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Estimating Understory Plant Cover With Rated Microplots

by Meredith J. Morris

Abstract

Plant cover measurements are used to detect changes caused by grazing, fire, and other factors. Tests on both high and low production sites of 17 areas in the West indicate that trained range personnel rate small plots similarly in respect to the area occupied by aerial and basal plant cover. Plots used ranged from 1/8 square inch to 8 square inches. Equal area rectangles and circles were used. All are well suited for rating plant cover, although the smaller sizes tended to be slightly more precise.

Oxford: 268.5. **Keywords:** Range measurements, range surveys, plant cover.

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Estimating Understory Plant Cover With Rated Microplots

by

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Contents

Estimating Understory Plant Cover With Rated Microplots

Meredith J. Morris

For some time, land managers on National Forest and other publicly owned rangelands ve expressed a need for an indicator of how luences such as livestock grazing, big game e, recreation, and other environmental factors e affecting the range. In my opinion, plant ver—percent area occupied by shrubs, forbs, d grasses—is the best single measure of these pacts upon understory vegetation. Several idies by other people and some preliminary ork of my own have shown that rating or oring the area occupied by plants inside small ots, or "microplots," might be used to estimate ant cover, both aerial and basal. If, in fact, ver could be estimated accurately and ficiently from rated microplots, then this chnique should be considered for general use d for possible incorporation into the "3-Step ethod" for measuring trend in range condition 'arker 1951). The plant cover index, as derived the 3-Step Method, is synonomous with the equency (of occurrence) figure long used by ant ecologists. The plot used in the 3-Step ethod is much smaller than what is generally sed by ecologists, however.

Frequency is partially dependent upon ant cover, so the two measures will be rrelated. The degree of correlation will depend oon many factors, however. Hence, the value of equency as an index to plant cover will vary om one set of conditions to another.

Previous Work

Although several authors pointed out that ant density or cover indexes were larger than timates of plant cover obtained by methods ich as points or line intercept, they did not give asons for the difference. Hutchings and olmgren (1959) discussed the relation between ant density index (frequency of aerial and isal cover) and actual plant cover, as well as the fects of plot size, number and size of plants, ant dispersion, and plant shape on the index. he overestimate of cover, or bias, obtained by se of the loop as discussed by Hutchings and olmgren (1959) is actually identical to the bias iscussed by Goodall (1952) in relation to the verestimation of cover with pins when the oints of the pins have greater than zero imension.

The idea of using rated plots for estimating plant cover is not new. The use of a very small plot, or "microplot," has been limited, however. Hutchings and Holmgren (1959) summarized the results of a test on synthetic plant populations composed of 29/32-inch-diameter circles with concentric 3/8-inch-diameter circles of different colors randomly located on a strip of paper 2 feet wide and 60 feet long. Several observers sampled these synthetic populations with a 13/16-inch-diameter loop at 1-foot intervals along randomly located 50-foot line transects. The loops were rated to the nearest one-tenth of area occupied. A large number of samples showed that the rated loops provided close estimates of the actual area occupied by the artificial populations of 3/8-inch and 29/32-inch circles. Estimates were 1.2 and 1.1 times greater than the actual for the two populations, respectively. Some of the differences between the actual and observed values could be attributed to sampling error, however, as the rated loop estimates were quite variable in these particular populations.

Cook and Box (1961) compared rated 3/4-inch loops with point-frame and single point readings for crown canopy and basal area along 100-foot transects in a mountain brush type in northern Utah. For the loop, a measurement was not recorded unless one-half or more of the loop was filled; this constitutes a 2-point scale. Only first contacts were recorded in aerial cover for all three methods. They found that the rated loop overestimated aerial cover for shrubby species and underestimated it for grasses. Estimates of aerial cover for forbs and basal area for all groups were essentially the same by all three methods.

Winkworth, Perry, and Rossetti (1962) compared estimates from three sizes and shapes of rated plots with those obtained from points and line intercepts in an arid tussock grassland in central Australia. The small plots used for rating or scoring were a circle of 1.9 cm (0.75 inch) diameter, and rectangles measuring 2 cm by 5 cm and 4 cm by 10 cm. Presence or absence of aerial cover in the circular plot was scored according to whether cover was greater or less than 50 percent. The rectangular plots were scored in 10 percent cover classes from 0 to 100. A comparison of means and variances showed that, while the line intercept method was in doubt, for all practical purposes the five methods gave similar and equally reliable estimates. The point method and the rated circular plot were more rapid than the others.

In July 1962, a preliminary test of rated microplots was conducted in the Fairfield District of the Sawtooth National Forest in

Idaho. A meadow site and a bunchgrass site were sampled with 25 randomly located points each. Four rectangles and four circles of varying size, fully described later in this report, were rated to the nearest one-tenth of area occupied by shrub, forb, and grass species for both aerial cover and basal area. Litter, rock, bare soil, erosion pavement, and mosses on the soil surface were also rated. The same items rated on the microplots were also recorded using a 10-point frame at the same sample points.

Although the data were not completely analyzed, summaries showed no apparent differences in the ratings from the different microplots. The point frame and the larger microplots detected more species, however. It was also noticed that some of the microplots were easier to score than others.

Since the use of rated microplots seemed to be feasible from the results of the preliminary test, a large-scale study was designed with the following objectives:

1. To determine the effect of selected microplot sizes and shapes on ratings of cover or percent area occupied by plants.
2. To estimate the optimum microplot on the basis of a minimized variance-cost function.
3. To compare cover estimates derived from rated microplots and pins in a point frame.

Procedures

Study Areas and Sampling Layout

The study was designed to sample the major range types at 17 locations in the western United States. These locations were selected within National Forests and Experimental

Table 1.--Vegetation types, locations on Ranger Districts (RD) of National Forests (NF) and Experimental Forests and Ranges, and sampling dates

Vegetation type	Location	Sampling date
Mountain grassland	Helena NF - Townsend RD, Townsend, Montana	June 1963
Mountain bunchgrass-Thurber fescue	Black Mesa Exp. Range, Crawford, Colorado	July 1964
Pacific bunchgrass	Sawtooth NF - Twin Falls RD, Twin Falls, Idaho	June 1963
Sod-forming grama	Sitgreaves NF - Pinedale RD, Snowflake, Arizona	October 1963
Mixed gramas	Santa Rita Exp. Range, Amado, Arizona	October 1963
Mountain meadow	Beaverhead NF - Jackson RD, Jackson, Montana	July 1964
Mountain meadow	Tahoe NF - Sierraville RD, Sierraville, California	August 1964
Upland herb-aspen	U.S. Sheep Station Exp. Range, Dubois, Idaho	August 1964
Sagebrush-grass	U.S. Sheep Station Exp. Range, Dubois, Idaho	June 1964
Chaparral	Prescott NF - Granite RD, Prescott, Arizona	April 1964
Mixed shrub	Roosevelt NF - Redfeather RD, Redfeather Lakes, Colorado	September 1964
Sagebrush-bitterbrush	Tahoe NF - Truckee RD, Truckee, California	August 1964
Pine-bunchgrass	Manitou Exp. Forest, Woodland Park, Colorado	August 1963
Pine-bunchgrass	Ochoco NF - Big Summit RD, Pineville, Oregon	June 1964
Pine-pinegrass	Starkey Exp. Range, LaGrande, Oregon	August 1963
Aspen-weed	Routt NF - Bears Ears RD, Craig, Colorado	July 1963
Annual grass	San Joaquin Exp. Range, Coarsegold, California	May 1964

Areas to represent most of the major range forage types of the National Forests.

The range types and locations sampled and sampling dates are shown in table 1. At each location we selected two contrasting test sites, one containing an abundance of vegetation and a similar site containing a sparse amount (fig. 1). The amount and homogeneity of the vegetation on the two sites were the criteria for selection as test areas.

The size of the sampling area varied from about 1/2 acre minimum to about 5 acres maximum. Fifty random sample points were marked on each site (high and low), making a total of 100 sample points for each location. Each sample point was located by means of compass

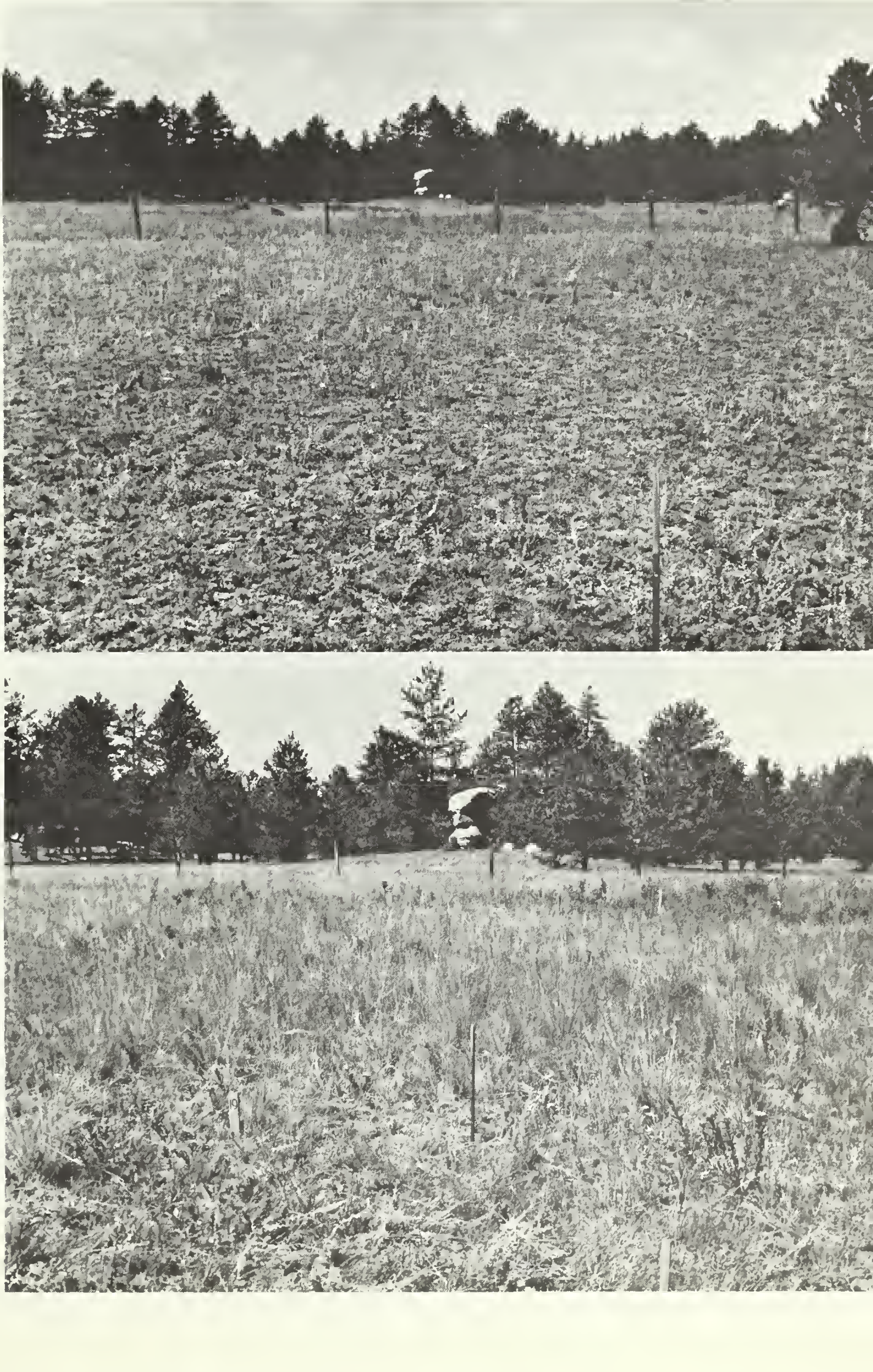

Figure 1.—Two contrasting test sites in the ponderosa pine-bunchgrass type, Manitou Experimental Forest, Colorado:

A low-production site

A high-production site

bearings and pacing, and marked with an angle iron stake with 3/4-inch flanges driven into the ground to provide a fixed locus for the microplots and point frame. All stakes were oriented so that the open side of the "V" faced north. The maximum height of the stakes aboveground was about 5 1/2 feet; measurements were taken only from the 4-foot level to the ground surface.

About 3 feet south of each metal stake, a surveyor's wooden stake was driven into the ground. Each wooden stake was numbered and tagged for permanent identification so that remeasurements could be made at a future time to measure vegetative or site changes.

Microplot Ratings

Two microplot shapes (circles and rectangles) with four sizes per shape were tested (fig. 2). The circle has the least perimeter of any geometric figure for a fixed area. The rectangle was arbitrarily designed with the length being twice the width. Each pair of shapes enclosed an equal area, so that microplot shapes could be directly compared. The areas in square inches and the dimensions in inches for each microplot size and shape were:

Rectangle	Area	Circle (diameter)
1/4 x 1/2	0.125	0.3989
1/2 x 1	.500	.7979
1 x 2	2.000	1.5958
2 x 4	8.000	3.1915

Aerial or crown cover and basal area by species for shrubs, forbs, grasses, and soil surface items were rated at each sample point. Items rated were defined as follows:

1. **Aerial cover.**—The vertical projection by species of all live plant parts from the 4-foot level to the ground surface.
2. **Basal area.**—The area occupied by live plant parts at the ground surface, or the area defined by live root crown. The basal area of plants with basal rosettes was understood to be the area defined by live root crowns only; the rest of the live parts were considered aerial cover.
3. **Litter.**—Dead organic material lying on the soil surface from previous years' growth. Dead centers of plants were also considered as litter if the parts were in contact with the ground surface. Animal droppings were considered as litter.

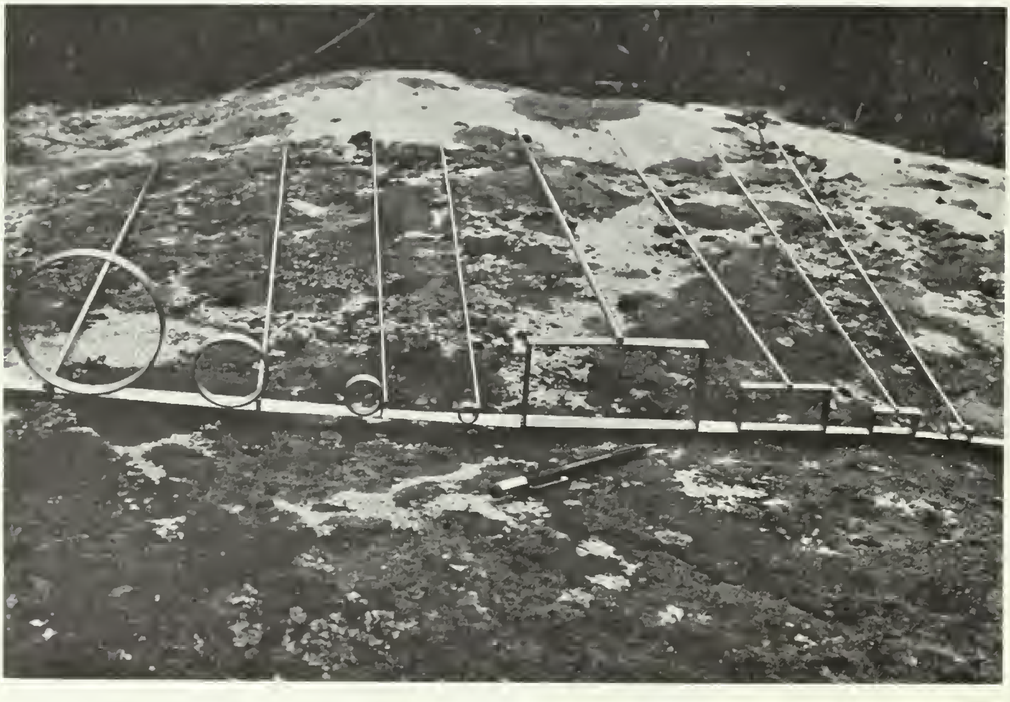

Figure 2.—Set of eight frames used in microplot study. The largest rectangle is 2 by 4 inches.

4. **Moss and lichens.**—Area covered by moss and lichens growing on the soil surface.
5. **Bare soil.**—All exposed mineral soil and rock particles up to 1/8 inch diameter, and well-dispersed rock particles up to 3/4 inch diameter that did not provide a continuous cover.
6. **Erosion pavement.**—Particles of rock from 1/8 to 3/4 inch in diameter forming a continuous cover on the soil surface. Individual rock particles from 1/8 to 3/4 inch in diameter that did not form a continuous cover were classified as bare soil.
7. **Rock.**—Stones larger than 3/4 inch in diameter at the soil surface.

Two teams of two men each worked at each site. One man on each team made the readings for all eight of the microplots at all the sample points in the site; the other man did all the recording. Therefore, two complete sets of readings were taken at each site. Forms were designed for field use that would allow data to be transferred directly to punch cards.

Sliding metal arms, which clamped securely to the angle iron stake at a desired height, were used to position the microplot frames in the same place (fig. 3). The eight microplots were rated, in random order, by each observer on each team to the nearest one-tenth (1/10 = score of 1; 10/10 = score of 10) of area occupied, for each of the items that occurred in that microplot. Only one randomly selected microplot frame at a time was used by each team until all the readings had been made at all 50 sample points in the site. Within each microplot, ratings of basal area and soil surface items could have only a maximum total of 10; the aerial cover ratings did not have any combined maximum value.

Figure 3.—Sliding metal arm used to position microplot frames in the same place.

Point-Frame Readings

After the ratings had been completed in a site by each of the two observers for all eight microplot frames, point readings from the 4-foot level to the ground were taken by means of a circular point frame containing 10 vertical pins. The point frame was designed so that the 10 pins were equally spaced on a circle with a circumference equal to that of the largest circular microplot (fig. 4). All hits by species on live aerial parts of plants and hits on basal area by species and soil surface items were recorded. Only one set of point readings was made on each site.

Time records were kept for each of the microplots and the point-frame readings (that is, for each set of 50 observations). When an observer started rating one of the microplots at the first sample point in a site, the recorder on the team started a stopwatch. At the completion of the last reading, the watch was stopped and the total elapsed time recorded. The watch was stopped during any interruptions. The time involved in taking the point readings was measured in a similar manner.

Data Analyses

Microplot and point-frame data were analyzed in the following steps: (1) Identifying and informative material such as plant species names were edited and coded numerically; (2) measurement and coded data were punched on cards; (3) computer programs were written and checked; and (4) detailed variance analyses were computed.

Figure 4.—Specially designed point frame used in microplot study.

Analyses of variance were made on the aerial cover data with plot shape, plot size, observers, sites, and locations being the main effects. A plant species thus had to be present on both sites within two or more locations. A maximum of seven locations could be used in the combined analysis because of storage limitations in the computer. The analyses were repeated for basal area ratings of each plant species and ratings of ground surface items. A mixed components-of-variance model was assumed in this study, with microplot shape, microplot size, and site being fixed effects and observer and location being random effects. The components of variance in this mixed model are shown in table 2. Note that the main effects, A, B, and D, and the interactions, AB, AD, BD, and ABD, have no error terms for making significance tests (*F* test). In these cases, approximate tests were used (Cochran 1951, Satterthwaite 1946).

Point-frame readings of aerial cover and basal area of plant species and ground surface items were summarized by observer, site, and location, and compared directly with the largest circular microplot ratings in analyses of variance. Methods (points versus ratings of two observers) and sites were assumed to be fixed effects, and locations a random effect. The components-of-variance model for this analysis is shown in table 3.

Results and Discussion

Microplot Ratings

If the "best" microplot or plots were determined for each plant species or soil surface item, each cover type, each site, and each location, it would be difficult to select the one optimum microplot for management purposes. Therefore, the microplot ratings were analyzed for a particular plant species or soil surface item and cover type occurring at two or more locations. Note in table 2 that individual observer, site, and location differences are evaluated. Grasses, forbs, shrubs, and soil surface items (different forms and shapes) were all represented in the combined location analyses.

Examples of combined location analyses are shown in tables 4 and 5. Table 4 is the analysis of variance for ratings of aerial cover of *Achillea lanulosa* Nutt., or woolly yarrow. The four locations are mountain bunchgrass-Thurber fescue, upland herb-aspen, pine-bunchgrass, and aspen-weed. Note that significant differences were found between locations in the main effects and in the interaction terms, shape-by-observer and site-by-location. Since observer and location effects are confounded (different observers were used at different locations), the significant terms are not important. And, of course, sites and

Table 2.--Components-of-variance model for microplot ratings--combined locations

Shape	A (a=2)	$\sigma^2 + rbd\sigma^2_{ACE}$	$+ rbcd\sigma^2_{AE}$	$+ rbde\sigma^2_{AC}$	$+ rbcde\sigma^2_{A}$
Size	B (b=4)	$\sigma^2 + rad\sigma^2_{BCE}$	$+ racd\sigma^2_{BE}$	$+ rade\sigma^2_{BC}$	$+ racde\sigma^2_{B}$
Observer	C (c=2)	$\sigma^2 + rabd\sigma^2_{CE}$	$+ rabde\sigma^2_{C}$		
Site	D (d=2)	$\sigma^2 + rab\sigma^2_{CDE}$	$+ rabc\sigma^2_{DE}$	$+ rabe\sigma^2_{CD}$	$+ rabce\sigma^2_{D}$
Location	E (e=2,3,..., 7)	$\sigma^2 + rabd\sigma^2_{CE}$	$+ rabcd\sigma^2_{E}$		
AB		$\sigma^2 + rd\sigma^2_{ABCE}$	$+ rcd\sigma^2_{ABE}$	$+ rde\sigma^2_{ABC}$	$+ rcde\sigma^2_{AB}$
AC		$\sigma^2 + rbd\sigma^2_{ACE}$	$+ rbde\sigma^2_{AC}$		
BC		$\sigma^2 + rad\sigma^2_{BCE}$	$+ rade\sigma^2_{BC}$		
ABC		$\sigma^2 + rd\sigma^2_{ABCE}$	$+ rde\sigma^2_{ABC}$		
AD		$\sigma^2 + rb\sigma^2_{ACDE}$	$+ rbc\sigma^2_{ADE}$	$+ rbe\sigma^2_{ACD}$	$+ rbce\sigma^2_{AD}$
BD		$\sigma^2 + ra\sigma^2_{BCDE}$	$+ rac\sigma^2_{BDE}$	$+ rae\sigma^2_{BCD}$	$+ race\sigma^2_{BD}$
ABD		$\sigma^2 + r\sigma^2_{ABCDE}$	$+ rc\sigma^2_{ABDE}$	$+ re\sigma^2_{ABCD}$	$+ rce\sigma^2_{ABD}$
CD		$\sigma^2 + rab\sigma^2_{CDE}$	$+ rabe\sigma^2_{CD}$		
ACD		$\sigma^2 + rb\sigma^2_{ACDE}$	$+ rbe\sigma^2_{ACD}$		
BCD		$\sigma^2 + ra\sigma^2_{BCDE}$	$+ rae\sigma^2_{BCD}$		
ABCD		$\sigma^2 + r\sigma^2_{ABCDE}$	$+ re\sigma^2_{ABCD}$		
AE		$\sigma^2 + rbd\sigma^2_{ACE}$	$+ rbcd\sigma^2_{AE}$		
BE		$\sigma^2 + rad\sigma^2_{BCE}$	$+ racd\sigma^2_{BE}$		
ABE		$\sigma^2 + rd\sigma^2_{ABCE}$	$+ rcd\sigma^2_{ABE}$		
CE		$\sigma^2 + rabd\sigma^2_{CE}$			
ACE		$\sigma^2 + rbd\sigma^2_{ACE}$			
BCE		$\sigma^2 + rad\sigma^2_{BCE}$			
ABCE		$\sigma^2 + rd\sigma^2_{ABCE}$			
DE		$\sigma^2 + rab\sigma^2_{CDE}$	$+ rabc\sigma^2_{DE}$		
ADE		$\sigma^2 + rb\sigma^2_{ACDE}$	$+ rbc\sigma^2_{ADE}$		
BDE		$\sigma^2 + ra\sigma^2_{BCDE}$	$+ rac\sigma^2_{BDE}$		
ABDE		$\sigma^2 + r\sigma^2_{ABCDE}$	$+ rc\sigma^2_{ABDE}$		
CDE		$\sigma^2 + rab\sigma^2_{CDE}$			
ACDE		$\sigma^2 + rb\sigma^2_{ACDE}$			
BCDE		$\sigma^2 + ra\sigma^2_{BCDE}$			
ABCDE		$\sigma^2 + r\sigma^2_{ABCDE}$			
Residual	(r=50)	σ^2			

Table 3.--Components-of-variance model for point-frame readings versus largest circular microplot ratings--combined locations

Method	A (a=3)	$\sigma^2 + rb\sigma^2_{AC} + rbc\sigma^2_A$
Site	B (b=2)	$\sigma^2 + ra\sigma^2_{BC} + rac\sigma^2_B$
Location	C (c=2,3,..., 7)	$\sigma^2 + rab\sigma^2_C$
AB		$\sigma^2 + r\sigma^2_{ABC} + rc\sigma^2_{AB}$
AC		$\sigma^2 + rb\sigma^2_{AC}$
BC		$\sigma^2 + ra\sigma^2_{BC}$
ABC		$\sigma^2 + r\sigma^2_{ABC}$
Residual	(r=50)	σ^2

Table 4.--Analysis of variance for microplot ratings of aerial cover of *Achillea lanulosa* at four locations

Source of variation		Degrees of freedom	Sum of squares	Mean squares
Shape	(A)	1	0.744	0.744
Size	(B)	3	8.36	2.79
Observer	(C)	1	0.620	0.620
Site	(D)	1	68.3	68.3
Location	(E)	3	119.0	39.6 **
AB		3	0.594	0.198
AC		1	0.439	0.439 **
BC		3	4.47	1.49
ABC		3	0.447	0.149
AD		1	0.263	0.263
BD		3	5.56	1.85
ABD		3	0.0355	0.0118
CD		1	1.41	1.41
ACD		1	0.000156	0.000156
BCD		3	3.51	1.17
ABCD		3	0.325	0.108
AE		3	0.0817	0.0272
BE		9	17.2	1.91
ABE		9	1.47	0.164
CE		3	2.76	0.920
ACE		3	0.0367	0.0122
BCE		9	10.1	1.13
ABCE		9	1.58	.176
DE		3	320.0	107.0 **
ADE		3	0.653	0.218
BDE		9	26.6	2.96
ABDE		9	1.31	0.146
CDE		3	0.590	0.197
ACDE		3	1.24	0.415
BCDE		9	12.1	1.35
ABCDE		9	0.601	0.0668
Residual		6262	5540.0	0.884
Total		6399	6150.0	

** - Significant at the 0.01 probability level.

Table 5.--Analysis of variance for microplot ratings of bare soil at six locations

Source of variation		Degrees of freedom	Sum of squares	Mean squares
Shape	(A)	1	17.7	17.7
Size	(B)	3	19.1	6.36
Observer	(C)	1	1.98	1.98
Site	(D)	1	6540.0	6540.0 **
Location	(E)	5	11200.0	2250.0 **
AB		3	12.0	3.99
AC		1	3.30	3.30
BC		3	32.2	10.7
ABC		3	6.31	2.10
AD		1	0.220	0.220
BD		3	3.26	1.09
ABD		3	1.80	0.599
CD		1	1.60	1.60
ACD		1	0.00667	0.00667
BCD		3	5.39	1.80
ABCD		3	10.4	3.47
AE		5	18.6	3.72
BE		15	36.7	2.45
ABE		15	31.0	2.07
CE		5	199.0	39.9 **
ACE		5	54.7	10.9
BCE		15	57.6	3.84
ABCE		15	43.4	2.89
CE		5	3520.0	704.0 **
ADE		5	16.9	3.38
BDE		15	137.0	9.16
ABDE		15	18.0	1.20
CDE		5	124.0	24.8 **
ACDE		5	12.5	2.50
BCDE		15	74.7	4.98
ABCDE		15	49.8	3.32
Residual		9408	58700.0	6.24
Total		9599	81000.0	

** - Significant at the 0.01 probability level.

locations were selected to be different. The mean cover estimates of the eight microplots corresponding to the analysis in table 4 were:

Mean cover

Size	Rectangle	Circle
1	0.314	0.320
2	.242	.228
3	.251	.206
4	.254	.221
Mean	.265	.244

Size 1 is the smallest plot, and size 4 is the largest.

Table 5 is the analysis of variance for ratings of bare soil at six combined locations—mountain grassland, mountain bunchgrass-Thurber fescue, upland herb-aspen, pine-bunchgrass, pine–pinegrass, and aspen-weed. Significant differences were found between sites and locations in the main effects and in the interaction terms, observer-by-location, site-by-location, and observer-by-site-by-location. The mean cover estimates of the eight microplots corresponding to the analysis in table 5 were:

Mean cover

Size	Rectangle	Circle
1	1.65	1.77
2	1.67	1.84
3	1.68	1.75
4	1.83	1.81
Mean	1.71	1.79

There were 22 analyses of the combined locations type for aerial cover of different plant species, and 20 analyses for basal area of plant species and soil surface items. The same pattern developed throughout all these analyses: differences in the main effects, except for site and location, were almost all nonsignificant. On a very broad basis, then, we can say that differences in microplot shape, microplot size, and observers are nonsignificant statistically for the populations studied. First-order interaction terms that were significant mostly involved site or location differences.

Point-Frame Readings

The ratings from the largest circular microplot (about 3.2-inch diameter) and the point-frame readings are compared statistically in table 6. This table is the analysis of variance for bare soil at the same six locations that are combined in table 5. Mean ratings of each of two observers are compared to point-frame readings in table 6, hence the two degrees of freedom for method.

Table 6.--Analysis of variance for methods comparison of bare soil readings at six locations (largest circular microplot versus point frame)

Source of variation		Degrees of freedom	Sum of squares	Mean squares
Method	(A)	2	27.1	13.5
Site	(B)	1	1250.0	1250.0 *
Location	(C)	5	1820.0	363.0 **
AB		2	3.64	1.82
AC		10	89.3	8.93 *
BC		5	571.0	114.0 **
ABC		10	40.4	4.04
Residual		1764	7870.0	4.46
Total		1799	11700.0	

* - Significant at the 0.05 probability level.
** - Significant at the 0.01 probability level.

For aerial cover, only one analysis out of 22 showed a significant difference (table 7). For basal area and soil surface items, only two analyses out of 19 showed significant differences (table 8).

Point-frame readings were higher in absolute value than the 3.2-inch plot ratings in all but two cases for the aerial cover analyses (table 7). This is to be expected, however, because the vertical projection within a fixed plot boundary will have a maximum value of 100 percent cover, while pin contacts can add up to over 100 percent cover since each contact for a species is recorded. Differences between the two methods were with grass species.

For soil surface items and basal area of plants, only 7 out of 19 analyses showed point-frame readings to be higher in absolute value than microplot ratings (table 8). Thus, there is a tendency for the rated microplots to give somewhat higher readings (12 out of 19) than the point frame, indicating a small positive bias. This bias is not considered to be important from a practical standpoint, however.

Table 7.--Mean values for 3.2-inch-diameter plots and point frames, and nearest plot means, sizes, and shapes for aerial cover

Species or soil item	Number of locations	3.2-inch plot	Point frame	Nearest plot values: Mean	Nearest plot values: Size and shape[1]
Annual forbs	4	0.276	0.310	0.286	1C
Achillea lanulosa	5	.221	.330	.320	1C
Agoseris glauca	3	.363	.473	.365	4R
Antennaria rosea	2	.693	.735	.693	4C
Fragaria virginiana	2	.138	.130	.128	4R
Lathyrus leucanthus	2	.143	.220	.225	1C
Taraxacum officinale	2	.128	.110	.122	3C
Annual grasses	2	.365	1.27	.673	1C
Agropyron spicatum	3	.283	.603	.365	1R
A. *trachycaulum*	2	.123	.595	.175	1C
Bouteloua gracilis	3	.518	.837	.580	4R
Calamagrostis rubescens	2	.418	1.14	.530	1R
Deschampsia caespitosa	2	1.13	2.53	1.14	1C
Festuca idahoensis	3	.970	2.46	.970	4C
Koeleria cristata	2	.163	.320	.163	4C
Poa secunda	3	.132	.367	.258	1C
Sitanion hystrix	2	.128 *	.180	.192	1C
Stipa comata	2	.030	.065	.060	2R
Carex spp.	2	1.11	1.19	1.18	2C
Artemisia frigida	2	.605	1.28	.633	4R
A. *tridentata*	3	.623	.873	.833	1C
Purshia tridentata	2	.833	1.26	.833	4C

* - Significantly different from points.

[1] - R = rectangle, C = circle, 1 to 4 = smallest to largest size.

Table 8.--Mean values for 3.2-inch-diameter plots and point frames, and nearest plot means, sizes, and shapes for basal area and soil surface items

Species or soil item	Number of locations	3.2-inch plot	Point frame	Nearest plot values: Mean	Nearest plot values: Size and shape[1]
Bare soil[2]	6	1.81	1.56	1.65	1R
Bare soil	5	3.06	2.80	2.99	1R
Bare soil	5	2.83	2.34	2.46	1R
Erosion pavement	6	.698	.442	.508	1R
Erosion pavement	5	.829	.760	.788	4R
Rock	3	.127	.150	.148	2C
Rock	5	.422	.448	.446	4R
Litter	7	7.02	7.41	7.47	1R
Litter	5	4.56 *	5.59	5.28	1C
Litter	5	5.51 *	6.05	6.05	1C
Moss and lichens	5	.866	1.18	1.08	1R
Agoseris glauca	2	.102	.020	.025	1C, 2C
Antennaria rosea	2	.572	.125	.367	1R
Agropyron spicatum	3	.095	.077	.078	1C
Bouteloua gracilis	3	.162	.067	.082	1C
Festuca idahoensis	3	.372	.337	.335	3R
Koeleria cristata	2	.065	.040	.040	3R
Poa secunda	2	.080	.120	.110	2C
Carex spp.	2	.375	.020	.152	All too high

* - Significantly different from points.

1 - R = rectangle, C = circle, 1 to 4 = smallest to largest size.

2 - Some items separated because of storage limitations in computer.

Efficiency

The final step consisted of comparing the efficiencies of the various microplots. Surprisingly, the average time required to read the four sizes of plots was about the same, although there was considerable variation among individual plots because of differences in plant size and form, community structure, and observers. The mean times in minutes required for estimating the individual plots by all the observers at all 17 locations were:

Mean times

Size	Rectangle	Circle
1	0.62	0.65
2	.67	.62
3	.71	.67
4	.80	.75
Mean	.70	.67

Time increased gradually from the smallest to the largest plots, but the differences are not significant. The largest plots (2-by 4-inch rectangle and 3.2-inch diameter) do, however, take enough more time to be excluded from consideration on a practical basis. Plot variances were all of about the same magnitude. The microplots were about five times as efficient, timewise, as the point frame.

Conclusions

The rated microplots used in this study are precise, efficient, and accurate, particularly for basal area and ground surface items. The different analyses did not identify any one best microplot or microplots for rating cover (objective 1), although the smaller, circular plots were usually nearer to the point-frame readings in absolute values (objective 3). Rated microplots are much more efficient than the point method from the standpoint of time involved in estimating cover, however. Moreover, the microplots are all about the same in efficiency (objective 2).

In general, the 1/2- by 1-inch rectangle is a good compromise in overall performance, although it has no great advantage over the 0.8-inch-diameter circle. Most of the people involved in the study preferred a rectangular plot over a circular one for rating, however, which tips the scales somewhat in favor of the rectangular plot. It is interesting to note that the 0.8-inch-diameter plot used in this study is very near in size to the 3/4-inch loop presently used in the 3-Step Method.

Rated plots will give a precise estimate of plant cover, a population parameter that can be defined specifically, whereas frequency depends upon several attributes in a plant community. Hence, frequency estimates are often difficult to interpret. Thus rated plots could be of benefit insofar as the existing loop method is concerned.

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Plant cover measurements are used to detect changes caused by grazing, fire, and other factors. Tests on both high and low production sites of 17 areas in the West indicate that trained range personnel rate small plots similarly in respect to the area occupied by aerial and basal plant cover. Plots used ranged from 1/8 square inch to 8 square inches. Equal area rectangles and circles were used. All are well suited for rating plant cover, although the smaller sizes tended to be slightly more precise.

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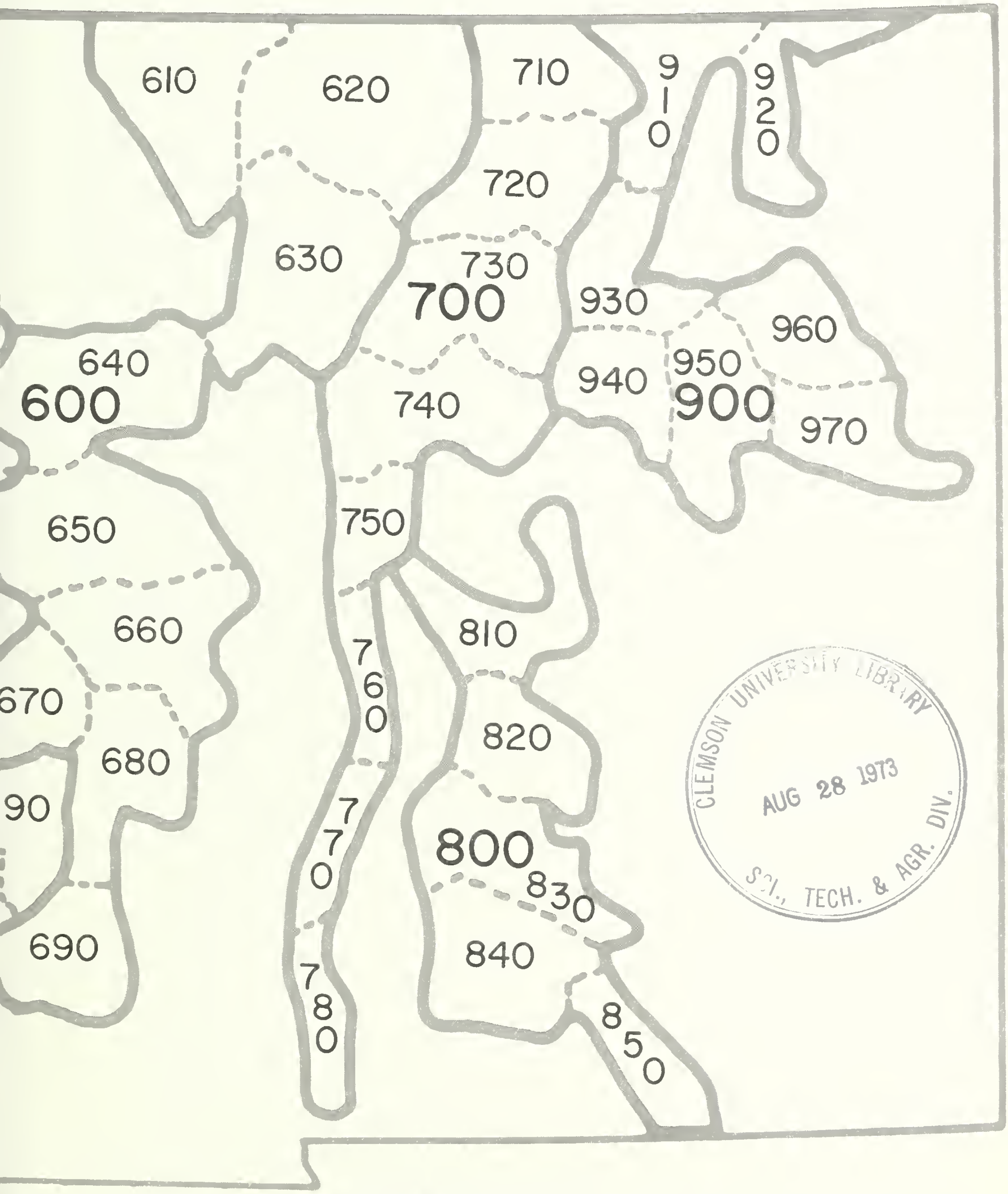
Provisional Tree Seed-Zone
d Cone-Crop Rating System
Arizona And New Mexico

USDA Forest Service
Research Paper RM-105

April 1973

ilbert H. Schubert and John A. Pitcher



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Abstract

The forested areas of Arizona and New Mexico were divided into 10 physiographic-climatic regions. These regions were then subdivided into five to nine seed collection zones about 50 miles wide. Provenance tests will be conducted to determine variation and need for adjustments. Seed used for reforestation should be limited to that collected within the local zone. A 10-unit classification system for rating cone crops is included.

Oxford: 232.312.1:232.311. **Keywords:** Cone collecting, forest seed collecting, forest seed production.

USDA Forest Service
Research Paper RM-105

April 1973

A Provisional Tree Seed-Zone and Cone-Crop Rating System for Arizona and New Mexico

by

Gilbert H. Schubert[1] and John A. Pitcher[2]

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Contents

A Provisional Tree Seed-Zone and Cone-Crop Rating System for Arizona and New Mexico

Gilbert H. Schubert and John A. Pitcher

Forest tree species occur over a wide range of climatic and physiographic conditions in the Southwest. Thousands of possible genotypes are represented in seed crops collected from wild stands. These stands have probably maintained a broad range of genetic variability, even in rather local areas. The trees growing in a particular environmental niche represent the progeny of a small proportion of each seed crop. Those genotypes that were adapted to the specific conditions survived, while the others failed.

Many studies in other regions have shown that seed origin affects both survival and growth of the progeny (Baron and Schubert 1963, Callaham and Hasel 1963, Dawson and Rudolf 1966, Shoulders 1965, Squillace and Bingham 1958, Squillace and Silen 1962).

The microclimate is most severe during the first few years after seedlings are planted. Temperature and moisture, either alone or in combination, are the two most critical factors affecting survival. Even small differences in these two factors may be highly significant. In large openings, there is little or no protective cover to shield the young seedlings from desiccating winds, high temperatures, or sudden freezes. Seedlings from a cooler climatic region start growth earlier to take advantage of a shorter growing season. These seedlings are frequently killed by a late spring freeze.

In Arizona, Larson (1966) reported that ponderosa pine[3] from eastern and southeastern seed sources survived at Fort Valley, whereas trees of northern and western sources failed. Early, hard fall freezes killed all the Angeles and Klamath and nearly all the Tahoe seedlings in the Fort Valley nursery. A severe fall drought eliminated 6 of the 14 sources planted in the study area the preceding spring. The larvae of May beetles killed many seedlings during the first few years. Seedlings from sources nearest the study area survived best, grew fastest, and developed into trees with the best form.

[3]*Common and scientific names are listed in table 1.*

The Need for Tree Seed Zones

Reforestation on National Forests in the Southwest is expected to expand greatly in the future. With this expansion, we cannot afford to make costly errors in seeding or planting trees from seed sources that are not adapted to the site. Seedlings that are not adapted to local conditions may be killed by frost or drought the first year, or succumb to other conditions at some later date before the trees mature. We have many examples of plantation failures, but we are often unsure of the reasons why the seedlings failed to survive, or why the trees failed to develop good quality characteristics. Frequently, the seed source of unsuccessful plantations is unknown.

In addition to National Forest reforestation needs, there are many thousand acres of unstocked land in other ownerships that should be reforested. The use of seed or planting stock from seed collected within these zones should also be followed in their reforestation efforts.

Seed-zone maps have helped managers use local seed in other forest regions. We need to set provisional seed zones for Arizona and New Mexico now, and begin tests of their adequacy. The maps in this Paper represent our best judgment of desirable limits of seed sources for the existing ecological and environmental conditions in the Southwest. Hopefully, they will hasten the time when only local seeds are used for reforestation in Arizona and New Mexico.

We also need a clearly defined system for rating current cone crops, to be used in conjunction with the seed-zone maps. We propose a cone-crop rating system based on the relative number of cones produced on a proportion of the seed trees at each sampling area.

Criteria for and Limitations of the Tree Seed Zones

To establish provisional seed zones, we divided the forested areas into 10 broad physiographic-climatic regions, each with five to nine seed-collection zones (see map). Maps of the major forest types (Choate 1966, Spencer 1966) and of the topographic features were used as the basis for division into regions.

Boundaries of the seed-collection zones within these regions were drawn along recognizable land features. These zones are approximately 50 miles wide. While we consider it most desirable to use seed within the zone collected, use of nearby seed from an adjacent zone within the same physiographic-climatic region is permissible for locations near the boundary of the zone. Seeds from an adjacent zone may be used on an emergency basis; however, the use should be cleared first through the Office of the Regional Forester, Southwestern Region, Albuquerque, New Mexico.

Some zones have elevational differences greater than 1,000 feet, have several forest types, and have differences in aspect. Since these differences within a zone may be as critical as the difference between regions, seed collections must be labeled to identify elevation, forest type, and aspect. These seeds should then be used in areas which most nearly match the local environment.

Most of our seed zones are dissected by deep, narrow canyons. The climate in these canyons may be vastly different from that at the top of the plateaus. For example, spruce and other species which normally do best on high mountain slopes can be found growing several thousand feet lower in these moist, cool canyons. Seedlings of these species would have a difficult time becoming established on the hotter and drier plateaus above the canyons.

The forest type maps reflect the environmental requirements of the various species found in the Southwest. We did not delineate the seed-collection zones along type boundaries. Therefore, many species will be found within each zone (table 1). Although the tabulation indicates up to 15 species growing in some zones, the species may be found in rather restricted locales in some zones.

Land supporting the pinyon-juniper type has been included in the seed-collection zones presented here. At present, there are some forest plantings contemplated in this type. Future markets for Christmas trees and other special products may make it desirable to grow these species on a commercial basis, however. Also, each year we receive requests for pinyon, Arizona cypress, and juniper seeds for the international seed exchange program. Identification by seed zones would be useful along with the other requested information.

Seed-Zone Regions

The 10 physiographic-climatic seed-zone regions for the Southwest are identified on the map.

