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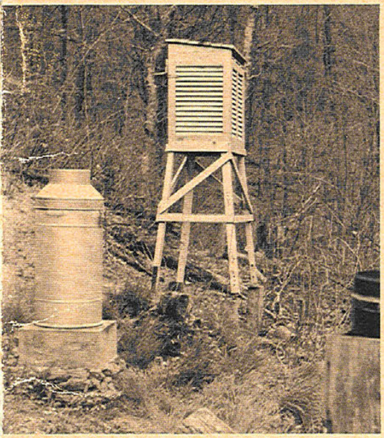

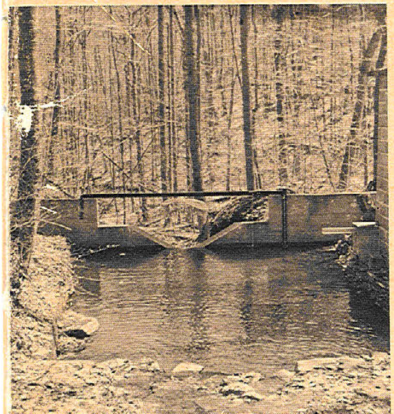

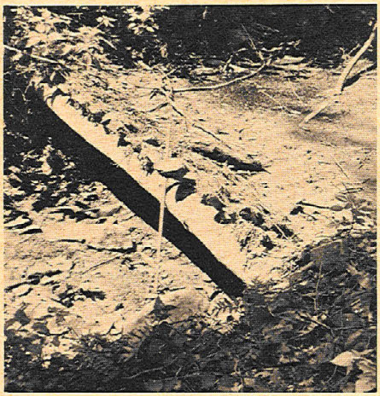

13 Years of FORESTRY RESEARCH in West Virginia

A progress report from the U.S. Forest Service Timber and Watershed Laboratory

by
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13 Years of
FORESTRY RESEARCH
in West Virginia

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Figure 1.—Location of the forestry research facilities in West Virginia.

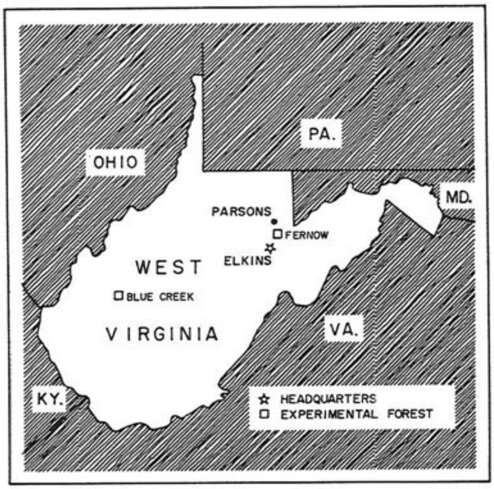

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Figure 2.—Field offices near Parsons, West Virginia.

"... To Conduct Research"

IN 1948 the Northeastern Forest Experiment Station of the U.S. Forest Service, Department of Agriculture, established a field unit to conduct research in forest and watershed management in the Northern Appalachian Mountain region. This is a progress report on the activities and accomplishments of this research unit during its first 13 years of existence.

Known initially as the Mountain State Research Center, later as the Elkins Research Center, and since 1962 as the Timber and Watershed Laboratory, this research unit has its administrative headquarters in the U. S. Forest Service Building at Elkins, West Virginia (fig. 1). However, most of the research facilities, including the Fernow Experimental Forest, are located near the town of Parsons, 22 miles to the northeast (fig. 2). A new laboratory is now being constructed at Parsons as field headquarters for this research unit.

The Fernow Experimental Forest, a 3,640 acre tract on the Monongahela National Forest, was set aside for the use of this research unit as an outdoor laboratory for studies in managing mountainous forest land. The forest stands here are mixtures of

Figure 3.—Typical forest land in West Virginia. The research program here deals with managing forested mountain land for timber, water, and other uses.

old-growth and second-growth hardwoods dating from around 1905, when heavy cuttings were made. In topography, history of cutting, climate, and variety of species the Fernow Forest is representative of much of the timberland in West Virginia and adjacent states (fig. 3).

Though the Fernow Forest has been the main locale of the research program, other studies have been made in other parts of West Virginia, in western Maryland, and in southwestern Pennsylvania. A number of study areas are located on the Monongahela National Forest. And in 1957 an agreement was made to cooperate in forest research with the Union Carbide-Olefins Company on their land near Charleston, West Virginia. Studies are now under way there on a 2,500-acre area known as the Blue Creek Experimental Forest.

The program of research at Elkins is concerned primarily with multiple use of forest land. It stresses integrated management studies aimed toward finding practical solutions to problems of managing the timber, water, and game resources of this area. Results from these studies should provide bases for judging compatibility of uses and determining use priorities. The pages to follow present an overall view of the Elkins research program and highlight the more significant results.

The Research Program on the Fernow Experimental Forest

Research efforts here have been concentrated in the field of management, with particular attention to timber and water. Wildlife studies have been integrated with this work through cooperative agreements with other agencies.

TIMBER MANAGEMENT RESEARCH

Compartment Management

Management studies on compartments (areas ranging in size up to 100 acres) are an important part of the research program on the Fernow Forest. These compartments are treated according to different forest-management practices. In timber management, the principal objective of the studies is to compare roadside costs and returns for products harvested under different practices. In correlated watershed-management studies, the objective is to compare quantity, distribution, and quality of water yields under some of the same types of forest management.

Supplementing these studies under the multiple-use concept, deer-management technicians of the West Virginia Conservation Commission are studying the effects of different practices on production of deer browse and use of different areas by deer (fig. 4). However, the wildlife studies make up a comparatively small part of the total program on the compartments.

Figure 4.—A deer exclosure used in a study of deer browsing.

Table 1.—*Treatments on forest-management research compartments on Fernow Experimental Forest*

(Number of areas in each category)

Treatment	Site quality (oak site index)			Total
	80	70	60	
Commercial clearcut	2	2	0	4
Diameter limit	2	2	3	7
Extensive selection:				
10-year cutting cycle	3	2	2	7
20-year cutting cycle	2	2	2	6
Intensive selection:				
5-year cutting cycle	2	2	0	4
Flexible cutting cycle	3	2	2	7
Even-aged management	3	3	3	9
Check area	1	1	1	3
Total	18	16	13	47

The major factors in the timber-management compartment studies are site quality and stand treatment or management program. Site quality is the potential of land to grow timber. It is expressed as site index, which is the height of dominant and codominant trees at 50 years of age according to Schnur's oak site index curves (*19*). Site-index designations on the compartments were determined by use of a site-estimating equation. This was developed by the Elkins project (*32*) and is explained later under "Site Quality Studies."

The major treatment variables or management programs are: commercial clearcutting, diameter-limit cutting, two levels of selection management, and three levels of even-aged management (table 1 and figs. 5 to 9).

A number of guides have been set up for the management programs. For the selection compartments, the guides specify the ultimate goals in terms of distribution of trees by diameter classes, number of trees per acre, volume to be left after cutting, and the size of trees that will be grown. For the even-aged compartments, they specify the different levels of intermediate treatments to be applied.

Figure 5.—A commercial clearcutting was made here. All merchantable stems were cut, including trees as small as 5 inches in diameter at breast height. Cull trees were left. Another profitable cutting will not be possible here for 60 or 70 years. An oak site index class 80.

Figure 6.—Here cutting was limited to merchantable trees 17 inches diameter and larger. Culls of this size were killed. It is expected that another cutting can be made here in about 20 years. An oak site index class 80.

Figure 7.—Extensive selection management is being tried here. Only sawlog-size trees are considered in management. Working with the stand above 11 inches in diameter, foresters select and mark each tree to be cut. Cull trees in this size range are killed. Another cutting can be made here in about 10 years. Site index is 80.

Figure 8.—An intensive type of selection management is being tested here, and two cuttings have already been made, at 5-year intervals. To improve the stand and keep it productive, foresters select and mark each tree to be cut, including trees as small as 5 inches. Culls are killed. Site index 80. Growth rate: 500 board feet per acre per year.

Figure 9.—A seed-tree cutting was made here. About 10 vigorous seed trees per acre, of the desired species, were left. After seed from these trees has started a new stand, these trees will be cut. The new stand will be managed as an even-aged forest.

Though many of the objectives of compartment management, including the principal one relating to costs and returns, will not be attained for years, the study is already yielding valuable information on logging practices, stand improvement, growth, reproduction, and timber quality.

Logging and Skidroad Studies

When work was begun by the research unit in 1948, one of the biggest obstacles to the practice of good forest management in the area was the belief among local operators that short skidroads and very heavy per-acre cuttings were primary requisites for making money in the woods. Cultural measures were considered expensive frills. We had to demonstrate the proper use

Figure 10.—The logs being loaded here were removed from the Fernow Forest in experimental cuttings. The local cooperator will haul them to his sawmill.

Figure 11.—The Fernow Forest personnel use a crawler tractor with a two-wheel arch to winch in and skid tree-length logs.

of modern logging equipment and develop cheap and efficient skidding methods and skidroad layouts before we could arouse much interest in any but the more elementary forms of forest management. Once we had demonstrated that good forest management was compatible with reasonable logging costs, many private operators and landowners became interested in practicing forestry.

