercus nigra L.
Oak, white	Quercus alba L.
Persimmon, common	Diospyros virginiana L.
Pine, eastern white	Pinus strobus L.
Pine, pitch	Pinus rigida Mill.
Pine, shortleaf	Pinus echinata Mill.
Pine, virginia	Pinus virginiana Mill.
Redbud, eastern	Cercis canadensis L.
Redcedar, eastern	Juniperus virginiana L.
Rhododendron	Rhododendron spp. L.
Sassafras	Sassafras albidum (Nutt.) Nees
Silverbell, Carolina	Halesia carolina L.
Serviceberry, downy	Amelanchier arborea (Michx. f.) Fern.
Sourwood	Oxydendrum arboreum (L.) DC.
Spruce, red	Picea rubens Sarg.
Sweetgum	Liquidambar styraciflua L.
Sycamore, American	Platanus occidentalis L.
Tupelo, black	Nyssa sylvatica Marsh.
Walnut, black	Juglans nigra L.
Willow, black	Salix nigra Marsh.
Yellow-poplar	Liriodendron tulipifera L.

APPENDIX B

THE RELATIVE DESIRABILITY OF MOIST-SITE SPECIES FOR TIMBER PRODUCTION IN THE SOUTHERN APPALACHIAN REGION[1]

Desirable Timber Species	Less Desirable Species	
	Timber Species	Minor Species—Seldom Attain Sawlog Size[3]
Ashes	American beech	River birch
American basswood	Yellow buckeye	American hornbeam
Yellow birch	Butternut	Pin cherry
Black cherry	Chestnut, American[2]	Chinquapin[2]
Fraser fir	Kentucky coffeetree	Crabapple
Sweet gum	Elms	Flowering dogwood[2]
Eastern hemlock	Black tupelo[2]	Hawthorns
Mockernut hickory	Carolina hemlock[2]	American holly
Pignut hickory[2]	Bitternut hickory	Eastern hophornbeam
Shagbark hickory	Honeylocust	Fraser magnolia
Black locust[2]	Red maple[2]	Striped maple
Cucumbertree	Silver maple	Mountain ash
Sugar maple	Pin oak	Red mulberry
Chinquapin oak	Shingle oak	Persimmon[2]
Northern red oak	Water oak	Eastern redbud
White oak	American sycamore	Rhododendron
Eastern white pine[2]		Azalea
Yellow poplar		Mountain Laurel
Red spruce		Sassafras[2]
Black walnut		Downy serviceberry[2]
		Carolina silverbell
		Sourwood[2]
		Black willow
		Umbrella magnolia

[1]R. H. Westveld. Applied Silviculture in the United States. ed. 2, John Wiley & Sons, Inc. New York, p. 153, 1949.

[2]Common also on dry sites.

[3]Flowering dogwood and persimmon have high value for small products but their slow growth makes them relatively low-value species (Cuno 1926).

APPENDIX C

THE RELATIVE DESIRABILITY OF DRY-SITE SPECIES FOR TIMBER PRODUCTION IN THE SOUTHERN APPALACHIAN REGION[1]

Desirable Timber Species	Less Desirable Species: Timber Species	Less Desirable Species: Minor Species—Seldom Attain Sawlog Size
Eastern redcedar	Black tupelo[2]	American chestnut
Pignut hickory[2]	Carolina hemlock[2]	Chinquapin[2]
Black locust[2]	Red maple[2]	Flowering dogwood[2]
Black oak	Post oak	Blackjack oak
Chestnut oak	Scarlet oak	Sassafras[2]
Southern red oak		Downy serviceberry[2]
Pitch pine		Sourwood[2]
Shortleaf pine		
Virginia pine		
Eastern white pine[2]		

[1]R. H. Westveld. Applied Silviculture in the United States. ed. 2, John Wiley & Sons, Inc. New York, p. 170, 1949.

[2]Common also on moist sites.