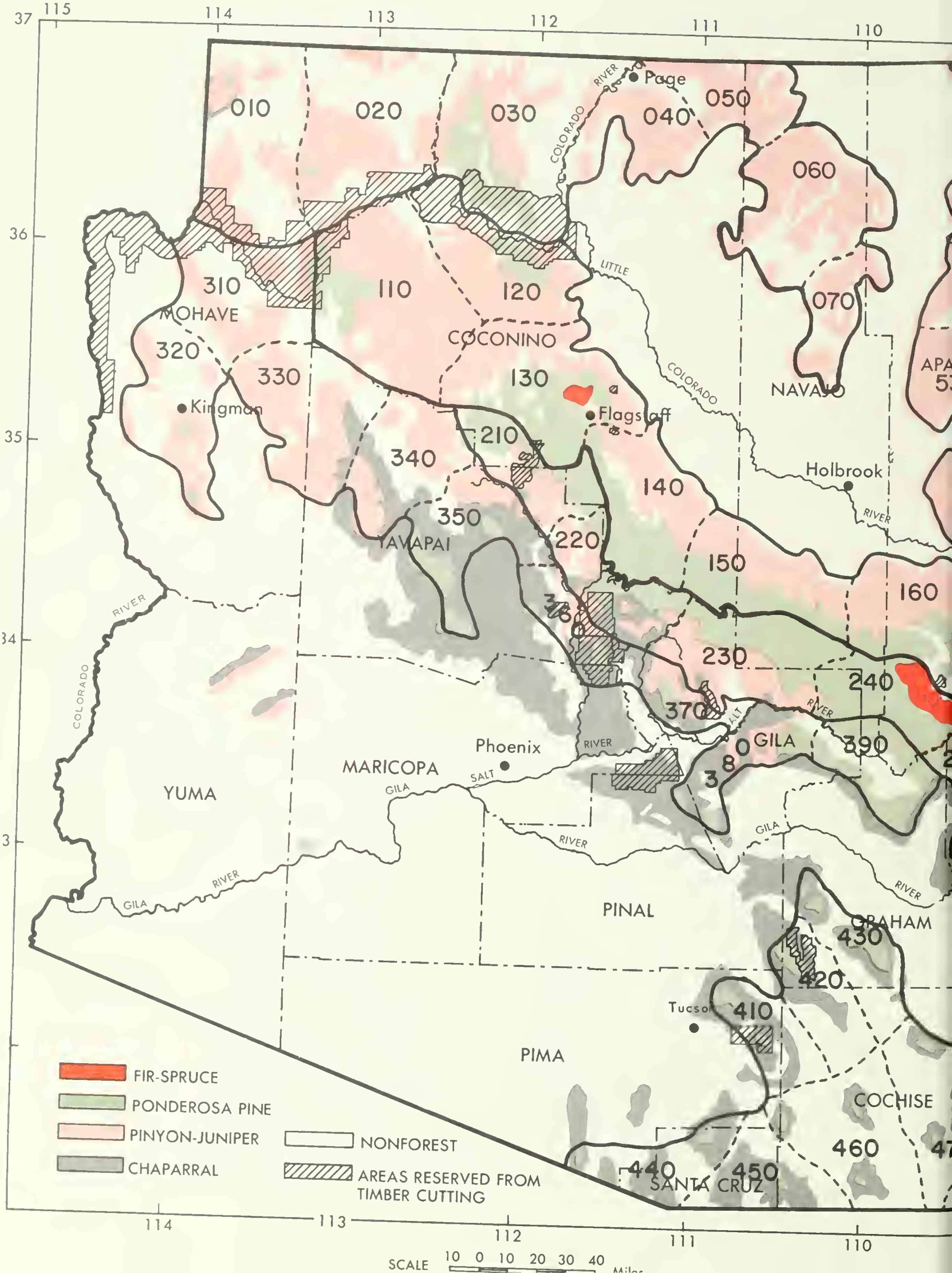
Seed collections were made in 1971 to evaluate the physiographic-climatic variation and to adjust the provisional seed-collection zones. In the interim, foresters should use seed for reforestation from the zone in which it was collected. Since the zone boundaries were located at roughly 50-mile intervals within the physiographic-climatic regions, seeds collected within 50 miles of the reforestation site could be used provided they came from the same physiographic-climatic region. Considerable variation exists within a seed zone; therefore, it would be advisable to plan seed collections which most closely match local conditions.

000 Northwest Plateaus (Seed Zones 010-070). —This region is composed primarily of the Shivwits, Uinkaret, Kaibab, Paria, Kaibito, and Black Mesa plateaus north of the Colorado and Little Colorado Rivers in northwestern and north-central Arizona. Differences in elevation and precipitation are great. Main species present in this region are the pinyons and junipers. Ponderosa pine, spruces, Douglas-fir, and the true firs occur mainly on the Virgin Mountains, Mount Trumbull, Kaibab Plateau, and Navajo Mountain. Stringers of ponderosa pine and Douglas-fir are scattered in the more moist canyons of the other plateaus, but cannot be considered as important forest components.

100 Central Plateaus (Seed Zones 110-180). —This region consists primarily of the Coconino and Mogollon Plateaus and associated mountains extending from the South Rim of the Grand Canyon in northwestern Arizona to the Continental Divide in New Mexico. Drainage in the region is primarily northward into the Colorado and Little Colorado Rivers. The Coconino Plateau is covered primarily by the pinyon-juniper type on the lower, drier sites, while ponderosa pine occurs on the higher, more moist sites. The Mogollon Plateau is about equally occupied by pinyon-juniper and the ponderosa pine types. Most of the ponderosa pine type is covered by nearly pure stands. Douglas-fir, Engelmann spruce, the true firs, and southwestern white pine are found on the mountains and in some of the moist, cool canyons along the Mogollon Rim. Elevation and aspect determine species composition on these mountains. A prominent feature of this region is the San

Table 1.--Occurrence of conifer species by physiographic-climatic regions (code number) in Arizona and New Mexico with approximate range in precipitation and elevation (Little 1950, 1971)

Scientific name	Common name	Physiographic-climatic regions										Precip-itation	Elevation
		000	100	200	300	400	500	600	700	800	900	Inches	Feet
Abies concolor (Gord. & Glend.) Lindl.	White fir	x	x	x	x	x	x	x	x	x		25-30	5,000-10,000
A. lasiocarpa (Hook.) Nutt.	Subalpine fir	x	x	x		x	x	x	x			30-35	8,000-12,000
A. lasiocarpa var. *arizonica* (Merriam) Lemm.	Corkbark fir	x	x	x		x	x	x	x			30-35	8,000-12,000
Cupressus arizonica Greene	Arizona cypress			x	x	x						12-20	3,500- 7,200
Juniperus californica Carr.	California juniper				x							10-20	2,000- 4,000
J. communis L.	Common juniper	x	x				x	x	x			25-30	8,000-11,500
J. deppeana Steud.	Alligator juniper		x	x	x	x	x	x	x	x		12-20	4,500- 8,000
J. monosperma (Engelm.) Sarg.	One-seed juniper		x	x	x	x	x	x	x	x	x	12-20	3,000- 7,000
J. osteosperma (Torr.) Little	Utah juniper	x	x	x	x		x	x				12-20	3,000- 7,500
J. pinchotii Sudw.	Pinchot juniper									x		12-20	3,000- 4,000
J. scopulorum Sarg.	Rocky Mountain juniper	x	x	x			x	x	x	x	x	12-20	5,000- 9,000
Picea engelmannii Parry	Engelmann spruce	x	x	x		x		x	x	x		30-35	9,000-12,000
P. pungens Engelm.	Blue spruce	x		x			x	x	x	x		30-35	7,000-11,000
Pinus aristata Engelm.	Bristlecone pine		x						x			30-35	9,000-11,500
P. cembroides Zucc.	Mexican pinyon			x		x						12-20	5,000- 7,500
P. edulis Engelm.	Pinyon	x	x	x	x		x	x	x	x	x	12-20	5,000- 7,000
P. engelmannii Carr.	Apache pine					x						19-25	5,000- 8,200
P. flexilis James	Limber pine		x						x			25-30	7,000-10,000
P. leiophylla var. *chihuahuana* (Engelm.) Shaw	Chihuahua pine			x	x	x						20-25	5,000- 7,800
P. monophylla Torr. & Frém	Singleleaf pinyon	x			x							12-20	4,500- 6,500
P. ponderosa Laws.	Ponderosa pine	x	x	x	x	x	x	x	x	x	x	19-25	5,500- 8,500
P. ponderosa var. *arizonica* (Engelm.) Shaw	Arizona pine					x						19-25	5,500- 8,500
P. strobiformis Engelm.	Southwestern white pine		x	x	x	x		x	x	x		25-30	7,000-10,000
Pseudotsuga menziesii (Mirb.) Franco.	Douglas-fir	x	x	x	x	x	x	x	x	x		25-30	6,500-10,000



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NAVAJO
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YUMA
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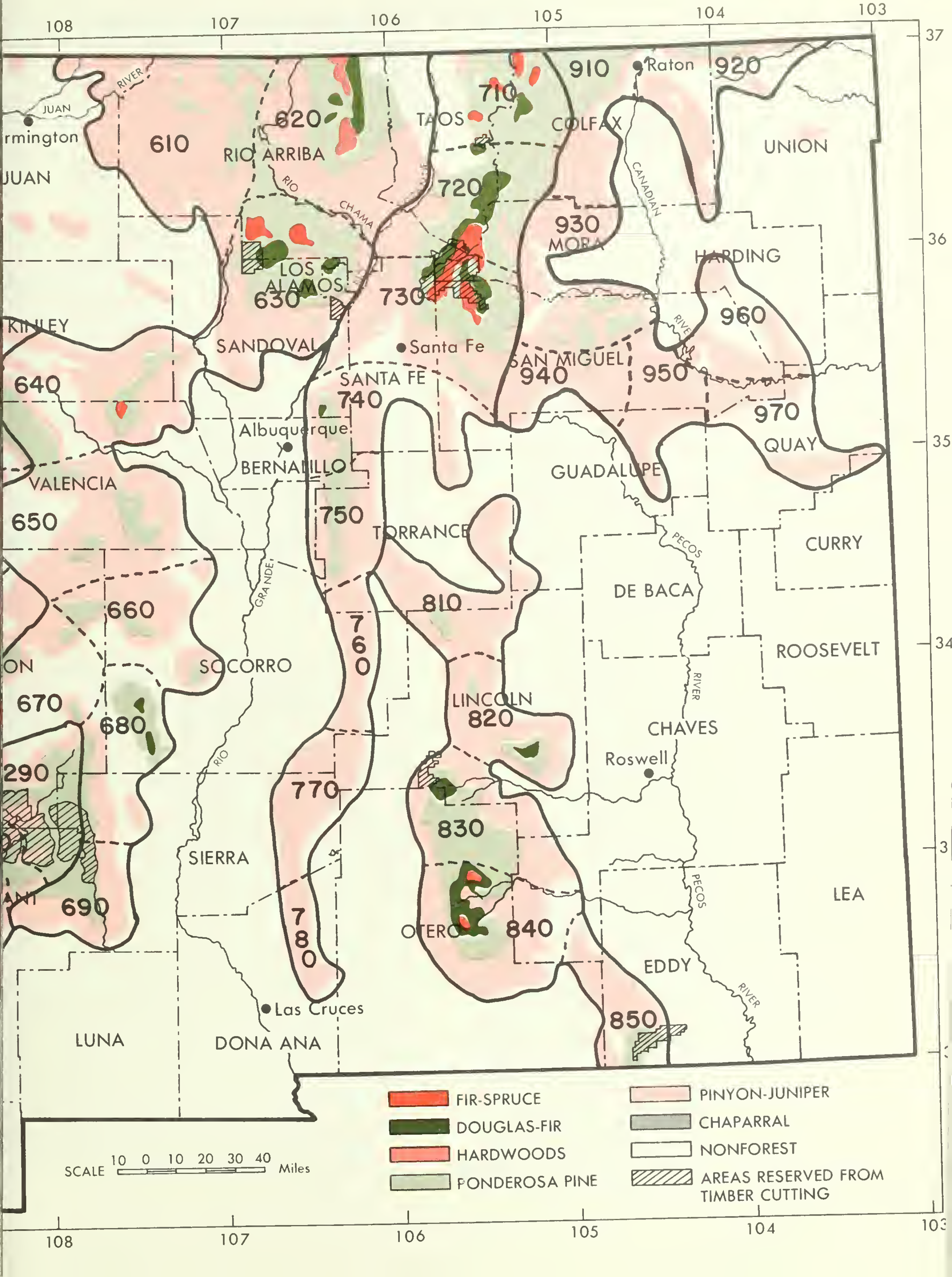
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SANDOVAL
Santa Fe
SANTA FE
SAN MIGUEL
QUAY
Albuquerque
BERNALILLO
VALENCIA
GUADALUPE
TORRANCE
CURRY
PECOS
DE BACA
GRANDE
SOCORRO
ROOSEVELT
LINCOLN
CHAVES
Roswell
RIO
SIERRA
OTERO
LEA
EDDY
Las Cruces
LUNA
DONA ANA
FIR-SPRUCE
DOUGLAS-FIR
HARDWOODS
PONDEROSA PINE
PINYON-JUNIPER
CHAPARRAL
NONFOREST
AREAS RESERVED FROM TIMBER CUTTING
SCALE 10 0 10 20 30 40 Miles

Francisco Peaks, with rather distinct species zonation from ponderosa pine at the base to Engelmann spruce at timberline. At the upper levels of the Peaks are found subalpine fir and bristlecone pine. The latter species is found in only one other area in the Southwest.

200 Mogollon Slope and Highlands (Seed Zones 210-290).—This region starts near Ashfork, Arizona, and extends along the south slope of the Mogollon Rim to the Continental Divide in New Mexico. This region, also known as the Transition Zone, divides the Mogollon Rim from the Tonto Basin, Sierra Ancha, and Natanes Plateau. It includes the White, Mogollon, Big Burro, and Pinos Altos Mountains. Below the Mogollon Rim the area slopes primarily southward. Further east, the numerous mountain ranges provide all aspects and pronounced elevational differences. Seed zones within this region are divided along major water drainages, highways, and the Continental Divide. The ponderosa pine and pinyon-juniper are the main species types. Douglas-fir, true fir, and southwestern white pine are found on the moist, cool sites. The White Mountains support mostly spruces and firs at the higher elevations.

300 Central Highlands (Seed Zones 310-390).—This region extends in a southeasterly direction from Lake Mead in Mohave County to the Natanes Plateau in Graham County, Arizona. A considerable portion of this region is covered with grass and chaparral. Ponderosa pine is restricted primarily to the mountains and plateaus, while pinyon-juniper occurs at the lower elevations in a more continuous belt. The best stands of ponderosa pine occur on the Hualapai, Mingus, Bradshaw, Mazatzal, and Sierra Ancha Mountains and Natanes Plateau. Douglas-fir, Chihuahua and southwestern white pines, and the true firs also occur on the higher mountains.

400 Southeast Desert Highlands (Seed Zones 410-480).—This region is composed primarily of rather widely separated mountains. The individual seed zones within this region divide the mountain ranges into separate groups, so each zone has great elevational and aspect differences. Tree species range from the pinyons and junipers at the lower dry elevations through ponderosa pine and Douglas-firs to spruce and fir at the higher, moist elevations. Other pines in this region are Apache, Arizona, limber, Chihuahua, and southwestern white pine.

500 Chuska-Zuni-Gallo Highlands (Seed Zones 510-570).—This region extends from the Four Corners south to the ridge of the Gallo Mountains in west central New Mexico. The most extensive stands of ponderosa pine occur in the Chuska and Zuni Mountains. Pinyons and junipers occupy most of the low-elevation dry sites. White and subalpine firs and blue spruce occur above the ponderosa pines in the northern end of the Chuska Mountains.

600 East Continental Highlands (Seed Zones 610-690).—This region extends from the San Juan Mountains at the Colorado border to the Mimbres in southeastern New Mexico. It lies between the Continental Divide and the Rio Grande except for seed zone 610, which is west of the Continental Divide in the Jicarilla Indian Reservation. Pinyon-juniper type covers an extensive part of this region, mainly at lower elevations and on the drier sites. The ponderosa pine type is found at higher elevations in the San Juan, Jemez, San Mateo, Cebolleta, Datil, Gallinas, Black Range, and Mimbres Mountains. Good stands of spruce, true fir, and Douglas-fir also occur in the San Juan, Jemez, and San Mateo Mountains with lesser amounts on some of the other high mountains. Water drainage in this region is almost entirely into the Rio Grande except for seed zone 610, which is drained by the San Juan River into the Colorado.

700 East Rio Grande Highlands (Seed Zones 710-780).—This region includes the southern Rocky Mountains bordering on the Rio Grande. The best ponderosa pines, along with the other high-elevation conifers, occur in the Sangre de Cristo Mountains in northern New Mexico. Ponderosa pine and Douglas-fir also occur in the Manzano Mountains south of Albuquerque. The lower three seed zones in this region are occupied mainly by the pinyon-juniper type. Bristlecone pine occurs at high elevation in seed zones 710, 720, and 730 of the Sangre de Cristo Mountains in New Mexico.

800 Sacramento-Guadalupe Range (Seed Zones 810-850).—This region lies in south central New Mexico east of Tularosa Valley, from Torrance County to the Mexican border. Major land features include the Juames Mesa and the Gallinas, Carrizo, Capitan, Sacramento, and Guadalupe Mountains. Species composition includes pinyon and junipers at lower elevations through ponderosa pine with Douglas-fir, true firs, and spruces at the higher elevations of Carrizo, Capitan, and Sacramento Mountains. The Pinchot juniper occurs only at the lower end of seed zone 850 near the Mexican border.

900 Northeast Plains (Seed Zones 910-970).—This region includes the plains and associated mountains in northeastern New Mexico. One-seed and Rocky Mountain junipers and pinyons are the most common species. Ponderosa pine is found only at high elevations in Colfax, Union, Mora, and San Miguel Counties.

Interim Cone-Crop Rating System

What do we mean by a "light", "medium", or "heavy" cone crop? In California, cone crop ratings are based on the number of cones per dominant tree larger than 19.5 inches d.b.h. (Fowells and Schubert 1956) and by the 5-unit classification system which relates cone abundance on an area basis (Schubert and Baron 1960).

We have some information on cone production on ponderosa pines, but none on the other conifers. Large, vigorous, isolated ponderosa pines are the best cone producers in terms of seed quantity, quality, and frequency of bearing in the Southwest (Larson and Schubert 1970). Ponderosa pines 28 inches in diameter may produce from 200 to 450 cones per year, while trees under 12 inches usually produce very few cones. Therefore, until information is available for the other species, we have elected to use an interim cone-crop rating system employing a 10-unit classification system (table 2).

The cone-crop rating is based on the relative number of cones produced on a proportion of the seed trees at each sampling area. A seed tree is defined as a dominant tree over 12 inches in diameter with a full, vigorous crown. These specifications are adequate for ponderosa pines, but not necessarily for all species. For example, the firs, spruces, junipers, Arizona cypress, and other pines produce excellent crops on smaller trees. These size differences will need to be recognized in rating the cone crops by species.

This 10-unit system provides the forester with intermediate ratings between those set for California, and provides recognition of bumper cone crops. An exact cone count is not required for a reasonable evaluation of the cone-crop rating. The ratings are subjective and should improve with practice.

Identification of Collected Cones

All seed collections must be properly labeled. Each sack of cones must have two labels, one to be placed inside the sack and the other tied

Table 2.--The 10-unit classification for rating cone crops on conifers in Arizona and New Mexico

Classification		Description[1]
1	None	No cones on any seed tree.
2	Very light	Few cones on less than one-fourth of the seed trees.
3	Very light to light	Few cones on one-fourth to one-half of the seed trees.
4	Light	Few cones on more than one-half of the seed trees.
5	Light to medium	Few cones on more than one-half any many cones on less than one-fourth of the seed trees.
6	Medium	Many cones on one-fourth to one-half of the seed trees.
7	Medium to heavy	Many cones on more than one-half of the seed trees.
8	Heavy	Many cones on more than one-half of the seed trees, with less than one-fourth to one-half of them loaded with cones.
9	Heavy to very heavy	Many cones on more than one-half of the seed trees, with one-fourth to one-half of them loaded with cones.
10	Very heavy	Many cones on more than one-half of the seed trees, with more than half of them loaded with cones.

[1]Cones per tree: few = 1 to 20; many = 21 to 160; loaded = 161 or more.

on the outside. The minimum data recorded on each label should include:

1. Species (common and scientific name).
2. Seed collection zone, elevation, and aspect.
3. Forest, District, township, range and section.
4. Stand density, site index, associated species.
5. Cone-crop rating.
6. Collected from felled or standing trees.
7. Day, month, and year of collection.
8. Collector's name.

Frequently it is necessary to have more data on special seed lots. For example, the following additional data are needed for seed exchange and testing provenances:

9. Latitude, longitude, and county.
10. General soil classification and associated rocks.
11. Tree size (diameter, height, and age).
12. Tree characteristics (bole, crown, branching, growth rate, and disease).
13. Number of trees from which cones were collected.
14. Whether trees can be relocated for future collections.
15. Map with pin prick to show location of collection area (the hole on reverse side should be circled and dated).

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The forested areas of Arizona and New Mexico were divided into 10 physiographic-climatic regions. These regions were then subdivided into five to nine seed collection zones about 50 miles wide. Provenance tests will be conducted to determine variation and need for adjustments. Seed used for reforestation should be limited to that collected within the local zone. A 10-unit classification system for rating cone crops is included.

Oxford: 232.312.1:232.311. **Keywords:** Cone collecting, forest seed collecting, forest seed production.

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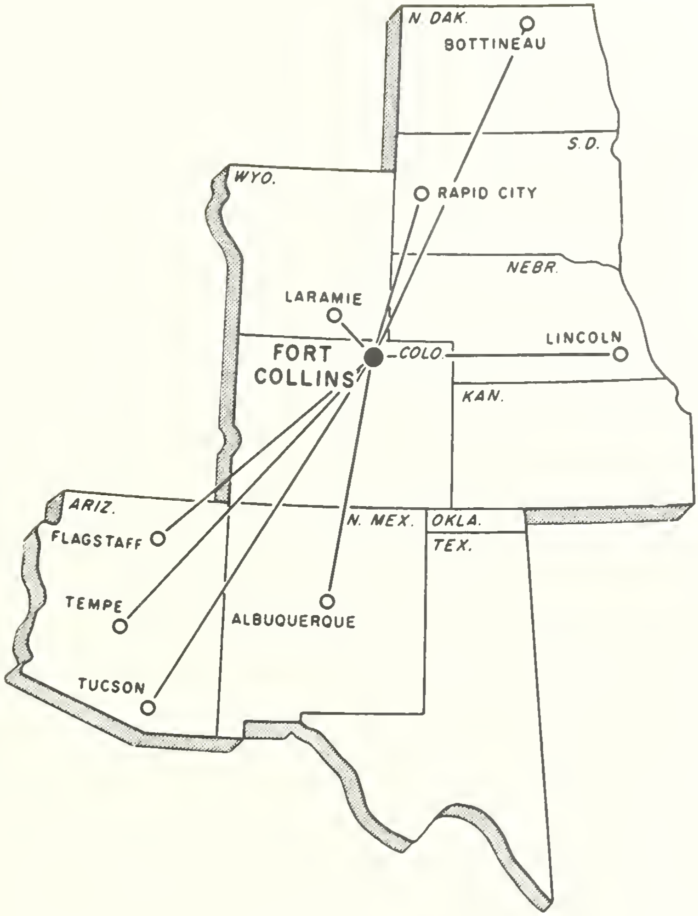
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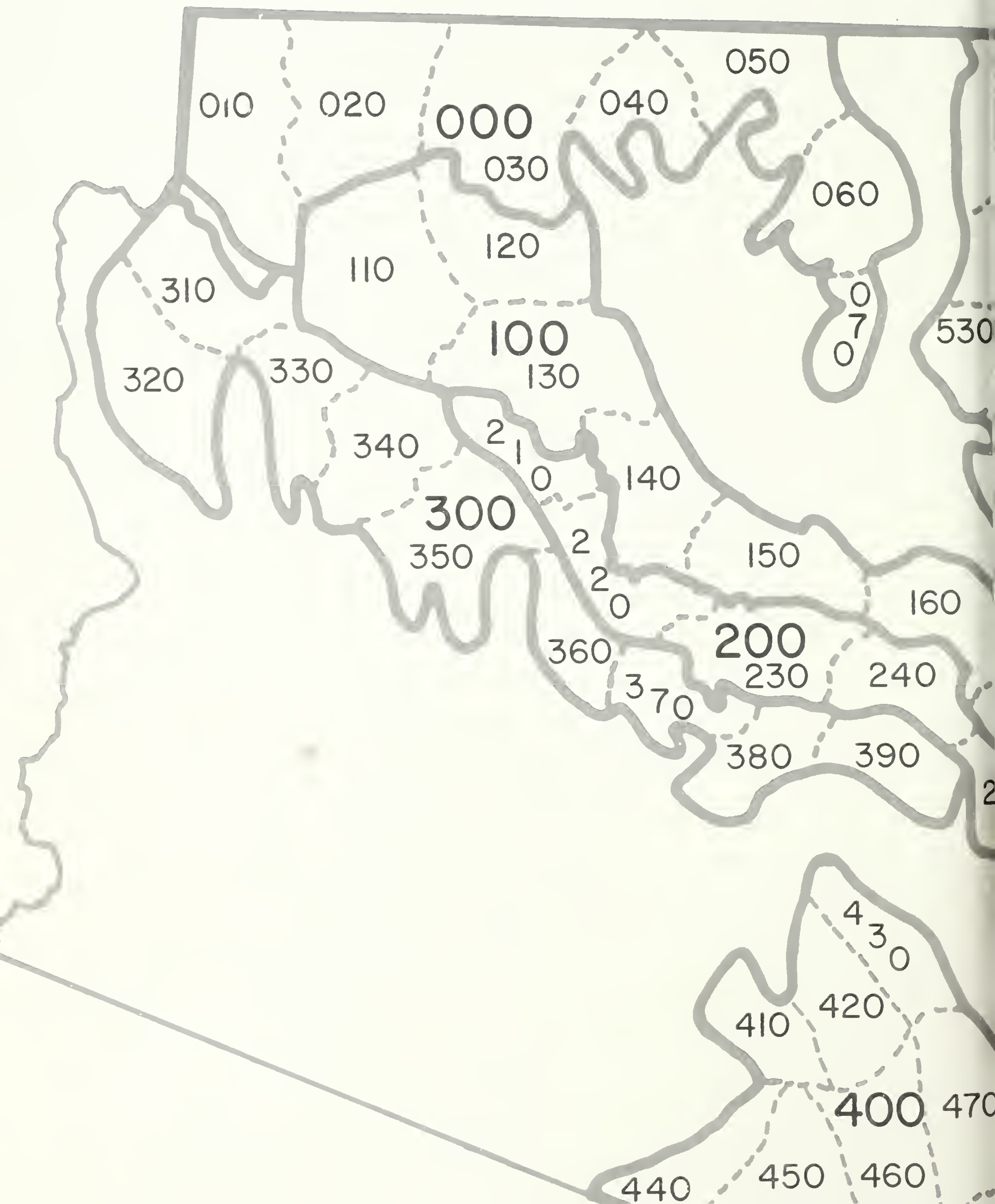
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)NTROL OF DWARF MISTLETOE ' A HEAVILY USED PONDEROSA NE RECREATION FOREST:

'rand Canyon, Arizona

ul C. Lightle and Frank G. Hawksworth
ncipal Plant Pathologists

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Abstract

Southwestern dwarf mistletoe has been a problem in ponderosa pine on the South Rim of Grand Canyon for many decades. The National Park Service program to control the parasite, begun in 1949, was the first large-scale attempt to control dwarf mistletoe in a recreational forest. The area has been sanitized at about 5-year intervals since the initial treatment. This Paper describes the control effort, and compares the treated and untreated stands after 20 years. The original goal of the project—to reduce the level of dwarf mistletoe and protect the ponderosa pine forest—has been achieved. Recommendations for dwarf mistletoe control in recreational forests, based on knowledge gained from this project, are summarized.

Oxford: 443.3:412. **Keywords:** Dwarf mistletoe control, recreational forests, silvicultural control, *Arceuthobium vaginatum* subsp. *cryptopodum*, *Pinus ponderosa*.

USDA Forest Service
Research Paper RM-106

April 1973

Control of Dwarf Mistletoe in a Heavily Used Ponderosa Pine Recreation Forest: Grand Canyon, Arizona

by

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FOREWORD

Dwarf mistletoe on the South Rim of Grand Canyon National Park is considered a native pathogen in the ponderosa pine forests of the area. The infection intensity became a matter of deep concern to Park managers in the 1930's. Research in the late 1940's indicated a possible change in species composition in the ponderosa pine type should the infection continue at the same intensity. Park administrators decided in the 1950's to adopt a course of resource management that would preserve the ponderosa pine forest type, and would sustain the scenic and esthetic values along the Park's South Rim. Control practices have been continued since that time.

We note with considerable satisfaction that the scenic values inherent in the South Rim ponderosa pine forest have been maintained along the East Rim Drive. As the Park approaches a new milestone in the project, the maintenance phase of the program, this Research Paper is being published to document the history of joint U. S. National Park Service-Forest Service effort in the preservation of the forest type and the esthetic values in a highly used recreational portion of a natural area. To the many forest research scientists, particularly the late Dr. Lake S. Gill, the present forest pathologists of the Rocky Mountain Forest and Range Experiment Station, Dr. Frank Hawksworth and Dr. Paul Lightle, and the staff members and the Superintendents of Grand Canyon National Park over three decades, forest pathologists of future generations will pay tribute for this documentation.

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Denver Service Center
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ACKNOWLEDGMENTS

So many people have assisted in various phases of the project since its initial planning in 1947 that it is impossible to acknowledge them all. However, we would particularly like to thank foresters Robert Peterson, S. T. Carlson, W. G. James, Eslie Lampi, and Clyde Fauley of the National Park Service for their sustained interest and cooperation in the project. Dr. Lake S. Gill provided technical direction for the project from its inception until the mid 1950's, and followed it with interest even after his retirement in 1960. S. R. Andrews and T. E. Hinds of the Rocky Mountain Station also assisted in technical aspects of the work.

Contents

Control of Dwarf Mistletoe in a Heavily Used Ponderosa Pine Recreation Forest: Grand Canyon, Arizona

Paul C. Lightle and Frank G. Hawksworth

HISTORY OF THE CONTROL PROJECT

On the South Rim of the Grand Canyon, mortality of ponderosa pine (Pinus ponderosa Laws.) due to parasitism by southwestern dwarf mistletoe (Arceuthobium vaginatum subsp. cryptopodum (Engelm.) Hawks. & Wiens) has been recorded since before the turn of the century (MacDougal 1899). The National Park Service expressed concern about the dwarf mistletoe situation along the South Rim as early as 1933, and became increasingly concerned over the impact of the infestation in the ponderosa pine stands east of Grand Canyon Village. The severity of the infestation was noted by Gill (1940, 1946) and Mielke (1945). Many pole-sized and mature pines were dying, and the growth of trees in all size classes was seriously affected. A factor of even more consequence to the esthetics of the area, however, was that in some places, the ponderosa pine type was being replaced by Gambel oak (Quercus gambelii Nutt.).

In August 1947, Division of Forest Pathology[2] and National Park Service personnel met to review the situation on the ground. As a result of this meeting, the Division of Forest Pathology was requested to make a preliminary study to determine (1) the need for and feasibility of control, and (2) the general procedures to be followed if control was to be practiced. The survey was made in the fall of 1947, and the results were summarized in a report by Gill (1949).

Gill emphasized that the Park Service's long-range plans for the area—including whether ponderosa pine, near the Rim at least, was worth preserving for future generations—had to be decided before control could be considered. He pointed out that, left unchecked, the ponderosa pine stands would continue to deteriorate, but that a decision to control the parasite must include the commitment to at least one additional sanitation treatment.

As native parasites, dwarf mistletoes are generally in long-term equilibrium with their hosts. At Grand Canyon, however, dwarf mistletoe on ponderosa pine appears to be an exception, probably because the stands are marginal. Ponderosa pine dwarf mistletoe is known to reduce seed production in heavily infected trees (Korstian and Long 1922), and in many areas it appeared to Gill (1949) that ponderosa pine stands had been replaced by Gambel oak. Apparently as older trees on the South Rim were killed by mistletoe, oak took over the sites. The increase in oak on the South Rim is unusual because it is due not only to root suckering, but also to seedling establishment. Elsewhere in the ponderosa pine type, oak increases almost exclusively due to suckering.

After thorough consideration of Gill's report in the light of Service policy, Park Service personnel decided the dwarf mistletoe infestation was so serious that a control project was warranted to save the stands along the East Rim Drive.

Financing for the control project with Pest Control funds was obtained by the National Park Service. Initial control was begun in September 1949 (Hawksworth 1951) and continued until June 1952 (Hawksworth 1952). Since then the area has been sanitized three times at about 5-year intervals. Technical guidance has been provided by the Division of Forest Pathology and the U. S. Forest Service. As part of the project, 10 sample plots were established in the treated areas and in nearby untreated stands so that the effectiveness of control could be assessed.

This is the first large-scale attempt to control dwarf mistletoe in a recreational forest. Since the project is well known and has been visited by many foresters, biologists, and forest pathologists, a thorough documentation of the project is warranted. To present a more complete historical account, we have therefore included references to several unpublished reports.

[2] *The Division of Forest Pathology, U. S. Department of Agriculture, was transferred from the Bureau of Plant Industry, Soils and Agricultural Engineering to the Forest Service in 1954, and became the Division of Forest Disease Research.*

The purpose of this Paper is to describe and evaluate the control effort after 20 years. The report consists of three major parts: (1) The control project, (2) the permanent study plots, and (3) suggestions for control in recreation forests.

THE FOREST AND DWARF MISTLETOE

The topography of the plateau south of the Rim is fairly uniform, with slightly rolling hills. Elevations range from 7,300 to 7,600 feet. The draws are usually less than 200 feet lower than adjacent ridges. In the eastern part of the area (from about 2 miles west of Grandview Point) the forest is nearly pure ponderosa pine. In the western portions, however, ponderosa pine predominates in the bottom sites, with pinyon (Pinus edulis Engelm.) and juniper (Juniperus osteosperma (Torr.) Little) on the ridges. Gambel oak is a frequent associate of ponderosa pine throughout the South Rim area. Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), white fir (Abies concolor (Gord. & Glend.) Lindl.), and aspen (Populus tremuloides Michx.) occur at or below the canyon rim, but are insignificant components of the forests on the plateau.

Dwarf mistletoe occurs on ponderosa pine from near Yaki Point for about 10 miles along the East Rim to near the east end of the ponderosa pine type (Hawksworth 1967, fig. 1). The ponderosa pine stands near Grand Canyon Village and the Park Headquarters are apparently free of the parasite.

THE CONTROL PROJECT

Control Strategy

At the outset of the project it was fully realized that ponderosa pine dwarf mistletoe was a native parasite, and that attempts would be made to control, not eradicate, it. No control was to be attempted in areas that were not to be developed for scenic and recreational purposes. The Grand Canyon control project was

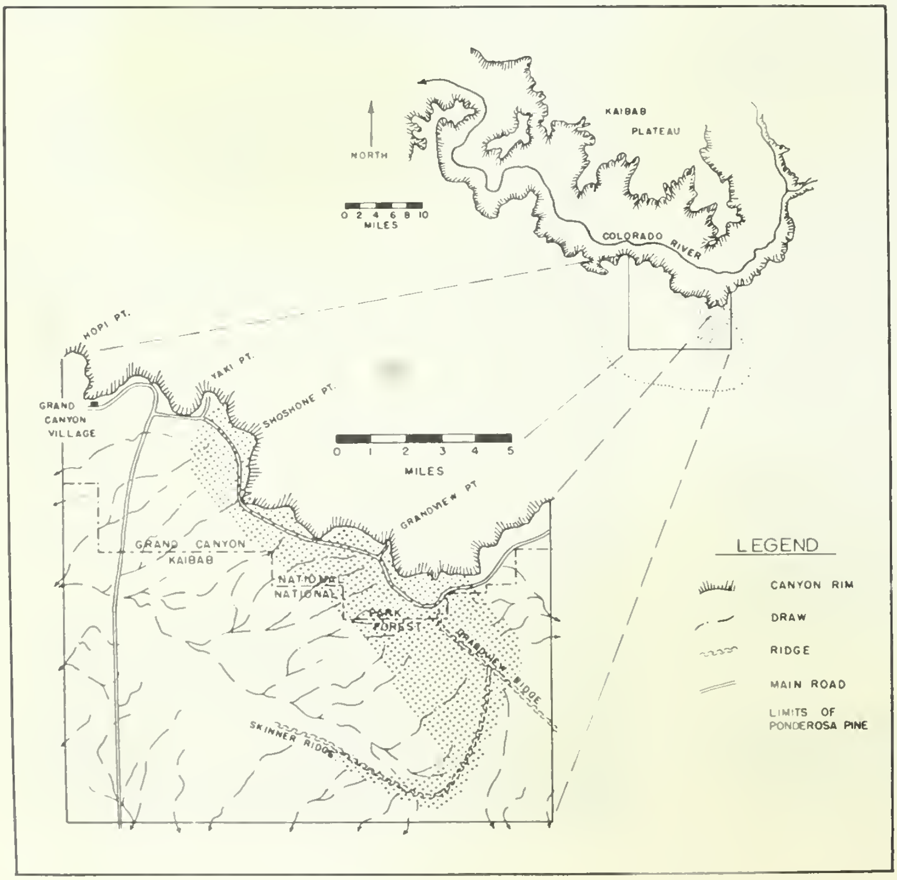


Figure 1.— The South Rim of Grand Canyon showing the location of ponderosa pine stands. The stippled area indicates the stands with dwarf mistletoe infection (from Hawksworth 1967).

undertaken to protect the ponderosa pine forest in the scenic and intensively used portions of the South Rim by reducing the levels of dwarf mistletoe. This was to be accomplished by removing mistletoe infections from trees to be protected, or otherwise isolating these trees from mistletoe infection (U.S. National Park Service 1949).

The plan was to apply control measures in sections 17 and 20 between the canyon rim and the East Rim Drive and Grandview Spur Road, a 300-foot strip along the south side of the East Rim Drive in sections 17 and 20, and a 300-foot roadside strip along both sides of this drive between Yaki Point Junction and the west boundary of section 17 (fig. 2). The 300-foot roadside strip was not continuous because of intervening pinyon-juniper areas (Hawksworth 1952). Dwarf mistletoe infected ponderosa pine was present on 680 acres (or 62 percent) of the 1,100 acres within the control area.

In 1956, Park personnel surveyed the area east of the original control area between the canyon rim and a proposed new road alinement, extending east to the end of the ponderosa pine type (James 1956). Because the survey showed that dwarf mistletoe was present throughout the area, an appraisal survey by the Albuquerque Forest Disease Laboratory, USDA Forest Service, was requested (Hawksworth 1956). Park personnel then decided to include this area in the control unit to (1) save the ponderosa pine type, (2) have a continuous roadside area pleasing to the visitor, and (3) have a consolidated control area that would be easier to maintain. Control measures were to be applied to infected ponderosa pines between the canyon rim and the East Rim Drive east of the originally treated area, to a 300-foot strip south of the Drive in the same area, and to infested areas further west along the realined road (fig. 2). (A 10-acre plot in section 21 was left untreated to compare with a 10-acre treated plot nearby in section 20.) Initial control work began in November 1956 and was completed in December 1957 (James 1958). This new area, designated as extension A, contained about 840 acres, most of which was uniformly and heavily infested with dwarf mistletoe.

In 1965 it appeared that dwarf mistletoe was reinvading the control area from the untreated stands to the south. A utility right-of-way about 30 feet wide had been clearcut near, and more or less parallel to, the south boundary of the control project. Park personnel decided to extend the control area to this clearcut strip to retard reinvasion of the treated area. Treatment of this area, called extension B, was begun in 1966 (fig. 2). About 408 acres of ponderosa pine type, most of which was heavily infested by dwarf mistletoe, were included in extension B.

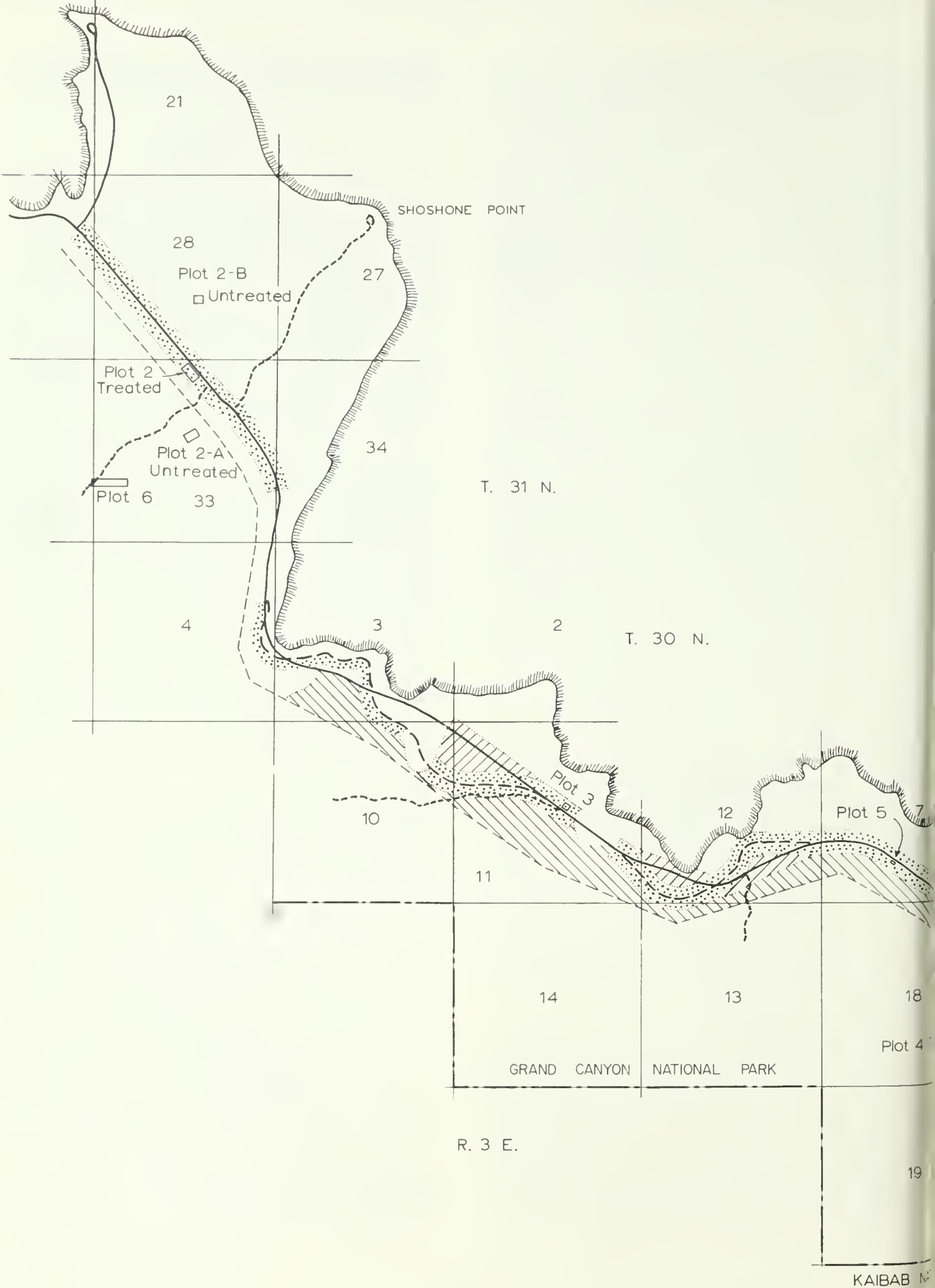
Control Methods

Feasibility of controlling ponderosa pine dwarf mistletoe by a systematic program of sanitation had already been demonstrated by studies at the Fort Valley Experimental Forest, near Flagstaff, Arizona (Gill and Hawksworth 1954). Sanitation consists of pruning lightly to moderately infected trees, and killing heavily infected ones.

Initial sanitation involved pruning, poisoning, or felling infected trees (Hawksworth 1951). For esthetic reasons, as many trees as possible were pruned. Trees were considered not prunable, and to be killed if:

1. Over half of the crown would be removed in pruning operations. This basic rule was not followed strictly, but was influenced by (a) the distribution of the mistletoe in the tree, (b) general tree health, (c) appearance of the tree after treatment, and (d) allowance for the later removal of additional infected branches that were not visibly infected at the time of the original treatment.
2. Mistletoe shoots were on or within 18 inches of the main stem. (In 1961 and subsequent years this was reduced to 12 inches.) Exceptions were: (a) some trees with infections on small branches, and (b) some trees with bole infections where the bole diameter was 12 inches or larger.

Gill (1949) emphasized that a satisfactory degree of control could not be achieved in one operation. Subsequent examination and sanitations were planned as an integral part of the project. The number of sanitations that would be required was not known at the beginning of the project, but inspections were to be made at 3- to 5-year intervals to determine the need for, and timing of, the next operation. A complicating factor in determining the extent of subsequent sanitation was that pruning was used very extensively in an attempt to save as many trees as possible (over half of the trees treated in the initial operation were pruned). It was realized at the outset that more sanitations would be needed for this type of operation than for control projects in timber-production forests, where infected trees are cut, and very few were pruned (for example, the mistletoe control operation on the Mescalero Apache Reservation, New Mexico — Hawksworth and Lusher 1956, Lightle and others 1967).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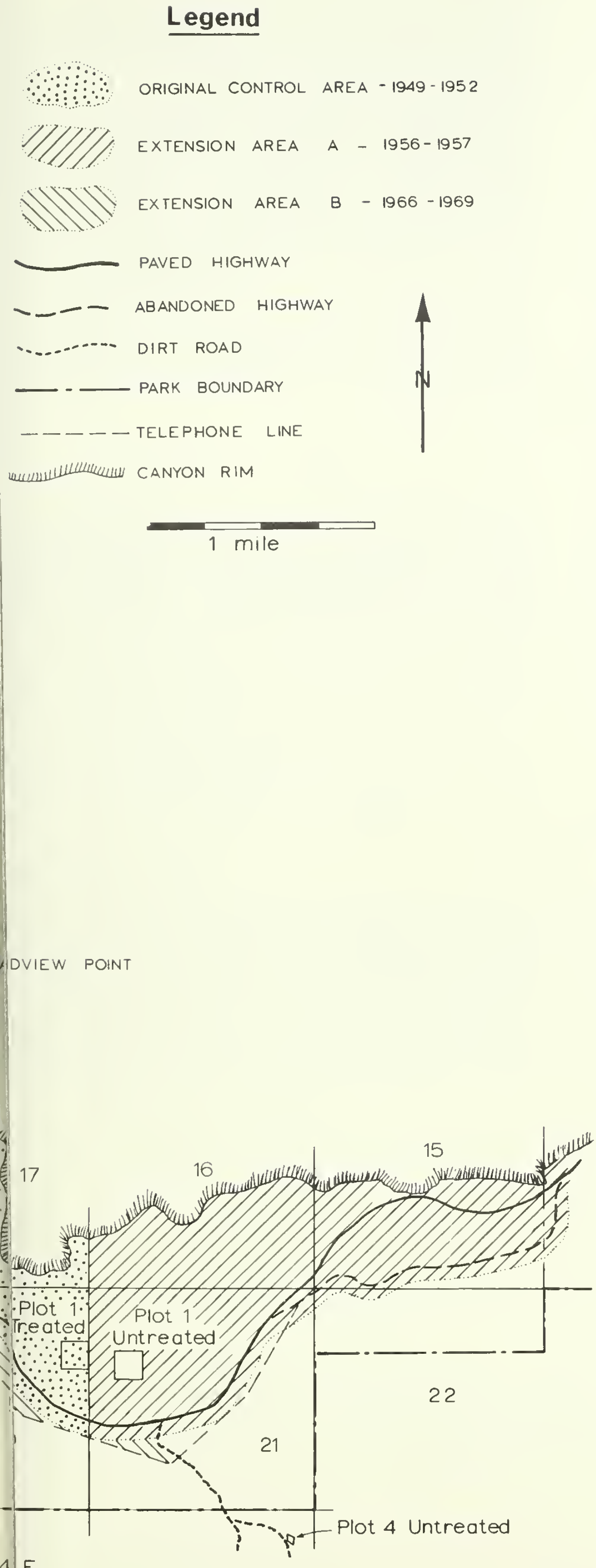


Figure 2.—

The Grand Canyon Dwarf Mistletoe Control Project, showing the areas covered in the initial operations and extension areas A and B. The 10 permanent plots are also shown.