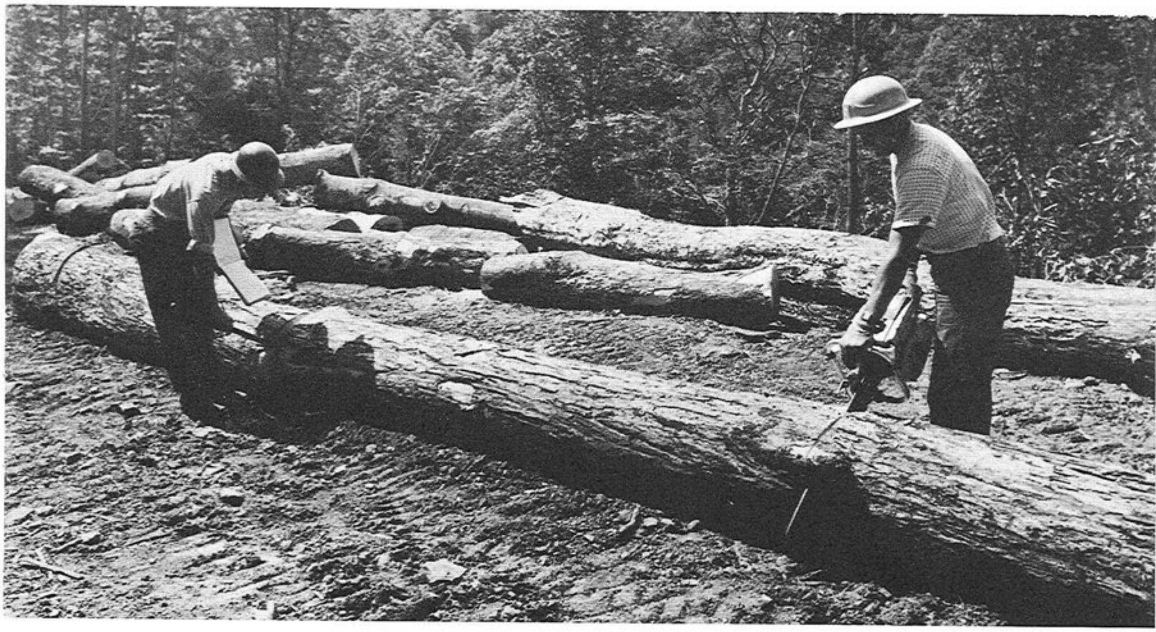
On the Fernow Forest, we do our own logging with a special crew under a cooperative agreement with a local sawmill operator. Logs are delivered to the roadside (truck road), where they are picked up by the cooperator (fig. 10). The cooperator pays the logging costs and, in addition, makes appropriate stumpage payments to the Treasury of the United States.

Recently we have been making stumpage sales of small or bulk products after the sawlog operations where such sales are compatible with research objectives. Culls, trees of undesirable species, and top and limb wood from sawlog cuttings thus are disposed of for use as such products as pulpwood, posts, rails, and charcoal wood. In all, about 3/4 million board feet equivalent are being harvested annually, most of which is sawlog volume.

Our skidding equipment consists of a TD-9 crawler tractor and a two-wheeled arch (fig. 11). This rig is operated mostly on tractor skidroads; only rarely is it driven around through the woods. Tree-length logs are winched both up and down hill to the skidroads. The usual winching distances are within 300 feet, but if necessary we can add an extra length of cable and reach out another 100 or 200 feet.

The tree-length logs are skidded to a roadside loading deck where one man, specially trained to recognize grade, does all the bucking (fig. 12). This facilitates gathering information on quality, increases the returns from the operation, and helps to demonstrate log quality as a goal of management. The cooperator pays for the logs on the basis of grade and species.

Figure 12.—Hauled to a landing, the tree-length logs are bucked, graded, and scaled. The bucking is done by a man specially trained to cut trees into the logs that will yield the highest grades of lumber.



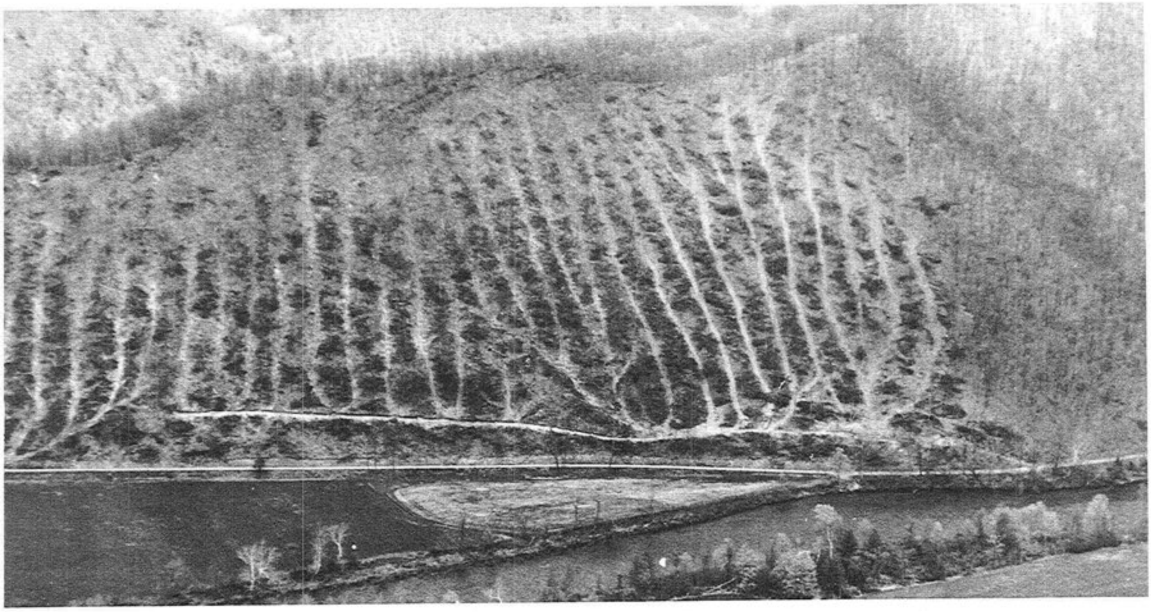


Figure 13.—The pattern of up-and-down-hill skidroads typical of a horse-logging operation.

Our control of the woods work has enabled us to conduct several studies on logging operations. Some of the results follow:

Logging damage during selection cutting.—Injuries severe enough to warrant removal before the next cutting were done to 3 to 5 percent of the residual trees (*28*). Felling damage was greater than skidding damage among the smaller trees (5 to 11 inches d.b.h.); the reverse was true for the larger trees.

Effect of grade on skidding costs.—With Fernow equipment, the lowest costs were recorded in downhill skidding on grades of 5 to 15 percent (*7*).

Area required for logging transport system. —In well-planned logging with a tractor and wheeled arch, about 5 percent of the forest area is required for the transport system (*10*). This breaks down to about 1.5 percent of the area in decks and truck roads and 3.5 percent in main skidroads. In contrast, a typical mountain horse-logging job seriously disturbs 10 to 15 percent of the land (fig. 13).

Directional felling.—Power-saw felling permits less directional control than crosscut-saw felling. To fell trees in the preferred direction when using a power saw, 15 to 38 percent of the trees on the Fernow require more effective means of nudging than conventional wedging. We have tried jacks for this job but found them inconveniently heavy and cumbersome for use in the woods (*23*). An efficient light-weight tool for this purpose remains to be developed.

Skidroad costs. —For logging 660 acres on the Fernow Forest, an average of 65 feet of bulldozed skidroad and 74 feet of nonbulldozed spur road were constructed per acre. This figured out to about 1 mile of skidroad (both types collectively) for 38 acres. Total cost per acre was about $4.70, of which $0.90 per acre was charged to road location and after-logging stabilization work (*26*).

Stand Improvement

The unmanaged stands on the Fernow Forest contained many cull trees—trees too defective to justify harvesting. On the average, there were 12 culls larger than 5 inches d.b.h. per acre, of which 5 trees exceeded 11 inches d.b.h. In 11-inch and larger culls gross volume averaged between 1,500 and 2,000 board feet per acre.

Selection management includes stand-improvement measures, and among these measures cull removal is rated first in priority in previously unmanaged stands. During the first or conditioning cutting in such stands, cull killing is a major operation and can best be done separately from the commercial harvest. In succeeding cuttings the cull-killing job becomes progressively smaller, and in the later cuttings in managed stands the few cull trees that are encountered can be treated most conveniently by girdling during logging operations.

Poisoning with ammate crystals applied in cups or notches chopped in the tree is the method most widely used on the Fernow Forest for cull elimination (fig. 14). However, both ax and chain-saw girdling are sometimes used, particularly when cull treatment is done as part of a logging job (*34*). Other methods that have been tried less successfully include frill applications of an amine

Figure 14. — Chopping cups in a cull tree. Chemicals placed in these cups will kill this worthless tree and thus will improve the stand.

salt formulation of 2,4,5-T and injector applications of 2,4,5-T ester (*42*).

Ammate treatment on culls acts quickly and is highly effective (*39*). In follow-up surveys, 45 percent of the treated trees on one area were found to be completely defoliated within 30 days and the others had lost, on the average, about 85 percent of their foliage. On another area, 91 percent of the treated trees definitely were dead after 3 years (table 2), and crown kill exceeded 95 percent on the few trees still showing life.

Table 2.—*Kills of ammate-treated culls on three areas after different intervals of time*

Area	Date of treatment	Date of observation	Elapsed time	Trees examined	Average d.b.h. of observed trees	Average d.b.h. of dead trees	Trees killed
			Months	*No.*	*Inches*	*Inches*	*Percent*
A	5/60	6/60	1	244	13.7	10.8	45
B	8/58	6/60	22	235	16.4	14.6	66
C	5/57	6/60	37	238	14.9	14.5	91

In the ammate tests, 6 to 15 culls per acre were treated at costs ranging from $1.32 to $3.61 per acre. These costs were based on labor at $1.20 an hour and ammate at 24½c a pound. Tree marking and supervisory costs were not included. Costs varied not only with size of culls and number per acre but also with competence of labor, accessibility of area, and roughness of terrain.