RS - AP

Checked ________

INVENTORY OF ________ EXPERIMENTAL FOREST

Comp. No. ________

Line No. ________

Plot No. ________

Type ________

Date ________

Party ________

																									Stumps		
DBH	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	P	H	DBH
1-3																											1-3
4																											4
5																											5
6																											6
7																											7
8																											8
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DBH	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	D	S	X	DBH
1-3																												1-3
4																												4
5																												5
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7																												7
8																												8
9																												9
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11																												11
12																												12
13																												13
14																												14
15																												15

1-3 = 0.6"-3.5", 4 = 3.6"-4.5", D = Dominant, S = Subordinate, X = Dead, P = Pine.
H = Hardwood, O = Sound cull, X = Rotten cull, *=Rotten cull for logs, sound for cord-

STAND DESCRIPTION

Sprouts				Fire Scars
Percent of dominants of sprout origin	☐	0 - 33	☐	Percent of dominants with open fire scars
	☐	34 - 66	☐	
	☐	67 - 100	☐	

REPRODUCTION

		Pine	Cedar	Hard.
Reproduction of desirable species per plot. Less than 0.6" d.b.h. and over 1 foot in height.	Less than 10	☐	☐	☐
	11 to 20	☐	☐	☐
	21 and over	☐	☐	☐

SAMPLE TREES

Species	C.C.	D.b.h.	Radial Gr.		Age	Total Ht.	Bark Thick.	% Cull	Tree Class
			0-5	5-10					

APPENDIX E

ANALYSIS OF ELEVATION CHARACTERISTICS
WATERSHED NO. 40

Limiting Contour Elevations (1)	Area between Contours Acres (2)	Percent of Total (3)	Percent of Total over given Lower Limit (4)
2,860-2,900	0.8	1.6	100.0
2,900-3,000	2.6	5.2	98.4
3,000-3,100	2.8	5.6	93.2
3,100-3,200	3.5	7.0	87.6
3,200-3,300	4.9	9.8	80.6
3,300-3,400	8.1	16.2	70.8
3,400-3,500	6.7	13.4	54.6
3,500-3,600	6.1	12.2	41.2
3,600-3,700	4.5	9.0	29.0
3,700-3,800	3.2	6.4	20.0
3,800-3,900	2.6	5.2	13.6
3,900-4,000	2.6	5.2	8.4
4,000-4,100	1.1	2.2	3.2
4,100-4,190	0.5	1.0	1.0

APPENDIX F

SUMMARY OF VOLUMES - WATERSHED NO. 40

Type	Acreage	Group I		Group II		Group III		Total	
		Cubic Feet[1]	Board Feet[2]	Cubic Feet[1]	Board Feet[2]	Cubic Feet[1]	Board Feet[2]	Cubic Feet[1]	Board Feet[2]
1	2.50	775	7,535	207	497	33		1,015	8,032
2	20.32	5,344	39,949	2,276	11,786	671		8,291	51,735
4	4.65	1,214	25,143	56	2,860	9		1,279	28,003
10	12.56	2,085	71,529	100	4,597	38		2,223	76,126
16	10.01	3,183	29,429	570	29,780	40		3,793	59,209
Total	50.04	12,601	173,585	3,209	49,520	791		16,601	223,105

[1]Includes 6 to 12-inch d.b.h. classes inclusive.

[2]Includes 13-inch d.b.h. and larger classes.