Control Operations

The entire control area included about 2,348 acres:

Control Unit	Sanitation operations Initial	Subsequent
	(Years)	
Original area (1,100 acres)	1949-52	1954-55 1961-62, 1966-70
Extension A (840 acres)	1956-57	1961-62, 1966-70
Extension B (408 acres)	1966-69	none

In all operations, 68,400 tree treatments were recorded. It is not known how many individual trees were treated because some were pruned from two to four times, and some pruned trees developed so much mistletoe they had to be killed later. Although complete records are not available on the type of treatment for all years of the operation, apparently about one-third of the trees were pruned and two-thirds were killed by cutting or poisoning.

The initial sanitation treatments on the original control area relied much more heavily on pruning (53 percent of the trees treated) than did the first sanitations in extension area A (33 percent) or extension area B (20 percent). Factors involved in this change were the high cost of pruning trees and the frequent need for their re-treatment.

The three areas covered by the project—initial control, extension area A, extension area B—will be discussed separately. A chronology of the operations in the various control units is given in table 1.

Original Control Area

The 1,100 acres (see fig. 2) were initially sanitized in 1949-52. Additional sanitations were made in 1954-55 and 1961-62. Most of the area (except along the East Rim Drive west of section 4) was again sanitized in 1966-70. Thus

Table 1.--Chronology of dwarf mistletoe sanitations at Grand Canyon National Park

Years	Sanitation	Area treated
1949-52	Initial	Original control area
1954-55	Second	Original control area
1956-57	Initial	Extension area A
1961-62	Third	Original control area
	Second	Extension area A
1966-69	Fourth	Original control area south of highway in sections 17 and 20, roadside west of Section 4
	Third	Extension area A south of highway in Section 21 and western portions of Section 4
	Initial	Extension area B
1969-70	Fourth	Original control area north of highway in Sections 17 and 20
	Third	Extension area A in Sections 14, 15, 16, and 21

most of the area has been resanitized after about 5, 10, and 20 years.

A total of 6,932 trees (6.3 per acre) was treated in the initial sanitation and 4,220 (3.8 per acre) in the second (table 2). Only trees over 6 feet high are included because records for the smaller trees are incomplete. Fifty-three percent of the trees were pruned initially and 70 percent in the second sanitation. The proportion of trees pruned was highest in mature trees — 63 percent initially and 84 percent in the second sanitation.

Data are not available on the number of trees treated in the third and fourth sanitations of the original control area because the totals were combined with those from extension area A.

Extension Area A

Extension area A (see fig. 2) was initially sanitized in 1956-57; a second sanitation was made in 1961-62, and a third in 1966-70. Thus this area was resanitized after about 5 and 13 years. Data on the number of trees treated in area A are available only for the initial sanitation because data for 1961-62 and 1968-70 operations were combined with those for the original control area.

A total of 9,648 trees of all size classes was treated during the initial operation on extension area A. Of these, 33 percent (3.8 per acre) were pruned and the rest (7.7 per acre) killed.

Extension Area B

Extension area B was initially sanitized in 1966-69 (see fig. 2). There have been no further sanitations to date, but a second treatment is scheduled for 1973. Data are not available on the number of trees treated in extension area B because the totals were combined with those from other areas.

PERMANENT STUDY PLOTS

Description

Ten permanent study plots[3] totaling 31.17 acres were established in or near the original control area to obtain information on the success of the control operation (see fig. 2). Five plots were within the treated area and were subjected to the same control measures as in the surrounding stands; the other five plots were outside the control area and were left untreated. The treated plots were first sanitized in 1949-52, with subsequent sanitations in 1954-55, 1961-62, and 1966-70. As will be discussed later, treated Plot 2 has not yet had its scheduled third sanitation. All plots, except Plot 6, were established in 1950 (Hawksworth 1951). Plot 6 was set up in 1952. All trees on the plots were examined in 1955, 1961, 1966, and 1970.

Individual tree data were obtained on these plots by tagging trees over 4 inches in d.b.h. in 1950. At the time of the 1961 examination, all trees over 3.5 inches d.b.h. were tagged. Details on the numbers of trees and basal areas on these plots are given in tables 3 and 4.

The ten plots were divided into six groups as follows:

Plot 1 Series. — Two 10-acre plots, one treated and one untreated. This series was established to determine the effectiveness of control measures in heavily infected overmature stands in the eastern portions of the area.

[3]*Stands on the study area consisted of (1) reproduction — young trees up to 3.5 inches d.b.h.; (2) poles — young trees 3.6 to 11.5 inches d.b.h.; (3) blackjacks — young trees 11.6 inches d.b.h. and larger, with black bark and pointed top; (4) mature trees, 11.6 inches d.b.h. and larger, but usually less than 24.0 inches, with yellow bark and tops beginning to flatten; (5) overmature trees, usually over 24 inches d.b.h., with yellow bark and flat top.*

Table 2.--Number of trees, by size class (over 6 feet high and 4½ to more than 30 inches diameter at breast height), treated in the initial and second sanitations on the original control area (1,100 acres)

Size class	Initial Sanitation		Second Sanitation	
	Pruned	Killed	Pruned	Killed
	- - - - - - -	Number	- - - - - - -	
Mature (over 30 inches d.b.h.)	751	440	1,059	204
Intermediate (trees 4½ to 30 inches d.b.h.)	2,016	2,115	950	313
Saplings (trees 6 feet high to 4½ inches d.b.h.)	921	689	931	763

Table 3.--Stand composition and dwarf mistletoe infection by diameter class on treated and untreated plots Grand Canyon National Park, 1950-70

	<6 inches				6-11 inches				12-23 inches				>23 inches				Total			
	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4	Plot 1	Plot 2[1]	Plot 3[2]	Plot 4
									No. of trees											
TREATED PLOTS--																				
Original stand, 1950:																				
Dead	1	4	2	6	6	2	4	1	12	1	1	1	3	0	0	0	22	7	7	8
Infected	28	57	5	184	35	77	5	11	71	35	14	0	27	2	0	0	161	171	24	195
Uninfected	22	39	4	70	13	49	1	0	10	19	11	0	1	2	2	0	46	109	18	70
Intentionally killed	11	29	2	100	14	31	3	6	54	8	3	0	11	0	0	0	90	68	8	106
Left	39	67	7	154	34	95	3	5	27	46	22	0	17	4	2	0	117	212	34	159
1951-70:																				
Ingrowth	9	34	0	0	3	1	0	0	0	0	0	0	0	0	0	0	12	35	0	0
Intentionally killed	4	22	1	94	11	22	0	5	11	11	0	0	4	0	0	0	30	55	1	99
Died	2	3	0	2	0	0	0	0	0	1	1	0	1	1	0	0	3	5	1	2
1970 stand:																				
Infected	0	10	0	2	3	32	1	1	2	20	2	0	0	1	0	0	5	63	3	3
Uninfected	5	23	4	45	42	70	4	10	29	29	19	0	15	2	2	0	91	124	29	55
Total	5	33	4	47	45	102	5	11	31	49	21	0	15	3	2	0	96	187	32	58
UNTREATED PLOTS--																				
Original stand, 1950:																				
Dead	1	0		0	9	8		0	15	2		0	2	0		0	27	10		0
Infected	32	27		44	56	50		34	84	55		6	51	1		0	223	133		84
Uninfected	29	35		10	23	18		9	11	29		3	4	3		0	67	85		22
Kill[3]	9	6		32	19	20		13	32	24		1	26	0		0	86	50		46
Ingrowth, 1951-70	15	1		0	16	0		0	0	0		0	0	0		0	31	1		0
Died, 1951-70	11	9		50	18	11		22	29	13		2	18	0		0	76	33		54
1970 stand:																				
Infected	15	22		5	59	53		21	80	56		7	39	2		0	193	133		33
Uninfected	13	17		1	28	11		4	7	23		1	4	2		0	52	53		6
Total	28	39		6	87	64		25	87	79		8	43	4		0	245	186		39
Kill[3]	12	11		5	36	36		20	48	30		8	25	0		0	121	77		33

1 Plot 2 untreated includes combined data from both plots.
2 No untreated are in plot 3.
3 Trees that would have been killed if stand had been sanitized.

Table 4.--Basal area per acre by diameter class of trees on treated and untreated plots Grand Canyon National Park, 1950-70

	<6 inches		6-11 inches		12-23 inches		>23 inches		Total	
	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2	Plot 1	Plot 2
	Square feet									
TREATED PLOTS--										
Original stand, 1950:										
Dead	([1])	0.1	0.3	0.4	1.9	0.6	1.1	0.0	3.3	1.1
Infected	0.2	2.6	1.4	11.2	13.2	20.1	11.2	3.1	26.0	37.0
Uninfected	0.2	1.9	0.5	7.3	1.9	10.9	0.4	2.8	3.0	22.9
Intentionally killed	0.1	1.3	0.6	4.1	9.8	3.6	4.5	0.0	15.0	9.0
Left	0.3	3.1	1.4	14.5	5.2	27.4	7.0	5.9	13.9	50.9
1951-70:										
Ingrowth	0.1	1.4	0.1	0.2	0.0	0.0	0.0	0.0	0.2	1.6
Intentionally killed	0.1	0.6	0.4	3.2	1.7	5.3	1.5	0.0	3.7	9.1
Died	([1])	0.1	0.0	0.0	0.0	0.5	0.4	1.4	0.4	2.0
1970 stand:										
Infected	0.0	0.5	0.2	4.9	0.2	12.3	0.0	1.2	0.4	18.9
Uninfected	0.1	1.2	1.7	10.7	4.9	17.7	6.5	2.9	13.2	32.5
Total	0.1	1.7	1.9	15.6	5.1	30.0	6.5	4.1	13.6	51.4
UNTREATED PLOTS--										
Original stand, 1950:										
Dead	([1])	0.0	0.4	1.4	1.9	1.4	0.8	0.0	3.1	2.8
Infected	0.3	1.1	2.7	10.3	14.5	33.8	23.0	1.8	40.5	47.0
Uninfected	0.3	1.0	0.9	2.9	2.4	19.1	2.1	5.3	5.7	28.3
Kill[2]	0.1	0.2	1.0	4.1	5.4	13.9	11.7	0.0	18.2	18.2
Ingrowth, 1951-70	0.1	([1])	0.5	0.0	0.0	0.0	0.0	0.0	0.6	([1])
Died, 1951-70	0.1	0.4	0.9	2.7	4.6	7.9	8.2	0.0	13.8	11.0
1970 stand:										
Infected	0.2	1.0	2.8	10.1	13.0	36.1	17.5	3.6	33.5	50.8
Uninfected	0.1	0.6	1.2	1.9	1.3	17.3	2.1	3.8	4.7	23.6
Total	0.3	1.6	4.0	12.0	14.3	53.4	19.6	7.4	38.2	74.4
Kill[2]	0.1	0.5	1.8	6.9	7.6	18.7	11.3	0.0	20.8	26.1

1 Basal area less than 0.1 square foot.
2 Basal area that would have been killed if stand had been sanitized.

Plot 2 Series. — Three plots — a 2.62-acre treated plot, and two untreated plots of 1.25 (2A) and 1.05 acres (2B). This series was established to determine the effectiveness of control measures in heavily infected blackjack stands in the western portions of the area.

Plot 3. — One plot of 0.51 acre. This plot was established to study effectiveness of treatment in a single infestation center in a blackjack stand.

Plot 4 Series. — Two plots — a treated plot of 0.41 acre and an untreated plot of 0.52 acre on the Kaibab National Forest just south of the National Park boundary. This series was established to determine the effectiveness of control measures in heavily infected reproduction and pole stands.

Plot 5. — One plot of 0.1 acre. This plot was established to determine the effectiveness of control measures in severely infected dense reproduction.

Plot 6. — One plot of 4.80 acres. This plot was established to determine the rate of invasion of dwarf mistletoe through a mature untreated stand.

Study Plot Results

Plot 1 Series

The stand and disease characteristics in 1950 and 1970 on the treated and untreated plots in the heavily infected mature ponderosa pine forests in the eastern portion of the control area (figs. 3-5) are summarized in table 5. The plots were comparable before treatment in 1950: 78 percent of the trees infected with an average plot rating of 2.8 on the 6-class scale[4] on the treated plot, and 77 percent of the trees infected with an average plot rating of 2.7 on the untreated plot. In 1950, the number of dead standing trees killed by mistletoe was also similar on both plots: 22 on the treated plot, and 27 on the untreated plot.

In the original sanitation, 9.0 trees per acre were killed, and 7.1 pruned on the treated plot. Subsequently, 3.0 more trees per acre were killed. By 1970, 9.6 trees per acre remained, but 95 percent of these were mistletoe-free. In contrast, 7.6 trees per acre were killed by dwarf mistletoe on the check plot, and the proportion of trees infected increased from 77 to 79 percent. If the current mortality rate continues, the untreated stand will have lost more trees by about 1985 than were killed or died on the treated area, and the untreated area will still be heavily infected with dwarf mistletoe.

Perhaps the most meaningful comparison is the average plot mistletoe rating in 1950 and 1970. This figure, based on all live trees in the plot, gives a useful overall comparison of the amount of mistletoe present. The extent of infection on the untreated plot in 1970 (mistletoe rating 3.5) was about 35 times that on the treated plot (mistletoe rating 0.1).

To evaluate the ponderosa pine reproduction, 100 0.004-acre temporary microplots, spaced on a 1-chain grid, were established in both Plots 1 treated and untreated in 1972. The age of each tree under 4 inches d.b.h. was estimated to be more than, or less than, 20 years old by counting the number of branch or stem whorls. Reproduction in the treated plot was found to be free of infection (table 6) and so abundant that a well-stocked, esthetically pleasing ponderosa pine stand can be expected. On the untreated area, however, pine reproduction is already infected (8 percent of the trees under 20 years and 13 percent of those over 20 years). This stand will probably never reach maturity, and will have minimal recreational potential.

Reproduction over 20 years old is somewhat more abundant on the untreated plot (table 6) because most of the visibly infected trees were removed on the treated plot. The number of trees less than 20 years old, however, is over five times greater on the treated area. Also, reproduction on the treated area is more uniformly distributed. (Twice as many microplots had trees under 20 years old on the treated area.) Some possible explanations for this condition are: (1) The more abundant production of viable seed by mistletoe-free and lightly infected trees, (2) creation of better seedbed conditions due to exposure of mineral soil by control activities, and (3) the wider spacing between older trees allowing for better survival of young trees.

The original observation that Gambel oak was replacing the ponderosa pine type in some heavily infested areas of the park (Gill 1949) has not yet been documented. Data taken in 1972 on Plots 1 treated and untreated showed no significant difference in the number of oak sprouts or seedlings. A time period much longer than the 20 years covered by this examination will probably be necessary to establish the relationship between dwarf mistletoe control activities and oak populations.

[4] *For this 6-class rating system, the crown of each tree is divided horizontally into thirds (Hawksworth 1961). Each third is then given a rating of zero (no mistletoe), 1 (light mistletoe), or 2 (heavy mistletoe). The three ratings are then totaled to give a tree rating which may range from zero (no mistletoe) to 6 (each third of the crown heavily infected). The ratings of all live trees are then averaged to obtain a plot rating.*

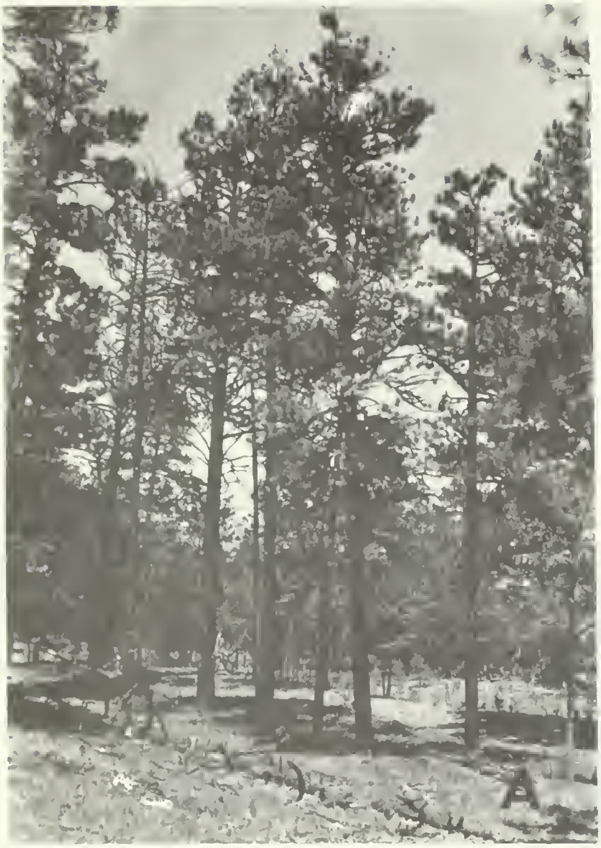
Figure 3.—
Plot 1 Treated, from the southeast corner:

A, 1949, before treatment;

B, fall of 1950, about a year after initial sanitation;

C, D, August 1971.

Note that reproduction has obscured the view in C; D was taken from about 15 feet above the original camera point.



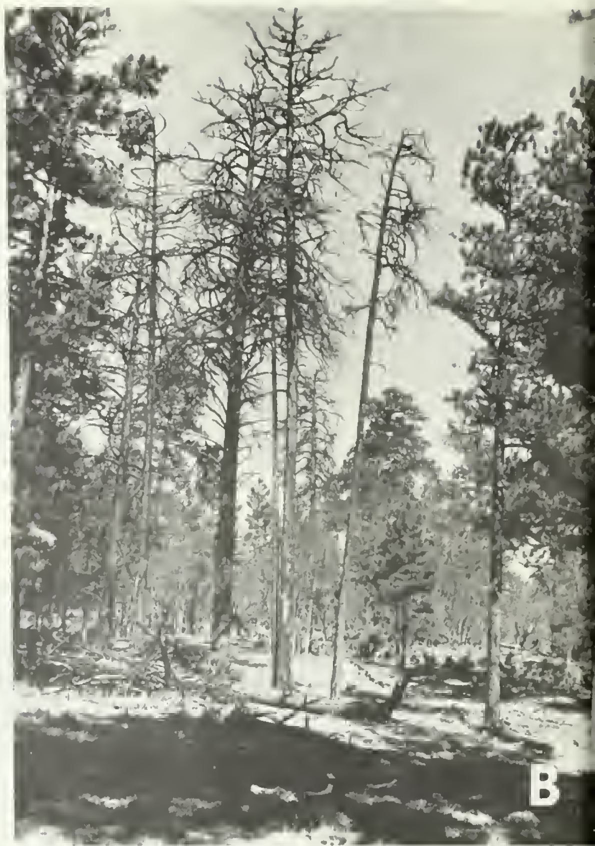


Figure 4.—
Plot 1 Untreated, near the southeast corner:

A, June 1950;

B, May 1955;

C, May 1971.

Figure 5.—Deterioration of the mature forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 1 Untreated:

A, June 1950;
B, May 1971;

C, June 1950;
D, May 1971.

Table 5.--Comparison (per-acre basis) of treated and untreated stands, Plots 1 and 2, Grand Canyon National Park, 1950-70

Plot description	Natural mortality of trees, 1950-70	Trees: Total	Trees: Healthy	Basal area: Total	Basal area: Healthy	Average d.b.h. live trees	Dwarf mistletoe rating
	No.	No.	Percent	Sq. ft.	Percent	Inches	
PLOT 1 (MATURE)							
Treated	0.5						
1950		20.7	22	29.0	10	13.5	2.8
1970		9.6	95	13.6	97	14.2	0.1
Difference		-11.1	+73	-15.4	+87	+ 0.7	-2.7
Untreated	7.6						
1950		29.0	23	46.1	12	14.5	2.7
1970		24.5	21	38.2	12	13.9	3.5
Difference		- 4.5	- 2	- 7.9	0	- 0.6	+0.8
PLOT 2 (BLACKJACK)							
Treated	1.9						
1950		106.7	39	22.8	38	9.2	1.7
1970		71.2	66	19.6	63	10.3	0.7
Difference		-35.5	+27	- 3.2	+25	+ 1.1	-1.1
Untreated	14.3						
1950		94.8	39	32.8	38	10.4	1.8
1970		80.9	28	32.3	32	11.5	2.9
Difference		-13.9	-11	- 0.5	- 6	+ 1.1	+1.1

Table 6.--Ponderosa pine reproduction (trees per acre under 4 inches d.b.h.) on Plot 1 series (based on 100 0.004-acre microplots on each plot)

	Total trees	Microplots with trees: Mean ± SE[1/]	Dwarf mistletoe-infected trees
	No.	- - Percent - -	
Trees less than 20 years old:			
Treated plot	510	46 ± 10	0
Untreated plot	95	20 ± 8	8
Trees more than 20 years old:			
Treated plot	235	23 ± 8	0
Untreated plot	415	37 ± 10	13

1/ Standard error.

Plot 2 Series

The stand and disease characteristics on the treated and untreated plots in the heavily infected blackjack stands in the western portions of the control area (figs. 6-7) are summarized in table 5. The plots were comparable before treatment in 1950: 61 percent of the trees were infected on both plots; the average plot mistletoe rating on the treated plot was 1.7 while that on the untreated plots was 1.8.

Since control started, 2 trees per acre on the treated plot have died of natural causes, and 21 trees per acre have been killed by treatment; 24 (34 percent) of the remaining trees were infected in 1970. On the untreated plots, 14 trees per acre have died, and 72 percent of the trees were infected in 1970. The average dwarf mistletoe rating was reduced from 1.7 in 1950 to 0.7 in 1970 by the control operations, but on the untreated plots the rating during this 20-year period increased from 1.8 to 2.9.

Control appears to have been less effective for this heavily infected blackjack stand than it was for the mature stand (Plot 1 Series). Additional considerations are necessary to understand this situation.

At the time of the 1970 examination, Plot 2 Treated had not yet received its scheduled fourth sanitation, and thus had not been treated since 1961. Fifty-two of the 63 trees now infected with dwarf mistletoe were infected in 1966 and should have been treated at that time. Had this been done, 12 trees would have been killed and the rest pruned. The number of trees showing new infections in 1970 would

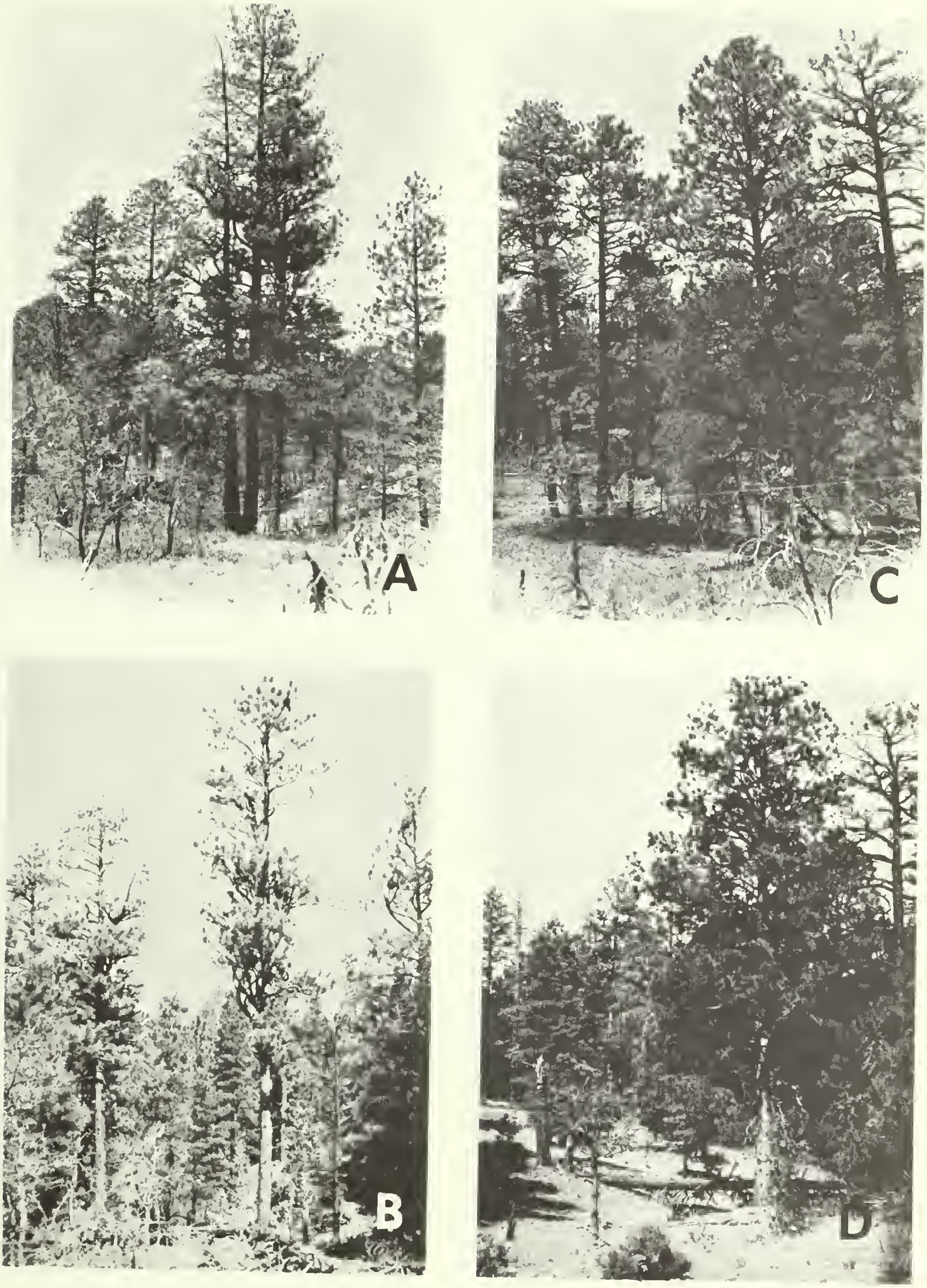


Figure 6.—Deterioration of the young forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 2A Untreated:

A, June 1950;
B, May 1971;

C, June 1950;
D, May 1971.

Figure 7.– Deterioration of the young forest, due to the effects of dwarf mistletoe, represented by two areas in Plot 2B Untreated:

A, June 1950;
B, May 1971 (note increase in height growth of Gambel oak);

C, June 1950;
D, May 1971.

undoubtedly have been reduced much below the 11 that were found, and the number of previously infected trees that are still infected would have been correspondingly lower.

What has happened on Plot 2 Treated is a good indication of what will happen when control efforts are stopped. A popular picnic area was installed in the northeast corner of this treated plot after its establishment. Without further treatment to control dwarf mistletoe, tree mortality in this area will accelerate. The stand adjacent to the picnic ground can be expected to become thin, and the foliage on the living trees will turn yellow. Its usefulness will, therefore, be greatly impaired, and it may eventually have to be abandoned because of the danger of dead trees falling on picnickers or their vehicles.

Plot 3

This single infestation center, in a 100-year-old blackjack stand, covered about 1/4 acre and involved 31 trees, 7 of which had been killed by dwarf mistletoe (see table 3). An additional 18 uninfected trees surrounding the center were included in the plot. In sanitizing this plot, 7 trees were killed and 16 pruned. One tree died in the 1950-70 period from causes other than mistletoe. Only three of the original trees in the center were infected in 1970, and there have been no newly infected trees. In 1950, 57 percent of the trees on the plot were infected, and the average plot mistletoe rating was 1.5. In 1970, 9 percent of the trees were infected and the average mistletoe rating was only 0.1. Control has clearly reduced the dwarf mistletoe population to an insignificant level.

Plot 4 Series

At the time of establishment, the treated plot contained groups of saplings, small poles, and very heavy reproduction in the south half (see table 3). The untreated stand differed in that there was much less reproduction, and some of the dominant trees were larger (see table 3). Dwarf mistletoe infection was comparable on the plots. The treated plot had 73 percent of the trees infected, and an average plot rating of 2.8; the untreated plot had 79 percent of the trees infected, and an average plot rating of 2.4.

No detailed comparison can be made between the plots because eight of the largest trees on the untreated plot on the Kaibab National Forest were cut in 1968. On the treated area, 258 trees per acre were killed during the original treatment in 1950, and an additional 241 trees per acre were killed in re-treatments, but only five other trees have died. Of the 141 trees per acre in 1970, 5 percent were infected, and the average plot mistletoe rating had been reduced from 2.8 in 1950 to 0.05. When the untreated plot was last examined in 1972, 104 trees per acre had died, and 88 percent of the remaining 96 trees per acre were dwarf mistletoe infected. The average plot rating increased from 2.4 in 1950 to 4.0 in 1972.

Even these marked differences do not portray the whole story, because the treated plot is now covered with a thrifty stand of young, mostly uninfected trees, whereas the untreated plot has virtually nothing but small dead and dying trees.

Plot 5

Although the overstory trees which were responsible for the infection were killed during treatment or died due to dwarf mistletoe, the reproduction was infected prior to treatment. In 1950 there were 3,250 trees per acre under 12 feet high on this plot. Forty-nine percent of these were infected, and most infected trees (1,200 per acre) were cut in 1950. Subsequent operations removed some additional trees. In 1972, only 2 percent of the remaining 1,370 trees per acre were infected. Thus the remaining stand of young trees is thrifty, and virtually free from dwarf mistletoe.

Plot 6

This plot is along the edge of the range of dwarf mistletoe about a mile from the canyon rim (see fig. 2). In 1952, 17 percent of the 251 trees on the plot were infected, and the average plot mistletoe rating was 0.4. In 1972, 34 percent of the trees were infected and the average plot rating had risen to 1.1. Detailed analyses on the rate of spread of dwarf mistletoe on this plot will be published elsewhere.

Analysis of Untreated Plots

Analysis of the data from the untreated plots (1, 2, 4, and 6) provides an insight into behavior of dwarf mistletoe on the South Rim.

A plot of the 20-year change in average basal area per tree for trees uninfected, and the six mistletoe infection classes, in 1950 (fig. 8)

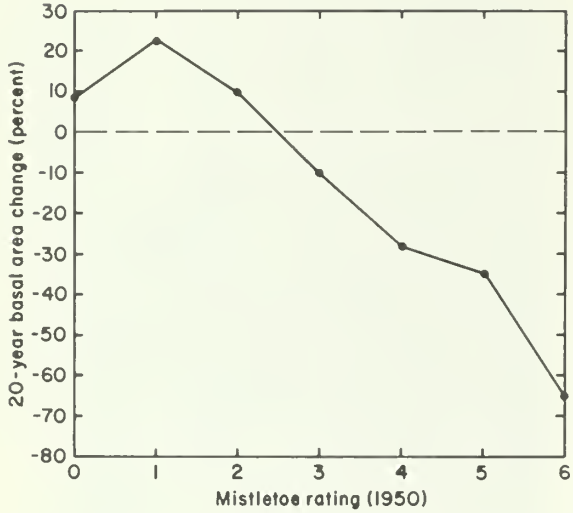


Figure 8.—
Comporison of the 20-year bosol oreo growth of 864 trees of vorious dworf mistletoe infection closses on the untreoted plots.

shows the effects of dwarf mistletoe on growth rate and mortality combined. The data are similar to the 11-year results on these plots published by Lightle (1966). The figures were obtained by dividing the total living basal area in 1950 and 1970 by the number of trees in each infection class in 1950. Uninfected trees and those in infection classes 1 and 2 increased in basal area by 10 to 20 percent during the period. Average basal area per tree fell below the 1950 level between infection classes 2 and 3, and decreased markedly in higher infection classes, reaching 65 percent less in class 6. The larger basal area change in infection class 1 over that of uninfected trees is due to their larger size, and not to stimulation by dwarf mistletoe. The trees in infection class 1 averaged about 1 inch in diameter larger than the uninfected trees in 1950.

Mortality during the 20-year period was directly related to intensity of dwarf mistletoe:

Dwarf mistletoe rating (1950)	Tree basis (Number)	Mortality between 1950 and 1970 (Percent)
0	361	4
1	88	3
2	83	12
3	59	27
4	46	37
5	62	42
6	60	63

Mortality rate in heavily infected (class 6) trees was more than 15 times that of healthy trees. The life expectancy of class 6 trees averages about 30 years, but will vary according to the sizes and ages of the trees.

Dwarf mistletoe intensified rapidly in the mature trees on untreated Plots 1 and 6. Mistletoe ratings of trees in classes 1 through 4 in 1950 advanced to the next higher rating in about 9 years. This is somewhat faster than other areas in the southwest that have been studied.

CONCLUSIONS

The conclusions drawn here apply to the original control area first sanitized in 1949-52, and to extension area A first treated in 1956-57. The control on extension area B has been too recent (1966-69) to evaluate its effectiveness.

Dwarf mistletoe populations in the treated plots were markedly reduced. For example, on the Plot 1 Series, the extent of dwarf mistletoe infestation (based on average plot mistletoe ratings) after 20 years is over 35 times as high on the untreated as on the treated plot.

In detailed examinations of the control area in 1965 by several Park Service personnel and the senior author, only 287 infected trees were found in an area of about 750 acres during 25 man-hours of intensive searching. These infected trees were generally in small groups, and lightly infected, usually with only one or two dwarf mistletoe plants per tree.

The results from the permanent plots plus examinations of the control area outside the plots clearly indicate that the original goal of the project—to reduce the level of dwarf mistletoe and protect the ponderosa pine forest—has been achieved. This has generally been accomplished without undue alteration of, or disturbance to, the ponderosa pine stands within the treated area. These stands are now thrifty, relatively free of dwarf mistletoe, and contain ample reproduction to insure the perpetuation of ponderosa pine along the scenic East Rim Drive.

SUGGESTIONS FOR DWARF MISTLETOE CONTROL IN RECREATIONAL FORESTS

The 20-year results of the Grand Canyon control project have yielded much information that may be useful in future operations in recreational forests.

1. In general, pruning should be limited to lightly infected trees (classes 1 or 2). Removal of more than 50 percent of the live crown is not recommended. The number and extent of sanitations necessary is directly related to the proportion of trees pruned initially. In the initial sanitation of the original control area, more than half of the trees were pruned in an attempt to save as many trees as possible. This necessitated many subsequent recleanings, because most trees had to be repruned, some of them two, three, or even four times. Also, pruned trees frequently developed so much reinfection that they had to be killed later. We suggest that the more recent operations, in which about 20 to 30 percent of the trees were pruned, were more successful because pruning was limited to lightly infected trees. Successful elimination of dwarf mistletoe by pruning is strongly correlated with amount of infection in the tree at the time of the initial operation because many pruned trees have to be killed later:

Original dwarf mistletoe rating	Proportion of pruned trees alive 20 years later (Percent)
1	70
2	50
3	40
4	10

2. Pruning should be confined, as far as possible, to the more isolated trees. Pruning even lightly infected residual trees in once heavily infected groups of pole-sized trees was generally unsuccessful. In such situations nearly all the pruned trees had to be repruned, and half of them were so heavily infected that they had to be killed.

3. In pruning, the infected branch should be cut off at the bole. Although it may at first appear easier to remove infected secondary or tertiary branches, the high incidence of latent dwarf mistletoe in the remaining branches makes this practice questionable. In most cases the branch has to be removed in subsequent prunings.

4. If large portions of the crown are removed by pruning, isolated living branches should not be left. Even though dwarf mistletoe may not be apparent in such branches, they almost invariably harbor incipient infections. Where it is possible to do so without removing too many branches, pruning for two or three whorls above the highest visible mistletoe should eliminate many latent infections and thus save a considerable amount of time in subsequent sanitations.

5. Prunability of branches is related to branch diameter. The rule applied in the early work — that trees with infections within 18 inches of the main stem (later reduced to 12 inches) were not considered to be prunable — has been found to be too restrictive. Extent of the endophytic (or root) system of ponderosa pine dwarf mistletoe is now known to be as follows (Hawksworth and Andrews 1965):

Branch diameter at bole	Minimum safe distance from bole to closest shoots (Inches)
Under 1 inch	6
1 to 2 inches	8
2 to 3 inches	10
3 to 4 inches	12

This guide need not be followed if the bole diameter at the infected branch is 8 inches or more (see suggestion number 6).

6. Not all trees with bole infections need be killed. The original guides suggested that trees larger than 12 inches in diameter did not need to be killed merely because they had infections in the main stem. This was based on the observation that infections on the boles of large trees are usually not vigorous, and therefore are negligible sources of infection to surrounding trees. Research is now underway to determine more precisely the relationship between diameter and vigor of bole infections. We tentatively suggest, however, that trees with infections on the bole, where the diameter at the point of infection is over 8 inches, offer very little threat to surrounding trees and need not be sacrificed.

7. Pruning heavily infected trees will prolong their life. We made a small study to determine the extent to which heavily infected trees would recover if the infected branches were pruned out. These heavily infected trees were usually of infection class 4 or even 5, and would have been killed in accordance with the marking rules for the rest of the control area. A series of 45 trees were pruned in 1950. Many of these were so severely infected that the tops of the crowns were thin and off-color due to the effects of the parasite. The results (figs. 9-10) show that such trees can recover, even

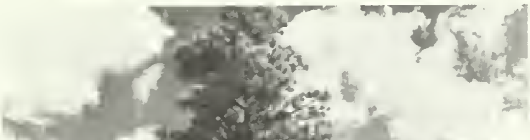


Figure 9.—

Increased vigor of a 17-inch d.b.h. black-jack tree 11 years after removal of dwarf mistletoe-infected branches:

A, June 1950, before pruning;

B, June 1952, after pruning;

C, September 1961.

Note the difference in crown density and needle length between A and C.

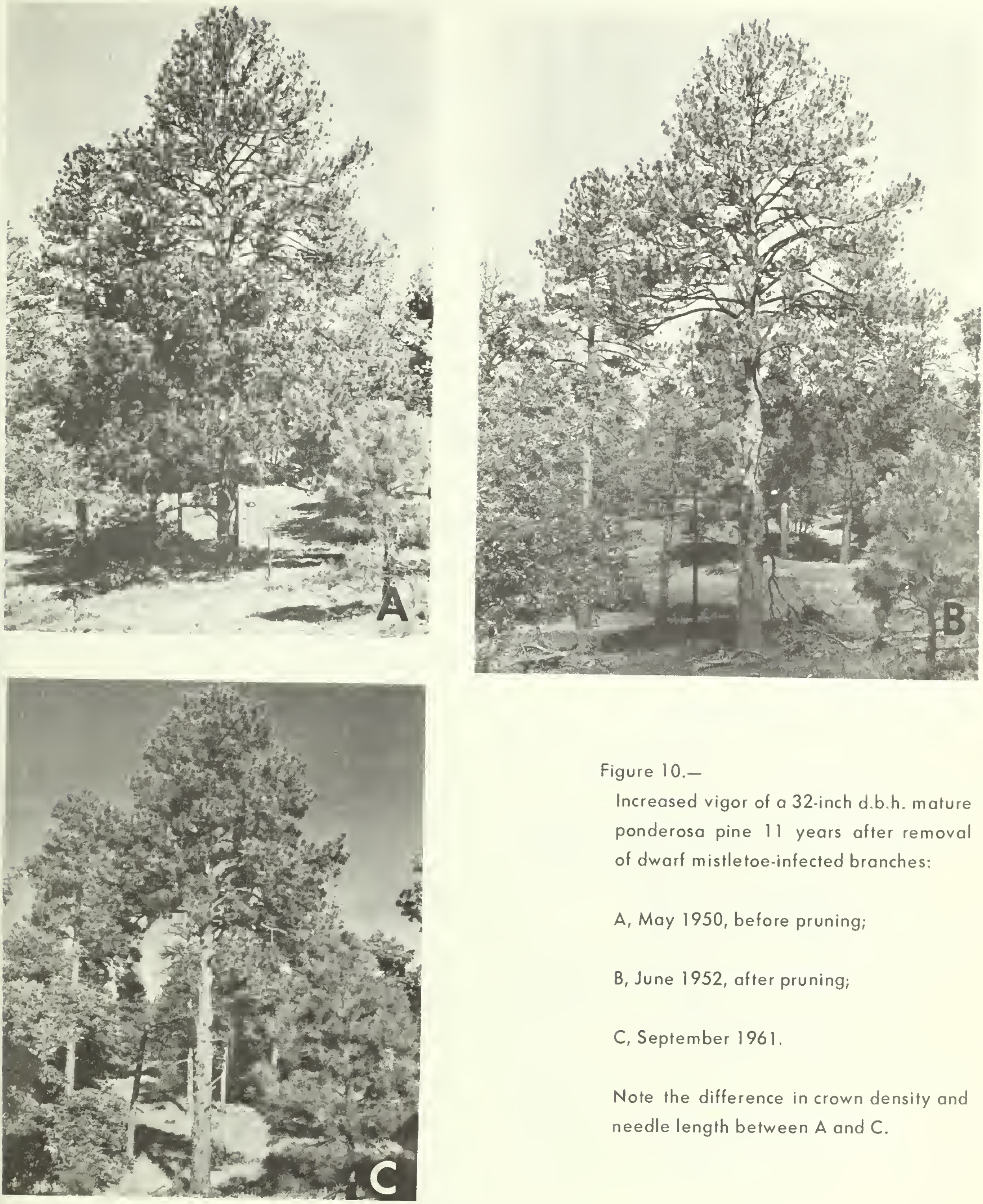


Figure 10.—
Increased vigor of a 32-inch d.b.h. mature ponderosa pine 11 years after removal of dwarf mistletoe-infected branches:

A, May 1950, before pruning;

B, June 1952, after pruning;

C, September 1961.

Note the difference in crown density and needle length between A and C.

though dwarf mistletoe is not necessarily eliminated from them. By removing the lower infected branches which are seriously reducing the vitality of the tree, the life span of the tree can be prolonged considerably. While such drastic pruning is not recommended as a routine control measure, it can be used to lengthen the life of particularly valuable or needed trees.

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Southwestern dwarf mistletoe has been a problem in ponderosa pine on the South Rim of Grand Canyon for many decades. The National Park Service program to control the parasite, begun in 1949, was the first large-scale attempt to control dwarf mistletoe in a recreational forest. The area has been sanitized at about 5-year intervals since the initial treatment. This Paper describes the control effort, and compares the treated and untreated stands after 20 years. The original goal of the project—to reduce the level of dwarf mistletoe and protect the ponderosa pine forest—has been achieved. Recommendations for dwarf mistletoe control in recreational forests, based on knowledge gained from this project, are summarized.

Oxford: 443.3:412. **Keywords:** Dwarf mistletoe control, recreational forests, silvicultural control, *Arceuthobium vaginatum* subsp. *cryptopodum, Pinus ponderosa.*

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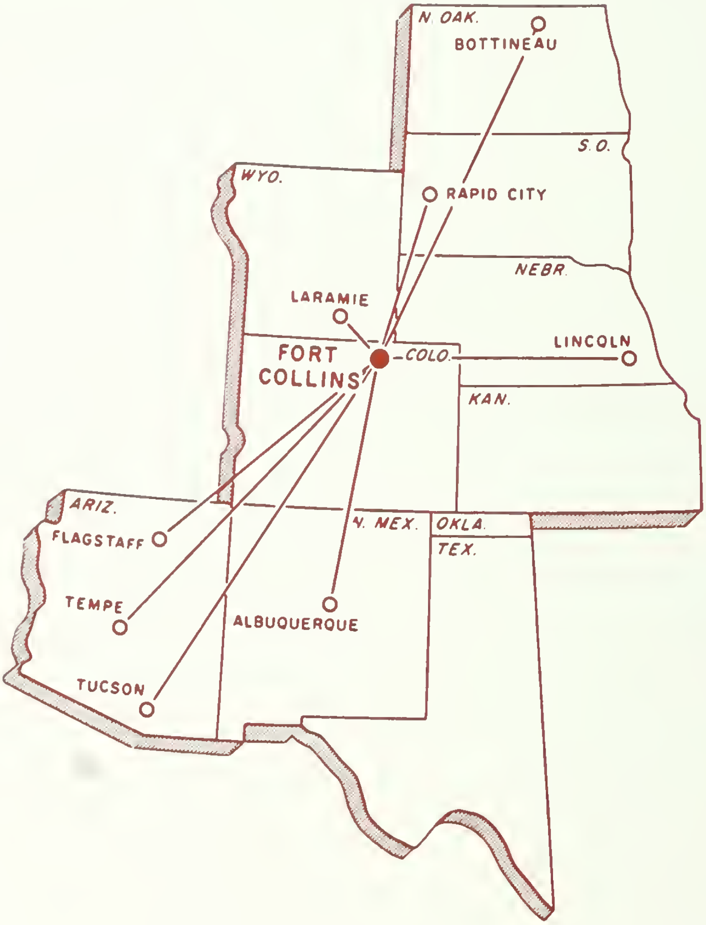
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Hydrologic Simulation Model of Colorado Subalpine Forest

by Charles F. Leaf and Glen E. Brink

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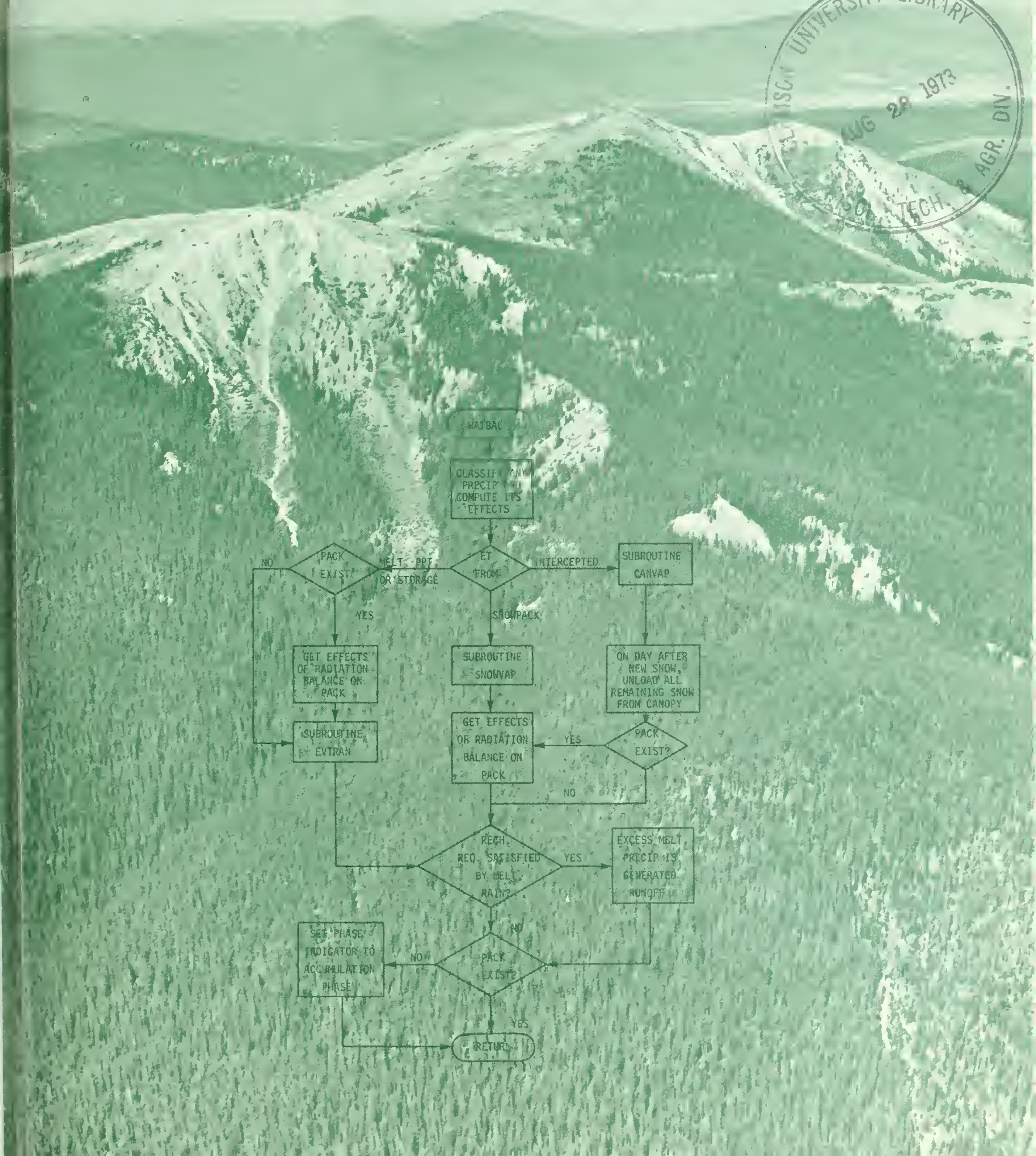

Abstract

A simulation model specifically designed to determine the probable hydrologic changes resulting from watershed management in the Colorado subalpine zone is described. The model simulates the total water balance on a continuous year-round basis and compiles the results from individual hydrologic response units into a "composite overview" of an entire drainage basin. Preliminary results are summarized for an 8-year test period on a 667-acre experimental watershed.