On the average, our crews treated 108 tree-diameter-inches per man-hour, and treated 44 diameter-inches per pound of ammate. Total tree-diameter-inches at breast height is a convenient measure of amount of timber treated, and it correlates well with costs per unit area. Average cost per diameter-inch was $0.017.

Other stand-improvement measures include weeding, thinning, and pruning. Work in weeding and hardwood pruning has only recently been started on the Fernow Forest; we have not yet done any thinning of young stands. In places, grape vines and rhododendron are our most troublesome weed species. Methods for controlling these plants are being studied on a small scale.

Growth

One of the most important criteria used in evaluating any system of forest management is the growth rate associated with it. Rate of timber growth is the basis of any management plan or any cutting budget. Two aspects of growth are being studied: stand growth and individual tree growth.

Stand growth.—Periodic 100-percent inventories are used in studying stand growth. Growth is studied in relation to the forest-management system, site capability, and stocking. It is expressed for the total stand over 5.0 inches d.b.h., or for various components of it, in the following volume units: cubic feet, board feet of sawtimber, board feet in different log-grade classes, and basal area.

Growth is under study on the compartments, on 5-acre management-intensity plots (*8, 25*), on woodlots (*11*), and on twelve 2½ acre growing-stock-level plots (figs. 15 and 16). The longest measuring period to date is 10 years, and measurements over a range of sites and degrees of stocking have been made for only 6 years. Although the measuring periods have been too short to permit firm comparisons of growth between management systems,

Figure 15.—Growth studies indicate that this stand, on an excellent site, contains about 20,000 board feet per acre in trees larger than 11 inches d.b.h.

Figure 16.—This stand, on a fair site, contains about 4,000 board feet per acre in trees 11 inches and larger. Growth studies demonstrate the importance of site.

the short-term data indicate that the ranges of board-foot growth rates under selection management for three site-capability classes (site indexes for oak) are about as follows:

Site index	*Annual board-foot growth per acre*[1]
80 (75-84) — excellent	400 to 600
70 (65-74) — good	250 to 400
60 (55-64) — fair	100 to 250

Tree growth.—Individual tree growth has been studied not only on the Fernow Forest but throughout West Virginia. Two survey-type studies have been made and reported.

One study dealt with diameter growth in relation to tree-vigor class and to tree diameter of yellow-poplar (*6*). Using vigor classes I, II, III, and IV—based largely on crown position and size, in descending order of vigor—10-year diameter growth was found to be significantly related to vigor class:

Vigor class	*Average diameter growth (inches)*
I	3.29
II	2.56
III	1.76
IV	1.07

The data were taken in well-stocked, even-aged yellow-poplar stands on good to excellent sites. Growth was significantly related to tree size only among trees in vigor class I.

The second study dealt with diameter growth of five upland oaks in relation to the same vigor classes, to d.b.h. class, and also to site index (*38, 24*). Significant growth differences were found among vigor classes and site-index classes (fig. 17). In only one species, red oak, and only among Vigor-I trees was growth significantly related to d.b.h. class. These data, too, were collected in well-stocked, even-aged stands.

We have started an individual-tree study to learn more in detail about the factors affecting growth in diameter, in total height, and in merchantable height. Periodic measurements are being taken

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[1] Based on International 1/4-inch kerf rule, for trees over 11 inches d.b.h. to an 8-inch top diameter inside bark.

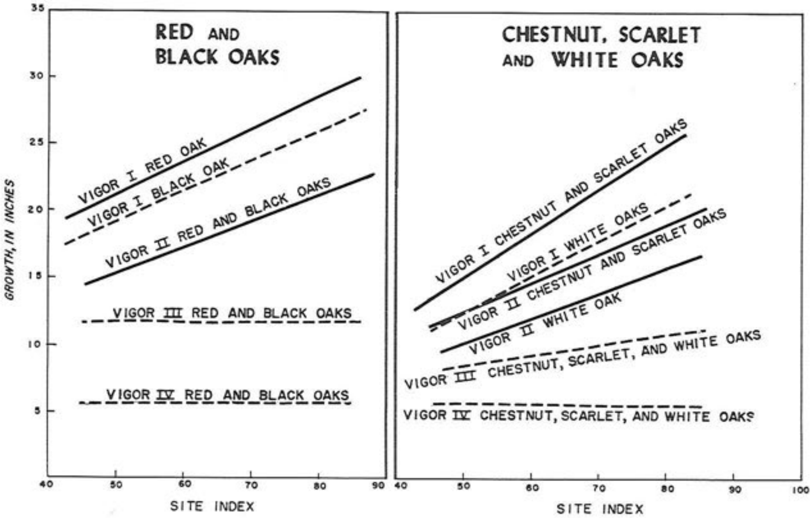

Figure 17.—Regressions and growth relations to site index. Curves show 10-year d.b.h. growth (in inches, inside bark) over site index. Solid lines represent regressions, dashed lines either percentage relationships or averages.

on about 1,200 trees to define how tree size, stand density, crown characteristics, and site quality affect growth. We plan eventually to study all of the major species in the northern Appalachian area.

Hardwood Log Quality

Improvement in log quality, which translates into improved lumber quality,[2] is a basic requirement for profitable hardwood forest management. The spread in stumpage value among logs of different grades is very wide. For the better lumber species on the Fernow Forest, the relative stumpage values of log-grades 1, 2, and 3 stand in an approximate ratio of 1 : 0.5 : 0.09 respectively. Lower-grade sawlogs often are operated at a loss.

The following steps to improve grade in forest stands should be part of every hardwood management program:

- Eliminate culls.

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[2] The yardstick to quality used here was the Forest Products Laboratory standards as published in HARDWOOD LOG GRADES FOR STANDARD LUMBER. PROPOSALS AND RESULTS. U. S. Forest Prod. Lab. Rpt. D1737, 15 pp., 1949.

- Grow large trees (large sawlogs produce more grade lumber).
- As periodic cuttings are made, mark to develop a well-stocked stand of straight, clean-boled trees of desirable lumber species.

Selectively managed areas on the Fernow Forest demonstrate the effectiveness of management in improving log quality in a 10-year period. Some results from our management-intensity plots and our small woodlots are given below. All stands were on good to excellent sites (site index 70-80 for oak).

On management-intensity plots.—On two 5-acre plots, selectively cut first in 1949 and again in 1959, good management in the brief span of 10 years has resulted in a marked improvement in stand quality. Culls have been eliminated, and the proportion of the volume in grades 1 and 2 has been substantially increased, as shown in the tabulation below (averages, in board feet, for both plots):

	Total per acre	*In log grades 1 & 2*	*In log grades 3, 4 & 5*	*In cull trees*
Before first cut (1949)	14,152	3,790	9,718	1,245
After second cut (1959)	9,553	3,916	5,636	0

On small woodlots.—Estimates of log grades (based on sampling grades in standing trees) were made on two 30-acre woodlots intensively managed over a 10-year period. Annual harvest cuttings were made in each. Here too, the proportion of the volume in grades 1 and 2 has been substantially increased. The tabulation below, in board feet, shows the changes in timber quality separately for each area:

Area 1	*Total per acre*	*In log grades 1 & 2*	*In log grades 3, 4, 5 & 6*[3]	*In cull trees*
Before first cut (1949)	5,357	876	3,735	746
After last cut (1959)	4,978	1,318	3,564	96
Area 2				
Before first cut (1949)	10,580	2,768	6,459	1,353
After last cut (1959)	9,685	4,465	5,036	184

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[3] Class 6 represents cull material in merchantable trees.

Reproduction

Only recently have intensive hardwood reproduction studies been undertaken by the Elkins project. However, periodic reproduction surveys have been made on all Fernow compartments and in connection with many plot studies (27). In addition, reproduction observations were made in well-stocked stands across a range of sites in West Virginia and in western Maryland during an oak site-index study.

The surveys on the Fernow compartments and plots showed that almost any kind of cutting in sawtimber stands will result in abundant reproduction of commercial species. They show also that the quality of the site and the severity of the cutting affect the amount, growth, distribution, and species composition of the reproduction.

These surveys reflect only the short-term effects (10 years at the longest); not until the present seedlings and saplings have reached pole-timber size will a clear picture of the relationships between cutting method and stand regeneration be obtained. Moreover, the nature and timing of cultural treatments, if any, and subsequent cuttings will modify the effects of original cuts.

In summation of the reproduction survey data, it can be said that:

- Reproduction is easy to establish; later development remains to be determined.
- Light selection cutting tends to result in reproduction composed largely of tolerant species unless a group-selection method is followed (figs. 18 and 19).
- Heavier cuttings predispose to higher proportions of sprout growth. Studies on the Fernow indicate that commercial clear-cuttings probably will produce stands composed of 35 percent or more sprouts; light selection cutting probably will result in stands containing less than 10 percent sprout stems.
- Differences in site quality are reflected in differences in species composition of the reproduction. For example, yellow-poplar reproduction is abundant on heavily cut areas on excellent sites