APPENDIX G

1952 TIMBER CRUISE - TYPE 1 (PER ACRE BASIS) - WATERSHED NO. 40

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
1-5	199.93			196.61			3,355.81			3,672.35		
	Cubic Feet											
6	13.32	2.615	27							13.32	2.615	27
7							3.33	0.890	13	3.33	0.890	13
8	3.33	1.163	20							3.33	1.163	20
9	3.33	1.471	30	3.33	1.471	30				6.66	2.942	60
10	3.33	1.816	40							3.33	1.816	40
11				3.33	2.198	53				3.33	2.198	53
12	9.99	7.846	193							9.99	7.846	193
Total	33.30	14.911	310	6.66	3.669	83	3.33	0.890	13	43.29	19.470	406

APPENDIX G (Continued)

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
	Board Feet											
13	4.98	4.591	275	1.66	1.536	58				6.64	6.127	333
14	1.66	1.775	106							1.66	1.775	106
15	4.98	6.111	435	1.66	2.037	141				6.64	8.148	576
16	1.66	2.318	304							1.66	2.318	304
17												
18	1.66	2.933	206							1.66	2.933	206
19												
20												
21												
22	3.32	8.764	905							3.32	8.764	905
23												
24												
25	1.66	5.659	783							1.66	5.659	783
Total	19.92	32.151	3,014	3.32	3.573	199				23.24	35.724	3,213

APPENDIX G (Continued)

1952 TIMBER CRUISE - TYPE 2 (PER ACRE BASIS) - WATERSHED NO. 40

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
1-5	295.26			389.20			1,016.75			1,701.21		
	Cubic Feet											
6	8.55	1.678	17	3.15	0.303	6	5.40	0.520	11	17.10	2.501	34
7	5.85	0.394	23	1.80	0.121	7	1.35	0.091	5	9.00	0.606	35
8	5.85	2.042	35	2.25	0.785	13	2.25	0.785	13	10.35	3.612	61
9	5.85	2.585	53	1.80	0.795	16	0.45	0.199	4	8.10	3.579	73
10	2.25	1.227	27	2.25	1.227	27				4.50	2.454	54
11	2.25	1.485	36	0.45	0.297	7				2.70	1.782	43
12	3.60	2.827	72	1.80	1.414	36				5.40	4.241	108
Total	34.20	12.238	236	13.50	4.942	112	9.45	1.595	33	57.15	18.775	408
	Board Feet											
13	1.15	1.060	51	0.69	0.636	26				1.84	1.696	77
14	2.53	2.705	165	0.46	0.492	32				2.99	3.197	197
15	1.69	2.074	55	0.23	0.282	12				1.92	2.356	67
16	1.61	2.248	162							1.61	2.248	162
17	1.61	2.538	209	0.92	1.450	155				2.53	3.988	364

APPENDIX G (Continued)

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
	B o a r d F e e t											
18	1.15	2.032	185	0.23	0.406	50				1.38	2.438	235
19	1.61	3.170	292							1.61	3.170	292
20	0.46	1.003	89	0.69	1.505	145				1.15	2.508	234
21	0.46	1.106	129	0.23	0.553	91				0.69	1.659	220
22	0.69	1.821	138							0.69	1.821	138
23	0.69	1.991	132	0.23	0.663	69				0.92	2.654	201
24	0.46	1.399	113							0.46	1.399	113
25												
26	0.23	0.848	40							0.23	0.848	40
27	0.23	0.915	43							0.23	0.915	43
28	0.23	0.983	78							0.23	0.983	78
29	0.23	1.055	85							0.23	1.055	85
Total	15.03	26.948	1,966	3.68	5.987	580				18.71	32.935	2,546

APPENDIX G (Continued)

1952 TIMBER CRUISE - TYPE 4 (PER ACRE BASIS) - WATERSHED NO. 40

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
1-5	513.93			23.73			209.79			747.45		
					Cubic Feet							
6	11.10	2.179	22	1.11	0.218	2	1.11	0.218	2	13.32	2.615	26
7	11.10	2.967	44							11.10	2.967	44
8	3.33	1.163	20							3.33	1.163	20
9	6.66	2,942	60	1.11	0.490	10				7.77	3.432	70
10	3.33	1.816	40							3.33	1.816	40
11	3.33	2.198	53							3.33	2.198	53
12	1.11	0.872	22							1.11	0.872	22
Total	39.96	14.137	261	2.22	0.708	12	1.11	0.218	2	43.29	15.063	275
					Board Feet							
13	1.68	1.549	99							1.68	1.549	99
14	2.24	2.395	131							2.24	2.395	131
15	1.68	2.062	168	0.56	0.687	48				2.24	2.749	216
16	1.68	2.346	175							1.68	2.346	175
17	0.56	0.883	60							0.56	0.883	60