Oxford: 116.21:U681.3. **Keywords:** Computer models, coniferous forest, forest management, model studies, simulation analysis, snowmelt, subalpine hydrology, vegetation effects, watershed management.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

USDA Forest Service
Research Paper RM-107

May. 1973

Hydrologic Simulation Model of Colorado Subalpine Forest

by

Charles F. Leaf, Hydraulic Engineer
and
Glen E. Brink, Computer Programer

Rocky Mountain Forest and Range Experiment Station[1]

[1] *Central headquarters maintained at Fort Collins in cooperation with Colorado State University. Research was conducted and partly financed in cooperation with the Division of Atmospheric Water Resources Management, Bureau of Reclamation, U.S. Department of the Interior.*

Contents

Hydrologic Simulation Model of Colorado Subalpine Forest

Charles F. Leaf and Glen E. Brink

Leaf and Brink (1973) have previously described a model for simulating snowmelt in central Colorado subalpine watersheds. Snowmelt over an area is described in terms of combinations of aspect, slope, elevation, and forest cover composition and density.

The hydrologic model described in this report is an expanded version of the snowmelt model. The model has been programed for the CDC 6400 computer at Colorado State University. It is designed to simulate the total water balance on a continuous, year-round basis, and to compile the results from individual hydrologic subunits into a "composite overview" of an entire watershed. The model has been designed to simulate watershed management practices and their resultant effects on the behavior of hydrologic systems. The model consists of (1) a "core" which performs the actual simulation, and (2) peripheral routines which specify hydrologic subunit parameters, obtain the input data, maintain continuity between simulation intervals, and output the results.

Figure 1 schematically shows the general flow of the model. Detailed flow chart descriptions of the water balance routines and pertinent hydrologic theory are presented in this report. Those routines which were incorporated from the snowmelt model without significant changes are not discussed here. Complete descriptions of the unrevised routines are given in Leaf and Brink (1973). The routines which were taken from the snowmelt model and

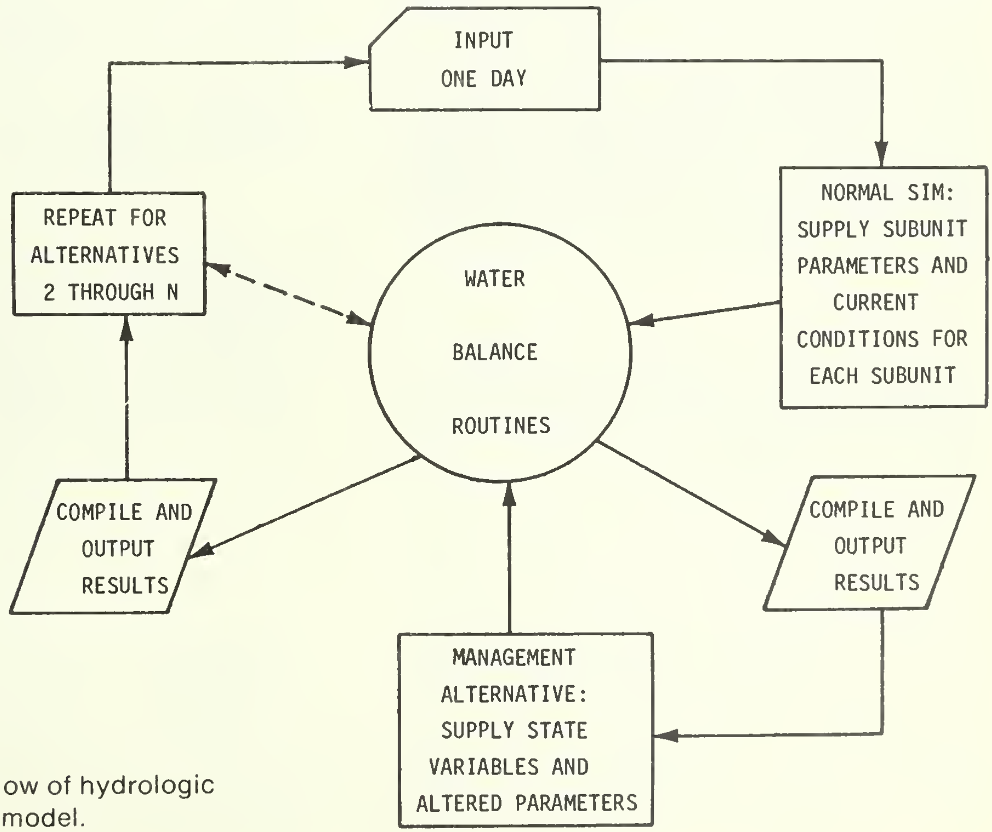

Figure 1. — General flow of hydrologic simulation model.

altered for compatibility with the water balance model are indicated by an asterisk (*) in the following tabulation.

Discussed in this report

WATBAL*
CANVAP
SNOWVAP
EVTRAN
RADBAL*
SNOWED*

Discussed in Leaf and Brink (1973)

AFFECTS
CALIN
CALOSS
DIFMOD
GETREF (now PACKREF)
LINK
MIXTURE
RAINED

Subroutine WATBAL (fig.2)

Subroutine AFFECTS from the snowmelt model (Leaf and Brink 1973) was expanded to include the decisions relating to evapotranspiration, and was renamed WATBAL. WATBAL is the primary routine in the water balance model. It receives input on a daily basis, the subunit parameters, and all state variables computed by the peripheral routines. (The only links between WATBAL and the peripheral routines are common block /WATRBAL/ and the formal parameters passed at the time of the call.)

Precipitation

Precipitation (if any) is classified as discussed in AFFECTS (Leaf and Brink 1973), and the degree to which it affects the energy balance is calculated.

Evapotranspiration

Morton (1971) points out that "the relationship between potential evaporation and regional (actual) evaporation includes the effects of hydrologic and climatologic feedback." The feedback includes moisture supply and the thermal and moisture characteristics of the overlying air, which are influenced by the actual evapotranspiration. This interaction in turn has a significant influence on the energy available for evapotranspiration.

These interactions have also been taken into account by Bouchet (1963), who argued that changes in regional and potential evaporation due to changes in regional moisture supply are complementary. If the potential evapotranspiration (ET) is computed from regional climatological observations and utilized in this concept, the regional (actual) evapotranspiration, which is a product of complex climatic, soil moisture, and vegetative processes may be estimated.

Of the several empirical methods available for computing potential evapotranspiration, the one developed by

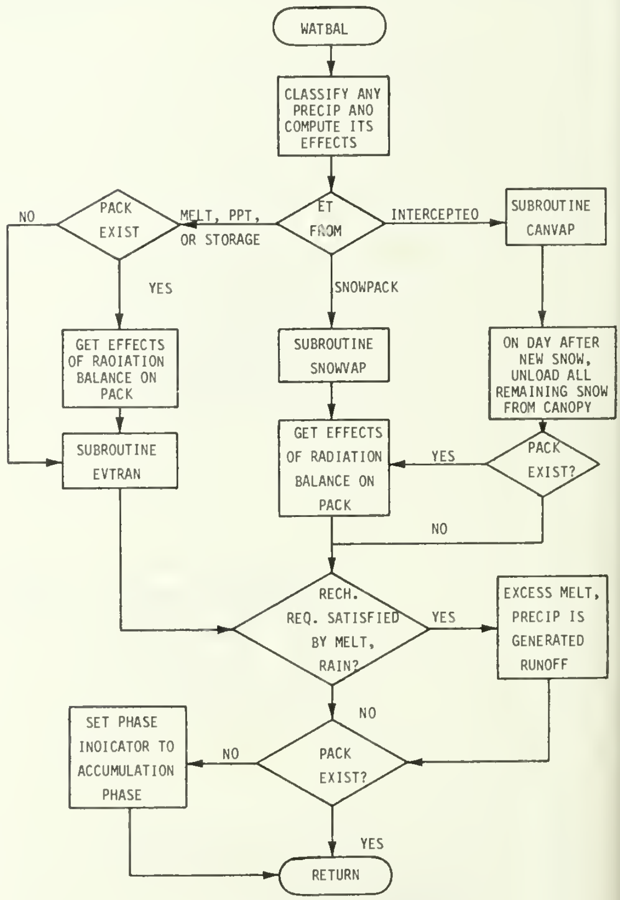

Figure 2. — Subroutine WATBAL.

Hamon (1961) appears to give the best results (Stephens and Stewart 1963, Russell and Boggess 1964, Takhar and Rudge 1970). Hamon formulated the expression:

$$E_h = CD^2P_t \qquad [1]$$

for computing average potential evapotranspiration, E_h (inches/day), for each month of the year
where

D = possible sunshine in units of 12 hours,
P_t = The saturated water vapor density (absolute humidity) at the daily mean temperature in grams per cubic meter, and
C = a coefficient (0.0055 according to Hamon).

Hamon's equation requires only latitude, converted to day length (adjusted for slope and aspect), and mean temperature, converted to saturation vapor density, for computing monthly E_h.

Equation [1] predicts the "average" evapotranspiration. In the Colorado subalpine zone, this average is less than half the amount that could occur under conditions of unlimited energy supply, assumed herein as potential solar radiation. Accordingly, the coefficient C in equation [1] was empirically adjusted upward to obtain an expression for potential evapotranspiration under maximum solar input:

$$E_m = C'D^2P_t \qquad [2]$$

where C' is the adjusted coefficient. The daily potential evapotranspiration for each of 12 months as derived by equation [2] is supplied as a set of parameters for each hydrologic subunit.

To adjust maximum daily evapotranspiration for available energy, the values determined by equation [2] were modified according to the expression

$$E_s = \frac{SW}{P} E_m \qquad [3]$$

where
E_s = evapotranspiration adjusted for available energy in inches/day,
SW = the observed daily shortwave radiation in langleys,
P = potential shortwave radiation for the day as computed by Frank and Lee (1966).

In the water balance routines, the adjusted evapotranspiration as derived above is then redefined, depending on the source, as selected by the following sequence:

1. If snow is intercepted on the forest canopy, evaporation occurs exclusively from that source and is computed by subroutine CANVAP.

2. If the canopy is free of snow, the next step in the source selection is to determine if losses result from evapotranspiration (see subroutine EVTRAN) or evaporation from the snowpack surface (see subroutine SNOWVAP). If evaporation is from the snow surface or from intercepted snow, control then passes to the radiation balance routines. If a snowpack exists, the radiation routines generate any possible melt for input; otherwise, the only input that can result is from a rain event. Subroutine EVTRAN then calculates the evapotranspiration requirements, which are taken first from the input and, if not satisfied, from the soil mantle storage.

The various methods of computing evaporation and transpiration are discussed in the descriptions of the subroutines named above.

Once the evapotranspiration requirements have been satisfied, any remaining input, either from snowmelt or rainfall, is used to satisfy the soil mantle recharge requirements (see subroutine EVTRAN). When field capacity is reached, the excess input is considered to be water available for streamflow (generated runoff).

As explained later in this report, subroutine RADBAL includes a phase indicator that determines which of two methods is to be used to compute the effects of the radiation balance. When the seasonal snowpack is completely melted, the phase indicator is reset to the "accumulation phase." It remains at that setting until certain conditions specified in subroutine RADBAL are met; it then returns to the "melt phase" setting. Upon completion of the water balance calculations, WATBAL returns the results and the new values for the state variables to the calling routine. Here, they are weighted according to the percent of the total area occupied by the various hydrologic subunits. These weighted values are then summed to generate the watershed composite.

Subroutine CANVAP (fig. 3)

Hoover and Leaf (1967), Hoover (1969), and Hoover (in press),[2] have discussed the process and significance of interception loss in central Colorado subalpine forests. Field studies indicate that mechanical removal of intercepted snow by wind is an important phenomenon. Accordingly, wind effects were considered in the snow interception subroutine.

In developing this portion of the model, the following assumptions were made:

1. The amount of snow intercepted varies according to forest cover type and density;
2. The intercepted snow rests on the canopy for only 1 day following the day of the snow event because turbulent winds remove the snow from the crowns; and
3. The residual intercepted snow which is not vaporized after 1 day is added to the snowpack.

The amount of snow intercepted by spruce-fir was assumed to vary as

$$P_{if} = 0.15 \frac{C_d}{C_{dmx}} I_s \qquad [4]$$

where

P_{if} = water equivalent of intercepted snow in inches

I_s = water equivalent input which occurs as snow in inches,

C_{dmx} = natural forest cover density, expressed as a decimal, and

C_d = reduced forest cover density, as a decimal.

Interception in lodgepole pine is given by the equation

$$P_{ip} = 0.10 \frac{C_d}{C_{dmx}} I_s \qquad [5]$$

The assumed maximum amounts of snow interception are 0.2 and 0.3 inch for lodgepole pine and spruce-fir, respectively. Snowfall inputs which exceed the above values are added to the snowpack.

Vaporization of intercepted snow on foliage surfaces is assumed to vary as a function of forest cover density, C_d, and evapotranspiration is adjusted for available energy (equation 3) as follows:

$$V_c = \frac{1}{C_d} E_s \qquad [6]$$

where

V_c = intercepted snow evaporation in inches,

$C_d > 0$

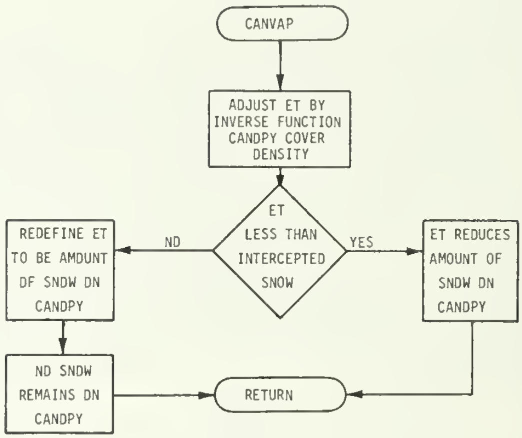

Figure 3. — Subroutine CANVAP.

If equation [6] yields a value which is less than the water equivalent of the intercepted snow, that water equivalent is merely reduced to satisfy the evaporation requirement, V_c. However, if equation [6] indicates a greater value than the intercepted water equivalent, V_c is reduced to the point where the requirement is satisfied by the water equivalent of the snow, which is completely vaporized from the canopy.

Subroutine SNOWVAP (fig. 4)

During conditions when the canopy is free of snow, that is, when time since the beginning of the last snowfall event is greater than 2 days, it is assumed that evaporation from the snowpack beneath the trees, V_s, takes place according to the relation

$$V_s = (1 - C_d) E_s \qquad [7]$$

when

C_d = 0(a forest opening),

$V_s = E_s$

[2] *Hoover, Marvin D. Snow interception and redistribution in the forest. Third Int. Seminar for Hydrol. Professors [Purdue Univ., Lafayette, Ind., July 1971] (in press).*

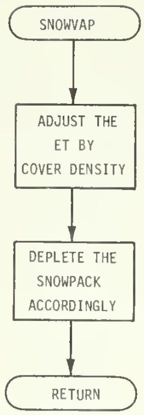

Figure 4. — Subroutine SNOWVAP.

Subroutine EVTRAN (fig. 5)

Available Soil Water Correction

There has been some work with crops and forest ecosystems to indicate that transpiration decreases as available water decreases (Denmead and Shaw 1962, Cowan 1965, Swanson 1967, Swanson 1969). Accordingly, equation [3] was further adjusted to account for available soil water. Denmead and Shaw (1962) point out that, in porous soils, the decline should not be pronounced until most of the "available water" is removed. Because subalpine soils are coarse textured (Retzer, 1962), it was assumed that transpiration of

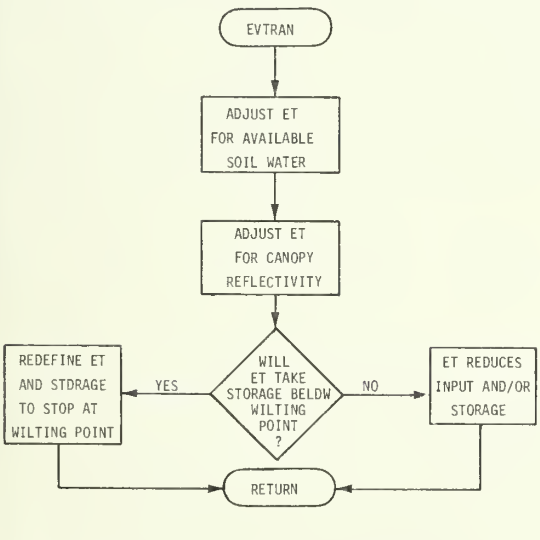

Figure 5. — Subroutine EVTRAN.

dense forest cover would proceed at rates given by equation [3] until the soil water is depleted to 50 percent of field capacity. Thereafter, transpiration is decreased in proportion to the amount of available soil water below one-half of field capacity. In open cutover areas, it was reasoned that the absence of dense vegetation would enable transpiration to proceed at rates given by equation [3] only when soil is at field capacity. In the model, it was assumed that the available soil water (mantle storage) is 5.3 inches in both the forest and open, based on an assumed average rooting depth of 4 feet, and a "wilting point" and "field capacity" of 4 percent and 15 percent by volume, respectively. Thus, equation [3] was expanded to obtain "actual" evapotranspiration in the forest, E_a, and in the open, E_{ao}, during the growing season as follows:

For Forest:

$$E_{af} = (1 - R_f)\ (0.377M)\ (E_s) \qquad [8]$$

For Open:

$$E_{ao} = (1 - R_f)\ (0.755M - 3)\ (E_s) \qquad [8a]$$

where

M = "available" mantle storage. When M exceeds 5.3 and 2.65 inches in the open and forest, respectively, evapotranspiration is computed by equation [3], and

R_f = reflectivity of the forest stand or open area as discussed below.

Radiation Balance and Evapotranspiration According to Forest Cover Density

Baumgartner (1967) and Tajchman (1971) have reported that evapotranspiration from coniferous forests is greater than from open land, although Tajchman reported smaller differences between forest and open land than did Baumgartner. Both Baumgartner and Tajchman discussed the differences in evapotranspiration from various cover types in terms of the differing energy balances. In presenting an analysis of the radiation balance and associated vapor loss, Baumgartner (1967) pointed out that "the only pertinent variations with regard to the latent heat flux are those associated with reflectivity . . . " Accordingly, a relationship was derived between reflectivity and forest cover density (Leaf and Brink 1973) to index the reduction of evapotranspiration as forest cover is removed. For lack of any field data, the following tentative relationships were assumed:

$$R_f = 0.5 - \frac{0.75\ C_d}{C_{dmx}} \qquad [9]$$

where

R_f = the reflectivity of the forest stand,
C_{dmx} = natural forest cover density, expressed as a decimal, and
C_d = reduced forest cover density, as a decimal.

Equation [9] only applies when $C_d \leq \frac{C_{dmx}}{3}$.

When $C_d > \frac{C_{dmx}}{3}$, the reflectivity is given by

$$R_f = 0.25 - \frac{0.15}{0.67C_{dmx}}\ (C_d - 0.33C_{dmx}) \qquad [10]$$

The relationship given by equations [9] and [10] is plotted in figure 6. Note that when cover density $C_d = C_{dmx}$, $R_f = 0.1$, whereas when $C_d = 0$, $R_f = 0.5$. These values qualitatively agree with values given by Baumgartner (1967), who summarized variations of absorption coefficient for several cover types, and Burroughs (1971), who developed a shortwave reflectivity model for lodgepole pine forest which accounts for varying stand characteristics and season of the year.

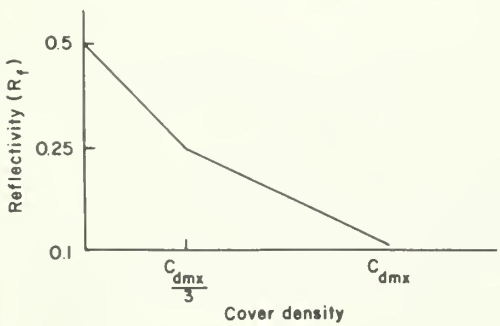

Figure 6. — Assumed variation of reflectivity (R_f) as a function of forest canopy density(C_d).

Seasonal Course of Transpiration

Swanson (1967) observed that transpiration can occur early in the snowmelt runoff season when there is still considerable snow cover. At the Fraser Experimental Forest, during the first week in May 1965, he observed a sharp upturn in sap flow when the snow cover still held an average of more than 5 inches of residual water equivalent. Accordingly, a threshold water equivalent was assumed in the model after which evapotranspiration is allowed to occur. This threshold is tentatively estimated to be 5 inches. Evapotranspiration is computed by equations [8] or [8a] above, and varies according to available energy, E_s, available mantle storage, M, and reflectivity, R_f, all of which have been discussed previously.

Once the evapotranspiration requirements have been established by the above adjustments, they are satisfied first from the input and then from the soil mantle storage. If the requirements would deplete storage below the wilting point, however, all values are adjusted to cause evapotranspiration to cease at that point.

During the winter, evapotranspiration is computed by equations [8] or [8a], provided the forest canopy is free of snow and the snowpack water equivalent is less than the critical 5 inches. When the snowpack exceeds 5 inches, only evaporation from intercepted snow and from the snow surface takes place.

Subroutine RADBAL (fig. 7)

This routine is essentially identical to the routine by the same name in the snowmelt model (Leaf and Brink 1973). The only changes necessary were to modify the calculations for year-round processing. Hence, the modification in RADBAL consists of a phase switch, which indicates optional methods of computing the radiation balance.

During the fall and winter before the diffusion model achieves mathematical stability (Leaf and Brink 1973), only shortwave radiation is used to compute snowmelt. Therefore, the only cold content in the snowpack results from newly fallen snow. (To insure snowpack accumulation during this phase, snowmelt is not "allowed" to take place on days when the mean air temperature is below 0° C.). Once the snowpack depth is sufficient for diffusion model stability (4.7 inches of water equivalent), the phase switch is reset to compute snowmelt according to the snowmelt simulation model (Leaf and Brink

1973). In other words, when the snowpack reaches the specified depth in the early winter, the switch is set to "melt when ready." The snowpack will continue to accumulate in this phase until the normal all-wave radiation balance produces snowmelt. The switch is reset to the snow accumulation phase at the end of the snowmelt season (when snowpack water equivalent is zero).

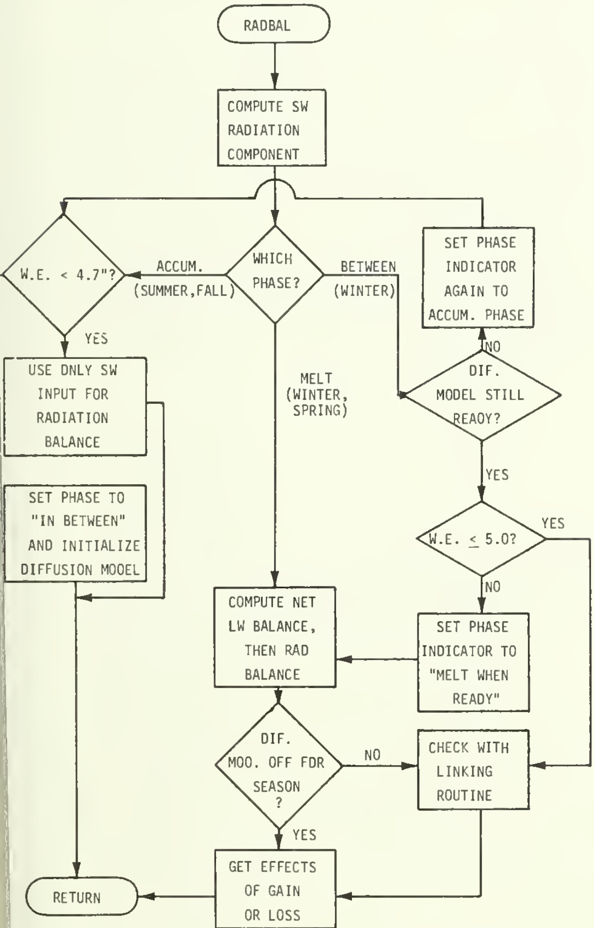

Figure 7. — Subroutine RADBAL.

Subroutine SNOWED (fig. 8)

The only difference between this routine and its counterpart in the snowmelt model (Leaf and Brink 1973) is the inclusion of interception calculations. The amount of snow intercepted on a given day is computed as a percentage, which is determined by the

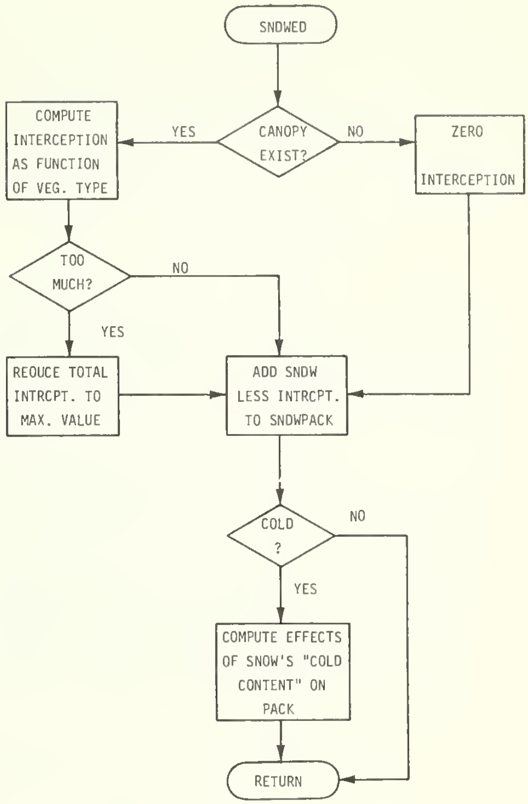

Figure 8. — Subroutine SNOWED.

vegetation type as discussed in subroutine CANVAP. The total amount which may remain on the canopy after several consecutive snow events is also determined by vegetation type.

Peripheral Routines

The peripheral routines are not flowcharted or discussed in detail on an individual basis, since they are primarily utility routines for input, output, and maintenance of continuity between simulation intervals. Subroutines GENDATA, RADCOMP, and RDMSTR are all concerned with input, and use various analyses to generate the daily input for each substation from observed base station data. Subroutines ETCODE and PLOTTER are output routines which aid in the interpretation of results.

All of the above routines are utilized on each run of the model, but to save time and core, most output options are included as overlays, only one of which is selected at a time to occupy core and process the data. Each overlay consists of a control routine, a normal simulation routine, a write routine, and any watershed management alternative simulation routines that may be needed.

A complete listing of the model described in this report is included in the appendix.

Applications

We have used the hydrologic model to simulate area snowmelt and water yield from the 667-acre Deadhorse Creek watershed at the Fraser Experimental Forest (Leaf 1971; Leaf and Brink 1972, 1973). Physical characteristics of this watershed vary from low-elevation (9,300 ft. m.s.l.) south slopes in lodgepole pine forest to high-elevation (11,000 ft.) north slopes in spruce-fir. Simulations from 10 subunits on the basin were weighted according to the percentage of the total area each represents to generate the watershed composite. Each subunit was selected according to forest cover type and density, slope, aspect, and average elevation. Simulations of the 1963-70 water years (October 1 to September 30) indicate to us that the model represents the inherent hydrologic characteristics of Colorado subalpine watersheds. Sample output in the form of 10-day summations for the 1967 water year is shown in table 1. Figure 9 summarizes 10-day fluctuations of several hydrologic variables for the 1965 water year. Figure 10 compares simulated and observed annual water yields from Deadhorse Creek for the 1964-71 record period.

We have predicted the change in rate and seasonal time distribution of snowmelt resulting from clearcutting small openings in old-growth forest with the snowmelt portion of the model (Leaf and Brink 1972). With the increased water balance simulation capability, we plan to develop the model into a useful tool for predicting the hydrologic consequences of several resource management practices. In the Colorado subalpine zone, these include weather modification and timber harvesting.

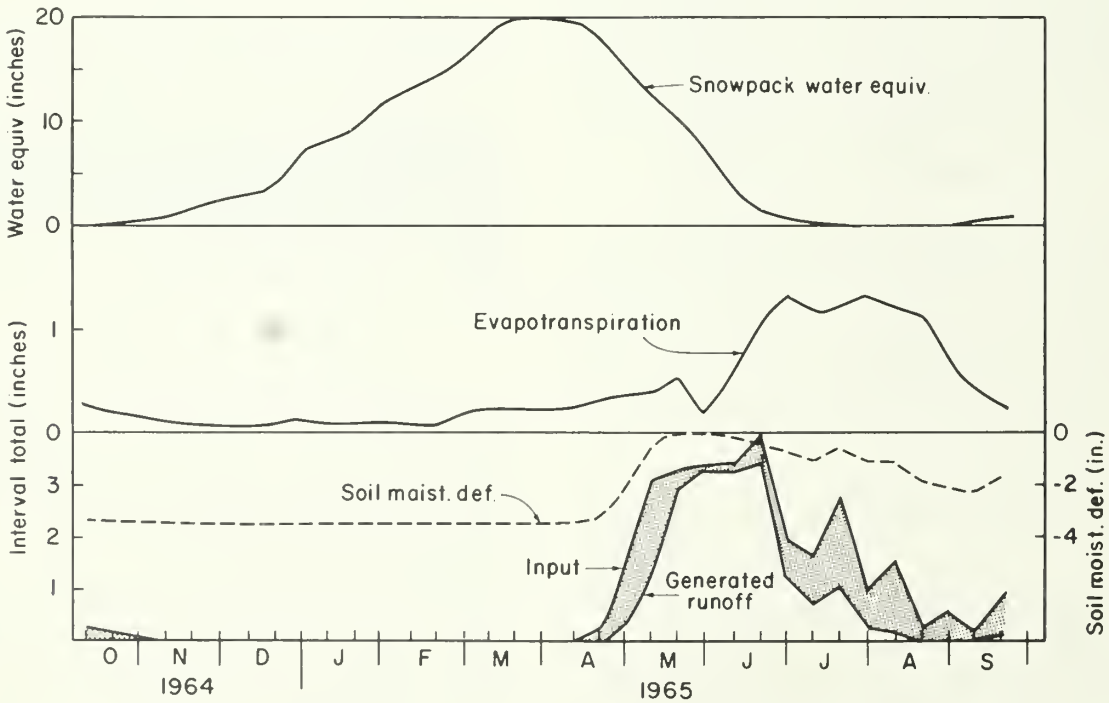

Figure 9. — Simulated 10-day fluctuations of several hydrologic components during the 1965 water year on Deadhorse Creek, Fraser Experimental Forest.

Table 1.--Water balance simulation, 1967 water year

Fraser Experimental Forest, Deadhorse Creek - 667 acres — Composite of 10 substations

Date	Current: Snowpack water equivalent	Current: Recharge requirement	Interval totals: Precipitation	Interval totals: Input	Interval totals: Evapotranspiration from--[1]	Interval totals: Generated runoff	Year to date: Precipitation	Year to date: Input	Year to date: Evapotranspiration	Year to date: Generated runoff	Year to date: Change in recharge requirement
	Inches										
10 10 66	0.16	-2.84	0.86	0.62	0.3498 C E	0.05	0.86	0.62	0.3498	0.05	0.29
10 20 66	.46	-2.60	.85	.47	.2687	.04	1.70	1.09	.6186	.09	.54
10 30 66	.34	-2.80	.00	.12	.3168 E	.00	1.70	1.21	.9354	.09	.34
11 10 66	1.43	-2.80	1.25	.08	.1571 C E	.00	2.95	1.30	1.0925	.09	.34
11 20 66	1.45	-2.85	.06	.04	.0959 C E	.00	3.01	1.33	1.1884	.09	.28
11 30 66	1.75	-2.87	.39	.05	.0971 C E	.00	3.40	1.38	1.2855	.09	.27
12 10 66	3.69	-2.87	2.04	.01	.1017 CSE	.00	5.44	1.39	1.3872	.09	.26
12 20 66	3.73	-2.90	.05	.00	.0333 CSE	.00	5.48	1.39	1.4205	.09	.23
12 30 66	3.87	-2.93	.15	.00	.0404 CSE	.00	5.63	1.39	1.4610	.09	.21
1 10 67	4.92	-2.93	1.14	.00	.1000 CSE	.00	6.77	1.39	1.5610	.09	.20
1 20 67	6.43	-2.94	1.64	.00	.1223 CSE	.00	8.41	1.39	1.6833	.09	.20
1 30 67	7.16	-2.92	.83	.02	.0907 CSE	.00	9.24	1.41	1.7740	.09	.21
2 10 67	8.49	-2.93	1.46	.00	.1179 CSE	.00	10.70	1.41	1.8920	.09	.21
2 20 67	10.69	-2.93	2.36	.00	.1788 CS	.00	13.06	1.41	2.0708	.09	.21
3 10 67	11.90	-2.93	1.49	.00	.2775 CS	.00	14.55	1.41	2.3483	.09	.21
3 20 67	13.20	-2.88	1.61	.05	.2612 CS	.00	16.16	1.46	2.6095	.09	.25
3 30 67	13.31	-2.68	.48	.20	.1762 CS	.00	16.64	1.66	2.7857	.09	.45
4 10 67	12.92	-2.43	.35	.42	.3183 CS	.16	16.99	2.08	3.1039	.26	.71
4 20 67	12.69	-1.87	.93	.87	.3418 CSE	.26	17.92	2.95	3.4457	.52	1.26
4 30 67	12.35	-1.45	.78	.89	.2632 CSE	.43	18.70	3.85	3.7089	.95	1.68
5 10 67	11.63	-1.35	.57	.94	.4397 CSE	.75	19.27	4.78	4.1487	1.70	1.78
5 20 67	9.49	- .58	.57	2.42	.3761 CSE	1.55	19.83	7.20	4.5247	3.26	2.56
5 30 67	6.04	- .07	.38	3.51	.5529 CSE	2.78	20.21	10.71	5.0777	6.03	3.06
6 10 67	2.83	- .27	.47	3.36	.9556 CSE	2.92	20.68	14.07	6.0333	8.96	2.86
6 20 67	1.47	- .05	1.58	2.85	.4260 CSE	2.29	22.26	16.92	6.4593	11.25	3.09
6 30 67	.68	- .54	.82	1.56	1.1143 CSE	.98	23.08	18.48	7.5736	12.23	2.59
7 10 67	.00	-1.34	.58	1.24	1.3991 SE	.66	23.66	19.71	8.9727	12.88	1.80
7 20 67	.00	-2.46	.40	.40	1.5228 E	.00	24.06	20.11	10.4955	12.88	.68
7 30 67	.00	-3.12	.58	.58	1.2406 E	.00	24.63	20.69	11.7362	12.88	.01
8 10 67	.00	-2.83	1.13	1.13	.8239 E	.02	25.76	21.82	12.5601	12.90	.30
8 20 67	.00	-3.58	.12	.12	.8617 E	.00	25.88	21.94	13.4218	12.90	- .44
8 30 67	.00	-3.95	.17	.17	.5433 E	.00	26.05	22.11	13.9651	12.90	- .81
9 10 67	.00	-4.17	.11	.11	.3346 E	.00	26.16	22.22	14.2997	12.90	-1.04
9 20 67	.00	-3.04	1.53	1.46	.3502 C E	.04	27.69	23.68	14.6499	12.94	.10
9 30 67	.00	-3.17	.47	.46	.5844 C E	.02	28.16	24.14	15.2343	12.96	.04

[1] C = interception loss
S = Evaporation from snowpack
E = Evapotranspiration

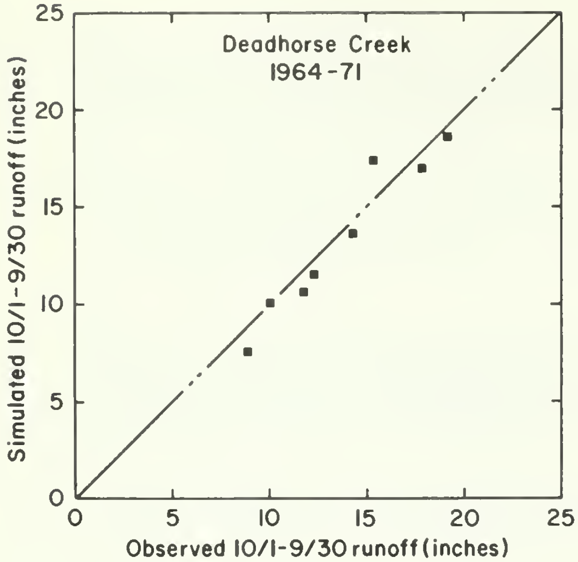

Figure 10. — Simulated versus observed annual runoff on Deadhorse Creek, 1964-71.

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Appendix I: Routines for Water Balance Model

Program WBMODEL

```
      OVERLAY (OLAYS,0,0)
      PROGRAM WBMODEL (INPUT,OUTPUT,PLOTS,TAPE5=INPUT,TAPE6=OUTPUT,
     1 TAPE11=PLOTS)
C-----THIS IS THE CONTROLLING ROUTINE FOR THE WATER BALANCE MODEL.  THE
C----- MODEL IS OVERLAYED TO SAVE TIME AND MEMORY. THE CORE OF THE MODEL
C----- IS SUBROUTINE WATBAL AND ITS RELATED ROUTINES. ALL OF THESE, PLUS
C----- SEVERAL I/O ROUTINES WHICH HAVE NO OPTIONS, ARE INCLUDED IN THIS
C----- MAIN OVERLAY SO THEY ARE AVAILABLE TO THE OVERLAYS WHICH ARE
C----- SELECTED BY OPTION.  THE FIRST OVERLAY LOADED ESTABLISHES THE
C----- WATERSHED DESCRIPTORS AND PARAMETERS AND INDICATES THE OVERLAYS
C----- TO BE SELECTED ACCORDING TO THE OUTPUT OPTIONS.  THE NEXT OVERLAY
C----- TO BE LOADED WILL CONTAIN THE OUTPUT ROUTINE SELECTED AND ITS
C----- NORMAL SIMULATION ROUTINE.  IT WILL THEN LOAD ONE OF ITS
C----- SECONDARY OVERLAYS WHICH WILL CONTAIN THE MAIN OPERATING PROGRAM
C----- FOR THIS RUN AND ANY ALTERNATIVES THAT ARE TO BE INCLUDED.
C-----
C-----THE CORE OF THE MODEL (SUBROUTINE WATBAL, ET AL) IS DESIGNED TO
C----- FUNCTION AS AN INDEPENDENT UNIT, TOTALLY UNCONCERNED WITH I/O AND
C----- MAINTENANCE  OF CONTINUOUS OR STATIC CONDITIONS.  THE ONLY LINKS
C----- WITH THE OPERATING PROGRAM, ITS ALTERNATIVES AND I/O ROUTINES,
C----- ARE THE FORMAL PARAMETERS AND COMMON BLOCK /WATRBAL/.  EACH
C----- ROUTINE WHICH UTILIZES THE CORE MUST MAINTAIN ITS OWN SET OF
C----- CONTINUOUS CONDITIONS AND MAKE THEM AVAILABLE AT THE PROPER TIME
C----- FOR USE BY THE CORE.  THE BLANK COMMON AND LABELLED COMMON BLOCKS
C----- ESTABLISHED HERE IN THE MAIN OVERLAY ARE PRIMARILY FOR THE USE OF
C----- THE NORMAL SIMULATION ROUTINE.  THEREFORE, SIMILAR LOCATIONS MUST
C----- BE SET ASIDE FOR MAINTENANCE  BY ANY AND ALL ALTERNATIVES.
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1  .   PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/CMPSITO/COMPS(16),YRTOT(5)
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTDNOW,OBSHYDR,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      DATA COMPS,YRTOT/21*0.0/
      DATA IYR,MSTREOF/1,0/
      CALL OVERLAY (5HOLAYS,1,0)
      CALL OVERLAY (5HOLAYS,LEVEL1,0)
C-----FILE -PLOTS- IS COPIED TO -OUTPUT- BY A STANDARD MONITOR COPY
      END
```