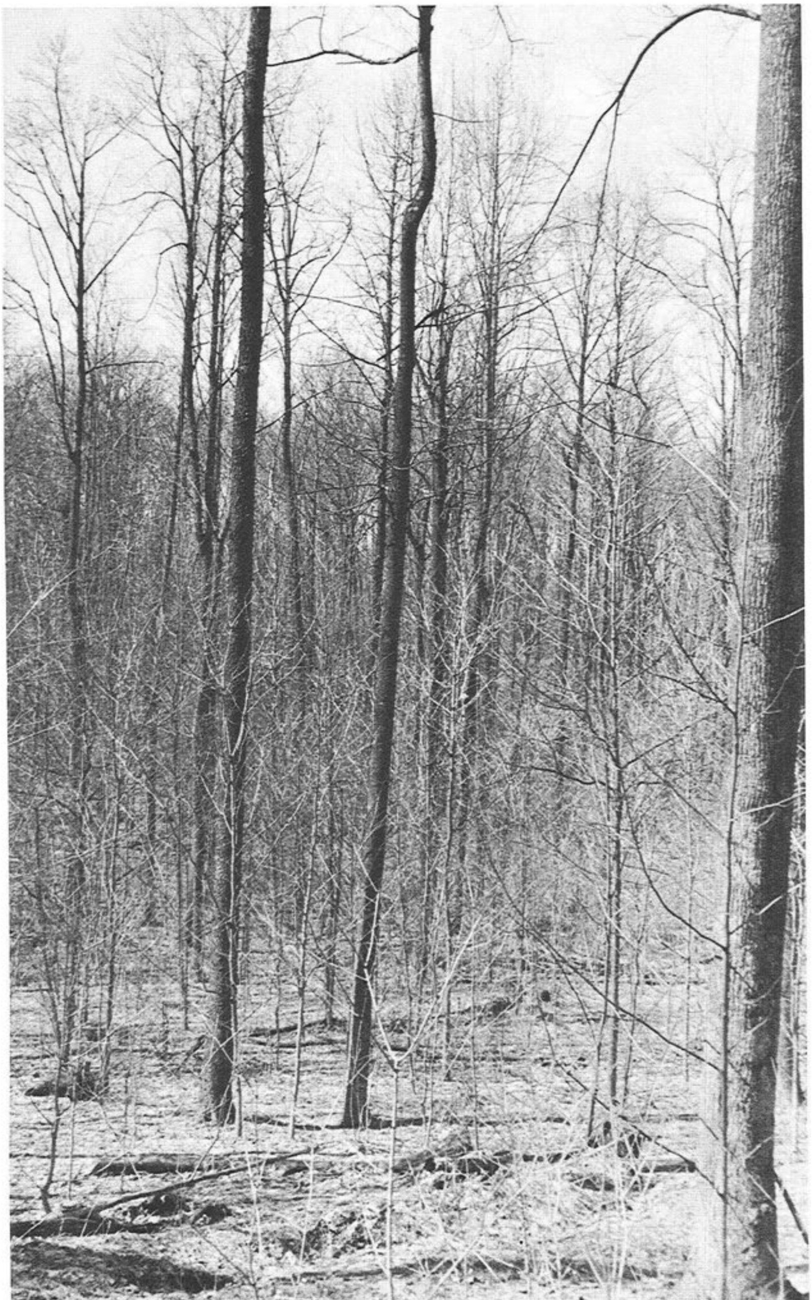

Figure 18.—A light selection cutting, showing reproduction of tolerant sugar maple.

Figure 19.—A group selection cutting, showing good reproduction of yellow-poplar in an opening.

but rare on heavily cut fair sites. Oak reproduction, almost absent on excellent sites (even with oak seed trees present in the overstory), is represented consistently but sparingly on the good sites, and is moderately plentiful on the fair sites.

- In our observations, sugar maple was the most prolific species on all sites and following all degrees of cutting, with these exceptions:
    1. On excellent sites following clearcuttings, where yellow-poplar was more numerous.
    2. On very lightly cut areas on good and fair sites at lower elevations, where beech and sassafras were more abundant.
- On partially cut areas, reproduction of intolerants was relatively much more abundant in openings than under canopy.

The oak site-index study sampled fully stocked stands in which oak species made up 30 percent or more of the overstory (*38*). Natural oak reproduction, like the distribution of oak trees, was more prevalent on the medium to poor sites (table 3).

Indications are that oaks may maintain themselves pretty well on areas with a site index 65 or lower. On better sites, competition from faster growing or more tolerant species appears to make conditions less conducive to the establishment of oaks.

There is a definite correlation between the prevalence of the different oak species and site quality (table 4). Northern red oak

Table 3.—*Natural reproduction under oak stands, by site index*

Site index	Plots	Trees per acre, all species	Oak reproduction: Per acre	Oak reproduction: Percent of all species	Oak reproduction: Relative frequency	Trees 5.0 inches d.b.h. and over that are oaks
	No.	*No.*	*No.*	*Percent*		*Percent*
40	4	3,600	1,700	47	1st	82
50	5	4,800	1,480	30	1st	82
60	17	4,200	1,100	26	1st	62
70	24	3,000	400	14	3rd	47
80	15	3,000	80	3	9th	32

Table 4.—*Distribution of oak reproduction, by species and site index*

Site index	No. of plots	Number of trees				
		Red oak	Chestnut oak	White oak	Scarlet oak	Total per acre
40	4	0	1,100	300	300	1,700
50	5	400	440	560	80	1,480
60	17	520	400	60	130	1,100
70	24	58	308	34	0	400
80	15	54	0	26	0	80

is absent on the areas of lowest site index and scarlet oak is absent from the better sites.

In 1960 a reproduction study was started on the even-aged management compartments. It included areas of oak site indexes 60, 70, and 80. Seed trees were left following the first reproduction cut; they will be harvested 3 years later. Objectives of the study are:

- To observe species composition, quantity and quality of reproduction, growth rates, and occurrence of sprouting.
- To test locally the hypothesis that this type of cutting will permit or encourage reproduction of certain desirable tree species (most of them intolerant).
- To measure and evaluate sprout growth by species, stump diameter, and tree-age classes.

Management Unit

The objective in this project is to manage by simple, practical methods a 600-acre tract of hardwoods, with emphasis on obtaining a maximum continuous return. The study will be a step toward translating research results into guides for better management plans for medium-sized forest holdings. It is a research project in economics, with considerable demonstration value.

The management unit is comparable to a private forest operated under current local conditions of markets, labor supply, transportation, and other economic factors.

Some limitations and imperatives are involved in the study: First, the woods must be cut under a sustained-yield schedule to provide material for our cooperator's mill. Second, the operation must pay all costs, including the appropriate forest-management costs, and yield a fair stumpage return. The type of forest management applied, including cultural measures, will be the best possible within the limitations. Simplified records are being kept for the purpose of calculating net returns. An important objective of the study is to evaluate such forestry costs as marking and management inventory.

The cutting program is under way. The first operations follow marking on a selection basis; a system of all-aged silviculture is envisioned. Approximately a 20-year period will elapse before the second cutting.

Small Forest Properties

In 1948, intensive selection management was started on two 31-acre demonstration woodlots. The purpose was to show that the owner of a small woodlot could obtain some income from it each year while at the same time he could build up stand quality and value for increasingly higher returns. Annual cuttings have been made in each woodlot, and results for the first decade of management have been analyzed (*11*). The analysis covers both silvicultural and economic aspects.

Each stand is on a good site. Both areas had been cut for sawlogs about 40 years before the study was begun. Area 1, being nearer an old logging railroad, had been cut more heavily; it also had been burned more severely. Consequently, the initial stand capital in 1948 was much less here than in Area 2. Table 5 shows stand data for the two areas in the beginning and after 10 years of management.

Returns from management of the woodlot areas have been realized in two forms: (1) monetary returns from the annual cuttings, and (2) increased value of the stands.

The cuttings during the 10-year period have yielded approximately 2,000 board feet per acre on Area 1 and 3,750 board feet per acre on Area 2. The increase in stand value came about

Table 5.—*Changes occurring during 10 years of management on small woodlots*

Date	Merchantable volume per acre	Percent of merchantable volume		Basal area in culls	Annual per acre growth for the period[1]
		In high-value species	In log grades 1 and 2		
	Bd.ft.	*Percent*	*Percent*	*Percent*	*Bd.ft.*
Area 1:					
1949	4,600	56	19	6.5	—
1959	4,880	76	27	1.7	230
Area 2:					
1949	9,200	69	30	10.0	—
1959	9,500	76	47	1.8	400

[1] Includes material removed as well as changes in stand volumes.

in these ways: (1) through a small increase in merchantable volume; (2) through a change in species composition, with increased volume in high-value species; and (3) through an improvement in log grade or quality.

We have set up management goals for each woodlot area in terms of merchantable volume and timber quality. We believe these goals to be realistic and attainable approximately as scheduled below:

Year	*Merchantable volume/acre (bd. ft.)*	*Sawlog volume in high-value species (percent)*	*Sawlog volume in log grades 1 & 2 (percent)*
Area 1:			
1959	4,880	76	27
1969	6,400	80	40
1979	8,100	80	50
1989	10,000	80	60
Area 2:			
1959	9,500	76	47
1969	10,000	80	60

WATERSHED-MANAGEMENT RESEARCH

The watershed-management-research program, from its inception in 1950 to the present, has grown in importance and complexity. Since watershed management is one of the main elements in multiple-use management of forest land, many aspects of watershed-management research impinge on timber-management practices, and vice versa. From the beginning, we have viewed watershed management and timber management as interrelated and complementary facets of forest-land management. In our watershed studies we have always tried to recognize the timber-management implications, and have tried to integrate our research in the two fields.

The broad objective of the watershed-management-research program is to determine the effects of land-use changes and forest practices on the quality and quantity of streamflow, and its distribution in time. Recommendations and prescriptions are coming from this research. The research program can be divided into two parts: studies of gaged watersheds, and other studies. Most of the research effort has gone into the gaged watersheds.

Gaged Watersheds

Because reports recently published (*16, 18*) treat in detail the work on gaged watersheds, only the highlights will be covered here.

In the spring of 1951 observations and records were started on five gaged watersheds on the Fernow Experimental Forest. Research installations included stream-gaging stations with V-notch weirs, water-level recorders, a weather station, and a rain gage network of three recording and nine standard gages (figs. 20 and 21). The forest areas behind the stream gages range from 38 to 96 acres. In 1951, all were undisturbed and supported well-stocked stands of hardwood timber. The five watersheds are nearly contiguous and are reasonably similar in forest types, soils, and topography (table 6).