APPENDIX G (Continued)

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
	Board Feet											
18	1.12	1.979	78							1.12	1.979	78
19	0.56	1.103	155							0.56	1.103	155
20				0.56	1.222	167				0.56	1.222	167
21	1.68	4.041	475							1.68	4.041	475
22	1.12	2.957	263	0.56	1.478	165				1.68	4.435	428
23	0.56	1.616	173	0.56	1.616	235				1.12	3.232	408
24	1.68	5.278	623							1.68	5.278	623
25												
26	1.12	4.129	590							1.12	4.129	590
27	0.56	2.227	263							0.56	2.227	263
28	0.56	2.395	272							0.56	2.395	272
29												
30	0.56	2.749	394							0.56	2.749	394
31												
32	0.56	3.128	355							0.56	3.128	355
33	1.12	6.652	580							1.12	6.652	580
34-37												
38	0.56	4.410	553							0.56	4.410	553
Total	19.60	51.899	5,407	2.24	5.003	615				21.84	56.902	6,022

APPENDIX G (Continued)

1952 TIMBER CRUISE - TYPE 10 (PER ACRE BASIS) - WATERSHED NO. 40

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
1-5	394.43			89.07			211.45			694.95		
	Cubic Feet											
6	17.43	0.118	35							17.43	0.118	35
7	14.11	3.772	56	0.83	0.222	3	0.83	0.222	3	15.77	4.216	62
8	9.96	3.477	60	0.83	0.290	5				10.79	3.767	65
9	2.49	1.100	22							2.49	1.100	22
10	1.66	0.905	20							1.66	0.905	20
11	9.13	6.026	146							9.13	6.026	146
12	4.15	3.259	83							4.15	3.259	83
Total	58.93	18.657	422	1.66	0.512	8	0.83	0.222	3	61.42	19.391	433
	Board Feet											
13	2.94	2.710	115							2.94	2.710	115
14	2.94	3.143	167							2.94	3.143	167
15	1.26	1.546	98							1.26	1.546	98
16	1.68	2.346	208							1.68	2.346	208
17	3.36	5.296	395	0.42	0.662	47				3.78	5.958	442

APPENDIX G (Continued)

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
	Board Feet											
18	1.68	2.969	250							1.68	2.969	250
19	2.10	4.135	392							2.10	4.135	392
20	0.42	0.916	69							0.42	0.916	69
21	1.26	3.031	368							1.26	3.031	368
22	0.42	1.109	118							0.42	1.109	118
23	2.52	7.271	667							2.52	7.271	667
24	0.84	2.639	286							0.84	2.639	286
25	1.26	4.295	406							1.26	4.295	406
26	0.42	1.549	214							0.42	1.549	214
27												
28												
29	0.84	3.853	540							0.84	3.853	540
30	0.84	4.123	527	0.42	2.062	319				1.26	6.185	846
31												
32	0.42	2.346	366							0.42	2.346	366
33-41												
42	0.42	4.041	509							0.42	4.041	509
Total	25.62	57.318	5,695	0.84	2.724	366				26.46	60.042	6,061

APPENDIX G (Continued)