Subroutine WATBAL

```
      SUBROUTINE WATBAL (F1,F2,F3,I1,F4,F5,I2,I3,F6,I4,F7,F8,F9,F10,F11,
     1 F12,F13,I5)
C-----THIS SUBROUTINE IS THE MAIN ROUTINE OF THE WATER BALANCE MODEL. IT
C----- RECEIVES THE DRIVING, STATIC AND CONTINUOUS VARIABLES FROM THE
C----- OPERATING ROUTINES, CONTROLS THE COMPUTATIONS ON THEM, AND
C----- RETURNS THE NEW VALUES FOR THE CONTINUOUS VARIABLES AND THE
C----- RESULTS OF THIS INTERVAL.  SEE THE REPLACEMENT STATEMENTS BELOW
C----- FOR THE VARIABLE DEFINITIONS OF THE PARAMETERS
C
C-----DICTIONARY OF WATER BALANCE COMMON BLOCKS
C
C      AVETEMC - THE MEAN TEMPERATURE FOR THE INTERVAL IN DEGREES C
C      BASTEMF - BASE TEMPERATURE DEGREES FARENHEIT, RAIN TURNS TO SNOW
C      CALDEF - THE CALORIE DEFICIT IS THE NUMBER OF CALORIES NEEDED
C                TO BRING THE SNOWPACK TEMPERATURE TO ZERO DEGREES
C                CENTIGRADE (NOTE SHOULD BE MADE THAT IT IS A POSITIVE
C                QUANTITY)
C      COVDEN - THE COVER DENSITY IS THE FRACTION OF THE GROUND OR SNOW
C                SURFACE SHADED FROM DIRECT SUNLIGHT OR RADIATION
C      DREADY = 0, DIFFUSION MODEL (SUBROUTINE DIFMOD) NOT INITIALIZED
C             = 1, DIFFUSION MODEL INITIALIZED AND READY FOR SNOWPACK
C                TEMPERATURE SIMULATION
C             = -1, DIFFUSION MODEL MAY NOT BE USED
C      ENGBAL - THE TOTAL CALORIC INPUT TO OR LOSS FROM THE SNOWPACK
C                DURING AN INTERVAL.  IT IS THE ALGEBRAIC SUM OF THE
C                ENERGY INVOLVED WITH THE PRECIPITATION AND THAT OF
C                THE RADIATION BALANCE
C      ENGBAL1 - THE VALUE OF -ENGBAL- AT THE END OF THE LAST INTERVAL
C      ETFROM = 1, EVAPORATION IS FROM THE CANOPY
C             = 2, EVAPORATION IS FROM THE SURFACE OF THE SNOWPACK
C             = 4, EVAPOTRANSPIRATION IS FROM SNOWMELT, RAIN OR THE
C                SOIL MANTLE STORAGE
C      EVAPOTR - WHEN FIRST RECEIVED, THIS VARIABLE IS THE POTENTIAL
C                EVAPOTRANSPIRATION AS COMPUTED BY THE HAMON METHOD
C                AND ADJUSTED FOR AVAILABLE RADIATION.  AFTER ACTION
C                IS TAKEN BY THE WATER BALANCE ROUTINES, THE ORIGINAL
C                VALUE HAS BEEN ADJUSTED FURTHER BY THE METHODS
C                DISCUSSED IN SUBROUTINES CANVAP, EVTRAN, AND SNOWVAP.
C                IT THEN REPRESENTS THE EVAPOTRANSPIRATION DURING THIS
C                INTERVAL
C      FREEWAT - THE FREE WATER BEING HELD BY THE SNOWPACK
C      LASTUSD - AN INDICATOR USED IN FUNCTION PACKREF TO DETERMINE
C                WHICH REFLECTIVITY FUNCTION TO USE
C      NDAYSNO - THE NUMBER OF DAYS SINCE NEW SNOW HAS FALLEN
C      ONTREES - THE VOLUME OF INTERCEPTED SNOW REMAINING ON THE CANOPY
C      PHASE = -1, THE SNOWPACK HAS BARELY ACCUMULATED TO THE POINT WHERE
C                THE DIFFUSION MODEL IS STABLE AND MAY BE USED TO
C                CONTROL THE SNOWPACK TEMPERATURE
C            = 0, THE SNOWPACK IS ACCUMULATING AND HAS NOT YET REACHED
C                A DEPTH WHICH WILL PROVIDE STABILITY FOR THE
C                DIFFUSION MODEL
C            = 1, THE SNOWPACK HAS REACHED A SUFFICIENT DEPTH TO ALLOW
C                THE DIFFUSION MODEL TO CONTROL THE PACK TEMPERATURE
C                UNTIL THE MELT SEASON, WHEN THE RADIATION ROUTINES
C                RESUME CONTROL TO GOVERN THE MELT PHASE
C      PRECIP - OBSERVED PRECIPITATION IN INCHES
C      PREWEQV - PREDICTED WATER EQUIVALENT OF THE SNOWPACK IN INCHES
C      RADIN - RADIATION IN IS THE TOTAL INCIDENT SHORT WAVE RADIATION
C      RADLWN - NET LONG WAVE RADIATION IS THE ALGEBRAIC SUM OF THE LONG
C                WAVE RADIATION FROM THE FOREST AND THE LONG WAVE
C                RADIATION LOST BY THE SNOWPACK TO THE CANOPY
C      RADSWN - THE CALORIC INPUT TO THE PACK BY THE NET SHORT WAVE
C                RADIATION
C      RECHRG - THE RECHARGE REQUIREMENTS, OR SOIL MANTLE STORAGE DEFICIT
C      SIMTEM1 - AN ARRAY USED PRIMARILY IN SUBROUTINE DIFMOD IN THE
C                SIMULATION OF THE AVERAGE SNOWPACK TEMPERATURE.
C                TO INSURE STABILITY OF THE DIFFUSION MODEL, THE
C                DAY IS PARTITIONED INTO 12 HOUR INTERVALS, AS
C                DISCUSSED IN SUBROUTINE DIFMOD.  THIS ARRAY STORES
C                THE CONDITIONS PRESENT DURING THIS INTERVAL FOR USE
C                IN THE SIMULATION ON THE NEXT INTERVAL.  LOCATION 1
C                STORES THE AVERAGE AIR TEMPERATURE (ASSUMED TO BE
C                THE SURFACE TEMPERATURE OF THE SNOWPACK), LOCATION 2
C                IS THE SNOWPACK TEMPERATURE AT A NODE MIDWAY
C                BETWEEN THE SURFACE AND THE GROUND, AND LOCATION 3 IS
C                THE GROUND TEMPERATURE.
C      TCOEFF - THE TRANSMISIVITY COEFFICIENT USED TO ESTIMATE THE NET
C                SHORT WAVE RADIATION REACHING THE SNOWPACK.  SEE
C                REIFSNYDER AND LULL, RADIANT ENERGY IN RELATION TO
C                FORESTS, USFS TECH. BUL 1344, 1965.
C      TEMPMAX - THE MAXIMUM TEMPERATURE DURING THE INTERVAL IN DEGREES
C                FARENHEIT
C      TEMPMIN - THE MINIMUM TEMPERATURE DURING THE INTERVAL IN DEGREES
C                FARENHEIT
C      THRSHLD - THE THRESHOLD TEMPERATURE FOR DETERMINING WHETHER OR NOT
C                TO RE-INITIALIZE THE REFLECTIVITY FUNCTION WHEN
C                THERE IS A SNOW EVENT.  IF THE MAXIMUM TEMPERATURE IS
C                GREATER THAN THE THRESHOLD VALUE DO NOT RE-INITIALIZE
C                THE FUNCTION REGARDLESS OF THE PRECIPITATION
C      WATERIN - THE SUM OF ANY SNOWMELT AND ANY RAIN WHICH PROVIDES
C                DIRECT INPUT TO THE WATER BALANCE
C
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASF,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      DATA AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,ENGBAL1,
     1 FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEQV,RECHRG,SIMTEM1,
     2 SIMTEM3,TCOEFF,THRSHLD,VEGTYPE/0.0,35.0,3*0.0,0,2*-1.0,0.0,2*0,
     3 0.0,0,6*0.0,1.0,0.0,1/
C-----OBTAIN THE STATION DESCRIPTORS
      COVDEN = F3
      COMAX = F2
      TCOEFF = F12
      VEGTYPE = I5
C-----RECALL THE CONTINUOUS VARIABLES NECESSARY FOR THE OPERATION OF THE
C----- MODEL DURING THIS INTERVAL
      CALDEF = F1
      DREADY = I1
      ENGBAL1 = F4
      FREEWAT = F5
      LASTUSD = I2
      NDAYSNO = I3 + 1
      ONTREES = F6
      PHASE = I4
      PREWEQV = F7
      RECHRG = F8
      THRSHLD = F13

      IF(DREADY) 20,20,10
   10 SIMTEM1(1) = F9
      SIMTEM1(2) = F10
      SIMTEM1(3) = F11
C-----AVETEMC = (((TEMPMAX-32)+(TEMPMIN-32))/2)*(5/9)
   20 AVETEMC = (TEMPMAX + TEMPMIN - 64.0) * 0.2777777778
C-----START THE ENERGY BALANCE AND THE INPUT AT ZERO FOR THIS INTERVAL
      ENGBAL = 0.0
      WATERIN = 0.0
C-----IF THERE IS NO PRECIP, THERE IS NO NEED TO PASS THROUGH THE
C----- CLASSIFICATION STATEMENTS
      IF(PRECIP) 90,90,30
C-----SEE IF THE PRECIP IS ALL SNOW
```

```
   30 IF(TEMPMIN.LE.32.0.OR.TEMPMAX.LT.BASTEMF) GO TO 80
C-----SEE IF ANY OF IT IS SNOW
      IF(TEMPMIN - BASTEMF) 40,50,50
   40 CALL MIXTURE
C-----THIS IS A RAIN EVENT.  IF THERE IS NO PACK, THE RAIN IS DIRECT
C----- INPUT TO THE WATER BALANCE.  BUT IF THERE IS A PACK, DETERMINE
C----- THE EFFECTS OF THE RAIN
   50 IF(PREWEQV) 60,60,70
   60 WATERIN = PRECIP
      GO TO 160
   70 CALL RAINEO (AVETEMC,PRECIP)
      GO TO 90
C-----THIS IS A SNOW EVENT
   80 CALL SNOWED (AMIN1 (AVETEMC,0.0),PRECIP)
C-----IF THERE IS SNOW ON THE TREES, EVAPORATE ONLY FROM THE CANOPY
   90 IF(ONTREES) 130,130,100
  100 CALL CANVAP
C-----ON THE FIRST DAY AFTER FRESH SNOW, ASSUME TURBULENCE HAS REMOVED
C----- ANY REMAINING INTERCEPTED SNOW AND ADDED IT TO THE PACK
      IF(NDAYSND - 1) 120,110,110
  110 PREWEQV = PREWEQV + ONTREES
      ONTREES = 0.0
C-----IF THERE IS NO SNOWPACK, BYPASS THE RADIATION ROUTINES
  120 IF(PREWEQV) 190,190,180
C-----DETERMINE WHETHER TO SATISFY THE EVAPOTRANSPIRATION REQUIREMENTS
C----- UNDER GROWING SEASON OR WINTER CONDITIONS
  130 IF(PREWEQV) 160,160,140
  140 IF(PREWEQV - 5.0) 150,150,170
C-----USE THE GROWING SEASON ROUTINES TO INCLUDE TRANSPIRATION
  150 CALL RADBAL
C-----ADD -WATERIN- TO THE RECHARGE REQUIREMENTS SO THE ET ROUTINE CAN
C----- OPERATE ON THE INPUT AS WELL AS THE STORAGE
  160 RECHRG = RECHRG + WATERIN
      CALL EVTRAN
      GO TO 200
C-----USE THE WINTER ROUTINES TO EVAPORATE FROM THE SNOWPACK SURFACE
  170 CALL SNOWVAP
  180 CALL RADBAL
C-----ADD -WATERIN- TO THE RECHARGE REQUIREMENTS
  190 RECHRG = RECHRG + WATERIN
C-----IF THE RECHARGE REQUIREMENTS WERE SATISFIED, THE EXCESS IS
C----- CONSIDERED TO BE GENERATED RUNOFF
  200 IF(RECHRG) 220,220,210
  210 GENRD = RECHRG
      FB = 0.0
      GO TO 230
  220 GENRD = 0.0
      FB = RECHRG
  230 I1 = DREADY
      F1 = CALDEF
      F4 = ENGBAL
      F5 = FREEWAT
      I2 = LASTUSD
      I3 = NDAYSND
      F6 = ONTREES
      F7 = PREWEQV
C-----WHEN THE PACK IS GONE, RESET THE PHASE INDICATOR
      IF(PREWEQV) 240,240,250
  240 I4 = 0
      RETURN
  250 I4 = PHASE
      IF(DREADY) 270,270,260
  260 F9 = SIMTEM1(1)
      F10 = SIMTEM1(2)
      F11 = SIMTEM1(3)
  270 RETURN
      END
```

Subroutine CALIN

```
      SUBROUTINE CALIN (CALORIN)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF THE CALORIC INPUT ON THE
C----- SNOWPACK
C      HOLDCAP - THE FREE WATER HOLDING CAPACITY OF THE SNOWPACK
C                (ASSUMED TO BE FOUR PERCENT OF THE WATER EQUIVALENT)
C-----
      COMMON/ONLYCDR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSND,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCDEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPDTR,GENRD,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----ADD THESE CALORIES INTO THE ENERGY BALANCE
      ENGBAL = ENGBAL + CALORIN
C-----SEE IF A CALORIE DEFICIT EXISTS IN THE PACK
      COMPARE = CALORIN - CALDEF
      IF(COMPARE) 10,20,30
C-----THERE IS A CALORIE DEFICIT, BUT THE INPUT DID NOT COMPLETELY
C----- WIPE IT OUT.  ALL OTHER CONDITIONS ARE UNCHANGED
   10 CALDEF = - COMPARE
      RETURN
C-----THE CALORIE DEFICIT WAS WIPED OUT, BUT ALL OTHER CONDITIONS ARE
C----- UNCHANGED
   20 CALDEF = 0.0
      RETURN
C-----ANY DEFICIT WHICH DID EXIST WAS WIPED OUT.  COMPUTE THE POTENTIAL
C----- MELT FROM THE REMAINING CALORIES (CALORIES/(80.0 * 2.54))
   30 POTMELT = COMPARE/203.2
      CALDEF = 0.0
C-----IF THE INPUT WAS ENOUGH TO MELT THE WHOLE PACK, CONTRIBUTE THE
C----- WATER EQUIVALENT TO THE SNOWMELT AND ZERO ALL CONDITIONS
      IF(POTMELT.LT.PREWEQV-FREEWAT) GO TO 40
      WATERIN = WATERIN + PREWEQV
      PREWEQV = 0.0
      FREEWAT = 0.0
      RETURN
C-----DEPLETE THE ICE PACK BY THE AMOUNT MELTED AND CONTRIBUTE THAT
C----- AMOUNT TO THE FREE WATER
   40 FREEWAT = FREEWAT + POTMELT
C-----COMPUTE THE NEW HOLDING CAPACITY OF THE PACK AND COMPARE IT WITH
C----- THE FREE WATER TO SEE IF SNOWMELT IS PRODUCED
      HOLDCAP = 0.04 * (PREWEQV - FREEWAT)
      COMPARE = FREEWAT - HOLDCAP
      IF(COMPARE.LE.0.0) RETURN
C-----THE SNOWMELT CONTRIBUTED IS IN -COMPARE-.  REDUCE THE FREE WATER
C----- TO LEAVE A PRIMED PACK AND REDUCE THE PREDICTED WATER EQUIVALENT
      PREWEQV = PREWEQV - COMPARE
      WATERIN = WATERIN + COMPARE
      FREEWAT = HOLDCAP
      RETURN
      END
```

Subroutine CALOSS

```
      SUBROUTINE CALOSS (CALOUT)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF THE CALORIC LOSS ON THE
C----- SNOWPACK
      COMMON/ONLYCDR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSND,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCDEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPDTR,GENRD,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----ADD ALGEBRAICALLY THESE CALORIES INTO THE ENERGY BALANCE
      ENGBAL = ENGBAL + CALOUT
C-----SEE IF THERE IS ANY FREE WATER IN THE PACK.  IF NOT, THE LOSS IS
C----- JUST CONTRIBUTED TO THE CALORIC DEFICIT OF THE SNOWPACK.
C----- REMEMBER THAT -CALOUT- IS NEGATIVE
      IF(FREEWAT.GT.0.0) GO TO 10
      CALDEF = CALDEF - CALOUT
      RETURN
C-----COMPUTE THE CALORIC LOSS NECESSARY TO FREEZE ALL OF THE FREE WATER
C----- (FREE WATER * 80.0 * 2.54)
   10 CALNEED = FREEWAT * 203.2
C-----NOW COMPARE THAT NECESSARY LOSS WITH THE ACTUAL LOSS.  IF THEY ARE
C----- THE SAME, THE FREE WATER IS WIPED OUT BUT NO OTHER CONDITIONS ARE
C----- ALTERED
      COMPARE = CALOUT + CALNEED
      IF(COMPARE) 20,30,40
C-----THE LOSS WAS MORE THAN ENOUGH TO FREEZE IT.  THE BALANCE CREATES
C----- AN ENERGY DEFICIT IN THE PACK AND THE FREE WATER IS WIPED OUT
   20 CALDEF = - COMPARE
   30 FREEWAT = 0.0
      RETURN
C-----ONLY PART OF THE FREE WATER FROZE.  COMPUTE THE BALANCE REMAINING
C----- BALANCE = EXISTING FREE WATER - AMOUNT FROZEN, WHERE
C----- AMOUNT FROZEN = CALORIES/(80.0 * 2.54)
   40 FREEWAT = FREEWAT + (CALOUT/203.2)
      RETURN
      END
```

Subroutine CANVAP

```
      SUBROUTINE CANVAP
C-----COMPUTE THE EVAPORATION FROM THE INTERCEPTED SNOW AS A FUNCTION OF
C----- THE CANOPY COVER DENSITY
      COMMON/ONLYCDR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSND,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCDEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPDTR,GENRD,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      ETFROM = 1.0
      EVAPDTR = EVAPDTR/COVDEN
      ONTREES = ONTREES - EVAPDTR
      IF(ONTREES) 10,20,20
   10 EVAPDTR = ONTREES + EVAPDTR
      ONTREES = 0.0
   20 RETURN
      END
```

Subroutine DIFMOD

```
      SUBROUTINE DIFMOD
C-----THIS SUBROUTINE WAS DERIVED FROM PROGRAM SIMTEM, A SNOWPACK
C----- TEMPERATURE DIFFUSION MODEL DEVELOPED BY LEAF (1970 STUDY PLAN
C----- FS-RM-1602, NO. 224, RMF+RES).  USING THE AVERAGE SURFACE TEMP
C----- AND THE GROUND TEMP AS BOUNDARY CONDITIONS, THE NEW AVERAGE
C----- SNOWPACK TEMPERATURE IS CALCULATED
      COMMON/ONLYCDR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSND,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCDEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPDTR,GENRD,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----
C-----DICTIONARY
C
C      CONST1 - THE FIRST CONSTANT IN THE EQUATION FOR THE SIMULATION
C      CONST2 - THE SECOND CONSTANT IN THE EQUATION FOR THE SIMULATION
C      H - THE DISTANCE BETWEEN NODES (CORRESPONDS TO THE -H- IN THE
C               STUDY PLAN)
C-----
C-----COMPUTE THE DENSITY OF THE SNOWPACK (THE FUNCTION WAS DERIVED FROM
C----- OBSERVED CONDITIONS ON THE FRASER EXPERIMENTAL FOREST)
      DENSITY = (EXP((0.0179 * PREWEQV) + 3.02))/100.0
C-----COMPUTE THE DISTANCE BETWEEN THE TWO NODES IN CENTIMETERS
```

```
C-----OEPTH = PREWEQV/OENSITY
C-----H = (OEPTH/2)*2.54
      H = (PREWEOV/OENS(TY) * 1.27
C-----THE THERMAL OIFFUSIVITY IS CALCULATEO FROM THE FUNCTION
C----- KV = 0.0I/((2.751 - OENSITY)* 0.4B).  MATHEMATICAL STABILITY
C----- REQUIRES THAT THE VALUE OF THE OUANTITY (INTERVAL IN SECONOS *
C----- KV/H**2) BE LESS THAN 0.5.  WHEN A 24 HOUR INTERVAL IS USED, THE
C----- SNOW OEPTH MUST EXCEEO 30 INCHES (20 PERCENT OENSITY) TO ACHIEVE
C----- STABILITY.  IN OROER TO INSURE STABILITY WITH SOMEWHAT SHALLOWER
C----- PACKS (ABOUT IB INCHES), THE OAY IS OIVIOEO INTO 2 TIME INTERVALS
C----- OF I2 HOURS (43200 SECONOS)
C-----CONSTI = (43200 * 0.01/((2.751 - OENSITY) * 0.4B))/H**2
      CONSTI = 900.0/((2.751 - OENSITY)*H*H)
C-----THE MINIMUM WATER EOUIVALENT WHICH WILL ACHIEVE STABILITY USING
C----- THE ABOVE OENSITY FUNCTION IS 4.7 INCHES
      IF(CONST( - 0.5) 20,I0,10
C-----THE MOOEL IS UNSTABLE - INOICATE THAT IT IS NOT REAOY FOR USE NOW.
C----- (IT MAY BE INITIALIZEO AGAIN BY AN OBSERVEO PACK TEMPERATURE CARO
C----- ANO STABILITY WILL BE ASCERTAINEO FROM THE WATER EQUIVALENT AT
C----- THAT TIME)
   10 OREAOY = 0
      RETURN
C-----GET THE SECONO CONSTANT
   20 CONST2 = I.0 - CONSTI - CONSTI
C-----PERFORM THE SIMULATION IN TWO PARTS (ONE FOR EACH I2 HOUR PERIOO).
C----- -SIMTEMI- HOLOS THE THREE TEMPERATURES FROM THE PREVIOUS INTERVAL
C----- THAT ARE NEEOEO TO SIMULATE SIMTEM2, THE NOOE AT THE CENTER OF
C----- THE PACK.  SIMULATE THE FIRST I2 HOURS NOW
      SIMTEM2 = (CONSTI * (SIMTEMI(I) + SIMTEMI(3))) + (CONST2 * SIMTEMI
     1(2))
C-----THE AVERAGE SNOWPACK TEMPERATURE IS THE AVERAGE OF THE 2 NOOES
C----- (MIOOLE ANO GROUNO) IN BOTH INTERVALS.  GROUNO TEMPERATURE IS
C----- CONSTANT, SO START THE AVERAGE NOW
      SIMTEM3 = SIMTEMI(3) + SIMTEMI(3) + SIMTEM2
C-----RESET -SIMTEMI- TO THE TEMPERATURES OF THE INTERVAL JUST SIMULATEO
C----- FOR USE IN THE SECONO I2 HOUR INTERVAL SIMULATION.  THE SURFACE
C----- AIR TEMPERATURE IS SPLIT INTO A LOW AVERAGE ( (MEAN+MIN)/2 ) AND
C----- A HIGH AVERAGE ( (MEAN+MAX)/2 ) FOR USE WITH THE TWELVE HOUR
C----- INTERVALS.  USE THE LOW AVERAGE NOW
      SIMTEMI(I) = AMINI (0.0,(((TEMPMIN-32.0)*0.5555555556)+AVETEMC)/
     1 2.0)
      SIMTEMI(2) = SIMTEM2
C-----SIMULATE THE SECONO I2 HOURS ANO COMPUTE THE AVERAGE SNOWPACK
C----- TEMPERATURE
      SIMTEM2 = (CONSTI * (SIMTEMI(I) + SIMTEMI(3))) + (CONST2 * SIMTEMI
     1(2))
      SIMTEM3 = (SIMTEM3 + SIMTEM2)/4.0
C-----RESET -SIMTEMI- USING THE HIGH AVERAGE FOR USE ON THE FIRST
C----- INTERVAL OF THE NEXT OAY
      SIMTEMI(1) = AMINI (0.0,(((TEMPMAX-32.0)*0.5555555556)+AVETEMC)/
     I 2.0)
      SIMTEMI(2) = SIMTEM2
C-----CHECK TO SEE IF THE GROUNO TEMPERATURE SHOULO BE RAISEO
      IF(SIMTEM3 + I.5) 60,40,30
   30 IF(SIMTEM3 + 0.5) 40,50,50
   40 IF(SIMTEMI(3).LT.-0.5) SIMTEMI(3) = -0.5
      RETURN
   50 SIMTEMI(3) = 0.0
   60 RETURN
      ENO
```

Subroutine EVTRAN

```
      SUBROUTINE EVTRAN
C-----COMPUTE THE EVAPORATION ANO TRANSPIRATION OURING THE GROWING
C----- SEASON
C-----
C-----OICTIONARY
C       AVABLE - THE FACTOR FOR AOJUSTING THE EVAPOTRANSPIRATION FOR
C                AVAILABLE SOIL WATER
C       CANREF - THE FACTOR FOR AOJUSTING THE EVAPOTRANSPIRATION
C                FOR CANOPY REFLECTIVITY
C-----
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALOEF,COMAX,COVOEN,OREAOY,ENGBAL,
     1 ENGBALI,FREEWAT,LASTUSO,NOAYSNO,ONTREES,PHASE,PREWEOV,RECHRG,
     2 SIMTEMI(3),SIMTEM3,TCOEFF,THRSHLO,VEGTYPE
      INTEGER OREAOY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      ETFROM = 4.0
C-----GET THE AOJUSTMENT FACTOR FOR AVAILABLE SOIL WATER.  IF THE
C----- RECHARGE REOUIREMENTS ARE SATISFIEO (I.E., FIFLO CAPACITY HAS
C----- BEEN REACHEO), MAXIMIZE THE AOJUSTMENT FACTOR
      IF(RECHRG) 20,20,10
   10 AVABLE = 1.0
      GO TO 80
C-----IN FORESTEO AREAS, USE THE MAXIMIZEO FACTOR UNTIL THE RECHARGE
C----- REOUIREMENTS ARE HALF OF THE FIELO CAPACITY.  AT THAT POINT, USE
C----- THE LINEAR FUNCTION Y = MX + B, WHERE B = 0.0 TO GET THE FACTOR
   20 IF(COVOEN) 50,50,30
   30 IF(RECHRG + 2.65) 40,I0,I0
   40 AVABLE = 0.377 * (5.3 + RECHRG)
      GO TO 80
C-----IN CLEARINGS, ASSUME THAT EVAPOTRANSPIRATION OECREASES LINEARLY
C----- FROM THE MAX(MIZEO VALUES AT FIELO CAPACITY TO ZERO AT
C----- THREE-FOURTHS OF FIELO CAPACITY
   50 IF(RECHRG + 1.325) 70,70,60
   60 AVABLE = (0.755 * (5.3 + RECHRG)) - 3.0
      GO TO 80
   70 EVAPOTR = 0.0
      RETURN
C-----COMPUTE THE FACTOR FOR AOJUSTING THE EVAPOTRANSPIRATION FOR CANOPY
C----- REFLECTIVITY (PROTECT AGAINST OIVISION BY ZERO - JUST OEFINE THE
C----- FACTOR FOR CLEARINGS AS THE MINIMUM VALUE)
   80 IF(COMAX) 90,90,100
   90 CANREF = 0.5
      GO TO 130
C-----COMPARE THE COVER OENSITY WITH THE MAXIMUM (CHECK FOR THINNING)
  100 IF(COVOEN - (COMAX/3.0)) II0,II0,I20
C-----FOR COVER OENSITIES THINNEO TO ONE-THIRO OF THE MAXIMUM OR LESS,
C----- USE THIS RELATIONSHIP
C-----CANREF = (.0 - (0.5 - ((0.75*CO)/COMX))
  II0 CANREF = 0.5 + ((0.75 * COVOEN)/COMAX)
      GO TO (30
C-----FROM MAXIMUM COVER OENSITY OOWN TO ONE-THIRO OF THAT VALUE, USE
C----- THE FOLLOWING RELATIONSHIP
C-----CANREF = I.0 - (0.25 - ((0.15/(0.67*COMX))*(CO-(0.33*COMX))))
  120 CANREF = 0.75 + ((0.15/(0.67 * COMAX))*(COVOEN - (0.33 * COMAX)))
C-----PERFORM THE AOJUSTMENTS
  130 EVAPOTR = EVAPOTR * AVABLE * CANREF
C-----SEE IF THE EVAPOTRANSPIRATION WILL OEPLETE THE MANTLE STOARGE
C----- BELOW THE WILTING POINT.  IF SO, ALTER THE EVAPOTRANSPIRATION
C----- ACCOROINGLY
      IF(RECHRG - EVAPOTR + 5.3) I40,150,150
  140 EVAPOTR = RECHRG + 5.3
      RECHRG = -5.3
      RETURN
  I50 RECHRG = RECHRG - EVAPOTR
      RETURN
      ENO
```

Subroutine LINK

```
      SUBROUTINE LINK (CALAIR,CALORIE,(RETURN)
C-----THIS SUBROUTINE IS THE INTERFACE BETWEEN THE RAOIATION BALANCE
C----- (SUBROUTINE RAOBAL) ANO THE OIFFUSION MOOEL (SUBROUTINE OIFMOO)
C-----
C-----OICTIONARY
C
C       CALOM - THE CALORIC LOSS OF GAIN AS COMPUTEO BY THE OIFFUSION
C               MOOEL
C
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALOEF,COMAX,COVOEN,OREAOY,ENGBAL,
     I ENGBALI,FREEWAT,LASTUSO,NOAYSNO,ONTREES,PHASE,PREWEOV,RECHRG,
     2 SIMTEMI(3),SIMTEM3,TCOEFF,THRSHLO,VEGTYPE
      INTEGER OREAOY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     ( TEMPMAX,TEMPMIN,WATERIN
C-----SEE IF THE RAOIATION BALANCE IS AN ENERGY LOSS OR GAIN
      IF(CALORIE) 10,10,80
C-----THERE WAS A LOSS.  IF THIS IS STILL WINTER (NO FREE WATER), JUST
C----- GO AHEAO ANO USE THE OIFFUSION MOOEL
   I0 IF(FREEWAT) 20,20,50
C-----USE THE OIFFUSION MOOEL TO SIMULATE THE CURRENT AVERAGE SNOWPACK
C-----TEMPERATURE
   20 IF(OREAOY.NE.I) GO TO I40
      CALL OIFMOO
      IF(OREAOY) 40,40,30
C-----NOW MAKE ANY NECESSARY AOJUSTMENTS IN THE RAOIATION BALANCE TO
C----- CAUSE THE PACK TEMPERATURE TO BE THE SAME AS -SIMTEM3-. GET THE
C----- OIFFERENCE BETWEEN THE CALORIE OEFICITS AS COMPUTEO BY THE
C----- OIFFERENT METHOOS
   30 CALOM = CALOEF + (SIMTEM3 * PREWEQV * 1.27)
C-----AOJUST THE LONG WAVE PORTION OF THE RAOIATION BALANCE BY THE
C----- OIFFERENCE BETWEEN THE CALORIES OERIVEO FROM THE OIFFUSION MOOEL
C----- ANO THE ENERGY BALANCE
      CALORIE = CALOM
      RAOLWN = CALORIE - RAOSWN
   40 IRETURN = 0
      RETURN
C-----THE LOSS IS USEO TO FREEZE PART OR ALL OF THE FREE WATER, BUT IT
C----- MAY NOT CREATE COLO CONTENT.  IF IT WOULO CREATE COLO CONTENT,
C----- RE-INITIALIZE THE OIFFUSION MOOEL TO 0 ANO AOJUST THE ENERGY
C----- BALANCE ACCOROINGLY
   50 CALL CALOSS (CALORIE)
      IF(FREEWAT - 0.05) 60,60,70
   60 SIMTEMI(1) = AMINI (AVETEMC,0.0)
      SIMTEMI(2) = 0.0
      SIMTEMI(3) = 0.0
      OREAOY = 1
C-----MAKE ANY NECESSARY AOJUSTMENTS TO THE ENERGY BALANCE TO COMPENSATE
C----- FOR THE COLO CONTENT THAT WOULO HAVE BEEN GENERATEO BY THIS LOSS
C----- ANO ZERO THE COLO CONTENT
      ENGBAL = ENGBAL + CALOEF
      RAOLWN = RAOLWN + CALOEF
      FREEWAT = 0.0
      CALOEF = 0.0
   70 IRETURN = 1
      RETURN
C-----THERE IS CALORIC INPUT TO THE PACK.  CHECK TO SEE IF CONOITIONS
C----- INOICATE THAT THE OIFFUSION MOOEL SHOULO BE TURNEO OFF ANO THE
C----- ENERGY BALANCE USEO FOR SPRINGTIME SIMULATION.  CONSIOER FIRST
C----- ANY COLO CONTENT (INCLUOING THAT OF THE PREVIOUS OAY ANO ANY
C----- CREATEO BY A SNOW EVENT ON THIS OAY).  IF THERE IS COLO CONTENT,
C----- CHECK THE AVERAGE AIR TEMPERATURE ANO THE SNOWPACK TEMPERATURE
C----- FROM THE PREVIOUS OAY FOR ARBITRARILY CHOSEN SPRINGTIME
C----- CONOITIONS ANO IF ALL ARE NOT SATISFIEO, GO AHEAO ANO USE THE
C----- OIFFUSION MOOEL
   80 IF(CALOEF) I70,I70,90
C-----0.889 = I.27 * 0.7 OEGREES C (ARBITRARY TEMP)
   90 IF(AVETEMC.LE.0.0.OR.CALOEF.GT.PREWEQV*0.889) GO TO 20
C-----SINCE SPRINGTIME CONOITIONS PREVAIL, RECOMPUTE THE BACK RAOIATION
C----- ANO THE NET RAOIATION BALANCE (REMEMBER, IF THERE IS SNOW, THE
C----- LONGWAVE IS ASSUMEO TO BE ZERO, SO THERE WOULO BE NO NEEO TO MAKE
C----- ANY AOJUSTMENTS)
      IF(NOAYSNO) 140,I40,100
  I00 USE = (TEMPMIN - 32.0) * 0.5555555556
      IF(USE.GT.0.0) USE = 0.0
```

```
      CALSNOW = 1.17E-7 * ((USE + 273.16) ** 4)
      IF(PRECIP) 110,110,120
  110 RADLWN = ((1.0 - COVDEN) * ((0.757 * CALAIR) - CALSNOW)) + (COVDEN
     1 * (CALAIR - CALSNOW))
      GO TO 130
  120 RADLWN = CALAIR - CALSNOW
  130 CALORIE = RADSWN + RADLWN
C-----RE-INITIALIZE THE DIFFUSION MODEL TO THESE CONDITIONS (BUT IF THE
C----- INPUT IS MORE THAN ENOUGH TO WIPE OUT THE CALORIE DEFICIT, JUST
C----- LET IT BRING THE PACK TO ISOTHERMAL.  IN THIS WAY, TWO CONSECU-
C----- TIVE DAYS OF INPUT ARE REQUIRED TO GENERATE FREE WATER)
  140 COMPARE = CALORIE - CALDEF
      IF(COMPARE) 160,150,150
C-----INITIALIZE THE DIFFUSION MODEL TO ISOTHERMAL CONDITIONS
  150 SIMTEM1(1) = 0.0
      SIMTEM1(2) = 0.0
      SIMTEM1(3) = 0.0
      SIMTEM3 = 0.0
      DREADY = 1
      GO TO 30
C-----REDEFINE THE SURFACE TEMPERATURE AND COMPUTE THE NEW AVERAGE PACK
C----- TEMPERATURE.  THEN COMPUTE THE MIDDLE NODE AS A FUNCTION OF THAT
C----- AVERAGE, THE SURFACE TEMPERATURE AND THE GROUND TEMPERATURE
C----- (WHICH REMAINED UNCHANGED)
  160 SIMTEM1(1) = AMIN1 (0.0,AVETEMC)
      SIMTEM3 = COMPARE/(PREWEQV * 1.27)
      SIMTEM1(2) = (3.0 * SIMTEM3) - SIMTEM1(1) - SIMTEM1(3)
      SIMTEM1(3) = 0.0
      DREADY = 1
      GO TO 30
C-----THERE IS INPUT TO THE PACK AND THE PACK IS ALREADY ISOTHERMAL.  IF
C----- THIS ENERGY WILL CREATE AT LEAST 0.05 INCH (ARBITRARY AMOUNT) OF
C----- FREE WATER, SET THE DIFFUSION MODEL TO STANDBY STATUS AND LET THE
C----- ENERGY BALANCE TAKE ITS COURSE
  170 IF(FREEWAT + (CALORIE/203.2) - 0.05) 150,180,180
  180 DREADY = 0
      IRETURN = 0
      RETURN
      END
```

Subroutine MIXTURE

```
      SUBROUTINE MIXTURE
C----THIS SUBROUTINE CONTROLS THE COMPUTATIONS FOR A PRECIPITATION
C----- EVENT THAT IS A MIXTURE OF SNOW AND RAIN
C-----
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLO,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----DICTIONARY
C-----
C      AMTRAIN - THE AMOUNT OF PRECIPITATION OCCURRING AS RAIN
C      TFORAIN - THE TEMPERATURE FOR COMPUTING THE DEPLETION OF THE TOTAL
C                CALORIE DEFICIT CAUSED BY THE RAIN (DEGREES C)
C      TFORSNU - THE TEMPERATURE FOR COMPUTING THE CONTRIBUTION OF THE
C                SNOW TO THE TOTAL CALORIE DEFICIT (DEGREES C)
C-----
C-----COMPUTE THE AMOUNT OF PRECIPITATION OCCURRING AS RAIN
C----- AMOUNT RAIN = P * (B/A), WHERE
C----- P = PRECIPITATION IN INCHES
C----- B = DAILY MAXIMUM TEMPERATURE - BASE TEMPERATURE (DEGREES F)
C----- A = DAILY MAXIMUM TEMPERATURE - MINIMUM TEMPERATURE (DEGREES F)
      B = TEMPMAX - BASTEMF
      A = TEMPMAX - TEMPMIN
      AMTRAIN = PRECIP * (B/A)
C-----NOW COMPUTE THE AVERAGE TEMPERATURES (DEGREES C) WHICH PRODUCE
C----- SNOW AND RAIN
      TFORSNO = (TEMPMIN + BASTEMF - 64.0) * 0.2777777778
      TFORAIN = (TEMPMAX + BASTEMF - 64.0) * 0.2777777778
C-----COMPUTE THE EFFECT OF THE SNOW ON THE SNOWPACK
      CALL SNOWED (TFORSNO,PRECIP-AMTRAIN)
C-----COMPUTE THE EFFECT OF THAT PORTION OF THE PRECIPITATION OCCURRING
C----- AS RAIN ON THE SNOWPACK
      CALL RAINED (TFORAIN,AMTRAIN)
      RETURN
      END
```

Function PACKREF

```
      FUNCTION PACKREF (DUMMY)
C-----GET THE REFLECTIVITY OF THE SNOWPACK
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLO,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----
C-----DICTIONARY
C
C      PASTINT - A VARIABLE SET EQUAL TO -NDAYSNO- AND ALTERED AS NEEDED
C                TO CHOOSE THE PROPER REFLECTIVITY FUNCTION
C      REFACUM - A REFLECTIVITY FUNCTION FOR THE SNOWPACK DURING THE
C                ACCUMULATION PHASE OF THE SNOWPACK
C      REFMELT - A REFLECTIVITY FUNCTION FOR THE SNOWPACK DURING THE
C                MELT PHASE OF THE SNOWPACK
C-----
      DIMENSION REFACUM(15),REFMELT(15)
      INTEGER PASTINT
      DATA REFACUM/.80, .77, .75, .72, .70, .69, .68, .67, .66, .65,
     1 .64, .63, .62, .61, .60/
      DATA REFMELT/.72, .65, .60, .58, .56, .54, .52, .50, .48, .46,
     1 .44, .43, .42, .41, .40/
      PASTINT = NDAYSNO
      IF(NDAYSNO) 80,80,10
C-----USE THE SAME FUNCTION AS LAST TIME
   10 IF(LASTUSD) 20,20,50
C-----ACCUMULATION PHASE - AFTER 15 DAYS, USE THE MELT FUNCTION
C----- STARTING AT THE FOURTH DAY
   20 IF(PASTINT - 15) 30,30,40
   30 PACKREF = REFACUM(PASTINT)
      RETURN
   40 PASTINT = PASTINT - 11
C-----MELT FUNCTION - AFTER 15 DAYS, USE A CONSTANT 40 PERCENT
   50 IF(PASTINT - 15) 70,70,60
   60 PASTINT = 15
   70 PACKREF = REFMELT(PASTINT)
      RETURN
C-----THERE IS NEW SNOW - DETERMINE IF THE FUNCTION IS TO BE RE-
C----- INITIALIZED
   80 IF(TEMPMAX - THRSHLO) 90,90,10
C-----IT IS, SO SEE WHICH FUNCTION IS TO BE USED
   90 IF(CALDEF) 110,110,100
  100 PACKREF = 0.91
      LASTUSD = 0
      RETURN
C-----THE PACK IS ISOTHERMAL, BUT IF THE ENERGY BALANCE FROM THE
C----- PREVIOUS INTERVAL WAS NEGATIVE, USE THE ACCUMULATION PHASE
C----- FUNCTION ANYWAY
  110 IF(ENGBAL1) 100,120,120
  120 PACKREF = 0.81
      LASTUSD = 1
      RETURN
      END
```

Subroutine RADBAL

```
      SUBROUTINE RADBAL
C-----THIS SUBROUTINE COMPUTES THE RADIATION BALANCE AND TRANSFERS
C----- CONTROL TO THE DIFFUSION MODEL IF IT IS NEEDED
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEQV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLO,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----
C-----DICTIONARY
C-----
C      CALAIR - POTENTIAL LONGWAVE CALORIC INPUT AT AIR TEMPERATURE
C      CALORIE - CALORIES OF HEAT ABSORBED OR RELEASED BY THE SNOWPACK
C                FROM THE NET RADIATION BALANCE
C      CALSNOW - POTENTIAL LONGWAVE CALORIC LOSS AT SNOW TEMPERATURE
C      SNOCAN - THE LONGWAVE RADIATION BALANCE BETWEEN THE SNOW AND THE
C                CANOPY
C      SNOSKY - THE LONGWAVE RADIATION BALANCE BETWEEN THE SNOW AND THE
C                SKY
C-----COMPUTE THE CALORIC INPUT FROM NET SHORT WAVE RADIATION AS A
C----- FUNCTION OF THE SNOWPACK REFLECTIVITY
      RADSWN = RADIN * (1.0 - PACKREF (0.0)) * TCOEFF
C-----IF THE PACK IS ACCUMULATING, BUT IS NOT DEEP ENOUGH FOR STABILITY
C----- IN THE DIFFUSION MODEL, USE THE FOLLOWING SIMPLIFIED METHOD FOR
C----- DERIVING THE RADIATION BALANCE
      IF(PHASE) 60,10,100
   10 IF(PREWEQV - 4.7) 20,50,50
C-----USE ONLY THE SHORTWAVE INPUT (THIS IMPLIES THAT THE ONLY COLD
C----- CONTENT GENERATED IN THE ACCUMULATING PACK IS THAT OF NEW SNOW)
   20 CALORIE = RADSWN
      RADLWN = 0.0
      CALL CALIN (CALORIE)
C-----IF THE MEAN TEMPERATURE WAS LESS THAN OR EQUAL TO 0 C, DO NOT
C----- ALLOW ANY MELT OR FREE WATER
      IF(AVETEMC) 30,30,40
   30 PREWEQV = PREWEQV + WATERIN
      RADLWN = -ENGBAL
      ENGBAL = 0.0
      WATERIN = 0.0
      FREEWAT = 0.0
      CALDEF = 0.0
   40 RETURN
C-----THE PACK HAS JUST REACHED A SUFFICIENT DEPTH.  INITIALIZE THE
C----- DIFFUSION MODEL, BUT RETAIN PSEUDO-CONTROL UNTIL THE DIFFUSION
C----- MODEL IS WELL ALONG INTO STABLE CONTROL
   50 PHASE = -1
      DREADY = 1
C-----START THE PACK AT -3 C (CAL DEF = PACK TEMP * PREWEQV * 1.27)
C-----3.81 = 3 * 1.27
      CALDEF = 3.81 * PREWEQV
      RADLWN = - CALDEF - RADSWN - ENGBAL
      ENGBAL = - CALDEF
      SIMTEM1(1) = AMIN1 (AVETEMC,0.0)
      SIMTEM1(2) = -3.0
      SIMTEM1(3) = -1.5
      FREEWAT = 0.0
      RETURN
C-----THE DIFFUSION MODEL HAS BEEN INITIALIZED PREVIOUSLY.  IF IT IS
C----- STILL STABLE AND IF THE PACK IS DEEP ENOUGH TO INSURE CONTINUED
C----- STABILITY UNTIL MELT, RELINQUISH CONTROL COMPLETELY TO THE
C----- NORMAL METHOD OF COMPUTING THE RADIATION BALANCE, INTERFACED WITH
C----- THE DIFFUSION MODEL
   60 IF(DREADY) 100,70,80
   70 PHASE = 0
      GO TO 10
   80 CALORIE = RADSWN
```

```
      CALAIR = 0.0
      RADLWN = 0.0
      IF(PREWEDV - 5.0) 160,160,90
   90 PHASE = 1
C-----USE THE NORMAL METHOD OF COMPUTING THE RADIATION BALANCE.  IF ANY
C----- OF THE PRECIP WAS SNOW, THE NET LONG WAVE RADIATION BALANCE IS
C----- ASSUMED TO BE ZERO
  100 IF(NDAYSNO) 110,110,120
  110 RADLWN = 0.0
      CALAIR = 0.0
      GO TO 150
C-----TO COMPUTE THE LONG WAVE RADIATION COMPONENTS, CONVERT THE AIR
C----- AND SNOW TEMPERATURES TO POTENTIAL CALORIES BY THE STEFAN -
C----- BLOTZMANN FUNCTION, CALORIES = S * (T ** 4), WHERE
C----- S = 1.17E-7 CAL/((CM**2)(DEGREES KELVIN)**4), AND
C----- T = ABSOLUTE TEMPERATURE (DEGREES KELVIN)
  120 CALAIR = 1.17E-7 * ((AVETEMC + 273.16) ** 4)
      USE = AVETEMC
C-----IF THE SNOWPACK IS ISOTHERMAL, USE THE MINIMUM TEMPERATURE FOR
C----- COMPUTING THE BACK RADIATION
      IF(CALDEF.EQ.0.0) USE = (TEMPMIN - 32.0) * 0.5555555556
C-----UNDER NO CIRCUMSTANCES MAY THE TEMPERATURE FOR COMPUTING THE BACK
C----- RADIATION BE GREATER THAN ZERO
      IF(USE.GT.0.0) USE = 0.0
      CALSNOW = 1.17E-7 * ((USE + 273.16) ** 4)
C-----COMPUTE THE LONG WAVE RADIATION COMPONENTS AS A FUNCTION OF THE
C----- FIRST, DETERMINE WHETHER THE SKIES ARE CLEAR OR CLOUDY
      IF(PRECIP) 130,130,140
C-----WITH CLEAR SKIES, THE DOWNWARD LONGWAVE RADIATION COEFFICIENT IS
C----- .757 (RUNOFF FROM SNOWMELT, EM1110-2-1406, US ARMY CORPS OF
C----- ENGINEERS, 1960, PAGE 7)
  130 SNOSKY = (1.0 - COVDEN) * ((0.757 * CALAIR) - CALSNOW)
C-----THE DOWNWARD LONGWAVE RADIATION COEFFICIENT IS 1.0 BENEATH THE
C----- FOREST CANOPY (OR BENEATH CLOUDY SKIES)
      SNOCAN = COVDEN * (CALAIR - CALSNOW)
      RADLWN = SNOCAN + SNOSKY
      GO TO 150
C-----WITH CLOUDY SKIES, WHEN THE DOWNWARD LONGWAVE RADIATION COEFFI-
C----- CIENT IS 1.0 INSTEAD OF .757, THE ABOVE THREE EQUATIONS MAY BE
C----- REDUCED ALGEBRAICALLY TO THE FOLLOWING SINGLE EQUATION
  140 RADLWN = CALAIR - CALSNOW
C-----COMPUTE THE CALORIC INPUT OR LOSS FROM THE NET EFFECT OF SHORT
C----- WAVE AND LONG WAVE RADIATION
  150 CALORIE = RADSWN + RADLWN
C-----THE SNOWPACK TEMPERATURE DIFFUSION MODEL (LEAF, 1970, STUDY PLAN
C----- FS-RM-1602, NO. 224.  ROCKY MOUNTAIN FOREST AND RANGE EXP STA) IS
C----- INCORPORATED TO CONTROL THE SNOWPACK TEMPERATURE AND COLD CONTENT
C----- DURING NON-ISOTHERMAL CONDITIONS.  SEE NOW IF THE DIFFUSION MODEL
C----- MAY BE USED (DREADY MAY NOT BE -1 AND PASS THROUGH LINK SINCE IT
C----- IS NOT DESIGNED TO WORK WITH IT.  THE -1 IS USED TO INDICATE THAT
C----- THE RADIATION ROUTINES ARE TO BE USED EXCLUSIVELY).  IF IT MAY BE
C----- USED, PASS THROUGH THE LINKING ROUTINE WHICH INTERFACES THE
C----- DIFFUSION MODEL AND THE RADIATION ROUTINES
      IF(DREADY) 170,160,160
  160 CALL LINK (CALAIR,CALORIE,IRETURN)
      IF(IRETURN) 170,170,190
  170 IF(CALORIE) 180,190,200
  180 CALL CALOSS (CALORIE)
  190 RETURN
  200 CALL CALIN (CALORIE)
      RETURN
      END
```