Figure 20.—A weir and gage house of the type used in watershed-management studies. This is a view from upstream.

Records on precipitation, runoff, and water quality were gathered on the undisturbed watersheds over a 6-year calibration period. This established the patterns of natural behavior, which then served as a yardstick for judging the effects of subsequent watershed treatments on runoff and water quality. To provide a reliable yardstick, the requisite length of calibration period was determined by interim statistical analyses of streamflow and precipitation data compiled by months, seasons, and years (*13*).

Also, inventories of the timber were made during the calibration period. Since the watersheds were destined, after treatment, to function as replicates in the timber-management compartment study, the inventories served two purposes: to provide a base for planning and specifying cutting treatments, and to provide a base for relating stream behavior to forest cover.

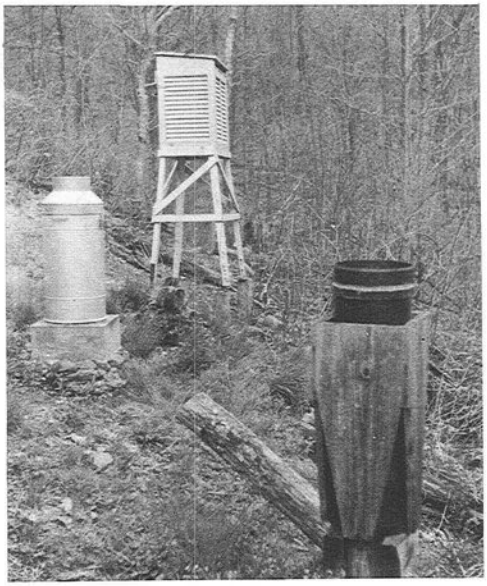

Figure 21.—Instrument installations used in watershed studies. Right foreground, a standard rain gage. Middle distance, left, a recording rain gage. Background, a weather-instrument shelter.

Four of the watersheds were treated between May 1957 and February 1959; the fifth was left undisturbed as a control. The treated areas were cut over according to different systems. These ranged from a commercial clearcutting, with skidroads located by the loggers up to maximum operable grades, to a conservative selection system of cutting, with carefully laid out and drained skidroads restricted to low grades (table 6).

Effects of the treatments in terms of water quality and stream flow are discussed below for the 3-year period from the start of treatment through April 1960; some data also are given for the 1960 growing season.

Water quality.—Water turbidities after treatment illustrate the striking results of the different logging practices. (Turbidity is expressed in parts of soil per million parts of water—ppm.) The water turbidity ranged from 15 ppm. on the control to 56,000 ppm. on the clearcut watershed.

Serious stream pollution occurred on the clearcut watershed and on one cut to a diameter limit. These were the heavier cuttings in the study, and skidroad locations were unplanned and unrestricted. On the other two watersheds, where road layouts were

Table 6.—*Characteristics of five gaged watersheds on the Fernow Experimental Forest*[1]

Water-shed No.	Timber management practice	Area	Basal area in trees over 5.0 inches d.b.h.		Range in elevation	Skidroad area steeper than—	
			Original	Removed		10%	20%
		Acres	*Sq. ft./acre*		*Feet*	*Percent*	
1	Commercial clearcut	74	98.2	81.0	2,040-2,610	78	46
2	Diameter limit	38	95.0	34.3	2,350-2,620	80	8
5	Extensive selection	90	111.4	24.0	2,400-2,760	64	7
3	Intensive selection	85	104.6	14.8	2,400-2,810	32	1
4	Control	96	105.7	0	2,400-2,820	0	0

[1] Soils are medium texture on all areas, mostly well-drained silt loams.

planned according to grade specifications and the cutting was selective, pollution was much less. On one of these watersheds, cut according to extensive selection standards, the effect on water quality was not serious and subsided soon after logging; on the other, cut according to intensive selection standards, the effect on water quality was negligible.

The impact of logging on water quality was greatest while the logging was in progress. This is shown below by some averages of periodic turbidity measurements made during and after logging the clearcut and diameter-limit watersheds:

	Average turbidity (ppm.)	*Range in turbidity*
Commercial clearcut:		
During logging	490	0-5000
First year after logging	38	0-700
Second year after logging	1	0-53
Diameter-limit:		
During logging	897	0-5000
First year after logging	6	0-88
Second year after logging	0	0

Heavy cutting widened the extremes of water temperatures. On the average, growing-season maximums in 1958 and 1959 were increased on the clearcut area by about 8° F., and dormant season minimums were reduced about 3½°. Slight effects of the same sort were observed on the diameter-limit watershed. But no appreciable effects were evident on the two selection watersheds.

Slight chemical changes in the water were also noted as a result of clear cutting: pH increased by about 0.3 and methyl orange alkalinity rose about 2 ppm. No appreciable changes occurred after the other three treatments.

Streamflow.—Treatment effects were analyzed in terms of: total discharge by years, seasons, and months; low flows; high flows; flow duration; and runoff as a percentage of precipitation. By using equations determined during the calibration period, after-treatment flow could be compared to the flow that would have occurred under comparable rainfall and weather regimens in the undisturbed stands. The treatments increased total discharge, more or less in proportion to the amount of timber cut (fig. 22). Most of the increase occurred in the summer and early fall.

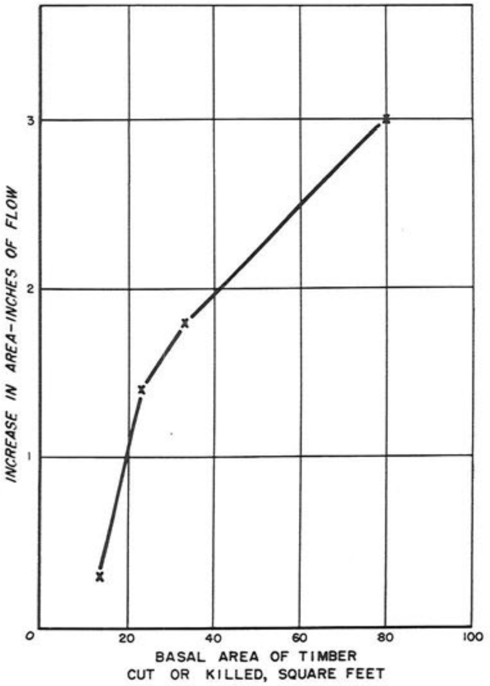

Figure 22.—Relationship between amount of timber cut or killed and increase in stream discharge, 1959 growing season.

Table 7.—*Effect of watershed treatment on discharge, by seasons*

Year	Increase in flow[1]							
	Commercial clearcut		Diameter limit		Extensive selection		Intensive selection	
	Area-inches	*Per-cent*	*Area-inches*	*Per-cent*	*Area-inches*	*Per-cent*	*Area-inches*	*Per-cent*
Growing season								
1958	4.4*	34	—	—	—	—	—	—
1959	3.0*	111	1.8*	53	1.4*	33	0.3	9
1960	1.8*	35	.7*	11	[2]–.3	4	.4	7
Dormant season								
1957-58	0.9	5	—	—	—	—	—	—
1958-59	.6	4	.2	1	–.1	1	3	2
1959-60	.5	3	.8	4	–.6	2	0	0

[1] Increase is expressed as a percentage of expected discharge.
[2] Negative value denotes a decrease.
*Increase is statistically significant at 5-percent level.

Predicted flows—if no cutting had been done—and measured flows, after different methods of cutting, were compared for growing and dormant seasons (table 7). On all treated watersheds except the one cut by intensive selection, significant increases in total discharge occurred in the first growing season after logging was completed. The largest increase, as would be expected, occurred on the clearcut watershed; and the smallest increase was where the cutting was lightest—on the intensive selection watershed. Although not statistically significant, the increase on the intensive-selection watershed was estimated to be 0.3 area-inch, or more than 8,000 gallons per acre; and it fell into a logical pattern in relation to results on the other watersheds. Even in the short period of observation, the streamflow records indicate that the increases in runoff due to cutting treatments are diminishing.

Dormant-season increases, ranging up to 5 percent on the clearcut watershed, were not statistically significant.

Effects of the treatments in augmenting low flow were particularly striking. For each treated watershed, equations were derived for predicting the number of days in the year that its flow would have fallen below 0.05 (about 50 gallons per acre per day) if no cutting had been done. Table 8 shows the expected days of low flow under no treatment and the actual days of measured low flow under the treatments. Fewer days in the measured column indicates that the treatment resulted in an increase in flow.

Table 8.—*Effect of treatment on number of days of low flow (below 0.05 csm)*

Treatment	Year	Number of days of low flow		
		Expected	Measured	Decrease
Commercial clearcut	1957	124	52	72*
	1958	38	0	38*
	1959	99	36	63*
	1960	46	7	39*
Diameter limit	1958	22	0	22*
	1959	74	27	47*
	1960	29	2	27*
Extensive selection	1959	58	37	21*
	1960	17	3	14*
Intensive selection	1959	65	60	5
	1960	20	7	13*

*Decrease is statistically significant at 5-percent level.

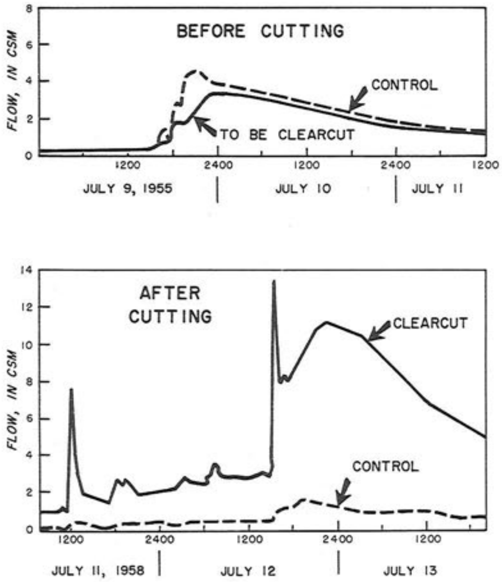

Figure 23. — Sample storm hydrographs of clearcut and control watersheds before and after treatment.