1952 TIMBER CRUISE - TYPE 16 (PER ACRE BASIS) - WATERSHED NO. 40

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume
1-5	400.40			134.75			709.17			1,244.32		
	Cubic Feet											
6	13.09	2.569	26	1.54	0.302	3	0.77	0.151	1	15.40	3.022	30
7	10.01	2.676	31	2.31	0.617	9	0.77	0.206	3	13.09	3.499	43
8	9.24	3.365	55	2.31	0.806	14				11.55	4.171	69
9	4.62	2.041	42	0.77	0.340	7				5.39	2.381	49
10	5.39	2.940	65	0.77	0.420	9				6.16	3.360	74
11	2.31	1.525	37							2.31	1.525	37
12	3.08	2.419	62	0.77	0.605	15				3.85	3.024	77
Total	47.74	17.535	318	8.47	3.090	57	1.54	0.357	4	57.75	20.982	379
	Board Feet											
13	1.90	1.751	101							1.90	1.751	101
14	0.76	0.812	59	0.76	0.812	77				1.52	1.624	136
15	0.83	0.466	16	0.38	0.466	28				0.76	0.932	44
16	0.38	0.531	38	0.76	1.061	55				1.14	1.592	93
17	1.14	1.791	189	0.76	1.198	99				1.90	2.989	288

APPENDIX G (Continued)

Diameter Breast Height	Group I			Group II			Group III			Total		
	No. of Stems	Basal Area	Volume	No. of Stems	Basal Area	Volume	No. of Stems	Basal Ares	Volume	No. of Stems	Basal Area	Volume
	Board Feet											
18	0.38	0.671	79							0.38	0.671	79
19	1.14	2.245	282							1.14	2.245	282
20	0.76	1.658	191	0.38	0.829	114				1.14	2.487	305
21	0.76	1.828	140							0.76	1.828	140
22	0.76	2.006	231							0.76	2.006	231
23	0.76	2.193	295							0.76	2.193	295
24				0.38	1.194	203				0.38	1.194	203
25												
26	1.14	4.203	518	0.38	1.401	141				1.52	5.604	659
27	0.76	3.022	510	1.14	4.533	561				1.90	7.555	1,071
28												
29				0.38	1.743	266				0.38	1.743	266
30												
31-33												
34	0.38	2.396	291	0.38	2.396	405				0.76	4.792	696
35-45												
46				0.38	4.385	1,026				0.38	4.385	1,026
Total	11.40	25.573	2,940	6.08	20.018	2,975				17.48	45.591	5,915

LITERATURE CITED

1. Anon. Managing and Harvesting a Watershed. Timberman LII: 50, continued 52, 54, 56, 1951.

2. Bates, C. G., and A. J. Henry. Forest and Streamflow Experiment at Wagon Wheel Gap, Colorado. U. S. Monthly Weather Rev. Sup. 30: 79 pp, 1928.

3. Croft, A. R. A Water Cost of Runoff Control. Jour. Soil and Water Cons. 5: 13-15, 1950.

4. Dunford, E. G., and P. W. Fletcher. Effect of Removal of Streambank Vegetation Upon Water Yield. Amer. Geophys. Union Trans. 28: 105-110, 1947.

5. Fletcher, P. W. The Hydrologic Function of Forest Soils in Watershed Management. Jour. Forestry 50: 359-362, 1952.

6. Forest Service, U. S. Watershed Management Research, Coweeta Experimental Forest. U.S.D.A. Southeastern For. Exp. Sta., Multilithed 33 pp, 1948.

7. ________________. Southern Appalachian Scribner Volume Tables 1950.

8. ________________. Trees, Grass, and Water. U.S.D.A. Rocky Mountain For. & Range Exp. Sta. Annual Report. 1951.

9. Garstka, Walter U. Hydrology of Small Watersheds Under Winter Conditions of Snow Cover and Frozen Soil. Amer. Geophy. Union Trans. (Part VI): 838-871, 1945.

10. Goodell, B. C. Watershed Management Aspects of Thinned Young Lodgepole Pine Stands. Jour. Forestry 50: 374-378, 1952.

11. Grondal, B. L. Relation of Runoff and Water Quality to Land and Forest Use in Cedar River Watershed. Jour. Amer. Water Works Assoc. 37: 15-20, 1945.

12. Hallin, William E. Unit Area Control in California Forests. U.S.D.A. Calif. For. & Range Exp. Sta., Res. Note 77, 1951. Multilith.