Subroutine RAINED

```
      SUBROUTINE RAINED (TFORAIN,AMTRAIN)
C-----THIS SUBROUTINE COMPUTES THE EFFECT OF RAIN ON SNOW
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEDV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----
C-----DICTIONARY
C       AMTRAIN - THE AMOUNT OF PRECIPITATION OCCURRING AS RAIN (INCHES)
C       CALRAIN - THE DEPLETION OF THE TOTAL CALORIE DEFICIT BY THIS RAIN
C                 (CALORIES)
C       TFORAIN - THE TEMPERATURE FOR COMPUTING THE DEPLETION OF THE TOTAL
C                 CALORIE DEFICIT CAUSED BY THIS RAIN (DEGREES C)
C-----
C-----ADD THIS AMOUNT OF PRECIPITATION TO THE PREDICTED WATER EQUIVALENT
      PREWEDV = PREWEDV + AMTRAIN
C-----SEE IF THERE IS A CALORIE DEFICIT IN THE PACK
      IF(CALDEF) 50,50,10
C-----COMPUTE THE AMOUNT OF RAIN AT THIS TEMPERATURE THAT IS NEEDED TO
C----- WIPE OUT THE DEFICIT AND COMPARE IT WITH THE ACTUAL AMOUNT
   10 CALRAIN = (80.0 + TFORAIN) * 2.54
      AMTNEED = CALDEF/CALRAIN
      COMPARE = AMTRAIN - AMTNEED
      IF(COMPARE) 30,20,40
C-----THERE WAS JUST ENOUGH TO WIPE OUT THE DEFICIT
   20 CALDEF = 0.0
      ENGBAL = ENGBAL + CALRAIN
      RETURN
C-----THERE WAS NOT ENOUGH TO WIPE IT OUT COMPLETELY.  JUST DEPLETE
C----- THE DEFICIT
   30 CALDEF = CALDEF - (CALRAIN * AMTRAIN)
      ENGBAL = ENGBAL + (CALRAIN * AMTRAIN)
      RETURN
C-----THERE WAS MORE THAN ENOUGH TO WIPE OUT THE DEFICIT.  THE AMOUNT
C----- OF RAIN NOT FROZEN IS FREE WATER
   40 FREEWAT = COMPARE
      CALL CALIN (TFORAIN * COMPARE * 2.54)
      RETURN
C-----ALL OF THE RAIN IS ADDED TO THE FREE WATER AND CONTRIBUTES CALORIC
C----- INPUT TO THE PACK
   50 FREEWAT = FREEWAT + AMTRAIN
      CALL CALIN (TFORAIN * AMTRAIN * 2.54)
      RETURN
      END
```

Subroutine SNOWED

```
      SUBROUTINE SNOWED (TFORSNO,AMTSNOW)
C-----THIS SUBROUTINE COMPUTES THE EFFECTS OF A SNOW EVENT ON THE
C----- SNOWPACK
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTDNOW,OBSHYDR,
     1 POTRAD,MSTREDF,IYR
      INTEGER DATE
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEDV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      REAL INTRCPT
C-----
C-----DICTIONARY
C-----
C       AMTSNOW - THE AMOUNT OF PRECIPITATION OCCURRING AS SNOW (INCHES)
C       CALSNOW - THE CONTRIBUTION OF THIS SNOW TO THE TOTAL CALORIE
C                 DEFICIT (CALORIES)
C       INTRCPT - THE AMOUNT OF SNOW INTERCEPTED DURING THIS PRECIP EVENT
C       TFORSNO - THE TEMPERATURE FOR COMPUTING THE CONTRIBUTION OF THIS
C                 SNOW TO THE TOTAL CALORIE DEFICIT (DEGREES C)
C-----
C-----DO NOT ALLOW ANY INTERCEPTION IN JULY AND AUGUST
      IF(DATE(1).EQ.7.OR.DATE(1).EQ.8) GO TO 10
C-----DETERMINE THE AMOUNT OF INTERCEPTED SNOW AS A FUNCTION OF COVER
C----- COMPOSITION AND COVER DENSITY
      IF(COMAX) 10,10,20
   10 INTRCPT = 0.0
      GO TO 80
   20 IF(VEGTYPE - 1) 30,30,40
C-----LODGEPOLE PINE
   30 PERCENT = 0.10
      GREATST = 0.20
      GO TO 50
C-----SPRUCE FIR
   40 PERCENT = 0.15
      GREATST = 0.30
   50 INTRCPT = AMTSNOW * PERCENT * (COVDEN/COMAX)
      IF(ONTREES + INTRCPT - GREATST) 70,70,60
   60 INTRCPT = GREATST - ONTREES
   70 ONTREES = ONTREES + INTRCPT
   80 NDAYSNO = 0
C-----ADD THIS AMOUNT OF PRECIPITATION TO THE PREDICTED WATER EQUIVALENT
      PREWEDV = PREWEDV + AMTSNOW - INTRCPT
C-----THE SNOW FALLING WHEN THE TEMPERATURE IS BETWEEN 35 AND 32 DEGREES
C----- DOES NOT ALTER THE CALORIC DEFICIT
      IF(TFORSNO.GE.0.0) RETURN
C-----COMPUTE THE CALORIE DEFICIT FOR THIS SNOW BY THE EQUATION
C----- CALORIE DEFICIT = S(I)*DELTA T*P, WHERE
C----- S(I) = SPECIFIC HEAT OF ICE (.5 CAL/CM/DEGREES C),
C----- DELTA T = CHANGE IN TEMPERATURE WITH RESPECT TO FREEZING (0.0
C-----  DEGREES CENTIGRADE), AND
C----- P = PRECIPITATION IN CM (CONVERSION FACTOR = 2.54 CM/IN).
C----- THEREFORE, CALORIE DEFICIT = 0.5 * (TFORSNO) * (AMTSNOW * 2.54)
      CALL CALOSS (TFORSNO * (AMTSNOW - INTRCPT) * 1.27)
      RETURN
      END
```

Subroutine SNOWVAP

```
      SUBROUTINE SNOWVAP
C-----COMPUTE THE EVAPORATION FROM THE SURFACE OF THE SNOWPACK AS A
C----- FUNCTION OF THE COVER DENSITY AND REDUCE THE PACK ACCORDINGLY
      COMMON/ONLYCOR/ AVETEMC,BASTEMF,CALDEF,COMAX,COVDEN,DREADY,ENGBAL,
     1 ENGBAL1,FREEWAT,LASTUSD,NDAYSNO,ONTREES,PHASE,PREWEDV,RECHRG,
     2 SIMTEM1(3),SIMTEM3,TCOEFF,THRSHLD,VEGTYPE
      INTEGER DREADY,PHASE,VEGTYPE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      ETFROM = 2.0
      EVAPOTR = (1.0 - COVDEN) * EVAPOTR
      PREWEDV = PREWEDV - EVAPOTR
      RETURN
      END
```

Subroutine ETCODE

```
      SUBROUTINE ETCODE (ETFROM,COMPS12)
C-----KEEP TRACK OF WHICH SOURCES WERE USED FOR EVAPOTRANSPIRATION
      IF(ETFROM - 2.0) 10,20,30
C-----EVAPORATION FROM INTERCEPTED SNOW ON CANOPY (ETFROM = 1)
   10 IF(COMPS12.NE.1.0.AND.COMPS12.NE.3.0.AND.COMPS12.NE.5.0.AND.
     1 COMPS12.NE.7.0) COMPS12 = COMPS12 + ETFROM
      RETURN
C-----EVAPORATION FROM SNOWPACK (ETFROM = 2)
   20 IF(COMPS12.NE.2.0.AND.COMPS12.NE.3.0.AND.COMPS12.LT.6.0) COMPS12 =
     1 COMPS12 + ETFROM
      RETURN
C-----EVAPOTRANSPIRATION FROM MELT, PRECIP OR STORAGE (ETFROM = 4)
   30 IF(COMPS12.LT.4.0) COMPS12 = COMPS12 + ETFROM
      RETURN
      END
```

Subroutine GENDATA

```
      SUBROUTINE GENDATA (N)
C-----GENERATE THE DATA FOR THIS SUBSTATION
C-----
C-----DICTIONARY
C
C      DD - THE EXACT POINT IN THE DEGREE-DAY TABLE WHICH IS TO BE USED
C                IN THE COMPUTATION OF THE INCOMING RADIATION
C      DDFACT - THE TABLE OF ADJUSTMENTS FACTORS FOR COMPUTING THE
C                INCOMING RADIATION
C      DDI - A REAL, TRUNCATED VALUE OF -DD- USED IN INTERPOLATION
C      ET - THE ADJUSTED POTENTIAL EVAPOTRANSPIRATION (MAINTAINED FOR
C                THE REDEFINITION OF -EVAPOTR- BY THE ALTERNATIVES
C      RADHORZ - THE INCOMING RADIATION COMPUTED FROM THE POTENTIAL AT
C                A HORIZONTAL SURFACE
C
      COMMON AIRTEMC(25,6)
      COMMON CALOEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1        PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDR,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/RAD/FRACTON,ISUB
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      EQUIVALENCE (DATE(1),MONTH)
      DIMENSION DDFACT(26)
      DATA DDFACT/ .20, .35, .45, .51, .56, .59, .62, .64, .655, .67,
     1 .682, .69, .70, .71, .715, .72, .722, .724, .726, .728, .73,
     2 .734, .738, .742, .746, .75/
C-----ADJUST THE TEMPERATURES
      IF(DATE(3) - 67) 10,20,20
   10 I = 5
      GO TO 30
   20 I = 3
   30 TEMPMIN = AIRTEMC(N,I) + (TMNMSTR * AIRTEMC(N,I+1))
      TEMPMAX = AIRTEMC(N,1) + (TMXMSTR * AIRTEMC(N,2))
      IF(TEMPMAX.GE.TEMPMIN) GO TO 40
      XXX = TEMPMAX
      TEMPMAX = TEMPMIN
      TEMPMIN = XXX
C-----COMPUTE THE INCOMING RADIATION AT THE BASE STATION FROM THE
C----- POTENTIAL BY THE DEGREE-DAY METHOD
   40 GO TO (50,50,50,50,60,70,70,70,60,50,50,50),MONTH
C-----OCTOBER - APRIL, DEGREE DAYS = .44 * TEMPMAX - 15.9 (+1.0 FOR
C----- SUBSCRIPTING)
   50 DD = (0.44 * TEMPMAX) - 14.9
      GO TO 100
C-----MAY AND SEPTEMBER, DEGREE DAYS = .53 * TEMPMAX - 19.5 (+1.0 FOR
C----- SUBSCRIPTING)
   60 DD = (0.53 * TEMPMAX) - 18.5
      GO TO 100
C-----JUNE, JULY AND AUGUST, DEGREE DAYS = .63 * TEMPMAX - 24.1 (+1.0
C----- FOR SUBSCRIPTING), EXCEPT ON DAYS WITH PRECIP.  DURING THESE
C----- MONTHS, USE A CONSTANT 44 PERCENT ON PRECIP DAYS
   70 IF(PPTMSTR) 90,90,80
   80 RADHORZ = POTRAD * 0.44
      GO TO 150
   90 DD = (0.63 * TEMPMAX) - 23.1
C-----WATCH FOR THE BOUNDARY VALUES, 0. AND 25.  (WITH THE 1.0 ADDED
C----- ABOVE, THE SUBSCRIPTS FOR THE TABULAR VALUES VARY FROM 1 TO 26)
  100 IF(DD - 1.0) 110,110,120
C-----USE THE FIRST TABLE VALUE (NO INTERPOLATION IS NECESSARY)
  110 RADHORZ = POTRAD * DDFACT(1)
      GO TO 150
  120 IF(DD - 26.0) 140,130,130
C-----USE THE LAST TABLE VALUE (NO INTERPOLATION IS NECESSARY)
  130 RADHORZ = POTRAD * DDFACT(26)
      GO TO 150
C-----THE SUBSCRIPT IS IN THE PROPER RANGE.  OBTAIN THE INTERPOLATION
C----- FRACTION AND SUBSCRIPTS THROUGH TRUNCATION OF -DD-
  140 J1 = DD
      DDI = J1
      J = J1 + 1
C-----THE TERM (DD-DDI)/1.0 IS THE INTERPOLATION FRACTION
      RADHORZ = POTRAD * (DDFACT(J1) + ((DDFACT(J) - DDFACT(J1)) * (DD -
     1 DDI)))
C-----ADJUST THE POTENTIAL EVAPOTRANSPIRATION AS COMPUTED BY THE HAMON
C----- METHOD FOR AVAILABLE RADIATION AS A PERCENT OF POTENTIAL
  150 EVAPOTR = ETDAILY(N,MONTH) * (RADHORZ/POTRAD)
      ET = EVAPOTR
C-----ADJUST THE RADIATION AT THE BASE STATION FOR SLOPE AND ASPECT
      RADIN = RADHORZ * (SLPASP(N,ISUB) + ((SLPASP(N,ISUB+1) - SLPASP(N,
     1 ISUB)) * FRACTON))
C-----ADJUST THE PRECIP TO ENSURE REACHING THE PEAK WATER EQUIVALENT
      IF(PPTMSTR) 160,160,170
  160 PRECIP = 0.0
      RETURN
  170 IF(PEAKPPT(N,IYR) - PPTONOW) 190,190,180
  180 PRECIP = PPTMSTR * ((PEAKWE(N,IYR) - PREWEQV(N))/(PEAKPPT(N,IYR)
     1 - PPTONOW))
      RETURN
  190 PRECIP = PPTMSTR
      RETURN
      END
```

Subroutine PLOTTER

```
      SUBROUTINE PLOTTER
C-----PLOT THE INFORMATION.  THE NORMAL SCALE IS 20 PRINT POSITIONS = 1
C----- INCH, BUT SEVERAL OF THE PLOTS HAVE ADDITIONAL SCALE FACTORS AS
C----- EXPLAINED BELOW TO ENHANCE THEIR VISIBLE REPRESENTATIONS
C-----
C-----DICTIONARY
C
C      BOUNDL - THE LOWER BOUNDARY FOR VALUES TO BE PLOTTED IN EACH OF
C                THE THREE LEVELS (AND THE PSEUDO FOURTH LEVEL)
C      BOUNDU - THE UPPER BOUNDARY FOR VALUES TO BE PLOTTED IN EACH OF
C                THE THREE LEVELS (AND THE PSEUDO FOURTH LEVEL)
C      LETTER - THE ONE DIGIT SYMBOL TO BE PLOTTED FOR EACH VARIABLE.
C                ALL VARIABLES FOR ALTERNATIVES ARE PLOTTED AS -A- AND
C                ARE PLOTTED IN THE SAME LEVEL AS THEIR NORMAL
C                COUNTERPART TO IDENTIFY THEM
C      POINT - THE ARRAY WHICH REPRESENTS ONE LINE ON THE PLOT.  IT IS
C                DIVIDED INTO THREE LEVELS (INDEPENDENT PLOTS), WITH A
C                BASE LINE PRINTING FOR EACH AT POSITIONS 1, 42, 83
C                AND 124.  THIS LEAVES 40 POSITIONS BETWEEN THE LINES
C                FOR PLOTTING PURPOSES
C      RAISE - THE QUANTITY NEEDED TO RAISE THE CURVE TO THE PROPER LEVEL
C      SCALE - THE SCALING FACTOR FOR EACH OF THE VARIABLES.  EACH
C                INCLUDES THE NORMAL SCALING FACTOR, 20.0, AND ANY
C                OTHER FACTOR DEEMED NECESSARY, AS EXPLAINED BELOW
C      TOPLOT - AN ARRAY OF LEVEL INDICATORS FOR EACH VARIABLE TO BE
C                PLOTTED.  IF IT IS ZERO, THE VARIABLE WILL NOT BE
C                PLOTTED.  THE VALUE OF TOPLOT MUST BE 1, 2 OR 3 FOR
C                ALL VARIABLES EXCEPT STORAGE.  SINCE STORAGE IS A
C                NEGATIVE VALUE AND PRINTS BELOW THE BASE LINE, IT MAY
C                NOT BE PRINTED AS PART OF LEVEL 1.  IT MAY, HOWEVER,
C                BE ASSIGNED TO THE PSEUDO LEVEL 4, AND THUS WILL
C                PRINT BENEATH THE TOP MOST BASE LINE
C
      COMMON AIRTEMC(25,6)
      COMMON CALOEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1        PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/FORDATA/ FOOTNOT(26),MAXLINE
      INTEGER FOOTNOT
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDR,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/PLOTS/PLOT(11)
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      INTEGER BOUNDL(4),BOUNDU(4),POINT(124)
      DIMENSION LETTER(11),RAISE(4),SCALE(11)
      EQUIVALENCE (DATE(2),IDAY)
      DATA BOUNDL,BOUNDU,RAISE/1,42,83,83,42,83,124,124,1.5,42.5,83.5,
     1 124.5/
      DATA POINT/1H.,40*1H ,1H.,40*1H ,1H.,40*1H ,1H./
C-----HYDROGRAPH - MAX VALUE = 0.5, MULTIPLY BY 4 AS WELL AS 20
      DATA LETTER(1),SCALE(1)/1HH,80.0/
C-----WATER EQUIVALENT - MAX VALUE = 30.0, DIVIDE BY 15 (1.33 = 20/15)
      DATA LETTER(2),LETTER(7),SCALE(2),SCALE(7)/1HW,1HA,2*1.33/
C-----INPUT - MAX VALUE = 2.0, NO EXTRA SCALING NEEDED
      DATA LETTER(3),LETTER(8),SCALE(3),SCALE(8)/1HI,1HA,2*20.0/
C-----EVAPOTRANSPIRATION - MAX VALUE = 0.5, MULTIPLY BY 4 AND 20
      DATA LETTER(4),LETTER(9),SCALE(4),SCALE(9)/1HE,1HA,2*80.0/
C-----STORAGE REQUIREMENTS - MIN VALUE = -5.3 (7.547 = 20/(5.3/2))
      DATA LETTER(5),LETTER(10),SCALE(5),SCALE(10)/1HS,1HA,2*7.547/
C-----RUNOFF - MAX VALUE = 2.0, NO EXTRA SCALING NEEDED
      DATA LETTER(6),LETTER(11),SCALE(6),SCALE(11)/1HR,1HA,2*20.0/
C-----SCALE EACH VARIABLE THAT IS TO BE PLOTTED, RAISE IT TO THE PROPER
C----- LEVEL AND IF IT IS WITHIN THE BOUNDARIES FOR THAT LEVEL, STORE
C----- THE CHARACTER FOR THE PLOT
      DO 20 I = 1,11
```

```
      IF(TOPLOT(I)) 20,20,10
   10 J = TOPLOT(I)
      IPOINT = (PLOT(I) * SCALE(I)) + RAISE(J)
      IF(I.EO.5.OR.I.EO.10) J = J - 1
      IF(IPOINT.GT.BOUNOL(J).ANO.IPOINT.LT.BOUNDU(J)) POINT(IPOINT) =
     1 LETTER(I)
   20 CONTINUE
C-----WRITE THE OATE BY TENS
      IF(IOAY.EQ.10.OR.IOAY.EO.20.OR.IDAY.EO.30) GO TO 30
      WRITE (11,910) POINT
  910 FORMAT(9X124A1)
      GO TO 40
   30 WRITE (11,920) OATE,POINT
  920 FORMAT(1X3I2,2H..124A1)
   40 00 50 I = 2,123
   50 POINT(I) = 1H
      POINT(42) = 1H.
      POINT(83) = 1H.
      RETURN
      ENO
```

Subroutine RADCOMP

```
      SUBROUTINE RAOCOMP
C-----COMPUTE THE POTENTIAL RAOIATION AT THE BASE STATION
C-----
C-----OICTIONARY
C
C     BETWEEN - THE TOTAL NUMBER OF OAYS BETWEEN THE RESPECTIVE
C                LOCATIONS OF THE OATES IN -NOATE-
C     OAYS - THE NUMBER OF OAYS THAT HAVE PASSEO SINCE THE BASE OATE
C              (-NOATE(ISUB)-) TO BE USED IN THE INTERPOLATION
C     FRACTON - THE FRACTIONAL PART NEEOEO IN THE INTERPOLATION BETWEEN
C                TABLE VALUES IN THE COMPUTATION OF THE RAOIATION
C     ISUB - THE SUBSCRIPT OF THE BASE TABLE VALUE USED TO OBTAIN THE
C             RAOIATION FROM THE TABLES BY INTERPOLATION
C     NOATE - THE OATES OF THE TABLES USEO IN COMPUTING THE RAOIATION
C
      COMMON AIRTEMC(25,6)
      COMMON CALOEF(25),COMAX(25),COVOEN(25)
      COMMON OREAOY(25)
      COMMON ENGBAL(25),ET,ETOAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMOO
      COMMON NOAYSNO(25),NOIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1        PREWEOV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBIO(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLO(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEOIO(6)
      COMMON YEARS(20),YYMMOO
      INTEGER OREADY
      INTEGER PHASE
      INTEGER SUBIO
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEOIO
      INTEGER YEARS,YYMMOO
      COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAO,MSTREOF,IYR
      INTEGER OATE
      COMMON/RAO/FRACTON,ISUB
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      OIMENSION BETWEEN(24),NOATE(24)
      OATA BETWEEN/13., 15., 13., 15., 14., 14., 15., 14., 15., 14.,
     1 21., 20., 15., 14., 15., 15., 14., 15., 14., 14., 14., 14., 19.,
     2 19./
      OATA NOATE/ 110,123,207,220,307,321,404,419,503,518,601,622,712,
     1 727,810,825,909,923,1008,1022,1105,1119,1203,1222/
C-----PLACE THIS OATE WITH RESPECT TO THE TABLES
      OO 10 I = 1,24
      IF(NOATE(I) - MMOO) 10,80,20
   10 CONTINUE
C-----A NORMAL TERMINATION OF THE OO LOOP MEANS THAT THIS OATE FALLS
C----- BETWEEN 12/23 ANO 12/31, INCLUSIVE.  USING THE ARRAY IN CIRCULAR
C----- FASHION, I/10 (SUBSCRIPT 1) IS THE CONTROLLING OATE
      I = 1
      GO TO 30
C-----THIS OATE FALLS BETWEEN THE ONES AT LOCATIONS I ANO I-1.  IF I IS
C----- 1, USE 24 FOR I-1 SINCE THE ARRAY IS CIRCULAR
   20 ISUB = I - 1
      IF(ISUB) 30,30,40
   30 ISUB = 24
C-----OBTAIN THE INTERPOLATION FRACTION.  START BY OETERMINING IF
C----- THIS OATE FALLS IN THE SAME MONTH AS THAT AT LOCATION I OR I-1
   40 IF(OATE(1) - (NOATE(ISUB)/100)) 60,50,60
C-----IT IS THE SAME AS I-1 ANO IT IS LARGER, SO SUBTRACT THE I-1 OATE
C----- TO OBTAIN THE NUMBER OF OAYS TO BE USED FOR INTERPOLATING
   50 OAYS = MMOO - NOATE(ISUB)
      GO TO 70
C-----IT IS THE SAME AS I, BUT IT IS SMALLER, SO SUBTRACT IT FROM THE I
C----- OATE.  THEN SUBTRACT THE RESULT FROM THE OAYS BETWEEN I ANO I-1
C----- TO OBTAIN THE NUMBER OF OAYS TO BE USED FOR INTERPOLATING
   60 OAYS = NOATE(I) - MMOO
      OAYS = BETWEEN(ISUB) - OAYS
C-----COMPUTE THE INTERPOLATION FRACTION
   70 FRACTON = OAYS/BETWEEN(ISUB)
      POTRAO = POTENT(ISUB) + (POTENT(I) - POTENT(ISUB)) * FRACTON
      RETURN
C-----THIS OATE IS IN THE TABLE - NO INTERPOLATION IS NECESSARY
   80 FRACTON = 0.0
      ISUB = I
      POTRAD = POTENT(I)
      RETURN
      ENO
```

Subroutine RDMSTR

```
      SUBROUTINE ROMSTR
C-----READ A CARO FROM THE MASTER DECK
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVOEN(25)
      COMMON OREAOY(25)
      COMMON ENGBAL(25),ET,ETOAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMOO
      COMMON NDAYSNO(25),NOIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1        PREWEOV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBIO(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLO(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEOIO(6)
      COMMON YEARS(20),YYMMOO
      INTEGER OREAOY
      INTEGER PHASE
      INTEGER SUBIO
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEOIO
      INTEGER YEARS,YYMMOO
      COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAD,MSTREOF,IYR
      INTEGER OATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      DIMENSION IN(8)
      EQUIVALENCE (OATE(1),IN(1))
      READ (5,910) IN
C-----THE FORMAT DECLARATORS ARE TYPED FOR THE EQUIVALENCEO WOROS OF
C----- -IN- RATHER THAN FOR THE INTEGER ARRAY ITSELF
  910 FORMAT(3I2,11X2F4.1,19X3F5.2)
      IF(EOF(5)) 20,20,10
   10 MSTREOF = 1
      RETURN
   20 MMOO = (OATE(1) * 100) + OATE(2)
      YYMMOO = (OATE(3) * 10000) + MMOO
C-----REOUCE -PPTONOW- TO ITS VALUE BEFORE THE PRECIP FOR THIS OAY WAS
C----- ADDED IN
      PPTONOW = PPTONOW - PPTMSTR
C-----SINCE RAOIATION MEASUREMENTS ARE NOT AVAILABLE, COMPUTE THE BASE
C----- STATION VALUE HERE
      CALL RAOCOMP
      RETURN
      ENO
```

Program SELECT

```
      OVERLAY (OLAYS,1,0)
      PROGRAM SELECT
C-----SELECT THE METHOO OF OUTPUT AND REAO THE WATERSHEO PARAMETERS
      COMMON AIRTEMC(25,6)
      COMMON CALOFF(25),COMAX(25),COVDEN(25)
      COMMON DREAOY(25)
      COMMON ENGBAL(25),ET,ETOAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMOO
      COMMON NOAYSNO(25),NOIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1        PREWEOV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBIO(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLO(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEOID(6)
      COMMON YEARS(20),YYMMOO
      INTEGER DREAOY
      INTEGER PHASE
      INTEGER SUBIO
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEOIO
      INTEGER YEARS,YYMMOO
      COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAO,MSTREOF,IYR
      INTEGER OATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RADLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      OATA IERR/1/
C-----READ THE OUTPUT SELECTION AND CHECK FOR ERRORS
      REAO (5,910) I,L1,L2,NOIVSBL
  910 FORMAT(A6,1X11,1X11,1X12)
      IF(I.EO.6HSELECT) GO TO 20
   10 WRITE (6,920) I,L1,L2,NOIVSBL
```

```
  920 FORMAT(*1THE SELECT CARO (FIRST CARD IN DECK) IS INCORRECT.  EITHE
     1R IT DOES NOT HAVE THE WORO -SELECT- IN COLUMNS 1-6, THE OUTPUT OP
     2TION*/* IS NOT 2, 3 OR 4, OR THE -DATE DIVISIBLE BY- VALUE IS INVA
     3LID*/5X*COLUMNS 1-6 = *A6/5X*OUTPUT OPTION (COL 8) =*I2/5X*ALTERNA
     4TIVE (COL 10) =*I2/5X*DATE OIVISIBLE BY (COL 11-12) =*I3/*-JOB ABO
     5RTED*)
      CALL EXIT
   20 IF(L1.EQ.3.OR.L1.EQ.4) GO TO 50
      IF(L1 - 2) 10,30,10
C-----OPTION 2 - CHECK THE OIVISIBILITY
   30 IF(NDIVSBL) 10,10,40
   40 IF(NDIVSBL - 31) 50,50,10
   50 LEVEL1 = L1
      LEVEL2 = L2 + 1
C-----READ THE PLOT CONTROL CARD AND CHECK FOR ERRORS
      READ (5,930) I,TOPLOT
  930 FORMAT(A5,3X11(1X11))
      IF(I.EQ.5HPLOTS) GO TO 60
      WRITE (6,940)
  940 FORMAT(*1THE SECOND CARD IN THE DATA DECK IS NOT THE PLOTS CARO -
     1JOB ABORTEO*)
      CALL EXIT
C-----HYDROGRAPH
   60 IF(TOPLOT(1) - 3) 80,80,70
   70 I = 10HHYDROGRAPH
      WRITE (6,950) IERR,I,TOPLOT(1)
  950 FORMAT(I1,*THE *A10,* MAY NOT BE PRINTED ON BASE LINE*I2,* OF THE
     1 PLOTS*)
      IERR = 0
C-----WATER EQUIVALENT
   80 IF(TOPLOT(2) - 3) 100,100,90
   90 I = 10HWATER EQV
      WRITE (6,950) IERR,I,TOPLOT(2)
      IERR = 0
C-----INPUT
  100 IF(TOPLOT(3) - 3) 120,120,110
  110 I = 10HINPUT
      WRITE (6,950) IERR,I,TOPLOT(3)
      IERR = 0
C-----EVAPOTRANSPIRATION
  120 IF(TOPLOT(4) - 3) 140,140,130
  130 I = 10HEVAPOTR
      WRITE (6,950) IERR,I,TOPLOT(4)
      IERR = 0
C-----STORAGE REQUIREMENTS (SINCE THIS IS A NEGATIVE QUANTITY, IT MAY
C----- NOT BE PRINTED AS PART OF LEVEL 1, BUT MAY BE PART OF A PSEUOO
C----- LEVEL, LEVEL 4)
  140 IF(TOPLOT(5).LT.4.AND.TOPLOT(5).NE.1) GO TO 150
      I = 10HSTORAGE
      WRITE (6,950) IERR,I,TOPLOT(5)
      IERR = 0
C-----RUNOFF
  150 IF(TOPLOT(6) - 3) 180,180,160
  160 I = 10HRUNOFF
      WRITE (6,950) IERR,I,TOPLOT(6)
  170 CALL EXIT
  180 IF(IERR) 170,170,190
C-----BE SURE THAT ALTERNATIVES PRINT ON THE SAME LEVEL AS THEIR
C----- COUNTERPARTS
  190 DO 210 I = 7,11
      IF(TOPLOT(I)) 210,210,200
  200 TOPLOT(I) = TOPLOT(I-5)
  210 CONTINUE
C-----READ THE WATERSHED OESCRIPTORS AND PARAMETERS
      CALL RDPARAM
C-----WRITE THE FIRST LINES OF THE PLOT
      REWIND 11
      WRITE (11,960) WSHEOID,NSUB
  960 FORMAT(*1*54X*WATER BALANCE SIMULATION*/
     1 1X6A10,41X*COMPOSITE OF*I3,* SUBSTATIONS*//
     2 *0*63X*LEGEND*/
     3 1X2(12X*CHAR  DEFINITION*15X*RANGE*12X)/
     4 14X*A     ALTERNATIVE RESULT FOR NEAREST CHARACTER      *
     5 10X*R     RUNOFF-SIMULATED GEN  0 TO 2.0 INCHES         */
     6 14X*E     EVAPOTRANSPIRATION    0 TO .2 INCH            *
     7 10X*S     STORAGE REQUIREMENTS  -5.3 TO 0 INCHES        */
     8 14X*H     HYDROGRAPH-OBS GENRO  0 TO .5 AREA INCHES     *
     9 10X*W     WATER EOUIV OF PACK   0 TO 30.0 INCHES        */
     A 14X*I     INPUT - MELT OR RAIN  0 TO 2.0 INCHES         */*0*)
C------RETURN TO THE MAIN OVERLAY FOR THE LOADING OF THE NEXT OVERLAY
      END
```

Subroutine RDPARAM

```
      SUBROUTINE RDPARAM
C-----READ THE WATERSHED PARAMETERS ANO OESCRIPTORS
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVOEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETOAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSND(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEOV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER OREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/CMPSITO/COMPS(16),YRTOT(5)
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONDW,OBSHYOR,
     1 POTRAO,MSTREDF,IYR
      INTEGER DATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RAOLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      INTEGER PEAKDAT
      DATA IERR,N/2*1/
C-----READ THE WATERSHEO TITLE AND NUMBER OF SUBSTATIONS
      READ (5,900) WSHEDIO,NSUB,NYEARS
  900 FORMAT(6A10,14X2I3)
      IF(NSUB.GE.1.AND.NSUB.LE.25) GO TO 10
      WRITE (6,901) IERR,NSUB
  901 FORMAT(I1,I3,* SUBSTATIONS MAY NOT BE RUN.  COLUMNS 76-77 OF THE W
     1ATERSHED ID CARD MUST BE 1 TO 25, INCLUSIVE (OR THE PROGRAM MAY BE
     2 REVISED)*)
      IERR = 0
   10 IF(NYEARS.GE.1.AND.NYEARS.LE.20) GO TO 20
      WRITE (6,902) IERR,NYEARS
  902 FORMAT(I1,I3,* YEARS MAY NOT BE RUN.  COLUMNS 79-80 OF THE WATERSH
     1ED ID CARD MUST BE 1 TO 20, INCLUSIVE (OR THE PROGRAM MAY BE REVIS
     2ED)*)
      IERR = 0
C-----READ THE POTENTIAL RADIATION CARDS (2 CARDS)
   20 READ (5,910) NAME,POTENT
  910 FORMAT(A10,10X12F5.0/20X12F5.0)
      IF(NAME.EQ.10HPOTENTIAL ) GO TO 30
      WRITE (6,911) IERR
  911 FORMAT(I1,*THE POTENTIAL RADIATION CARDS DO NOT FOLLOW THE WATERSH
     1ED ID CARD*)
      IERR = 0
C-----SEE IF THERE ARE SUBSTATIONS TO BE READ
   30 IF(NSUB) 210,210,60
   60 NSETS = NSUB
C-----READ A SET OF SUBSTATION DESCRIPTORS.  START WITH THE ID AND
C----- CONSTANT PARAMETERS
   70 READ (5,930) (SUBID(N,I),I=1,6),TCOEFF(N),COVDEN(N),COMAX(N),
     1 WEIGHT(N),THRSHLO(N),VEGTYPE(N)
  930 FORMAT(6A10,4F4.2,F2.0,1X11)
      IF(COMAX(N).GE.COVDEN(N)) GO TO 80
      WRITE (6,931) IERR,(SUBIO(N,I),I=1,6),COVDEN(N),COMAX(N)
  931 FORMAT(I1,*ON THE SUBSTATION ID CARD ENTITLEO *6A10/* THE COVER DE
     1NSITY SPECIFIED IN COLUMNS 65-68 (*F5.2,*) IS GREATER THAN THE MAX
     2IMUM COVER DENSITY IN COLUMNS 69-72 (*F5.2,*)*)
      IERR = 0
   80 IF(WEIGHT(N).GT.0.0.AND.WEIGHT(N).LE.1.0) GO TO 90
      WRITE (6,932) IERR,WEIGHT(N),(SUBID(N,I),I=1,6)
  932 FORMAT(I1,*INVALIO WEIGHT (*F5.2,*) IN COL 73-76 OF SUBSTATION ID
     1CARO ENTITLED *6A10/* WEIGHT MUST BE BETWEEN 0.001 ANO 1.0, INCLUS
     2IVE*)
      IERR = 0
   90 IF(VEGTYPE(N).EQ.1.OR.VEGTYPE(N).EO.2) GO TO 100
      WRITE (6,933) IERR,VEGTYPE(N),(SUBIO(N,I),I=1,6)
  933 FORMAT(I1,*INVALID VEG TYPE (*I1,*) IN COLUMN 80 OF SUBSTATION ID
     1CARD ENTITLED *6A10/* VEGETATION TYPE = 1 (LODGEPOLE PINE), = 2 (S
     2PRUCE FIR)*)
      IERR = 0
C-----READ THE INITIAL CONDITIONS CARD
  100 READ (5,940) NAME,SIMTEM1(N,2),PREWEQV(N),RECHRG(N),SIMTEM1(N,1),
     1 DREAOY(N)
  940 FORMAT(A10,10X4F5.2,I5)
      IF(NAME.EQ.10HINITIAL CO) GO TO 110
      WRITE (6,941) IERR,(SUBIO(N,I),I=1,6)
  941 FORMAT(I1,* THE INITIAL CONDITIONS CARD ODES NOT FOLLOW THE SUBSTA
     1TION IO CARO ENTITLED*/1X6A10)
      IERR = 0
      GO TO 130
C-----CONVERT THE PACK TEMPERATURE TO CALORIE DEFICIT (AS A POSITIVE
C----- QUANTITY), INCLUDE THE WEIGHTED RECHARGE REOUIREMENT FOR USE IN
C----- THE -CHANGE IN STORAGE- COMPUTATION, ANO OEFINE THE GROUND
C----- TEMPERATURE FOR THE SIMULATION MODEL
  110 CALOEF(N) = - SIMTEM1(N,2) * PREWEQV(N) * 1.27
      YRTOT(4) = YRTOT(4) + (RECHRG(N) * WEIGHT(N))
      SIMTEM1(N,3) = - 1.5
C-----READ THE OAILY ET VALUES
  130 READ (5,950) NAME,(ETDAILY(N,I),I=1,12)
  950 FORMAT(A10,10X12F5.4)
      IF(NAME.EO.10HDAILY ET  ) GO TO 140
      WRITE (6,951) IERR,(SUBID(N,I),I=1,6)
  951 FORMAT(I1,* THE DAILY ET VALUES CARO DOES NOT FOLLOW THE INITIAL C
     1ONDITIONS CARD IN THE CARDS FOLLOWING THE SUBSTATION ID CARD ENTIT
     2LEO*/1X6A10)
      IERR = 0
C-----READ THE AIR TEMPERATURE COEFFICIENTS
  140 READ (5,960) NAME,(AIRTEMC(N,I),I=1,6)
  960 FORMAT(A10,10X6F5.3)
      IF(NAME.EQ.10HAIR TEMP C) GO TO 150
      WRITE (6,961) IERR,(SUBID(N,I),I=1,6)
  961 FORMAT(I1,*THE AIR TEMPERATURE COEFFICIENTS CARO DOES NOT FOLLOW T
     1HE DAILY ET CARD IN THE CARDS FOLLOWING THE SUBSTATION IO CARD ENT
     3ITLED*/1X6A10)
      IERR = 0
C-----READ THE SLOPE/ASPECT AOJUSTMENT FACTORS

  150 READ (5,970) NAME,(SLPASP(N,I),I=1,24)
  970 FORMAT(A6,2X24F3.2)
      IF(NAME.EQ.6HSLP/AS) GO TO 160
      WRITE (6,971) IERR,(SUBID(N,I),I=1,6)
```

```
  971 FORMAT(1I1,*THE SLOPE/ASPECT CORRECTION FACTORS CARD DOES NOT FOLLO
     1W THE AIR TEMPERATURE COEFFICIENTS CARD FOLLOWING THE SUBSTATION I
     2D CARD*/1X6A10)
      IERR = 0
C-----READ THE PEAK WATER EQUIVALENT, ITS DATE AND THE DATE BY WHICH THE
C----- PACK MUST BE ISOTHERMAL FOR EACH YEAR
  160 DO 190 I = 1,NYEARS
      READ (5,980) PEAKWE(N,I),TEMP,PEAKDAT,ITEMP
  980 FORMAT(20X2F5.2,1X16,1X16)
C-----FOR RAPID AND MORE ACCURATE BINARY COMPARES IN SUBROUTINE GENDATA,
C----- LOWER THE PEAK PRECIP SLIGHTLY
      PEAKPPT(N,I) = TEMP - 0.001
      IF(N - 1) 170,170,180
  170 YEARS(I) = MOD(PEAKDAT,100)
      GO TO 190
  180 IF(YEARS(I).EQ.MOD(PEAKDAT,100)) GO TO 190
      K = MOD(PEAKDAT,100)
      WRITE (6,981) IERR,(SUBID(N,J),J=1,6),YEARS(I),K,(YEARS(J),J=1,
     1 NYEARS)
  981 FORMAT(I1,*THE PEAK W.E. CARDS FOLLOWING THE SUBSTATION ID CARD EN
     1TITLED *6A10/* DO NOT CORRESPOND TO THE YEARS AND/OR ORDER OF THE
     2FIRST SET READ.  WHEN*I3,* WAS EXPECTED,*I3,* WAS READ.*/* THE FIR
     3ST SET IS0*20I4)
      IERR = 0
C-----CONVERT THE ISOTHERMAL DATE TO YYMMDD FORMAT FOR RAPID COMPARES
  190 ISOTHRM(N,I) = 110000 * ITEMP) - (999999 * (ITEMP/100))
C-----GO ON TO THE NEXT SET
      N = N + IERR
      NSETS = NSETS - 1
      IF(NSETS) 200,200,70
  200 IF(IERR) 210,210,220
  210 WRITE (6,990)
  990 FORMAT(*0*/*0JOB ABORTED FOR ABOVE REASON(S) WHILE OPERATING IN SU
     1BROUTINE RDPARAM*)
      CALL EXIT
C-----INITIALIZE THE VARIABLES THAT HAVE NOT BEEN DEFINED ABOVE
  220 DO 230 N = 1,25
      ENGBAL(N) = -1.0
      FREEWAT(N) = 0.0
      LASTUSO(N) = 0
      NDAYSNO(N) = 0
      ONTREES(N) = 0.0
  230 PHASE(N) = 0
C-----SUM THE WEIGHTS TO CERTIFY THAT A COMPLETE SET OF PARAMETERS IS
C----- INCLUDED
      SUM = 0.0
      DO 240 N = 1,NSUB
  240 SUM = SUM + WEIGHT(N)
      IF(SUM.GT.0.97.AND.SUM.LT.1.03) RETURN
      WRITE (6,991) IERR,SUM
  991 FORMAT(I1,*THE TOTAL OF THE WEIGHTING FACTORS (*F6.3,*) IS OUTSIDE
     1 THE TOLERABLE TOTALS, 0.97 TO 1.03*)
      GO TO 210
      END
```

Program INTSUM

```
      OVERLAY (OLAYS,2,0)
      PROGRAM INTSUM
C-----INTERVAL SUMS OF VALUES CONCERNED WITH WATER - LOAD APPROPRIATE
C----- OPERATING PROGRAM TO WORK WITH THE SUBROUTINES IN THIS OVERLAY
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDP,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      CALL OVERLAY (5HOLAYS,2,LEVEL2)
C-----RETURN TO THE MAIN OVERLAY TO TERMINATE NORMALLY
      END
```

Subroutine NORM2

```
      SUBROUTINE NORM2 (N)
C-----THE VERSION OF THE NORMAL SIMULATION SUMS THOSE VALUES CONCERNED
C---- WITH WATER FOR OUTPUT ON DATES DIVISIBLE BY THE SPECIFIED NUMBER
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/CMPSITD/COMPS(16),YRTOT(5)
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDR,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/PLOTS/PLOT(6)
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----MAKE THE PASS THROUGH THE WATER BALANCE ROUTINES
      CALL WATBAL (CALDEF(N),COMAX(N),COVDEN(N),DREADY(N),ENGBAL(N),
     1 FREEWAT(N),LASTUSO(N),NDAYSNO(N),ONTREES(N),PHASE(N),PREWEQV(N),
     2 RECHRG(N),SIMTEM1(N,1),SIMTEM1(N,2),SIMTEM1(N,3),TCOEFF(N),
     3 THRSHLD(N),VEGTYPE(N))
C-----CHECK THE MANDATORY ISOTHERMAL DATE
      IF(YYMMDD - ISOTHRM(N,IYR)) 20,10,20
C-----TURN OFF THE DIFFUSION MODEL, SET THE PACK TO 0 C AND ADJUST THE
C----- ENERGY BALANCE ACCORDINGLY
   10 DREADY(N) = -1
      ENGBAL(N) = ENGBAL(N) + CALDEF(N)
      RADLWN = RADLWN + CALDEF(N)
      CALDEF(N) = 0.0
C-----WEIGHT AND STORE THIS DATA
   20 WT = WEIGHT(N)
      COMPS(1) = COMPS(1) + (PREWEQV(N) * WT)
      COMPS(2) = COMPS(2) + (RECHRG(N) * WT)
      COMPS(13) = COMPS(13) + (PRECIP * WT)
      COMPS(14) = COMPS(14) + (WATERIN * WT)
      COMPS(15) = COMPS(15) + (EVAPOTR * WT)
      COMPS(16) = COMPS(16) + (GENRO * WT)
      CALL ETCODE (ETFROM,COMPS(6))
      RETURN
      END
```

Subroutine WRITE2

```
      SUBROUTINE WRITE2 (K,COMPS)
C-----THIS VERSION OF THE OUTPUT ROUTINE PRINTS INTERVAL AND YEAR-TO-
C----- DATE SUMS OF ALL VALUES CONCERNED WITH WATER
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,20)
      COMMON LASTUSO(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEQV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEDID(6)
      COMMON YEARS(20),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMON/FORDATA/ FOOTNOT(26),MAXLINE
      INTEGER FOOTNOT
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDR,
     1 POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      DIMENSION COMPS(12),FROM(7)
      DATA LINES/-1/
      DATA FROM/3HC  ,3H S ,3HCS ,3H  E,3HC E,3H SE,3HCSE/
      COMPS(6) = FROM(COMPS(6))
C-----DETERMINE HOW TO WRITE THE LINE
      IF(K.EQ.1H$) GO TO 10
      WRITE (6,910) K,COMPS
  910 FORMAT(1XA10,2E10.2,6X2F8.2,F8.4,1XA3,E9.2,7X2F8.2,E10.4,1X2E10.2)
      LINES = LINES - 1
      RETURN
C-----CHECK THE LINE COUNTER
   10 IF(LINES) 20,20,30
   20 WRITE (6,920) FOOTNOT,WSHEDID,NSUB
  920 FORMAT(*0*13A10/1X13A10/*1*54X*WATER BALANCE SIMULATION*/
```

```
     1 1X6A10,41X*COMPOSITE OE*13,* SUBSTATIONS*/
     2 *0*16X*C U R R E N T*12X*I N T E R V A L    T O T A L S*13X
     3 *-  -  -  Y E A R    T O    O A T E  -  -  -*/
     4 14X*SNOWPACK  RECHARGE*23X*EVAPOTRANS  GENERATEO*38X
     5 *GEN     CHANGE IN*/
     6 16X*W. E.       REO          PRECIP    INPUT          EROM     RUNOFF
     7      PRECIP    INPUT  EVAPOTRANS     RUNOFF  RECHRG RQ*/)
       LINES = MAXLINE
   30 WRITE (6,930) OATE,COMPS
  930 EORMAT(* *313,1X2E10.2,6X2F8.2,E8.4,1XA3,E9.2,7X2E8.2,E10.4,1X
     1 2F10.2)
       LINES = LINES - 1
       RETURN
C-----OOUBLE SPACE BETWEEN YEARS
       ENTRY WRITOT
       WRITE (6,910)
       LINES = LINES - 1
       RETURN
       END
```