There was a definite effect of treatment on high flow, at least on the clearcut watershed. This effect was much more difficult to analyze than the effects on other aspects of streamflow. The high-flow responses after treatment were not consistent for different storms. The variations appear to be associated with time of year, antecedent precipitation and soil-moisture conditions, presence or absence of snow, and other factors. Too few high flows occurred to permit stratification by these factors.

Under some conditions, storm flow from the clearcut watershed was several times that from the control. Figure 23 shows sample hydrographs for these two watersheds before and after treatment. The two pretreatment hydrographs are similar; the rounded peaks are characteristic of undisturbed forested watersheds where overland flow is negligible.

In an effort to define the effects of heavy cutting on storm flow, several different analyses were made. Two of these are noted below. All were in general agreement in indicating higher high flows after the treatment than before. One analysis compared predicted and measured values of instantaneous peak flows. On the average, the absolute height of peaks during the growing seasons was increased 21 percent. In another analysis, the volume of discharge above 10 csm. was determined for the period of high flow. On the average, flow above 10 csm. during the growing season was increased 75 percent.

The treatments had little effect on high flows during the dormant season: both small decreases and small increases occurred. Effects of treatment on the rate of snow melt probably accounted for most of the dormant-season variations. Treatment effects on high flows on the other three watersheds were small as compared to those on the clearcut area.

This study of gaged treated watersheds is being continued to determine changes in streamflow resulting from regrowth of the vegetation and to learn the effects of future cuts.

Additional analyses of accumulated data may enhance our understanding of precipitation-streamflow-treatment relationships. The possibility of relating streamflow to such weather variables as temperature and humidity remains to be explored. Separation of streamflow into surface runoff, subsurface flow, and ground water should give a better understanding of the role of these three components in the overall relationships.

Other Gaging Studies

Four untreated watersheds are now being calibrated. Two are forested watersheds on the Fernow Experimental Forest where additional studies of cutting effects will be made in a few years. Two others are brushy mountain pastures off the forest that now are reverting naturally to woodland. On these areas methods of conversion to forest will be studied in relation to streamflow and water quality.

Other Watershed-Management Research

Besides the gaging studies, our most notable watershed research has concerned practices and after-logging treatments to control erosion on logging roads. This work was started early in the Fernow program. Several other small miscellaneous studies will be mentioned briefly.

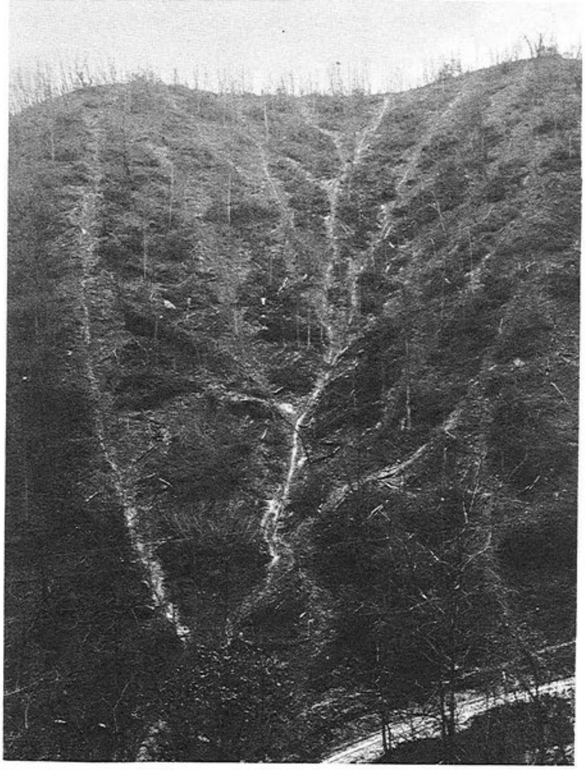

Figure 24.— These skid-roads, running straight up and down the hill, wash and gully with every rain.

Control of logging-road erosion—Logging-road erosion was studied in relation to steepness of slope, provision for drainage, intensity of use, soil factors, and revegetation measures. Results of these studies have been reported in a number of publications (*33, 35, 29, 36, 31, 21, 22*). The study findings have led to the following recommendations for the general northern Appalachian area:

- Disturb as little soil as possible; plan and construct a minimum mileage of roads.
- Keep grades of bulldozed roads under 10 percent, if possible (fig. 24 illustrates what not to do in road location).
- Locate roads on side slopes so they can be adequately drained.
- Bulldoze only where necessary and only for permanent roads. Subsoil is more susceptible to erosion and it stabilizes more slowly than topsoil.
- When bulldozing a road, make frequent dips and breaks in grade.
- Log and get out. Logging should be concentrated in one sec-

Table 9.—*Soil loss from skidroads, by intensity of use, in inches*

Road	During skidding	First two months after skidding	Total after-logging erosion[1]
Heavily used			
No. 1	5.4	0.4	[2]1.8
No. 2	2.0	1.1	2.1
Lightly used			
No. 1	.8	.1	[2].8
No. 2	1.3	.3	1.0
No. 3	.8	.1	.7

[1] This covers the period until the road surface was considered to be stabilized.

[2] Water bars were installed after logging on both No. 1 roads but not on the other roads.

tion of a logging chance at a time so that the skidding period can be reduced to a minimum. Erosion is greatest during the period of use (table 9).

- Keep road-building and skidding away from stream courses. Divert water from skidroads onto the forest floor where the sediment can be filtered out, rather than directly into streams.
- When skidding on a road is finished, install water bars or outslope drainage at appropriate intervals determined by the grade. A workable rule of thumb for determining the spacing in feet between drainage points is to divide the slope percent of the road into 1,000.
- On areas of high erosion hazard, apply lime and fertilizer after drainage has been installed, and seed coarse meadow or cereal grasses for additional erosion control (fig. 25).

Miscellaneous Studies

Ground rainfall intensity.—Rainfall intensities and throughfall were measured under a fully stocked hardwood forest over a period of 1 year. (Throughfall is the rain that falls through the tree crowns; the amount that runs down the tree trunks—stemflow—is excluded). Maximum 5- and 15-minute intensities were compared with similar measurements in the open. The results

Figure 25.—Log decks can be a source of erosion. *A,* this log deck was seeded to produce new cover. *B,* this log deck was not seeded. Both photos were taken 1½ years after logging.

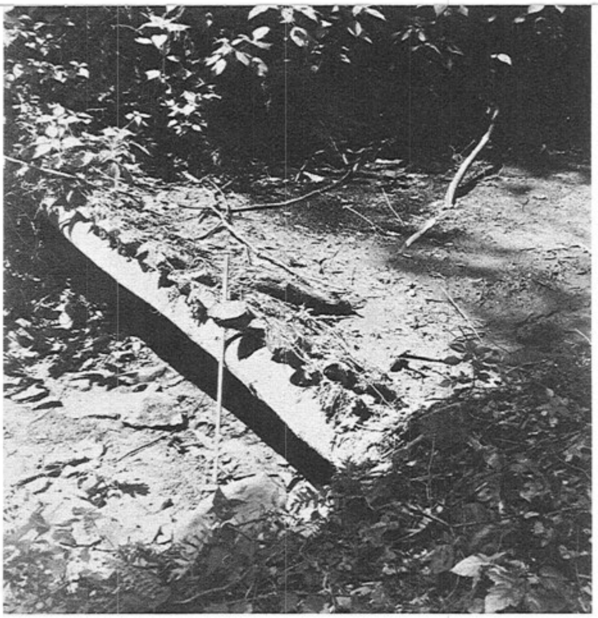

Figure 26.—A small filter dam, used to trap sediment. The dam was made of a crosslog, posts, stock wire, and straw.

were analyzed separately for bare-canopy winter and for full-leaf summer conditions. Regression equations were calculated for estimating intensities and throughfall under canopy from measured rainfall in the open. In the study, low rainfall intensities were reduced more by summer canopy, and high intensities were reduced more by winter canopy. Throughfall was reduced about the same amount in both summer and winter (*30*).

Streamfilter.—A small filter dam was developed to catch stream sediment from an area that was being logged without regard for watershed damage. Several of these dams on the stream prevented much of the sediment from moving into a municipal reservoir below (*14*) (fig. 26).

Humus studies.—On several watersheds periodic observations are being made to determine the effects of different intensities of cutting on type and depth of humus. Humus depth 3 years after the commercial clearcutting showed a significant reduction of 1/3 inch in the A_1 horizon.

Automatic water sampler and trash screen lifter.—The Elkins and Laconia (New Hampshire) projects jointly developed a "Rube Goldberg" type of automatic apparatus for collecting water samples and raising trash screens when streamflow reaches predetermined stages (*17*). The apparatus is operated by tripping devices activated by rising water in the weir pond.

Soil-moisture study.—Some soil-moisture investigative work has been done on the watersheds both by conventional gravimetric sampling and with one of the earlier types of neutron moisture probes. This work, while inconclusive, did lead to the development of certain hypotheses concerning soil moisture in this area. These may form the bases of future soil-moisture research.

Also in connection with our soil-moisture work, a method was developed to adjust moisture content for stone volume (*15*). In gravimetric sampling, moisture-content estimates can be improved by removing stones from the samples and deducting the weight of stones from total soil weight and the weight of moisture in stones from weight of moisture in the sample. Adjustments must also be made when determining soil bulk density if moisture content by volume is desired, and in applying soil-moisture values to soil areas that include stone.