13. Heilman, John M. Forest Management for Newark. Jour. Amer. Water Works Assoc. 39: 1, 1947.

14. Hoffman, B. E. Seattle's Watershed Controversy. Jour. Forestry 32: 558-568, 1934.

15. Hoover, M. D. Effect of Removal of Forest Vegetation Upon Water Yields. Amer. Geophys. Union Trans. (Part VI): 969-975, 1944.

16. ____________, and C. R. Hursh. Influence of Topography and Soil-Depth on Runoff from Forest Land. Amer. Geophys. Union Trans. (Part II): 693-698, 1943.

17. Hursh, C. R. Local Climate in the Copper Basin of Tennessee as Modified by the Removal of Vegetation. U.S.D.A. Cir. 774, 1948.

18. __________ Research in Forest-Streamflow Relations. UNASYLVA V: 2-9, 1951.

19. Jemison, G. M. and G. H. Hepting. Timber Stand Improvement in the Southern Appalachians. U.S.D.A., Forest Service, Miscell. Pub. 693, 1949.

20. Kittredge, J. J. Natural Vegetation as a Factor in the Losses and Yields of Water. Jour. Forestry 35: 1011-1015, 1937.

21. _____________ Forest Influences. ed 1, McGraw-Hill Book Co., Inc. New York, 394 pp, 1948.

22. Kunigk, W. A. Relation of Runoff and Water Quality to Land and Forest Use in the Green River Watershed. Jour. Amer. Water Works Assoc. 37: 21-31, 1945.

23. Lassen, Leon, Howard W. Lull, and Bernard Frank. Some Plant-Soil-Water Relationships in Watershed Management. U.S.D.A. Cir. 910, 1952.

24. Lieberman, J. A., and M. D. Hoover. Protecting Quality of Streamflow by Better Logging. South. Lumberman 177: 236-240, 1948.

25. ______________________________ The Effect of Uncontrolled Logging on Stream Turbidity. Water and Sewage Works XCV: 255-258, 1948.

26. Little, Elbert L., Jr. Check List of Native and Naturalized Trees of the United States (Including Alaska). U.S.D.A., Forest Service, Agr. Handbook No. 41, 1953.

27. Lutz, H. J. and R. F. Chandler, Jr. Forest Soils. John Wiley & Sons, Inc. New York. p. 263, 1946.

28. Moore, W. L. The Influence of Forests on Climate and on Floods. U. S. Weather Bureau, Washington, D. C., 1910.

29. Smith, James L., and Geo. A. Crabb, Jr. Progress Report on the Wooded Watershed on the Michigan Hydrologic Research Station. Mich. Ag. Exp. Sta. Quarterly Bull. 34: 383-394, 1952.

30. Thompson, Allen E. Forest Management on the Cedar River Watershed. Jour. Forestry 49: 201-205, 1951.

31. Toumey, Janes W. and Clarence F. Korstain. Foundations of Silviculture. ed 2, rev. John Wiley & Sons, Inc. New York, 468 pp, 1947.

32. Wahlenberg, W. G. Three Methods of Rehabilitation for Depleted Appalachian Hardwood Stands. Jour. Forestry 51: 874-880, 1953.

33. Westveld, R. H. Applied Silviculture in the United States. ed. 2, John Wiley & Sons, Inc. New York, pp. 137-190, 1949.

34. Wilm, H. G., and E. G. Dunford. Effect of Timber Cutting on Water Available for Streamflow from a Lodgepole Pine Forest. U.S.D.A. Tech. Bull. 968, 1948.

35. Wisler, C. O., and E. F. Brater. Hydrology. John Wiley & Sons, Inc. New York, pp 38-69, 1949.

36. Zon, R. Forests and Water in the Light of Scientific Investigation. U. S. Nat. Waterways Comm. Final Rpt., App. V: 205-302, 62d Congress, 2d Sess., Sen. Doc. 469, 1927.

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