Program INTSUMO

```
       OVERLAY (OLAYS,2,1)
       PROGRAM INTSUMO
C-----OPERATING PROGRAM EOR PRINTING INTERVAL SUMS FOR THE NORMAL
C----- SIMULATION WITHOUT ANY ALTERNATIVES
       COMMON AIRTEMC(25,6)
       COMMON CALOFF(25),COMAX(25),COVDEN(25)
       COMMON OREAOY(25)
       COMMON ENGBAL(25),ET,ETOAILY(25,12)
       COMMON FREEWAT(25)
       COMMON ISOTHRM(25,20)
       COMMON LASTUSO(25),LEVEL1,LEVEL2
       COMMON MMOO
       COMMON NOAYSNO(25),NOIVSBL,NSUB,NYEARS
       COMMON ONTREES(25)
       COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEQV(25)
       COMMON RECHRG(25)
       COMMON SIMTEM1(25,3),SUBIO(25,6),SLPASP(25,24)
       COMMON TCOEEE(25),THRSHLD(25),TOPLOT(11)
       COMMON VEGTYPE(25)
       COMMON WEIGHT(25),WSHEOIO(6)
       COMMON YEARS(20),YYMMOO
       INTEGER OREAOY
       INTEGER PHASE
       INTEGER SUBIO
       INTEGER TOPLOT
       INTEGER VEGTYPE
       INTEGER WSHEOIO
       INTEGER YEARS,YYMMOO
       COMMON/CMPSITO/COMPS(16),YRTOT(5)
       COMMON/EOROATA/ FOOTNOT(26),MAXLINE
       INTEGER FOOTNOT
       COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAO,MSTREOF,IYR
       INTEGER OATE
       COMMON/PLOTS/PLOT(11)
       COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
       INTEGER FOOTNTE(26)
       OATA FOOTNTE/260HNORMAL SIMULATION ONLY
     1
     2
     3
     4
C-----OEEINE THE FOOTNOTE
       OO 1 N = 1,26
     1 FOOTNOT(N) = FOOTNTF(N)
C-----MAXLINE = 52 - NUMBER OF ALTERATIONS
       MAXLINE = 52
C-----WRITE THE FOOTNOTE ON THE PLOT
       WRITE (11,900) FOOTNOT
  900 FORMAT(/*0*13A10/1X13A10//)
C-----REAO A MASTER CARO
   10 CALL ROMSTR
       IF(MSTREOE) 20,20,170
C-----GENERATE THE OATA ANO PERFORM THE SIMULATION EOR EACH SUBSTATION
   20 OO 30 N = 1,NSUB
       CALL GENOATA (N)
       CALL NORM2 (N)
   30 CONTINUE
C-----STORE THE INFORMATION FOR THE PLOTS
       PLOT(1) = OBSHYOR
       PLOT(2) = COMPS(1)
       PLOT(3) = COMPS(14)
       PLOT(4) = COMPS(15)
       PLOT(5) = COMPS(2)
       PLOT(6) = COMPS(16)
C-----AOO THESE VALUES INTO THE INTERVAL LOCATIONS
       COMPS(3) = COMPS(3) + COMPS(13)
       COMPS(4) = COMPS(4) + COMPS(14)
       COMPS(5) = COMPS(5) + COMPS(15)
       COMPS(7) = COMPS(7) + COMPS(16)
C-----ZERO THE DAILY COMPOSITE LOCATIONS
       OO 40 N = 13,16
   40 COMPS(N) = 0.0
C-----SEE IE THIS OAY IS TO BE PRINTEO
       IE(MOO (OATE(2),NOIVSBL)) 70,50,70
C-----AOO THESE TOTALS INTO THE YEAR-TO-OATE LOCATIONS, GET THE CHANGE
C----- IN THE RECHARGE REQUIREMENTS AND PRINT THE LINE
   50 COMPS(8) = COMPS(8) + COMPS(3)
       COMPS(9) = COMPS(9) + COMPS(4)
       COMPS(10) = COMPS(10) + COMPS(5)
       COMPS(11) = COMPS(11) + COMPS(7)
       COMPS(12) = COMPS(2) - YRTOT(4)
       CALL WRITE2 (1H$,COMPS)
C-----ZERO THE INTERVAL ACCUMULATING LOCATIONS
       OO 60 N = 3,7
   60 COMPS(N) = 0.0
C-----PERFORM THE PLOTS BETWEEN APRIL 1 ANO SEPTEMBER 30
   70 IF(MMOO - 401) 160,140,80
   80 IE(930 - MMOO) 160,90,150
C-----ON 9/30, STORE THE CURRENT RECHARGE REQUIREMENT, ZERO THE YEARLY
C----- ACCUMULATING LOCATIONS, AND RESET THE OIEEUSION MOOEL SWITCHES
   90 YRTOT(4) = COMPS(2)
       OO 100 N = 8,11
  100 COMPS(N) = 0.0
       OO 110 N = 1,NSUB
  110 OREAOY(N) = 0
C-----CHECK THE YEARS TO BE SURE ALL OECKS STILL CORRESPONO TO THE
C----- PARAMETER OECK
       IF(OATE(3) - YEARS(IYR)) 120,130,120
  120 WRITE (6,910) OATE(3),IYR,IYR,YEARS(IYR)
  910 EORMAT(*1THE OATA OECKS ARE OUT OE PHASE WITH THE WATERSHEO PARAME
     1TER OECK.  THE WATER YEAR JUST ENOING (19*I2,*) IS OECK NUMBER*I3,
     2 *,*/*  BUT SPECIFIEO CONOITIONS CARO NUMBER*I3,* FOR EACH SUBSTAT
     3ION IS EOR 19*I2)
       CALL EXIT
  130 IYR = IYR + 1
C-----OOUBLE SPACE BETWEEN YEARS
       CALL WRITOT (1H$,YRTOT)
       GO TO 150
C-----ON 4/1, WRITE THE OROINATE LINE
  140 WRITE (11,920)
  920 FORMAT(9X124(1H.))
  150 CALL PLOTTER
C-----ZERO THE CURRENT LOCATIONS
  160 COMPS(1) = 0.0
       COMPS(2) = 0.0
       GO TO 10
C-----ALL CAROS HAVE BEEN REAO.  IF A LINE WAS NOT PRINTEO ON THE LAST
C----- OAY PROCESSEO, OO IT NOW
  170 IF(MOO (MMOO,NOIVSBL)) 180,190,180
  180 COMPS(8) = COMPS(8) + COMPS(3)
       COMPS(9) = COMPS(9) + COMPS(4)
       COMPS(10) = COMPS(10) + COMPS(5)
       COMPS(11) = COMPS(11) + COMPS(7)
       COMPS(12) = COMPS(2) - YRTOT(4)
       CALL WRITE2 (1H$,COMPS)
C-----WRITE THE FOOTNOTE ON THE LAST PAGE
  190 WRITE (6,930) FOOTNOT
  930 FORMAT(*0*13A10/1X13A10)
C-----RETURN TO THE MAIN OVERLAY EOR NORMAL TERMINATION
       END
```

Program DAILY

```
       OVERLAY (OLAYS,3,0)
       PROGRAM OAILY
C-----COMPOSITE OAILY OUTPUT - LOAO APPROPRIATE OPERATING PROGRAM TO
C----- WORK WITH THE SUBROUTINES IN THIS OVERLAY
       COMMON AIRTEMC(25,6)
       COMMON CALOEF(25),COMAX(25),COVOEN(25)
       COMMON OREAOY(25)
       COMMON ENGBAL(25),ET,ETOAILY(25,12)
       COMMON EREEWAT(25)
       COMMON ISOTHRM(25,20)
       COMMON LASTUSO(25),LEVEL1,LEVEL2
       COMMON MMOO
       COMMON NOAYSNO(25),NOIVSBL,NSUB,NYEARS
       COMMON ONTREES(25)
       COMMON PEAKPPT(25,20),PEAKWE(25,20),PHASE(25),POTENT(24),
     1       PREWEQV(25)
       COMMON RECHRG(25)
       COMMON SIMTEMI(25,3),SUBIO(25,6),SLPASP(25,24)
       COMMON TCOEFF(25),THRSHLO(25),TOPLOT(11)
       COMMON VEGTYPE(25)
       COMMON WEIGHT(25),WSHEOIO(6)
       COMMON YEARS(20),YYMMOO
       INTEGER OREAOY
       INTEGER PHASE
       INTEGER SUBIO
       INTEGER TOPLOT
       INTEGER VEGTYPE
       INTEGER WSHEOIO
       INTEGER YEARS,YYMMOO
       COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAO,MSTREOF,IYR
       INTEGER OATE
       COMMON/WATRBAL/ETEROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
       CALL OVERLAY (5HOLAYS,3,LEVEL2)
C-----RETURN TO THE MAIN OVERLAY TO TERMINATE NORMALLY
       END
```

Subroutine NORM3

```
       SUBROUTINE NORM3 (N)
C-----THIS VERSION OE THE NORMAL SIMULATION MAINTAINS ALL INEORMATION
C----- NECESSARY OE THE PRINTING OF ONE LINE PER OAY FOR THE WATERSHEO
C----- COMPOSITE
       COMMON AIRTEMC(25,6)
       COMMON CALOEF(25),CDMAX(25),COVOEN(25)
       COMMON OREAOY(25)
       COMMON ENGBAL(25),ET,ETOAILY(25,12)
       CUMMON FREEWAT(25)
```

```
      COMMON ISOTHRM(25,2D)
      COMMDN LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDO
      COMMDN NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMDN ONTREES(25)
      COMMDN PEAKPPT(25,2D),PEAKWE(25,2D),PHASE(25),PDTFNT(24),
     1       PREWEOV(25)
      CDMMON RECHRG(25)
      COMMDN SIMTEMI(25,3),SUBID(25,6),SLPASP(25,24)
      COMMDN TCOEFF(25),THRSHLD(25),TOPLOT(I1)
      COMMDN VEGTYPE(25)
      COMMDN WEIGHT(25),WSHEDIO(6)
      COMMON YEARS(2D),YYMMDD
      INTEGER DREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEDID
      INTEGER YEARS,YYMMDD
      COMMDN/CMPSITD/COMPS(16),YRTOT(5)
      COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYDR,
     I POTRAD,MSTREOF,IYR
      INTEGER DATE
      COMMON/PLOTS/PLOT(6)
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RADIN,RADLWN,RADSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
C-----MAKE THE PASS THROUGH THE WATER BALANCE ROUTINES
      CALL WATBAL (CALDEF(N),CDMAX(N),COVDEN(N),DREADY(N),ENGBAL(N),
     1 FREEWAT(N),LASTUSD(N),NDAYSNO(N),ONTREES(N),PHASE(N),PREWEOV(N),
     2 RECHRG(N),SIMTEMI(N,1),SIMTEMI(N,2),SIMTEMI(N,3),TCOEFF(N),
     3 THRSHLO(N),VEGTYPE(N))
C-----CHECK THE MANDATORY ISOTHERMAL DATE
      IF(YYMMDO - ISOTHRM(N,IYR)) 2D,10,2D
C-----TURN OFF THE DIFFUSION MODEL, SET THE PACK TO 0 C AND ADJUST THE
C----- ENERGY BALANCE ACCORDINGLY
   1D OREADY(N) = -1
      ENGBAL(N) = ENGBAL(N) + CALDEF(N)
      RADLWN = RAOLWN + CALDEF(N)
      CALDEF(N) = D.D
C-----WEIGHT AND STORE THIS DATA
   2D WT = WEIGHT(N)
      COMPS(1) = COMPS(1) + (TEMPMAX * WT)
      COMPS(2) = COMPS(2) + (TEMPMIN * WT)
      COMPS(3) = COMPS(3) + (PRECIP * WT)
      IF(PREWEOV(N)) 4D,4D,3D
   3D COMPS(4) = COMPS(4) + (ONTREES(N) * WT)
      COMPS(5) = COMPS(5) + (RAOSWN * WT)
      COMPS(6) = COMPS(6) + (RAOLWN * WT)
      COMPS(7) = COMPS(7) + (ENGBAL(N) * WT)
      COMPS(8) = COMPS(8) + (CALDEF(N) * WT)
      COMPS(9) = COMPS(9) + (PREWEOV(N) * WT)
   4D COMPS(1D) = COMPS(1D) + (WATERIN * WT)
      COMPS(11) = COMPS(11) + (EVAPOTR * WT)
      COMPS(13) = COMPS(13) + (RECHRG(N) * WT)
      COMPS(I4) = COMPS(14) + (GENRO * WT)
      CALL ETCODE (ETFROM,COMPS(12))
      RETURN
      END
```

Function ROUNDF

```
      FUNCTION ROUNDF (SIGN)
C-----DETERMINE THE SIGN FOR ROUNDING
      IF(SIGN) 1D,2D,2D
   1D ROUNDF = -D.5
      RETURN
   2D ROUNDF = 0.5
      RETURN
      END
```

Subroutine WRITE3

```
      SUBROUTINE WRITE3 (K,COMPS)
C-----THIS VERSION OF THE OUTPUT ROUTINE PRINTS ONE COMPOSITE LINE PFR
C----- OAY
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),COMAX(25),COVDFN(25)
      COMMON DREAOY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,2D)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NOIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,2D),PEAKWE(25,2D),PHASE(25),POTENT(24),
     1       PREWEQV(25)
      COMMON RECHRG(25)
      COMMDN SIMTEM)(25,3),SUBID(25,6),SLPASP(25,24)
      COMMON TCOEFF(25),THRSHLD(25),TOPLOT(11)
      COMMON VEGTYPE(25)
      COMMON WEIGHT(25),WSHEOID(6)
      COMMON YEARS(2D),YYMMDO
      INTEGER OREADY
      INTEGER PHASE
      INTEGER SUBID
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHED!D
      INTEGER YEARS,YYMMOO
      COMMON/FORDATA/ FOOTNOT(26),MAXLINE
      INTEGER FOOTNOT
      COMMON/MASTER/DATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAD,MSTREOF,IYR
      INTEGER OATE
      COMMDN/WATRBAL/ETFROM,EVAPDTR,GENRO,PRECIP,RADIN,RADLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      DIMENSION COMPS(16),FRDM(7),ITEMPS(3),OUT(13),OUT1(7)
      EQUIVALENCE (OUT(1),OUT1(1))
      OATA LINES/-1/
      DATA FROM/3HC   ,3H S ,3HCS ,3H  E,3HC E,3H SE,3HCSE/
      J = D
      IF(COMPS(14).LE.D.D) J = -1
      ITEMPS(1) = COMPS(1) + ROUNDF (COMPS(1))
      ITEMPS(2) = COMPS(2) + ROUNDF (COMPS(2))
      ITEMPS(3) = COMPS(15) + ROUNOF(COMPS(15))
      OUT(1) = COMPS(3)
      OUT(2) = COMPS(16)
      IF(COMPS(9)) 10,1D,5D
   1D OUT1(3) = COMPS(10)
      OUT1(4) = COMPS(11)
      OUT1(5) = FROM(COMPS(12))
      OUT1(6) = COMPS(13)
      OUT1(7) = COMPS(14)
      J = J + 7
C-----DETERMINE HOW TO WRITE THE LINE
      IF(K.EO.1H$) GO TO 2D
      WRITE (6,91D) K,ITEMPS,(OUT1(I),I=1,J)
  91D FORMAT(1XA10,2X3I4,2F6.2,5DXF5.2,2XF6.4,2XA3,5XF5.2,6XF5.2)
      LINES = LINES - 1
      RETURN
C-----CHECK THE LINE COUNTER
   2D IF(LINES) 30,3D,4D
   3D WRITE (6,920) FOOTNOT,WSHEOID,NSUB
  92D FORMAT(*D*13A1D/1X13A10/*1*54X*WATER BALANCE SIMULATION*/
     1 1X6A1D,41X*COMPOSITE OF*I3,* SUBSTATIONS*/
     2 *D*15X*TEMP (F)    PRECIP (IN)   INTERCEPTED  RAD (CAL) ENG BAL
     3 SNOWPACK      INPUT  EVAPOTRANS     RECHARGE    GENERATEO*/
     4 5X*OATF      MAX MIN AVE    OAY ACCUM          (IN)        SW     LW  (CA
     5L)    TEMP(C) WE(IN)    (IN)   (IN)   FROM      REO (IN)  RUNOFF (IN)*)
      LINES = MAXLINE
   4D WRITE (6,930) DATE,ITEMPS,(OUT1(I),I=1,J)
  930 FORMAT(* *3I3,3X3I4,2F6.2,50XF5.2,2XF6.4,2XA3,5XF5.2,6XF5.2)
      LINES = LINES - I
      RETURN
C-----ALL THE INFORMATION IS TO BE PRINTED
   5D DO 6D I = 3,13
   6D OUT(I) = COMPS(I+1)
      OUT(11) = FROM(COMPS(12))
      J = J + 13
C-----DETERMINE HOW TO WRITE THE LINE
      IF(K.EQ.1H$) GO TO 7D
      WRITE (6,940) K,ITEMPS,(OUT(I),I=1,J)
  94D FORMAT(1XA1D,2X3I4,2F6.2,5XF6.4,3X3F6.1,4XF4.1,2XF6.2,2XF5.2,2X
     1 F6.4,2XA3,5XF5.2,6XF5.2)
      LINES = LINES - 1
      RETURN
C-----CHECK THE LINE COUNTER
   7D IF(LINES) 80,8D,9D
   8D WRITE (6,92D) FOOTNOT,WSHEDIO,NSUB
      LINES = MAXLINE
   90 WRITE (6,950) OATE,ITEMPS,(OUT(I),I=1,J)
  950 FORMAT(* *3I3,3X3I4,2F6.2,5XF6.4,3X3F6.1,4XF4.1,2XF6.2,2XF5.2,2X
     1 F6.4,2XA3,5XF5.2,6XF5.2)
      LINES = LINES - 1
      RETURN
C
C-----YEARLY TOTALS
C
      ENTRY WRITOT
C-----DETERMINE HOW TO WRITE THE LINE
      IF(K.EO.1H$) GO TO 1DD
      WRITE (6,960) K,(COMPS(I),I=1,5)
  96D FORMAT(1XA1D,2DXF6.2,49XF6.2,F8.4,9XF6.2,4XF7.2/)
      LINES = LINES - 2
      RETURN
C-----CHECK THE LINE COUNTER
  100 IF(LINES) 11D,11D,12D
  11D WRITE (6,920) FOOTNOT,WSHEOID,NSUB
      LINES = MAXLINE
  120 WRITE (6,97D) OATE,(COMPS(I),I=1,5)
  97D FORMAT(*OTOTALS THROUGH*3I3,7XF6.2,49XF6.2,F8.4,*  (CHNG =*F6.2,*)
     1*3XF7.2/)
      LINES = LINES - 3
      RETURN
      END
```

Program DAILYO

```
      OVERLAY (OLAYS,3,1)
      PROGRAM OAILYD
C-----DAILY COMPOSITE OUTPUT, NO ALTERNATIVES
      COMMON AIRTEMC(25,6)
      COMMON CALDEF(25),CDMAX(25),COVDEN(25)
      COMMON DREADY(25)
      COMMON ENGBAL(25),ET,ETDAILY(25,12)
      COMMON FREEWAT(25)
      COMMON ISOTHRM(25,2D)
      COMMON LASTUSD(25),LEVEL1,LEVEL2
      COMMON MMDD
      COMMON NDAYSNO(25),NDIVSBL,NSUB,NYEARS
      COMMON ONTREES(25)
      COMMON PEAKPPT(25,2D),PEAKWE(25,2D),PHASE(25),POTENT(24),
     1       PREWFOV(25)
      COMMON RECHRG(25)
      COMMON SIMTEM1(25,3),SUBIO(25,6),SLPASP(25,24)
      COMMON TCOFFF(25),THRSHLO(25),TOPLOT(11)
      COMMON VEGTYPE(25)
```

```
      COMMON WEIGHT(25),WSHEOIO(6)
      COMMON YEARS(20),YYMMOO
      INTEGER OREAOY
      INTEGER PHASE
      INTEGER SUBIO
      INTEGER TOPLOT
      INTEGER VEGTYPE
      INTEGER WSHEOIO
      INTEGER YEARS,YYMMOO
      COMMON/CMPSITO/COMPS(16),YRTOT(5)
      COMMON/FOROATA/ FOOTNOT(26),MAXLINE
      INTEGER FOOTNOT
      COMMON/MASTER/OATE(3),TMXMSTR,TMNMSTR,PPTMSTR,PPTONOW,OBSHYOR,
     1 POTRAO,MSTREOF,IYR
      INTEGER OATE
      COMMON/PLOTS/PLOT(11)
      COMMON/WATRBAL/ETFROM,EVAPOTR,GENRO,PRECIP,RAOIN,RAOLWN,RAOSWN,
     1 TEMPMAX,TEMPMIN,WATERIN
      INTEGER FOOTNTE(26)
      OATA FOOTNTE/260HNORMAL SIMULATION ONLY
     1
     2
     3
     4
C-----OEFINE THE FOOTNOTE
      OO 1 N = 1,26
    1 FOOTNOT(N) = FOOTNTE(N)
C-----MAXLINE = 52 - NUMBER OF ALTERATIONS
      MAXLINE = 52
C-----WRITE THE FOOTNOTE ON THE PLOT
      WRITE (11,900) FOOTNOT
  900 FORMAT(/*0*13A10/1X13A10//)
C-----REAO A MASTER CARO
   10 CALL ROMSTR
      IF(MSTREOF) 20,20,130
C-----GENERATE THE OATA ANO PERFORM THE SIMULATIONS FOR EACH SUBSTATION
   20 OO 30 N = 1,NSUB
      CALL GENOATA (N)
      CALL NORM3 (N)
   30 CONTINUE
C-----WRITE OUT THE COMPOSITE LINE
      COMPS(15) = (COMPS(1) + COMPS(2)) * 0.5
      COMPS(16) = COMPS(16) + COMPS(3)
C-----CONVERT THE CALORIE OEFICIT TO A PACK TEMPERATURE
      IF(COMPS(9).NE.0.0) COMPS(8) = - COMPS(8)/(COMPS(9) * 1.27)
      CALL WRITE3 (1H$,COMPS)
C-----AOO THESE VALUES INTO THE YEARLY TOTALS
      YRTOT(2) = YRTOT(2) + COMPS(10)
      YRTOT(3) = YRTOT(3) + COMPS(11)
      YRTOT(5) = YRTOT(5) + COMPS(14)
C-----STORE THE INFORMATION FOR THE PLOTS
      PLOT(1) = OBSHYOR
      PLOT(2) = COMPS(9)
      PLOT(3) = COMPS(10)
      PLOT(4) = COMPS(11)
      PLOT(5) = COMPS(13)
      PLOT(6) = COMPS(14)
C-----PERFORM THE PLOTS BETWEEN APRIL 1 ANO SEPTEMBER 30
      IF(MMOO - 401) 110,90,40
   40 IF(930 - MMOO) 110,50,100
C-----ON 9/30, PRINT THE YEARLY TOTALS, ZERO THE ACCUMULATEO PRECIP ANO
C----- RESET THE OIFFUSION MOOEL SWITCHES
   50 YRTOT(1) = COMPS(16)
      YRTOT(4) = COMPS(13) - YRTOT(4)
      CALL WRITOT (1H$,YRTOT)
      YRTOT(4) = COMPS(13)
      YRTOT(2) = 0.0
      YRTOT(3) = 0.0
      YRTOT(5) = 0.0
      COMPS(16) = 0.0
      OO 60 N = 1,NSUB
   60 OREAOY(N) = 0
C-----CHECK THE YEARS TO BE SURE ALL OECKS STILL CORRESPONO TO THE
C----- PARAMETER OECK
      IF(OATE(3) - YEARS(IYR)) 70,80,70
   70 WRITE (6,910) OATE(3),IYR,IYR,YEARS(IYR)
  910 FORMAT(*1THE OATA OECKS ARE OUT OF PHASE WITH THE WATERSHEO PARAME
     1TER OECK.  THE WATER YEAR JUST ENOING (19*I2,*) IS OECK NUMBER*I3,
     2 *,*/*  BUT SPECIFIEO CONOITIONS CARO NUMBER*I3,* FOR EACH SUBSTAT
     3ION IS FOR 19*I2)
      CALL EXIT
   80 IYR = IYR + 1
      GO TO 100
C-----ON 4/1, WRITE THE OROINATE LINE
   90 WRITE (11,920)
  920 FORMAT(9X124(1H.))
C-----PERFORM THE PLOT, THEN ZERO THE COMPOSITE LOCATIONS
  100 CALL PLOTTER
  110 OO 120 N = 1,14
  120 COMPS(N) = 0.0
      GO TO 10
C-----ALL CAROS HAVE BEEN REAO.  IF THE OECK ENOEO ON 9/30, ALREAOY
C----- CAUSING THE WATER YEAR TOTALS TO PRINT, JUST ENO THE JOB.  BUT ON
C----- ANY OTHER OAY, PRINT OUT THE YEAR TO OATE TOTALS HERE
  130 IF(MMOO - 930) 140,150,140
  140 YRTOT(1) = COMPS(16)
      YRTOT(4) = PLOT(5) - YRTOT(4)
      CALL WRITOT (1H$,YRTOT)
C-----WRITE THE FOOTNOTE ON THE LAST PAGE
  150 WRITE (6,930) FOOTNOT
  930 FORMAT(*0*13A10/1X13A10)
C-----RETURN TO THE MAIN OVERLAY FOR NORMAL TERMINATION
      ENO
```

griculture-CSU, Ft. Collins

Leaf, Charles F., and Glen E. Brink.
1973. Hydrologic simulation model of Colorado subalpine forest. USDA For. Serv. Res. Pap. RM-107, **23** p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

A simulation model specifically designed to determine the probable hydrologic changes resulting from watershed management in the Colorado subalpine zone is described. The model simulates the total water balance on a continuous year-round basis and compiles the results from individual hydrologic response units into a "composite overview" of an entire drainage basin. Preliminary results are summarized for an 8-year test period on a 667-acre experimental watershed.

Oxford: 116.21:U681.3. **Keywords:** Computer models, coniferous forest, forest management, model studies, simulation analysis, snowmelt, subalpine hydrology, vegetation effects, watershed management.

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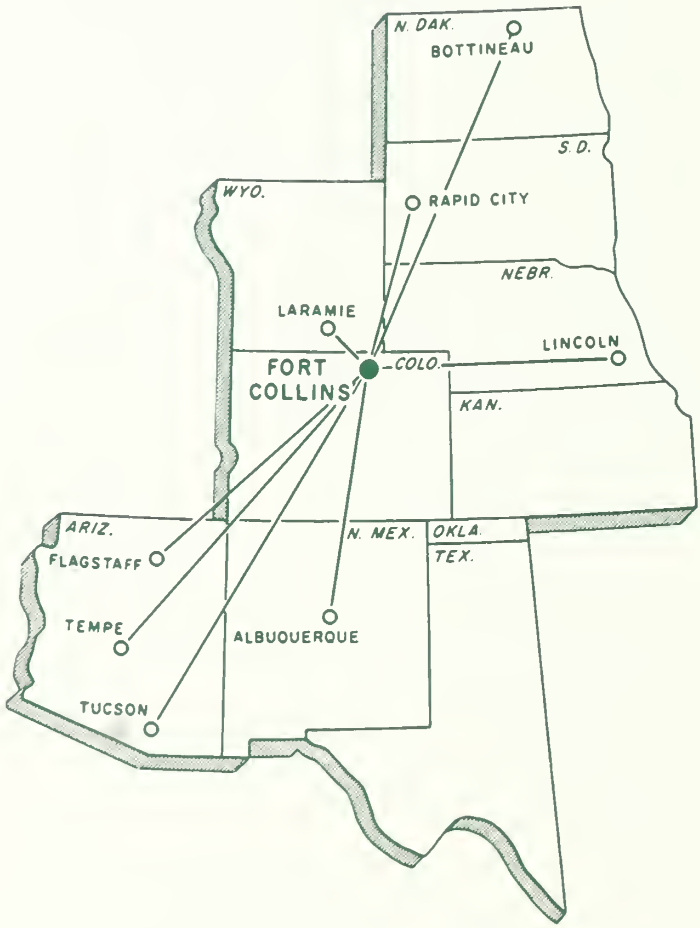
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conomics of Containerized Conifer Seedlings

arilyn K. Colby and Gordon D. Lewis

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Abstract

Containerized seedlings, grown in a newly developed, controlled environment greenhouse, can substantially reduce the time required to produce high quality seedlings, improve seedling survival rates in outplantings, and reduce net reforestation and afforestation costs. Plantable containerized stock can be produced in a greenhouse in 1 year as compared to 2 years for bare-root nursery stock and 3 years for potted seedlings. Moreover, the survival rate in outplantings for containerized seedlings is expected to be equal that for potted stock and almost twice that for bare-root stock. As a result, the costs per thousand surviving trees are estimated to be $460 for 2-0 bare-root stock, $441 for 2-1 potted stock, and $393 for containerized greenhouse seedlings. An equation is presented for determining the cost per thousand trees and for comparing between systems.

Oxford: 232.329.6:651.72. **Keywords:** Reforestation, planting (forest), nursery stock (forestry), regeneration (economic evaluation).

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

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Economics of Containerized Conifer Seedlings

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and

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Rocky Mountain Forest and Range Experiment Station[1]

[1]*Central headquarters maintained in cooperation with Colorado State University at Fort Collins.*

Contents

Economics of Containerized Conifer Seedlings

Marilyn K. Colby and Gordon D. Lewis

Bare-root conifer seedlings grown in conventional forest tree nurseries are used in most reforestation efforts in the Rocky Mountain region. Bare-root stock is easy to handle and plant, and is relatively inexpensive to produce, but survival can be a problem in the varied climatic and topographic conditions found in the West.

The major problems relating to the production and use of nursery grown bare-root stock involve time and survival. Because it takes 2 to 3 years to grow nursery stock, the demand for seedlings must be predicted several years ahead. The long period in the nursery also exposes the seedlings to adverse weather, and disease and insect damage while in the seedbed, and lifting and storage must be coordinated with the length of the planting season, potential moisture, and site conditions.

Bare-root seedlings suffer root damage during lifting, and a drastic change in environment during lifting, packing, storage, transporting, and transplanting. These shocks adversely affect initial survival and growth rates after outplanting.

Potting procedures have been devised in an effort to improve survival under adverse soil and climate conditions on the planting site. Trees are lifted from the seedbeds or transplant beds as small bare-root seedlings, placed in tarpaper pots filled with soil or other suitable potting materials, and allowed to grow for an additional year or more. The potted seedlings are then outplanted, container and all.

The primary benefits of potting have been increased survival and growth rates of newly planted trees since the roots are not divested of soil. Potting seedlings is relatively expensive, however, and the other problems of growing nursery seedlings remain. In addition, transportation and planting costs may be significantly increased.

A process for growing containerized conifer seedlings in greenhouses is currently being explored to offset the disadvantages of nursery operations. The seeds are placed directly into a container with growing media, and germinated and grown under some form of enclosed environmental regulation. These environmental systems may range from simple regulation of heating and ventilation to careful control of heating and cooling, special lighting to prevent dormancy, a carbon dioxide enriched atmosphere, mycorrhizal inoculation, and automatic watering and fertilizing.[2]

The containerized greenhouse seedling system solves many of the traditional nursery problems. Trees are protected from weather, and the disease and insect problems normally encountered in the open atmosphere can be controlled. The greenhouse site may be selected with more regard for convenient location than for climate, topography, or soil. Size of area is not too important, since 1 acre can support 1 million trees or more. Estimated capacity of a greenhouse structure 120 by 34 feet is 110,000 seedlings in large (2- by 2- by 8-inch) containers. Since greenhouse operations can be highly mechanized, the importance of labor supply and labor costs are diminished.

Container systems are capable of producing trees quickly, and do not entail prediction of demand several years hence. Depending on the type of system, conifer seedlings grown in greenhouses may be ready for outplanting in less than one-third the time required for those grown in conventional nurseries. Survival and growth rates are usually improved over those for bare-root stock, especially on adverse sites for early- or late-season planting.

The principal drawback to the greenhouse system is that production costs are higher than those for bare-root stock. For a simple, open system the difference may be slight, but for the closed greenhouse system, production costs per thousand plantable trees may exceed those for bare-root stock by a factor of two or three. Transportation costs also increase, because the containers and growing media are shipped along with the trees. Planting costs may be greater, smaller, or remain the same, depending on methods and planting sites.

[2]*Much of the experimental work with the closed greenhouse system has been done by Richard W. Tinus, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota.*

The problem, then, is to choose among systems for growing stock for outplanting. Bare-root nursery stock is cheaper to produce, but has several drawbacks. Potting improves survival and growth rates, but is more costly. Containerization eliminates most of the difficulties associated with nursery production, but is also more expensive.

This Paper will compare relative costs of the three methods in terms of planting conditions in the Rocky Mountains. Although it is not possible to quantify all the elements involved, many of the most important factors can be stated in terms of dollars. There will be four primary areas of consideration: the cost of producing seedlings, transportation costs, planting costs, and survival rates. All initial costs are based on 1,000 plantable trees.

Factors Considered

Costs of Production

The costs of seedling production can be divided into two major categories, direct and indirect. Direct costs for the bare-root nursery include seedbed preparation and seeding, weeding, fertilization, irrigation, lifting and packing, cold storage, and all other costs directly connected with tree production. For potted stock, the cost would also include labor for potting and potting materials. Direct costs of greenhouse production would include those for containers, growing media, fertilizer, water, electricity, gas, greenhouse maintenance, and labor associated with the setup and maintenance of the operation. The primary differences between the nursery and greenhouse systems are that (1) the nursery system is more labor intensive, with a large amount of the cost attributable to wages, and (2) in the greenhouse system, utilities which maintain the controlled environment account for most of the costs.

Indirect costs consist mainly of administration and depreciation of facilities. There is no reason to believe that administration will vary greatly among the systems. The capital investment for the greenhouse, associated structures, and equipment is high, and as a result, depreciation per thousand plantable trees is relatively high. In the West, however, containerized seedlings are held for a year or less, as opposed to 2 or 3 years for bare-root and potted trees. Accumulated depreciation attributed to nursery stock may therefore approach the amount ascribed to greenhouse seedlings.

Total production costs of containerized seedlings may vary from little more than bare-root stock up to three times as much.

Transportation Costs

Transportation costs of containerized stock increase with the size of container, because containers and growing media are transported along with the seedlings. For instance, a large tractor-trailer can carry 300,000 to 500,000 bare-root seedlings, but only between 17,000 and 20,000 large potted seedlings. Shipping costs per tree for large (2- by 2- by 8-inch) containerized or potted stock are estimated to run from \$0.02 to \$0.10 per tree (\$20 to \$100 per thousand). Shipping costs for bare-root stock are less than \$0.005 per tree (\$1 to \$5 per thousand).[3] Although absolute transportation costs vary directly with distance from nursery to planting site, relative cost differences between types of stock should be similar regardless of hauling distance.

Where planting jobs are relatively small, transportation costs for bare-root stock may be relatively higher. For instance, at a spacing of 680 trees per acre, a truckload of 300,000 bare-root seedlings should be enough to plant 440 acres. Shipment of fewer trees in the same vehicle would increase transportation cost per thousand trees.

Planting Costs

Large variations in planting costs have been noted for both bare-root and containerized seedlings. Excluding site preparation, hand planting of bare-root seedlings has cost as little as \$30 per thousand in Colorado, and more than \$300 per thousand in Wyoming. Reported costs of hand planting containers run from \$15 per thousand to \$100 per thousand seedlings, with the higher cost attributable to the larger containers.

Costs on National Forest sites, which may be expected to run somewhat higher, have been about the same for hand planting both bare-root stock and containers under similar conditions.

Costs for machine planting the two types of seedlings are very similar. A tree planter is easily adapted to containerized stock, especially where the seedlings are removed from the containers as they are planted ("plug"-type seedlings).

[3] *Transportation cost estimates were determined from information furnished by Marvin D. Strachan, Colorado State Forest Service, Fort Collins, Colorado; Richard W. Tinus, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota; John A. Adams, U.S. Forest Service, R-8, Atlanta, Georgia; and C.D. McAninch, U.S. Forest Service R-2, Denver, Colorado.*

Survival Rates

Survival rates probably give the most valuable comparison between the various types of seedling production. High initial survival rates will result in a well-stocked stand sooner, and will reduce or eliminate replanting costs.

In most cases, greenhouse seedlings survive better than bare-root seedlings, particularly on adverse sites and under difficult planting conditions. For instance, in Montana, August plantings of bare-root ponderosa pine are usually total failures, while first-year survival of containerized stock may be almost 90 percent.[4] Poor survival of bare-root seedlings would require replanting to achieve the minimum acceptable survival rate.

Some increased growth is also realized the first year or two with container stock, but there is little advantage after the trees are reasonably well established.

A Comparative Example

To evaluate the cost relationships, a comparison was drawn for ponderosa pine raised under three different systems. The three types of stock are 2-0 bare-root stock, grown at the USDA Forest Service's Mount Sopris Nursery at Carbondale, Colorado; 2-1 potted stock of the type produced by the Colorado State Forest Service Nursery at Fort Collins, Colorado; and containerized seedlings of the type to be produced in a greenhouse planned for the Mount Sopris Nursery.

A 2-0 bare-root seedling was defined as one which has spent 2 years in the seedbed, and has had the soil removed from the roots at the time of lifting for outplanting. A 2-1 potted seedling has been grown in the seedbed for 2 years, then lifted and placed in a pot, where it has remained 1 year. A 1-0 greenhouse containerized seedling has been seeded directly into its container and grown under controlled conditions for 1 year. A plug-type containerized seedling is removed, with root ball intact, from the container immediately before planting.

A 3-0 bare-root seedling is approximately the same size as 2-1 potted stock and 1-0 greenhouse stock. However, no 3-0 ponderosa pine is used in the Rocky Mountain Region (Region 2, USDA Forest Service), as 2-0 bare-root stock appears to have better survival and a better top/root ratio.

[4] *Correspondence with Wayne Hite, Anaconda Forest Products, Bonner, Montana.*

Production Costs

Costs of producing 2-0 bare-root stock were based on cost determinations for Mount Sopris Nursery for fiscal years 1971 and 1972. Costs were broken down on a year-by-year basis and compounded at 5 percent annually to incorporate the length of growing period. No allowance was made for inflation.

Costs of producing 2-1 potted stock were based on information obtained from Marvin Strachan, Colorado State Forest Service Nursery. Costs were compounded at 5 percent annually to incorporate the length of growing period. No allowance was made for inflation.

Greenhouse production costs were based on a 1-year cycle in the proposed structure for the Mount Sopris Nursery. Setup and operating costs for the cycle were derived from records for a smaller experimental greenhouse operated during 1971-72 by the Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota. Costs are detailed in tables 1 and 2.

Transportation Costs

Transportation costs for bare-root seedlings were approximated from Mount Sopris costs for fiscal year 1972. For potted seedlings, the transportation costs were an average of estimates from various sources. They indicate that the cost is 5 to 25 times higher for potted seedlings than for bare-root stock.

Transportation costs of containerized seedlings were assumed to be basically the same as for potted seedlings, as the containers are about the same size. Because the plug-type seedlings are moved in blocks of containers, however, and up to 20 percent of the containers may not contain a plantable seedling, transportation costs per plantable seedling were somewhat higher than for the potted stock.

Planting Costs

Planting costs for bare-root stock were based on average contract costs for Region 2, USDA Forest Service. Because no data were available for container planting in the Region, planting costs were assumed to be slightly higher for container and potted stock due to bulk and weight.

Survival Rates

Survival rates were based on unpublished information on file in Timber Management

Table 1.--Projected capital cost and depreciation for proposed greenhouse at USDA Forest Service Mount Sopris Nursery, Carbondale, Colorado[1]

Item	Total cost	Depreciation per-- Year[2]	Depreciation per-- 1,000 plantable trees[3]
Mechanical-electrical systems:			
Pad cooling system	$ 2,800	$ 80.00	$ 0.91
Exhaust fan system	1,050	30.00	.34
Heating system	3,800	108.57	1.23
Watering system	1,500	42.86	.49
Lighting system	2,600	74.29	.84
CO_2 generator system	150	4.29	.05
Controls and wiring	4,000	114.29	1.30
Total	15,900	454.30	5.16
Greenhouse	18,000	514.29	5.84
Utilities	1,500	42.86	.49
Buildings[4]	--	220.00	2.50
Total	$35,400	$1,231.45	$13.99

[1]Proposal is a modification of a greenhouse project designed for the State of Kansas by Region 2, USDA Forest Service.

[2]Depreciation for fiberglass greenhouse structure and associated equipment was calculated by straight-line method over a 35-year life.

[3]Estimated greenhouse capacity is 110,000 trees, 80 percent of which are plantable at end of cycle.

[4]Existing buildings will perform functions of headhouse; depreciation for buildings was determined by Region 2, USDA Forest Service.

Research, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, and Anaconda Forest Products, Bonner, Montana. The survival rate for bare-root stock in the Rocky Mountain region is most likely to fall somewhere between 25 and 50 percent, perhaps somewhat higher on the better sites. In general, it appears that large greenhouse seedlings and potted stock both survive better than bare-root seedlings, especially under adverse conditions.

Cost of Surviving Trees

In this example, the cost of producing 2-0 bare-root stock was $52.18 per thousand (table 3); that of producing 2-1 potted stock was much higher at $197.12 per thousand; and the cost of greenhouse seedlings was intermediate at $145.81 per thousand. These were costs per thousand plantable trees, and included an allowance for losses in the nursery or greenhouse.

Transportation charges were much higher for potted and containerized seedlings, due to the transportation of bulky pots and soil (table 3). This difference would become more pronounced the farther the hauling distance, and would be one argument for locating a greenhouse in an area reasonably close to prospective planting sites. This choice is not always possible when bare-root stock is considered.

The third major category in table 3 is site preparation and planting. Region 2, USDA Forest Service, estimates average contract costs for this operation to be $0.12 per seedling, with

Table 2.--Projected cost of tree production for proposed greenhouse at Mount Sopris Nursery, Carbondale, Colorado[1] (labor was estimated at $3 per hour for all activities)

Item	Costs per--	
	1-year cycle	1,000 plantable trees[2]
Setup:		
Containers[3]	$ 3,300	$ 37.50
Container assembly	935	10.62
Peat and perlite	240	2.73
Fertilizer	515	5.85
Replace fiberglass	375	4.26
Fill, seed, transfer	1,325	15.06
Total	6,690	76.02
Operation:		
Electricity	1,800	20.45
Fuel	1,200	13.64
Repairs	1,500	17.05
Routine care	360	4.09
Emergency care	50	.57
Total	4,910	55.80
Total direct cost	11,600	131.82
Depreciation[4]	1,231	13.99
Total cost	$12,831	$145.81

[1]Estimated from figures furnished by Richard W. Tinus, Shelterbelt Laboratory, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota, for a pilot model greenhouse, and from specifications for the Kansas project.

[2]88,000 trees (80 percent of capacity) assumed plantable.

[3]The containers considered here are serviceable for only one cycle; cost would decrease if reusable containers are employed.

[4]See table 1.

an additional cost of $30 per thousand seedlings for contracting and supervision. This results in a total cost of $150.00 per 1,000 seedlings for site preparation and hand planting for bare-root stock. No estimates were available for planting costs of containerized stock in Region 2. However, the Colorado State Forest Service estimates that, because potted and containerized stock is bulkier and heavier to handle, planting costs should be about $20.00 per 1,000 seedlings more than those for bare-root stock. Site preparation costs are the same for both types of planting stock.

Total cost per thousand trees planted was determined by adding production cost, transportation cost, and planting cost (table 3). For bare-root stock, the figure was $207.18; for potted stock, $397.12; and for greenhouse seedlings, $353.31.

The comparative benefits of the three methods were measured as survival rates. By dividing the appropriate survival figure into cost per thousand planted trees, cost per thousand surviving trees was determined. On the basis of table 3, the greenhouse seedling had the lowest cost per surviving thousand trees, $392.57. Potted seedlings were more expensive at $441.24 per thousand, and bare-root stock had the highest price at $460.40 per thousand.

Table 3.--Relative costs for establishing ponderosa pine 2-0 bare-root, 2-1 potted, and 1-0 greenhouse stock

Type of cost	Cost or rate per thousand plantable trees[1]		
	2-0 Bare-root	2-1 Potted	1-0 Greenhouse
Production costs:[2]			
1st (seed) year	$ 20.15	$ 30.87	$145.81
2nd year	13.35	26.25	--
3rd (potting) year	--	100.00	--
Lift (sort) year	18.68	40.00	--
Total	52.18	197.12	145.81
Transportation costs	5.00	30.00	37.50
Site preparation and planting costs	150.00	170.00	170.00
Total cost of trees planted	207.18	397.12	353.31
Survival rate	45 percent	90 percent	90 percent
Cost per thousand surviving trees	$460.40	$441.24	$392.57

[1]All costs incurred during the growing season are prorated to plantable trees. Sources of data are discussed in text.

[2]For comparison, all production costs were compounded at 5 percent per year to year of planting.

A Comparative Equation

The same general procedure used to construct table 3 can be applied to any specific instance where greenhouse production is considered in competition with nursery stock. If all four items (cost of production, transportation cost, planting cost, and survival rate) are known or can be approximated, the best system can be determined by a simple formula:

$$X_1 = \frac{Pr_1 + T_1 + P_1}{S_1} \gtrless \frac{Pr_2 + T_2 + P_2}{S_2} = X_2 \qquad [1]$$

where

X = Total cost per thousand surviving trees.

Pr = Production cost per thousand plantable seedlings, including depreciation and overhead. To account for length of holding period, compound annual costs incurred prior to the planting year at an appropriate interest rate.

T = Transportation cost per thousand plantable seedlings from production site to planting site.

P = Site preparation and planting cost per thousand trees.

S = Survival rate of trees planted, preferably at the time trees are considered established.

1 = Data for the greenhouse system.

2 = Data for any alternative system.

If X_1 is less than X_2, the greenhouse system is less expensive.

Using the figures for bare-root and greenhouse stock in table 3, the analysis would be:

$$X_1 = \frac{\$145.81 + 37.50 + 170.00}{0.90} \gtrless \frac{52.18 + 5.00 + 150.00}{0.45} = X_2$$

$$X_1 = 392.57 < 460.40 = X_2$$

A change in any of the four major factors will affect the relationship between the methods. Suppose that for a particular project all costs are the same as those in table 3, except that planting costs of potted and greenhouse stock are estimated at $200 per thousand, and because the site is more favorable, the survival rate is estimated to be 65 percent for bare-root stock and 95 percent for potted and greenhouse stock. Under these conditions, potted stock would be the most expensive at $449.60 per thousand, greenhouse seedlings would be cheaper at $403.48 per thousand, but bare-root stock would be the least costly at $318.74 per thousand.

The magnitude of the difference between two systems is important. Where the difference is small, a minute change in any one factor could reverse the result, and nonmonetary considerations would influence the decision. On the other hand, if the difference was large, conditions would have to be altered greatly to change the cost/benefit outcome.

If any one of the factors is unknown, a break-even value can be determined. Given the following costs per thousand surviving seedlings:

	Greenhouse	Bare-root
Production	$150	$50
Transportation	50	5
Planting	100	75

what survival rate would be required to economically justify the use of greenhouse seedlings? If survival of bare-root seedlings is expected to be 40 percent, the procedure would be as follows, using greenhouse survival (Z) as the unknown:

$$\frac{150 + 50 + 100}{Z} \leq \frac{50 + 5 + 75}{0.4}$$

$$\frac{300}{Z} \leq 325$$

$$Z \geq 0.923 \text{ or } 92.3 \text{ percent}$$

Survival of greenhouse seedlings then, would have to be quite high to compensate for their greater cost of production, transportation, and planting.