The Research Program On Other Areas

SITE-QUALITY STUDIES

Soon after establishment of the Elkins projects, we became aware that forest land site quality (the potential of land to grow timber) in this area varies greatly, even over short distances. Variations in site, accompanied as they are by differences in species composition and growth rates, obviously would have to be considered, both in studies of treatment effects and in the development of forest management and silvicultural prescriptions.

The most readily available and best recognized measures of site quality were the standard site indexes—the heights of dominant and codominant trees at 50 years of age. But site index can be determined accurately only from trees growing in undisturbed, reasonably well-stocked, even-aged stands. Many—probably most—of our forest stands fail to meet these conditions. Therefore other methods of determining forest land productivity were needed.

In 1953 work was begun to find ways of determining site index, from the site itself, for the principal timber species in this general area. We started with the oaks because they comprise at least half of the timber resource in the area, and because good site curves and yield-table[4] data were available (*19*).

From this work an estimating equation was developed by regression analysis for well-drained, medium-textured soils originating from sandstone and shale, except the Ashby series. The equation applies to the Allegheny Plateau and Allegheny Mountain regions of northeastern West Virginia and western Maryland (*32, 37*). We found the following four variables to have a major influence on site index of a given plot of land: (1) aspect or compass direction faced by the slope of the land; (2) its position on the slope—that is, its distance from the ridge line in percentage of total length of the slope; (3) its grade or percentage of slope; and (4) soil depth to rock.

In the regression equation, site index (Y) is expressed as its logarithm to the base 10. The four independent variables named above were made linear with respect to site index by expressing them as follows:

1. Aspect (X_1) as the sine of the azimuth taken clockwise from the southeast and adding 1.
2. Slope position (X_2) as the percentage of distance from the ridge line.
3. Grade (X_3) as the percent slope.
4. Soil depth to bedrock (X_4) as its reciprocal in feet. Or, more concisely, the elements in the equation were defined as shown below:

Y = log site index

X_1 = sine (azimuth from SE) + 1

X_2 = percent distance from the ridgeline

X_3 = percent slope

$$X_4 = \frac{1}{\text{soil depth in feet}}$$

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[4] Yield tables, based on actual measurements in well-stocked stands, indicate the approximate timber yields that can be expected from different sites.

The equation developed from the study is: $Y = 1.9702 - 0.0618\ X_1 + 0.0012\ X_2 - 0.0020\ X_3 - 0.1509\ X_4$. The correlation coefficient of 0.8683 is significant at the 1-percent level. The standard error of estimate is approximately 9 percent at the point of average site index—66 feet. The effect of these factors can best be seen when expressed in tabular form (table 10).

Factors other than those used in the equation, such as soil texture, drainage, and stoniness, also modify site quality. The effects of these variables are discussed in the technical report of this work (*32*).

Table 10.—*Site index of oak as related to aspect, slope position, slope percent, and soil depth*

Aspect	Soil depth in feet	Slope percent							
		10	30	50	70	10	30	50	70
		TOP OF SLOPE				UPPER SLOPE			
SW (225°)	0.5	34	31	28	26	37	33	31	28
	1.0	46	43	40	36	52	47	43	39
	2.0	57	52	47	43	62	56	51	47
	3.0	60	55	50	45	65	60	54	50
NW (315°) and SE (135°)	0.5	39	35	32	29	42	39	35	32
	1.0	55	50	46	42	60	55	50	45
	2.0	65	59	54	49	71	65	59	54
	3.0	69	63	57	52	75	69	63	57
NE (45°)	0.5	45	41	37	34	49	44	41	37
	1.0	63	58	53	48	69	63	57	52
	2.0	75	69	63	57	82	74	68	62
	3.0	80	73	66	60	87	79	72	66
		LOWER SLOPE				BOTTOM OF SLOPE			
SW (225°)	0.5	40	37	33	30	44	40	37	33
	1.0	57	52	47	43	62	57	52	47
	2.0	68	62	56	51	74	68	62	56
	3.0	72	65	59	54	78	72	65	60
NW (315°) and SE (135°)	0.5	46	42	39	35	50	46	42	38
	1.0	66	60	55	50	72	66	60	54
	2.0	78	71	65	59	85	78	71	65
	3.0	83	75	69	63	91	83	75	69
NE (45°)	0.5	53	49	44	41	58	53	49	44
	1.0	76	69	63	57	83	76	69	63
	2.0	90	82	75	68	99	90	82	75
	3.0	95	87	79	72	104	95	87	79

After the results of this study had been published, further analysis—strengthened by the addition of more data—showed that site index could be estimated without the measurement of soil depth. Otherwise, the same factors were used; that is, X_1 (aspect), X_2 (position on slope), and X_3 (percent slope). Elimination of soil depth as a separate variable resulted in an equation almost as precise as the original one. This does not mean that soil depth has little effect on site index. On the contrary, it is a most important factor, as is shown in figure 27. It can be omitted from the equation without much loss of precision only because of the close correlation that exists between soil depth and the slope factors. The shorter equation is: $Y = 1.9375 - 0.07036 X_1 + 0.00132 X_2 - 0.00267 X_3$. The use of an equation without soil depth permits much quicker and easier measurements of the variables in the field.

A supplemental site study on the limestone-derived Belmont soils was recently completed for the same area covered in the

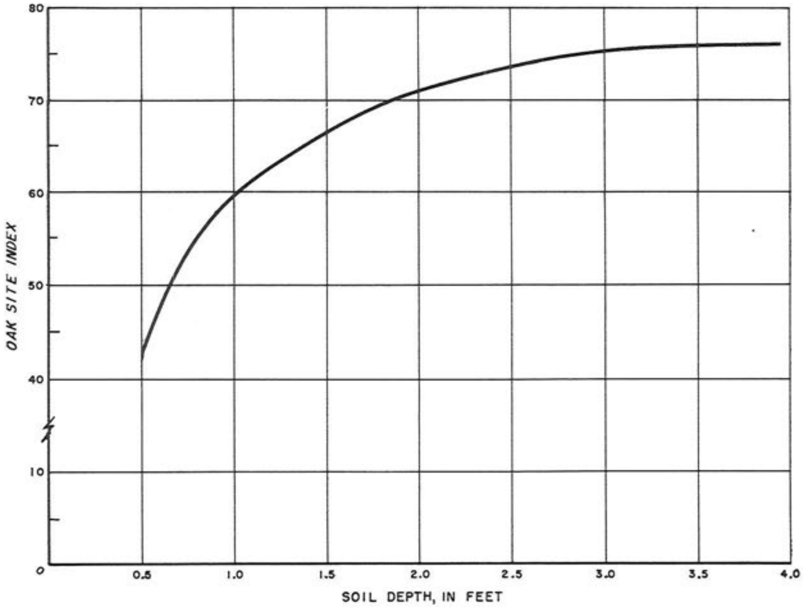

Figure 27.—Site index in relation to soil depth. Other factors are constant: 30-percent slope, one-third distance from bottom, aspect southeast.

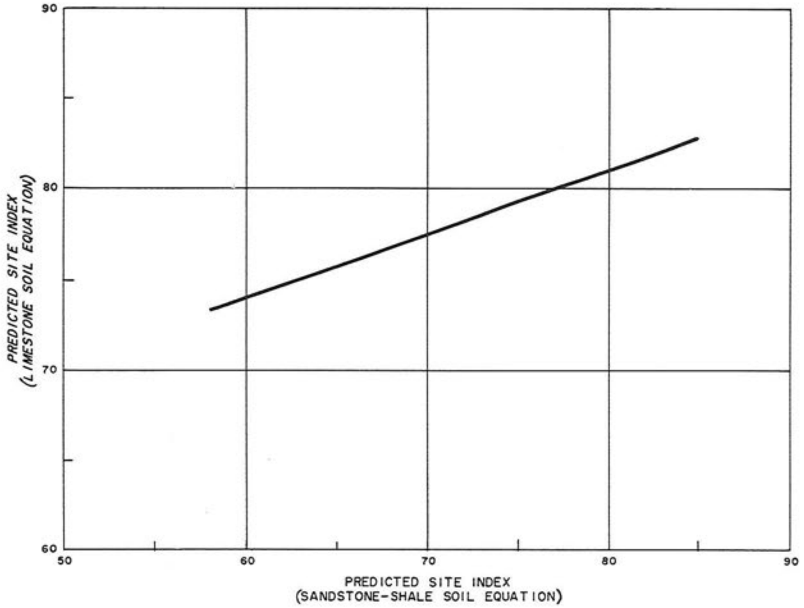

Figure 28.—Relationship between sandstone-shale soils and Belmont limestone soils, for oak site index.

original study on sandstone and shale soils. On the Belmont soils oak site indexes showed a unique relationship to site indexes on the sandstone and shale soils. For the combinations of topography and soil depth that are associated with the poorer sites, the Belmont soils had considerably higher site indexes than the sandstone-shale soils. For example, in situations where sandstone-shale soils had an index of, say, 60 feet, Belmont soils in similar situations had an index of about 74 feet. However, as the location and soil-depth factors became more favorable, the influence of the soil itself declined and, on the excellent sites, was insignificant. For combinations of topography and soil depth favorable enough so that the site index would be 83 feet on sandstone-shale soils, the index would be no better on Belmont soils (fig. 28). A publication on this work is in preparation.

Two additional oak site studies now are under way in the area east of the main ridge of the Alleghenies in West Virginia and Western Maryland. One concerns the same group of sandstone and shale soils that was studied originally in the Plateau and Mountain sections. The other deals with the Ashby soils, which also are derived from sandstone and shale but seem to support distinctly poorer tree growth than other soils in the region. For that reason, we are examining the Ashby soils separately.

SPECIES-CONVERSION STUDY

It is generally believed that our northern Appalachian forests contained considerably more white pine in the past than they do now. Heavy early cutting and fires probably reduced this species. There are indications that, on poor sites, white pine will grow better and produce more high-quality timber than the oaks and other hardwoods that now occupy such sites.

In 1954 a small study was started to: (1) identify the sites where white pine should be favored or could profitably be introduced in mixture with the hardwoods; and (2) to determine, by oak site-index classes, the cultural measures needed to establish white pine and to enable it to compete successfully with the hardwoods.

The 6-year results of this study (*40*) are in accord with findings from other places in the range of white pine (*9, 20*). These results show that on fair to good sites white pine should not be introduced because of the intense competition from the hardwood undergrowth; whereas on poor sites, where the undergrowth typically is less aggressive, pine can be planted with good chances for success (figs. 29 and 30). The results indicate further that:

- Where 50-year or older hardwood stands occupy land of site index 40 to 60 for oaks, white pine can be planted with reasonable success after a heavy cutting of all hardwoods down to about 5 inches d.b.h. Trees above about 5 inches d.b.h. that are not harvested should be girdled or poisoned. A mixed white pine-hardwood stand should result, with a fair number of the planted pines in the dominant canopy.
- From 3 to 5 years after planting, a release from hardwood

Figure 29. — Planted white pine on site index 60 for oaks. Here hardwood brush is competing strongly against the pine.

Figure 30.—On oak site index 43, this planted white pine is outgrowing the competing hardwood brush.

sprouts will, in most instances, increase survival and growth of the pines. However, a fair proportion of the pines should come through without release.

- If little or no after-logging release is to be done, the upper marginal site for the introduction of white pine into hardwood stands appears to be between site indexes 50 and 60. This study did not include the more intensive types of release treatments. However, it may be pointed out that, by proper use of herbicides, the marginal site index could probably be somewhat higher.

Information on species conversion on sites poorer than site index 40 for oak is not available from this study. Such sites may not be good enough for white pine, and on them perhaps conversion should be based upon less demanding species, such as Virginia pine. More research is needed on these extremely poor sites.

REGENERATING RED SPRUCE SITES

In 1940-41 the Southeastern Forest Experiment Station put in seeding and planting experiments on a number of former red spruce sites in the Appalachians, including several locations in northern West Virginia. We re-examined some of the test plantings and seedlings in our territory in 1950, and reported on them in 1954 (*1*).

The areas involved were high-country sites where the virgin spruce stands had been clearcut and burned around the turn of the century. Several experiments, all concerned with seedling survival and growth, were begun. One dealt with the effects of vegetative cover on planted and seeded red spruce and red pine; another dealt with the effects of release cuttings on established red spruce, and another experiment compared seeded and planted red spruce and southern balsam fir (*Abies fraseri*) on rocky sites where most of the organic soil had been burned off. Although the results were far from conclusive, the study produced some worthwhile information:

- Bracken fern interfered more seriously with planted red spruce than with red pine. Spruce competed better with over-topping woody shrubs and trees.
- Early release of red spruce increased survival but had little effect on height growth.
- Direct seeding failed with all species. On the rocky sites the catches from direct seeding, although poor, were somewhat better for the fir than for the spruce.
- On the rocky sites, planted spruce survived better than planted fir, but the fir grew faster.

WHITE PINE PLANTATION THINNING

In a fast-growing white pine plantation (the Clover Run plantation) on the Monongahela National Forest, near Parsons, a small study is under way to determine the approximate level of stocking for maximum board-foot volume yields. Averaging about 17,000 board feet per acre at 27 years of age, with trees 70 to 75 feet tall (site index 100), this probably is one of the best existing plantations of eastern white pine (*2, 4, 41*).

Figure 31.—A light thinning in the Clover Run white pine plantation.

Three treatments have been applied to twice replicated plots: (1) control—unthinned; (2) thinned from below, leaving sufficient trees so that crowns touch but do not overlap; (3) thinned in general from below but removing enough trees in the dominant canopy so that crowns of residual trees are approximately 5 feet apart (fig. 31). Ten permanent sample trees were designated on each plot to provide data on height and d.b.h. growth of individual trees. Stands will be thinned at 5-year intervals.

PLANTING OF STRIP MINE SPOIL AREAS

Stripping for coal has drastically disturbed the surface of many forested areas in West Virginia (fig. 32). The resultant spoils have created problems of water pollution, wasted land resources, and dreary repellent landscapes.

Although revegetation to trees appeared to be the best form of land use for most of the stripped areas, no comprehensive studies of tree establishment on strippings in West Virginia had been made up to 1949. Accordingly, a survey type of study was made at that time to assemble information on the possibility of planting trees on the spoil banks. The study included examination of such earlier plantings as could be found, but did not include planting tests. Results of this study were published in 1951 (*12*). Some findings were:

- Ungraded or partially graded spoils appeared to offer better survival and growing conditions for trees than completely graded spoils.
- Revegetation was definitely related to acidity of the spoil material. Where pH values were lower than 4.0, less than 1 percent of the area had revegetated naturally; where the values were 4.0 or higher, herbaceous and woody species generally were becoming established in some abundance.
- Except where limited by excessive soil acidity, natural revegetation increased with age of the spoil area. Average density of cover for 1-year-old ungraded spoils was about 8 percent,

Figure 32.—An area disturbed by strip mining.

and for 3-year-old spoils about 48 percent. After 3 years the rate of increase tapers off, but most 5-year spoils were more than 50 percent covered. In contrast, graded spoil areas showed only 2 percent cover at 1 year and 12 percent at 3 years.

- As a result of this survey and of planting studies in nearby states, the following tree species were recommended for plantings on West Virginia mine-spoils of pH 4.0 and higher:

Conifers	*Hardwoods*
Red pine	Black locust
Pitch pine	Yellow-poplar
Jack pine	Red maple
Virginia pine	Sycamore

Hybrid-poplar clonal test-planting on acid strip-mine spoil banks at high elevations in West Virginia gave poor results after 11 years. Liming resulted in some—not much—improvement in survival and growth.

In 1958 and 1959 the Elkins project participated, along with The Pennsylvania State University, in a study of mine-spoil plantings in Pennsylvania (*5*).

GENETICS

Genetics research has not been a specific part of the program here. However, in the Northeastern Station's over-all testing program for hybrid poplars (Populus), 50 clones in replicated plantings have been under observation near Parsons for 11 years. Seven of the clones appear to have done well enough to be recommended for planting under soil and climatic conditions similar to those at the West Virginia test area (*3*). These seven clones all grew at average rates of 3.6 feet per year or better. They are all hybrids of *P. maximowiczii.*

The Northeastern Station also is conducting a white pine provenance test in which one of the field plantings is near Parsons. Growth and survival of seedlings from many areas are being studied in this test.

THE BLUE CREEK EXPERIMENTAL FOREST

An agreement, entered into in 1957 by the Union Carbide-Olefins Company and the Northeastern Forest Experiment Station, led to the establishment of the Blue Creek Experimental Forest, 25 miles from Charleston, in southern West Virginia. Climate, sites, and species composition of the stands there are more representative of southern Appalachian mountain hardwood forests than the stands on the Fernow. The Experimental Forest, comprising some 2,500 acres of company land, will be used in a joint research program. So far, three timber-management studies have been started.

One study, involving several different methods of partial cutting, has been begun on 5-acre replicated plots on an excellent site; it is to be extended later to a nearby area of poorer site. The main independent variables are site and treatment. Growth, reproduction characteristics, and log quality are the principal dependent variables.

Work is under way on a replicated plot study on an excellent site to compare production at two growing-stock levels: 40 and

80 square feet of basal area per acre in trees over 9.0 inches d.b.h.

The third study is a thinning test in even-aged stands of mixed basswood and yellow-poplar: replicated plots will be thinned to 60 percent of full stocking at 10-year intervals by two methods—low thinning and selection thinning. The dependent variables are volume produced and log quality. Individual tree growth and quality development will be studied on a number of sample trees.

FOREST-PATHOLOGY INVESTIGATIONS

In 1961 forest pathology investigations were begun at the Elkins unit. Currently under way, or planned, are studies on: *Fomes annosus*[5]—its occurrence and treatment; the effectiveness of actidione in combating chestnut blight in sprouts of native chestnut; the transmission of the oak wilt pathogen; the effectiveness of antibiotic treatments (phytoactin) on resistance of white pine seedlings to blister rust infection; and the relationships of various factors to the decline of red and scarlet oaks.

Research Aspects

Philosophically, our program has three aspects:

1. *Research in depth, where the tools of management are studied and defined.* Stand and individual-tree growth and quality studies, site-capability investigations, the relationship of cutting methods and site to reproduction, studies of the factors affecting road erosion, and development of methods of analysis of streamflow are a few examples.

2. *Testing of hypotheses where various types of forest land management are practiced and compared on a large scale.* The compartment-management studies (for both timber and water) exemplify hypothesis testing.

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[5] *Fomes annosus* is a fungus that causes root and butt rots in conifers. This is a serious menace to conifer plantations.

3. *Demonstration, where certain forest practices are carried out, as the name implies, primarily for demonstration rather than experimental purposes.* The small forest properties and the management unit fall in this category.

Many studies overlap into two or all three of the above categories. For instance, the compartments designed for hypothesis testing are the framework for much research in depth and also provide excellent demonstration areas. The small forest properties and the management unit, organized primarily as demonstration areas, provide the data and the locale for economic studies. The hypothesis testing and demonstration aspects of the early research program played an important role in arousing general interest in better forestry in this area, and they still do.

With the increasing interest in the practice of more intensive forestry and the rising awareness that forestry has a multiple-use role to play in resource development, emphasis in the research program has shifted over the years from answering questions in the realm of "What happens?" to those in the "Why?" and "How?" realm. This means that more attention today is being given to research in depth.

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