Replanting must be considered where a minimum acceptable standard exists, such as in shelterbelts, where 80 percent is desirable. On many forest lands, 50 percent or less would be considered adequate, depending on spacing in the plantation. If a minimum acceptable rate of survival is 50 percent of the original planting density, then, for the situation represented in table 3, the bare-root stock would have to be replanted once. The other two types would not have to be replanted. Cost per surviving tree would not change for bare-root stock, but replanting would reduce the amount of land which could be planted each season, and cost per acre would increase each time the site was replanted.

Conclusions

The higher initial costs associated with the greenhouse system can be offset by better survival. From an economic standpoint this is especially important where adverse sites must be regenerated quickly. This factor can be partially taken into account by penalizing the slower growing nursery stock through the use of a higher interest rate in compounding costs to the planting year. Additional benefits such as quality control through the use of genetically improved seed and the capacity for sounder planning and a more flexible operation may be obtained, but little specific information is presently available.

Nursery costs are rising, largely because nurseries are labor-intensive operations, and labor costs are increasing. This trend will have less effect on the greenhouse system, since it is more capital-intensive and requires little labor.

Similarly, container systems do not require the same quality in land that nursery systems do, nor do they require the quantities of land needed for nursery operation. Where land values are high and/or rising, the greenhouse system could represent considerable cost saving.

Because the techniques are new, the cost of greenhouse container seedlings should decrease with technological improvements, more mechanization, and a better internal survival rate. On the other hand, nursery procedures have been pretty well standardized, and improvement cannot be expected at the same rate as in greenhouse nurseries.

Another factor that can decrease the cost of greenhouse seedlings is a scale economy effect due to better utilization of auxiliary buildings and management. This effect would be valid up to about 500,000 seedlings for the greenhouse system presented in tables 1 and 2.

Because planting costs are high, more needs to be known about the differences between planting containerized seedlings and other stock, and how these differences influence costs.

In summary, the production of containerized greenhouse seedlings appears to be favorable in the light of current trends. Much remains to be learned, however, about the economics and physical capabilities of various types of greenhouses, and the economic/biological trade-offs related to various levels of environmental control.

Colby, Marilyn K., and Gordon D. Lewis.
1973. Economics of containerized conifer seedlings. USDA For. Serv. Res. Pap. RM-108, **7** p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Containerized seedlings, grown in a newly developed, controlled environment greenhouse, can substantially reduce the time required to produce high quality seedlings, improve seedling survival rates in outplantings, and reduce net reforestation and afforestation costs. Plantable containerized stock can be produced in a greenhouse in 1 year as compared to 2 years for bare-root nursery stock and 3 years for potted seedlings. Moreover, the survival rate in outplantings for containerized seedlings is expected to be equal that for potted stock and almost twice that for bare-root stock. As a result, the costs per thousand surviving trees are estimated to be $460 for 2-0 bare-root stock, $441 for 2-1 potted stock, and $393 for containerized greenhouse seedlings. An equation is presented for determining the cost per thousand trees and for comparing between systems.

Oxford: 232.329.6:651.72. **Keywords:** Reforestation, planting (forest), nursery stock (forestry), regeneration (economic evaluation).

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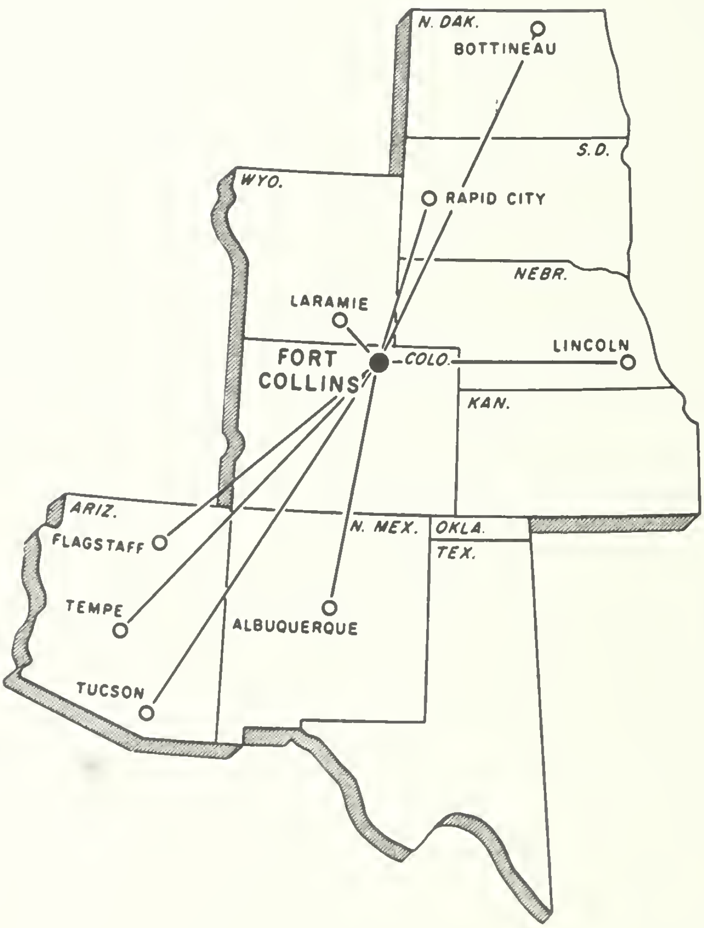
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USDA Forest Service
Research Paper RM-109

July 1973

Simulating Changes in Even-Aged Timber Stands

by
Clifford A. Myers

Rocky Mountain Forest and Range Experiment Station
U. S. Department of Agriculture
Forest Service

Abstract

Growth and volume relationships are assembled in a computer program, written in FORTRAN IV, that simulates timber management by shelterwood, seed tree, or clearcutting systems. Tree growth, intermediate and regeneration cuts, planting, and catastrophic losses are among the changes computed. Annual and periodic costs and returns, analysis of rate earned, and other statements of volume and value are printed. Supersedes USDA For. Serv. Res. Pap. RM-42.

Oxford: 524.37:U681.3. **Keywords:** Stand yield tables, timber management, forest management, simulation, *Pinus ponderosa, Pinus contorta.*

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

USDA Forest Service
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Simulating Changes in Even-Aged Timber Stands

by

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[1]*Forest Service, U.S. Department of Agriculture, with central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

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Simulating Changes in Even-Aged Timber Stands

Clifford A. Myers

Computer program MANAGD (Myers 1968) was developed so that managers could simulate operations in managed, even-aged timber stands. The original relationships and analytic procedures have now been modified and improved to the point where computer program MANGD2, described in this new Paper, has been written to supersede the original program MANAGD. Major modifications permit more general treatment of regeneration cuttings and more accurate estimates of the effects of intermediate cuttings on stand characteristics. Other changes are the result of increases in available data and experience gained in use of program MANAGD. Program organization now provides a means for accommodating a large number of species with a single copy of the source program.

MANGD2 is written in standard FORTRAN IV and can be run on almost any computer that provides at least 28,544 (67,600 octal) memory locations.

Persons wishing to prepare data decks and use the program should read the entire Paper carefully. Those who are interested only in knowing what MANGD2 can do for them can concentrate on the sections headed "Uses of Simulation" and "An Application of MANGD2."

Uses of Simulation

Several characteristics of the business of timber production make the gathering of information on which to base management decisions for forest lands unusually difficult. Among these problem characteristics are:

1. The long time needed to mature a crop. Final results of a series of changes may not be evident for many years, especially with slower growing species.
2. The slowness with which the results of a single change may appear. Today's questions may not be answered for many years. Conversely, the desire for on-the-ground experimentation will be restrained because results of unfavorable treatments will not disappear for some time.
3. The large land areas and the numerous possible combinations of biological and economic conditions for which decisions must be made. Many possible combinations result in many possible options, among which there may be one or several that will conform to the capabilities and goals of the organization.
4. The expense of imposing treatments on forest stands. Expense limits the number of options that can be examined on the ground and increases the value of information.

A managerial tool designed for managers faced with such problems is available. It is the technique of mathematical simulation on a digital computer. Simulation is particularly useful where an outcome depends on many variables and parameters, and the computation steps are numerous (Cremeans 1967).

Simulation involves the creation and operation of a model that resembles logically the system studied (Martin 1968). Solving a problem by following the changes that occur during model operation constitutes the technique of simulation (Gordon 1969). The system may be a sawmill, a working circle, or other item of interest. Only as much of the system is modeled as is necessary to answer the questions that prompt the study. Mathematical models, such as MANGD2, represent all necessary components and interactions of the system by a series of mathematical relationships. Properly used, they can aid in the discovery of new facts and the test of alternatives.

Simulation answers questions of the type: "What would happen if I did this . . .?" Once a forest system has been modeled and the model found to be acceptable, a manager has great flexibility in imposing changes on his forest model. He can vary his management goals and the conditions of his stands with no ill effects to the real stands from any undesirable alternatives. With adequate mathematical relationships, the manager can predict probable future performance and yield of his forest (Chorafas 1965). In seconds, he can get an estimate of the long-term effects of proposed changes on growth, yield, and money return. The changes can involve rotation length, cutting cycle, frequency and intensity of thinning, and other controls. Estimates of potential advantages from reductions in certain costs or from increases in selling prices can be obtained.

MANGD2 was designed to be one of a set of tools useful as aids in decisionmaking. The tools and a possible pattern of their use are:

1. The manager can compute yield tables for managed stands to help him establish controls on his operations. For example, he can determine that certain combinations of frequency and intensity of thinning are not acceptable alternatives because more than one noncommercial thinning would be needed. Perhaps stands of low site quality should not receive any treatment other than protection. Yield tables will help decide what the limit should be. Procedures for computing yield tables are described elsewhere (Myers 1971).
2. Since goals will not be set on the basis of growth and yield in volumetric units alone, the manager will, therefore, use MANGD2, described in this Paper, to obtain additional information. Only through simulation can the long-term effects of changes in rotation length, cutting cycle, and other controls be determined. Likewise, simulation is needed to express the results in terms of present worth and rate earned. MANGD2 will usually be used to answer questions of the type: "What do I want my working circle to be when it has been converted to managed stands?"
3. Once the controls have been established (subject, of course, to future reappraisal), the manager needs a guide to assist him in current operations. The guide should contain such items as allowable cut, present and desired distribution of acres by age and site quality classes, and work to be completed during the current planning period. The guide should be computed at least annually, using data from conventional inventory and other sources of stand description. Procedures for preparing such a guide are described elsewhere (Myers 1970).
4. Once the controls have been established and a management guide is available, the manager is concerned with converting his forest to match his goals. A simulation program that uses actual inventory data as stand inputs will be useful. Simulation with MANGD2 helps set the goals; a second simulation program, not restricted to growth of managed stands, can show him how to attain them.
5. An important step in decisionmaking may be necessary after each of the previous steps. This is the return to earlier steps in the decision process whenever new information indicates a need for such action.

Description of Program MANGD2

Program MANGD2 is a tool for simulating the management of even-aged timber stands for wood products. It contains provisions for stand growth, thinnings, regeneration cuts, planting of nonstocked areas, and other changes in forest conditions. Inputs to the program permit wide choice in the management alternatives and stand conditions to be examined. Possible options and alternatives are described in the appropriate parts of this section. Program organization permits ready modifications to fit local tree species or utilization standards.

MANGD2 consists of a main program and 21 subroutine subprograms (appendix 1). Content and purpose of each routine are given in the sections that follow. Variable names are defined with the source program in appendix 1 and in the listing of contents of the data deck. The test problem described on page 16 and reported in appendix 2 provides additional explanation of the program.

The terms batch, test, and game are used to identify individual simulation jobs performed with various groupings of alternatives. The BATCH name identifies one entire group of tests and games to be completed as a single job by a computer. A test consists of one or more games, all of which are based on a single yield table and one set of stumpage prices. Games of a test may differ from one another in one or more of the following: (1) distribution of acres by age classes, (2) total area, (3) area planted annually, (4) area lost annually, (5) costs of operations, and (6) limitations on the annual cut.

As shown in the program listing (appendix 1), a single program deck can be used for several tree species. One program at a central location can thus serve the needs of many managers. Each part of a subroutine that involves species-specific relationships begins with a computed GO TO statement. Each GO TO is followed by as many FORTRAN statements for species-specific relationships as desired. The label of each statement appears in the computed GO TO. The GO TO counter is read in initially as a numerical species index, together with the species name as it will appear in table headings.

In appendix 1, the program provides for three species. In each set of species-specific relationships, the first equation applies to ponderosa pine (Pinus ponderosa Laws.) in the Black Hills of South Dakota and Wyoming. The second equation applies to lodgepole pine (Pinus contorta Dougl.) in Colorado and Wyoming. Space for an equation applicable to a third species is occupied by a dummy statement in the form of a CONTINUE statement. The relationships included can be replaced by those for other species, or each computed GO TO can be expanded to provide for additional species.

Main Program

The main program calls 15 subroutines in proper sequence, and uses counter IJK to call a sixteenth (REPRT1) at specified intervals. The first two subroutines called (BASIS1, CHEK1) read and check that part of the data deck common to all games of one test. The next two subroutines (YIELD, ANVOL) compute and print a yield table and potential volumes per acre at each year of stand age.

Of the remaining 12 subroutines, one may be called at the end of each test, six are called once each game, four are called each year of each game, and REPRT1 is called as needed. Four routines (BASIS2, CHEK2, START, AREAS) read and check the data deck for a game, generate a working circle with the specified number of acres in each age class, and print conditions at the start of the game. Four routines (COVER, HRVST, SUMS, ANUAL) create the desired annual changes. Annual operations include stand growth, thinnings, regeneration cuts, losses, and other changes in volume and value. Dollar values useful in determination of the rate earned are printed at the end of each game (WORTH), as is a complete summary of volumes and values (REPRT2). An optional subroutine (SUMRY) prints selected values from all games of a test, one set per page, to simplify comparisons.

The main program enters BATCH name and the number of tests in one run or job into computer memory. Loops that control the number of tests, the number of games in a test, and the number of years in a game are in the main program.

Subroutine BASIS1

BASIS1 is called once each test to read values that apply to all games of the test. Values entered include stumpage prices, minimum commercial volumes, and items used to compute a yield table. Stand age at regeneration cut, frequency of cut, and density of any residual stand are entered to select and control the silvicultural system used for regeneration. Controls on the program are entered as number of games in the test. number of years in each game, and the columns of REPRT2 to be printed by SUMRY. Variables that pertain to an entire test are initialized by BASIS1.

Definitions of the variables, restrictions on their values, and other necessary information are presented in the section headed Data Deck.

Subroutine CHEK1

CHEK1 edits the data cards read by BASIS1 to insure that certain errors do not occur. Terminal indexes of DO loops and counters of computed GO TO are checked to be sure they are not smaller than one or larger than the dimensions specified for related variables. Variables used in growth and other equations are checked to be sure they do not have zero or negative values. Additional statements can be added to further edit the data cards, such as specifying maximum values for various variables.

Identification of an error by CHEK1 prevents continuation of the job. The two error flags are examined when control is returned from CHEK1 to the main program. A nonzero value of either flag will cause the printing of an error message and termination of the job.

Subroutine YIELD

YIELD computes and prints yield tables for managed, even-aged stands. It is called once each test to produce the yield table that will apply to all games of the test. Values in each yield table reflect prior decisions on the frequency and intensity of intermediate cuttings and the nature of reproduction cuttings. Data related to these decisions are read in by BASIS1.

Computations performed by the subroutine follow procedures described in detail elsewhere (Myers 1971). Average stand diameter (d.b.h.) and number of trees per acre just before initial thinning are used as read in by BASIS1. Reasonableness of the values will have been checked previously by comparison with measurements of actual stands of suitable ages, densities, and site qualities. Basal area and the average height of dominant and codominant trees are computed. YIELD then calls subroutine VOLS to compute volumes per acre before thinning. Subroutine CUTS is called to compute d.b.h. after cutting to the residual level defined in equations based on values in table 1 and by THIN from BASIS1. The stand will not be thinned if its density is already at or below the appropriate residual. Postthinning basal area and average height are computed and subroutine

Table 1.--Basal areas after intermediate cutting in relation to average stand diameter. Growing stock level 80.

Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre
	Sq. ft.		Sq. ft.		Sq. ft.		Sq. ft.
2.0	12.1	4.0	35.2	6.0	56.6	8.0	72.5
2.1	13.2	4.1	36.4	6.1	57.6	8.1	73.1
2.2	14.4	4.2	37.6	6.2	58.5	8.2	73.7
2.3	15.5	4.3	38.7	6.3	59.4	8.3	74.3
2.4	16.7	4.4	39.9	6.4	60.3	8.4	74.8
2.5	17.9	4.5	41.0	6.5	61.2	8.5	75.3
2.6	19.0	4.6	42.2	6.6	62.1	8.6	75.8
2.7	20.2	4.7	43.4	6.7	62.9	8.7	76.3
2.8	21.3	4.8	44.5	6.8	63.8	8.8	76.7
2.9	22.5	4.9	45.7	6.9	64.6	8.9	77.1
3.0	23.7	5.0	46.8	7.0	65.4	9.0	77.5
3.1	24.8	5.1	47.8	7.1	66.2	9.1	77.9
3.2	26.0	5.2	48.8	7.2	67.0	9.2	78.2
3.3	27.1	5.3	49.8	7.3	67.7	9.3	78.5
3.4	28.3	5.4	50.8	7.4	68.5	9.4	78.8
3.5	29.5	5.5	51.8	7.5	69.2	9.5	79.1
3.6	30.6	5.6	52.8	7.6	69.9	9.6	79.3
3.7	31.8	5.7	53.8	7.7	70.6	9.7	79.5
3.8	32.9	5.8	54.7	7.8	71.2	9.8	79.7
3.9	34.1	5.9	55.7	7.9	71.9	9.9	79.8
						10.0+	80.0

VOLS is called again to compute volumes per acre. D.b.h. is then increased by the amount of periodic growth, and the number of trees is reduced, if necessary. CUTS is called again to perform the second thinning, this time to level DLEV read in by BASIS1. The sequence of steps is repeated as many times as necessary until terminated by the final cut at the age appropriate to the regeneration system used. Stand age and other state variables are printed at the end of each series of operations.

Table 1 gives residual basal area after intermediate cutting for various average stand diameters. The values represent one possible series of densities that could be used to guide successive thinnings in a stand. Basal area increases with diameter until 10.0 inches diameter is reached, and remains constant thereafter. The series in table 1 is labeled "growing stock level 80" to indicate that reserve basal area is 80.0 square feet per acre when d.b.h. after cutting is 10.0 inches or larger. Other stocking levels are named the same way. For example, stocking level 100 means that reserve basal area will be 100 square feet when d.b.h. after cutting is 10.0 inches or larger. Basal areas for level 100 and for diameters smaller than 10.0 inches are obtained by multiplying each basal area of level 80 by the amount 100/80. Values for other stocking levels, perhaps from 50 to 160, are computed similarly. The ratio is computed frequently in MANGD2 as THIN/GIDE or DLEV/GIDE.

Data used to obtain the base curve, level 80 in table 1, came from permanent and temporary plots. A graph of desired basal area over average stand d.b.h. was drawn for plots of local average site quality. "Best" stand density for each average diameter sampled was based on such criteria as production in cubic feet and probable length of saw-log rotations.

Increases in d.b.h. due to tree growth, percentages of mortality, and other periodic changes in stand conditions are for a specific length of projection period. The length, in number of years, is entered as RINT by BASIS1. Equations in the listing of YIELD in appendix 1 are for a projection period of 10 years. Intervals between intermediate cuttings are one or more projection periods long.

The yield table will show numbers of trees and other values appropriate to the regeneration system selected. Data card type 5 that controls the operations has entries in up to seven fields: REGN (1), VLLV (1), CYCNW (1). REGN (2), VLLV (2), CYCNW (2), and REGN (3). If a value is punched for REGN(1) and all other fields are left blank, the yield table will show regeneration by clearcutting. The value entered for REGN(1) is the desired rotation length. YIELD will, however, add a 20-year period to REGN(1) so the final entry in the table will be REGN(1) plus 20. This permits computation of volumes for stands that will not be regenerated until they have passed rotation age. The table may show an intermediate cut at what is really rotation age. For stands cut at or beyond rotation age, the apparent intermediate cut is added to the reported reserve to get correct final volume.

If a value is assigned REGN(2), there must also be values for REGN(1), VLLV(1), and CYCNW(1). A value for REGN(2) and a blank for REGN(3) calls for the seed tree system or two-cut shelterwood. REGN(1) is stand age at time of first cut and REGN(2) is stand age at final cut. VLLV(1) is the percentage of the growing stock level used for intermediate cuts (DLEV) that will remain after the cut at age REGN(1). For example, if DLEV is 100 and VLLV(1) is .50, the residual stand at REGN(1) will have a basal area of 50 square feet. CYCNW(1) is the number of years from REGN (1) to REGN(2).

Assignment of a nonzero value to REGN(3) calls for use of three-cut shelterwood. The first removal cut will occur at age REGN(1), a second cut at REGN(2), and the final cut at REGN(3). VLLV(2), like VLLV(1), is a percentage of the growing stock level DLEV. Now, however, DLEV is not the value read in originally but the level computed with VLLV(1) for the first cut. For example, if the original DLEV is 100 and VLLV(1) and VLLV(2) both equal .50, reserve basal area after the second cut at REGN(2) will be 25 square feet (100 x .5 x .5). Other variables are as explained above.

Preparing input data for the clearcutting option is not complicated. Age at initial thinning (AGEO), interval between cuts (CYCL), and rotation length (REGN(1)) control the operations. Computations proceed until adjusted rotation age is reached. The interval between cuts must be equal to or some multiple of the projection period of the growth and mortality equations (RINT) and a factor of the interval between AGEO and REGN(1).

Tests involving seed tree or shelterwood systems require much more advance planning. Events in the lives of the old and new crops must be scheduled sensibly in relation to each other. The final stand is not removed at or near rotation age but at an older age, the felling age. Length of the rotation becomes the length of the period between similar cuts, and intervening activities must be well described chronologically.

Scheduling of operations may be assisted by drawing a sketch similar to figure 1. The stand shown is managed under a rotation of 110 years, with a final felling age of 140 years.

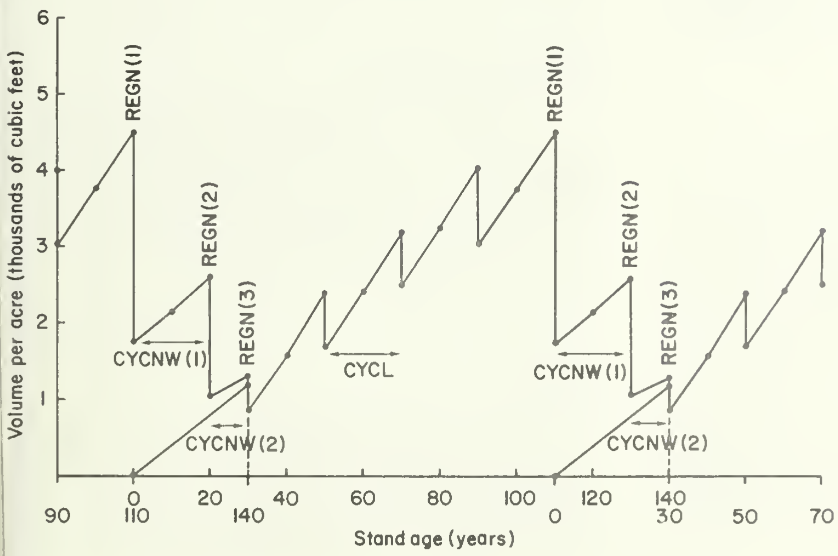

Figure 1.--
Volume changes with three-cut shelterwood. Management controls: cutting cycle, 20 years; rotation, 110 years; final felling age, 140 years. Labels are the variable names used in MANGD2.

Intermediate cuts are made at 20-year intervals, with the first thinning at time of the final cut of the overstory. The two removal cuts are 20 years apart. A final cut is made 10 years after the second removal cut. Inspection of the sketch shows that overstory and understory operations occur in proper relation to each other and that similar events occur at intervals equal to the 110-year rotation desired.

It is often desirable to make simulations more realistic by varying the values estimated by equations or contained in tabulations. For example, repeated computations of DBHO without change in values of the independent variables will always give the same numerical result. In reality, actual and estimated values differ frequently. A way of providing variability in estimates of DBHO is contained in the program segment between statements 250 and 300. Similar statements could be written for other variables.

Variability is obtained in three steps: (1) generation of a pseudorandom number, (2) use of this number as an independent variable to compute the value of a residual (range: -0.3 to +0.3 inch), and (3) addition of the residual to the computed value of DBHO. The pseudorandom number generator, statement 250, is of the form:

$$X_i \equiv AX_{i-1} + C \text{ (modulo M)}$$

(Greenberger 1961). Values of all elements of the generator are specified except for X_{i-1}, which is read in as variable GNTR. The statement to compute RES is an empirical distribution function obtained by fitting a polynomial to the normally distributed residuals of the DBHO equation (Evans et al. 1967). An approximation to the normal distribution function may also be used (Burr 1967).

Subroutine VOLS

VOLS is called by subroutine YIELD to compute total cubic feet per acre and the factors used to obtain volumes in other units. Total cubic volumes per acre, from ground line to tip of each tree, are computed from basal area, d.b.h., and tree height by means of stand volume equations. Factors transferred from VOLS are used to convert total cubic volume to other units. With the program listed in appendix 1, factors are obtained for merchantable cubic feet to a 4-inch top and for board feet. Yields in units other than volume, such as by weight (Myers 1960), could also be computed if desired. Total cubic volumes are multiplied by the appropriate factors in subroutine YIELD.

Standards for minimum d.b.h. and top diameters will vary by species and locality. Statements are provided at the end of subroutine YIELD so the limits applicable to yield table volumes will be recorded in table footnotes.

Subroutine CUTS

CUTS is called by subroutine YIELD to determine the increase in average d.b.h. due to thinning to any specified level. The equation for DBHE estimates diameter after thinning when the diameter before thinning and the percentage of trees retained are known (Myers 1971). The percentage of trees that will be retained to reach any specified growing stock level is never known. Successive percentages are therefore tested until d.b.h. after thinning, number of trees, and basal area agree with the desired thinning intensity entered as THIN or DLEV by BASIS1 and as defined in table 1.

Equations for DBHP and SQFT in subroutine CUTS are both expressions for the combinations of diameter and basal area in table 1. Statements for DBHP compute a d.b.h. less than 10.0 inches when the corresponding basal area is known. Statements for SQFT determine basal area when d.b.h. is known. DBHP computes estimates of the diameter required to meet the standards of THIN or DLEV. Basal areas computed with diameters from the equation for DBHE are used in the computations. When DBHP and DBHE are equal to the nearest 0.1 inch, iterations of CUTS terminate and post-thinning basal area (BAST) is computed by SQFT. The ratios GIDE/REST and REST/GIDE in CUTS convert values from growing stock level 80 of table 1 to the levels specified by THIN and DLEV.

Subroutine ANVOL

ANVOL is called once each test to compute volumes per acre for each year from initial thinning to maximum stand age. Volumes in cubic and board feet are obtained by linear interpolation and printed on page type 2. Average stand diameters at each year of stand age are also computed by interpolation of yield table values. Diameters are used later as "independent" variables in computation of the cubic volume obtainable as a byproduct from saw-log cuts.

The last few statements of the routine expand the arrays of volumes removed to assign the volume of each intermediate cut to each of the years before the next cut is made. Volumes cut are added to potential reserve volumes from the yield table, if necessary, to simulate a complete removal of volume when called for and the yield table shows that partial removals normally occur at that stand age.

Stand age cannot exceed 179 years unless dimensions of the 18- and 180-location arrays of acres and annual volumes are increased.

Subroutine BASIS2

BASIS2 is called once each game to enter numerical values of variables that may differ for each game of a test. Descriptive data include area of the working circle, distribution of area by age classes, nonstocked area, and number of acres to be planted annually. Various costs and the rate at which they change from year to year are also read. One to ten combinations of limiting price, allowable cut, and minimum cutting age are read in for determination of the annual cut. This operation is described by Gould and O'Regan (1965), and in the section of this Paper headed Data Deck. Variables that have zero values at the start of each game are initialized by BASIS2.

Definitions of the variables, restrictions on their values, and other information are also presented in the section that describes the data deck.

Subroutine CHEK2

CHEK2 edits the data cards read by BASIS2 to insure that certain errors do not occur. Terminal indexes of DO loops are checked to be sure they are not smaller than one or larger than the dimensions specified for them or related variables. Variables used in various computations are checked to be sure that they do not have unwanted zero or negative values. Additional statements can be added to further edit the data cards, such as specifying maximum values for various variables.

As with CHEK1, location of an error causes termination of the simulation. A nonzero value for either error flag will cause printing of an error message and end of the job.

Subroutine START

START is called once each game to print a record of conditions for that game. Some of the values read by BASIS1 and BASIS2 are printed on page type 3 under the heading "alternatives for this game." Values that appear elsewhere, such as site index on page type 1, are not printed by START.

Subroutine AREAS

AREAS is called once each game to compute volumes and area distributions at the end of the year before simulation begins. Acres in each 1-year age class are expanded to obtain a record of the age of each individual acre, and are then totaled by 1- and 10-year age classes. Separate records are kept for overstory and understory if seed tree or shelterwood systems are used.

Each acre is assigned an initial treatment status code if seed tree or shelterwood systems are used. Simulation begins as though the same silvicultural system has already been in effect for a number of years. Each overstory acre where regeneration has started has an understory of the appropriate age. The treatment status code controls the timing of future removal or final cuts of the overstory. The code also helps keep appropriate overstory and understory ages together in later list processing operations.

Initial growing stock volume is totaled in board feet and in cubic feet. Volume of an acre will be added to the total of only one of the two volume units. The unit will be board feet if board-foot volume on the acre equals or exceeds the value of the variable BFMRCH read by BASIS1. No volume will be credited to the acre if stand age is less than the specified minimum (AGMRCH).

Volume and money variables that require nonzero values at start of simulation are computed. Each value is then stored in one of two 2-dimensional arrays for printing by REPRT2.

Total area (LAND) cannot exceed 1,000 acres unless the dimensions of AGEOS(I), AGEUN(I), and TRET(I) are increased. Age of the oldest acre cannot exceed 179 years unless dimensions of the 18- and 180-location arrays for acres and volumes are increased.

Subroutine REPRT1

REPRT1 is called several times each game to print a table of the distribution of acres by 1-year and 10-year age classes on page type 4. REPRT1 is called first to record the distribution of acres before simulation begins, as computed by AREAS. It is also called at the end of the first year of each game and at the end of each decade.

Subroutine COVER

COVER is called once each year of each game to increase forested acreage by direct seeding or planting and to reduce the timbered area by the amount of catastrophic losses. A specified area (IPLNT) is seeded or planted each year, if nonstocked acres exist. Nonstocked acres are those deforested by fire or other catastrophe, and do not include regenerating stands that will restock in the allotted time. Some or all clearcut acres could be added to nonstocked area to simulate delays or failures in natural regeneration.

Understory and overstory age and treatment codes are increased by one when COVER is called at the beginning of each year. Results are the stand ages and treatment codes applicable to that year.

Age of each acre destroyed and added to nonstocked area is selected at random with a pseudorandom number generator of the form:

$$X_i \equiv AX_{i-1} + C \text{ (modulo M)}$$

(Greenberger 1961). All values are present in the FORTRAN statement except for X_{i-1}. This term is the variable ANUL, read from the data deck by subroutine BASIS2. The generator in COVER has a periodicity of 128. Any value of ANUL from 0 to 127 may be read by BASIS2, to vary the pattern of loss. As listed in appendix 2, the sawtimber on any acre destroyed will be salvaged if it is not less than a specified minimum volume (BFSALV). Stands with less than minimum board-foot volumes will be cleaned up at a predetermined cost per acre (CLOSS) unless stand age is equal to or less than that specified for first thinning (AGEO). Young stands are assumed to have no material to be salvaged or that will require cleanup before planting. All these limits may be changed, if desired, to better apply to local conditions and management practices.

COVER was written to provide for the loss of whole acres only. Partial acres lost will be accumulated until an entire acre can be zeroed out in the age and treatment arrays. If very high annual losses are assumed, appropriate parts of COVER will be repeated until all but fractional acres are accounted for.

After each acre selected by the pseudorandom number generator is destroyed, it is put at the end of the sequence of acres arranged according to age. This is necessary because the subroutines that simulate regeneration cuts will select the acre with the oldest eligible stand for cutting first.

Subroutine HRVST

HRVST is called once each year to perform any scheduled intermediate and regeneration cuts. Stand ages at time of intermediate cuts are determined by age at first thinning (AGEO) and interval between treatments (CYCL). Ages of stands to receive regeneration cuts are specified by values of REGN(I) and FMRCHD(I).

Allowable annual cut is the number of acres to be regenerated by clearcutting or to receive the first regeneration cut of the seed tree or shelterwood systems. The annual cut equals the constant or variable allowable limit less any losses of one or more entire acres. Determination of the allowable limit is described in the section headed Data Deck. Regeneration cuts are performed by calls to subroutines CLEAR or SHWD.

Every acre of appropriate age is thinned, regardless of whether or not the volume to be removed exceeds minimum commercial limits. Thinning cost (CTHN) will be assessed against each acre receiving a noncommercial operation. Yields will be determined in board feet if the amounts removed equal or exceed minimum limits for board feet. Otherwise, commercial cuts will be measured in cubic feet of roundwood. If the main cut is credited to board-foot volume, an additional amount in cubic feet will be determined as merchantable volume not in saw logs.

Subroutine CLEAR

CLEAR is called annually by subroutine HRVST if needed to perform regeneration cuttings by the clearcutting system. As explained above, this system is specified by punching only one nonzero felling age on the type 5 data card. The number of acres to be regenerated during the year is computed in HRVST.

As with thinnings, commercial volumes removed will be recorded in board feet if not less than the minimum commercial board-foot cut. Otherwise, the volume will be computed in cubic feet. With board-foot yields, the cubic feet of roundwood not in saw logs will also be determined.

Subroutine SHWD

SHWD is called annually if needed by subroutine HRVST to perform regeneration cuttings by the seed tree or shelterwood systems. Harvested volumes will be determined in cubic feet or in board feet and cubic feet, as in subroutine CLEAR. As each acre is cut, the treatment status code is changed so future regeneration cuts on the area will be scheduled correctly.

Subroutine ARNG is called by SHWD, as described below.

Subroutine ARNG

ARNG is called periodically by subroutine SHWD to rearrange the sequence in which individual acres are stored in age and treatment code arrays. During a simulation run, young overstories are created in two ways: (1) by removal of the previous overstory, and (2) by replacement of stands destroyed by catastrophe. During rearrangement, overstories of equal age are brought together in the age and treatment arrays. All stands will then be regenerated in proper sequence when treated in order of age during long simulation periods.

Subroutine SUMS

SUMS is called once each year of each game to perform the following operations: (1) compute growing stock volume at the end of the year, (2) determine the number of acres in each 1-year and 10-year age class, (3) compute the costs and returns resulting from the year's activities, and (4) increase all costs by the desired annual rate, if one has been specified in the data deck.

Subroutine ANUAL

ANUAL is called each year of each game to compute 40 volume, area, or money totals and to store them for later use. Each total is stored in one of two 2-dimensional arrays. The first dimension identifies the variable, the second the year of a game to which the value applies. Numerical value of each year subscript is year plus one, so year zero of a game can be included in the array. Array values are used in the three subroutines described below.

Subroutine REPRT2

REPRT2 is called at the end of each game to print the results of each year of the game. Array values computed and stored by ANUAL are printed in 40 numbered columns that extend across four (five with shelterwood) pages of page type 5 (appendix 2). Entries under column headings are printed at the rate of 40 lines, or years, per page.

Subroutine WORTH

WORTH is called at the end of each game to discount all costs incurred and all income received. Value of the growing stock at the end of the simulation period is discounted to beginning of the period. The program discounts each future value at each of 20 compound interest rates. Rates range from 1.0 to 10.5 percent at intervals of 0.5 percent. The limits and interval can be changed by modification of statements for CRATE(I) and CRATE(K) in the first set of statements after the initializing operations. The subroutine will produce 20 rates unless changes are made in the dimension statement and the terminal indexes of the DO loops.

WORTH prints a table that gives the present value of each of the following for each discount rate: (1) future growing stock, (2) all incomes, (3) sum of items 1 and 2, (4) all costs, and (5) item 3 minus the sum of item 4 and the value of the growing stock at beginning of the game. Net discounted revenues (present worths, item 5) may be plotted over discount rates to determine the internal rate of return applicable to the duration and conditions of the game.

Subroutine SUMRY

SUMRY may be called at the end of each test to summarize results of the games of the test. If this option is used, SUMRY is also called at the end of each game to store specified volume or money values in a 3-dimensional array. Values stored correspond to the columns of REPRT2 that have their column numbers entered as KOL(I) by BASIS1. Any of the 40 numbered columns of REPRT2 (appendix 2) may be reproduced. Not more than six columns may be summarized for one test unless the dimensions of variables KOL(I) and SUMM(I,J,K) are increased. The statement that causes reading of KOL(I) by BASIS1 must also be changed. As listed in appendix 1, results of as many as 10 games may be summarized at one time.

Summaries of the games of a test are produced together as the final output of the test. A separate page of page type 7 is printed for each variable (column) selected in advance.

Data Deck

Fourteen types of punch cards, listed below, are used to enter initial values of variables into computer memory. Most cards are not optional and must be included in the data deck so READ statements will be executed properly. Three types are optional (7, 8, 10) and are omitted from the data deck if the options are not to be exercised.

Data cards are read by three routines in the order in which the types are numbered. The type 1 card is read once by the main program to enter BATCH name and the number of tests to be performed in the batch. These identify the job and control the number of times the rest of the main routine is repeated.

Card types 2 to 8, inclusive, are read by BASIS1. One card of each type except types 7 and 8 must be read once each test. Card types 7 (15 cards) and 8 (15 cards) are omitted from the data deck if their options are not to be used. Nonzero stumpage prices (BDPRI and/or CFPRI) on card type 6 cause the corresponding READ statements for variable prices of card types 7 or 8 to be skipped.

Card types 9 to 14, inclusive, are read by BASIS2 once each game. Each type consists of one card except for optional type 10, which requires 10 punch cards. Statements that refer to card type 10, variable area by age classes, are bypassed when a nonzero value is punched for KAREA on card type 9.

Card types 11, 12, and 13 contain values for the price control procedure of Gould and O'Regan (1965). The number of acres harvested annually can be made to vary with the current stumpage price of saw logs. For example, as shown on page type 3 of the second game of the test problem (appendix 2), 5 acres will be cut if price per thousand board feet does not exceed \$12.00. Eight acres will be cut if stumpage price is \$12.01 to \$15.00, and 12 acres will be cut if price exceeds \$15.00 but is less than \$99.00. The \$99.00 value is merely an arbitrary upper limit that prices will not reach. Minimum cutting age can also vary with stumpage price if the clearcutting option is used.

Sequence of regeneration cuts is from oldest acre to youngest, so full allowable cut will be taken only if sufficient acres above minimum cutting age are available. If price control is not wanted, entries for allowable cut in columns 1 to 4 of card type 12 and for cutting age in columns 1 to 8 of card type 13 are the desired constant limits. A critical price greater than the largest possible price (for example, \$99.00) is entered in columns 1 to 8 of card type 11.

Whether price control is wanted or not, the potential annual cut will be reduced automatically each time an acre is lost to fire or other catastrophe. The effect is to impose area control by having the total of acres cut and lost equal the annual cutting budget. The reduction of harvestable acres may be prevented, if desired, by removing LOSS from the statement labeled 10 in subroutine HRVST.

Card type 14 enters the costs of various operations and the rate at which these costs may increase annually.

The order in which data cards will be read can be illustrated by a job consisting of two tests with two games per test. The sequence is as follows:

1. The type 1 card for the job.
2. Card types 2 to 8 for the first test.
3. Card types 9 to 14 for game one of the first test.
4. Card types 9 to 14 for game two of the first test.
5. Card types 2 to 8 for the second test.
6. Card types 9 to 14 for game one of the second test.
7. Card types 9 to 14 for game two of the second test.

Any number of tests and games may be performed in one job. Unless modified, subroutine SUMRY cannot report the results of more than 10 games.

Order and Contents of the Data Deck for Program MANGD2

Card type	Optional	Read by	Frequency read	No. of cards	Variable name	Columns	Format	Description of variable
1	NO	Main	Batch	1	BATCH(I)	1-24	3A8	Descriptive name to identify output of one pass through the computer.
					NTSTS	25-28	I4	Number of tests in the batch, each with a yield table.
2	NO	BASIS1	Test	1	SPEC	1-40	5A8	Name of species being examined; for table headings.

rd pe	Optional	Read by	Frequency read	No. of cards	Variable name	Columns	Format	Description of variable
					NSP	41-43	I3	Code number of the species being examined. Used to select species-specific relationships.
3	NO	BASIS1	Test	1	DESCR(I)	1-40	5A8	Phrase to describe conditions of one test; to identify output.
					NGAME	41-44	I4	Number of trials (games) to be operated in one test.
					NOYRS	45-48	I4	Number of years simulated in each game. Can be up to 150, but will usually be less.
					NKOLS	49-52	I4	Number of columns of REPRT2 to be printed by SUMRY.
					KOL(I)	53-76	6I4	Numbers of the columns of REPRT2 to be printed by SUMRY. Column numbers, 1 to 40, are given in the column headings of page type 5 (Appendix 2).
4	NO	BASIS1	Test	1	SITE	1-5	F5.0	Site index. Base age and crown classes same as used to derive growth equations.
					CYCL	6-10	F5.0	Interval between intermediate cuts. Equal to or a multiple of RINT.
					RINT	11-15	F5.0	Number of years for which a growth projection is made by the equations in YIELD.
					THIN	16-20	F5.0	Density level after initial thinning at age AGEO. Based on table 1 and procedure given in description of subroutine YIELD. May equal DLEV.
					DLEV	21-25	F5.0	Density level for intermediate cuts after initial thinning. Based on table 1 of this publication and procedure described in YIELD.
					AGEO	26-30	F5.0	Stand age at time of initial thinning. First age given in the yield table.
					DENO	31-35	F5.0	Number of trees per acre at age AGEO.
					DBHO	36-40	F5.2	Average diameter breast high of the stand at age AGEO.
					GIDE	41-45	F5.0	Base level of set of growing stock levels, as the 80.0 shown in the example of appendix 2.
	NO	BASIS1	Test	1	REGN(1)	1-8	F8.3	Stand age when first regeneration cut will occur. Must not be zero or blank as this is rotation length for clearcutting.
					VLLV(1)	9-16	F8.3	Percentage of previous DLEV to be left at age REGN(1). Will be zero with clearcutting.

Card type	Optional	Read by	Frequency read	No. of cards	Variable name	Columns	Format	Description of variable
					CYCNW(1)	17-24	F8.3	New interval between cuts in effect after age REGN(1). Will be zero wit clearcutting.
					REGN(2)	25-32	F8.3	Stand age at which second regeneration cut, if any, will occur. Remova of seed trees or second cut of shelterwood.
					VLLV(2)	33-40	F8.3	Percentage of previous DLEV (including effect of VLLV(1) to be left at age REGN(2). Will be zero if REGN(3 equals zero.
					CYCNW(2)	41-48	F8.3	New interval between cuts in effect after REGN(2). Will be zero if REGN(3) equals zero.
					REGN(3)	49-56	F8.3	Stand age at which third regeneration cut, if any, will occur. Final cut of 3-cut shelterwood.
6	NO	BASIS1	Test	1	AGMRCH	1-5	F5.0	Minimum stand age for an acre to be included in growing stock volume.
					BFMRCH	6-10	F5.2	Minimum volume in M bd. ft. for an acre to be included in board-foot growing stock volume.
					BFSALV	11-15	F5.2	Minimum volume per acre in M bd. ft. for commercial salvage after fire, wind, or other loss.
					COMCU	16-20	F5.0	Minimum cut per acre in merchantable cubic feet for a cut to be of positive commercial value.
					EXTCU	21-25	F5.0	Minimum commercial cut per acre in merchantable cubic feet when by-product of sawlog operation.
					COMBF	26-30	F5.2	Minimum cut per acre in M bd. ft. for a cut to be of positive commercial value.
					BFPCT	31-35	F5.3	Ratio, as a decimal, of board-foot stumpage values of thinnings to board-foot stumpage values of harvests.
					CFPCT	36-40	F5.3	Ratio, as a decimal, of cubic-foot stumpage values of thinnings to cubic-foot stumpage values of harvests.
					GNTR	41-45	F5.0	Any number between 0 and 1023 used to generate random element of the increase from DBHT to DBHO. Enter number larger than 1024 to bypass this step.

ard ype	Optional	Read by	Frequency read	No. of cards	Variable name	Columns	Format	Description of variable
					BDPRI	46-50	F5.2	Stumpage price per M bd. ft. of final harvest if price is constant for all years of a game. Enter zero if variable prices will be entered with card type 8.
					CFPRI	51-55	F5.2	Stumpage price per 100 cubic feet of final harvest if price is constant for all years of a game. Enter zero if variable prices will be entered with card type 7.
7	YES	BASIS1	Test	15	PRICF(I)	1-80	10F8.3	Stumpage price per 100 cubic feet of harvest for each of 150 years. Used when CFPRI equals zero.
8	YES	BASIS1	Test	15	PRIBD(I)	1-80	10F8.3	Stumpage price per M bd. ft. of harvest for each of 150 years. Used when BDPRI equals zero.
9	NO	BASIS2	Game	1	GMNAM(I)	1-24	3A8	Descriptive name to identify each game of a test.
					LAND	25-28	I4	Total acres in simulated working circle. Maximum is 1,000 acres.
					MOLD	29-32	I4	Age of oldest stand in the working circle at start of a game. Maximum is 179 years.
					NONSTK	33-36	I4	Number of acres nonstocked at start of a game. Does not include acres harvested the year before simulation begins if regeneration will take place in the allotted time.
					KAREA	37-40	I4	Number of acres in each 1-year age class when there is equal area in each class except for NONSTK.
					IPLNT	41-44	I4	Number of acres of NONSTK regenerated annually by direct seeding or planting at a cost of CPLT per acre.
					DEFOR	45-52	F8.5	Percentage, as a decimal, of the area of forest lost annually to fire, wind, etc.
					ANUL	53-60	F8.5	Any number between 0 and 127 used to begin generation of pseudorandom numbers that represent ages of stands lost to fire or other agency.
0	YES	BASIS2	Game	10	IACRE(I)	1-72	18I4	Acres in each 1-year age class from 0 to not more than 179. Use if constant area KAREA is not wanted. Include NONSTK in IACRE(1) as well as on card type 9.
1	NO	BASIS2	Game	1	PRIDIV(I)	1-80	10F8.3	Limiting prices used to determine annual cut in acres and minimum cutting age.

Card type	Optional	Read by	Frequency read	No. of cards	Variable name	Columns	Format	Description of variable
12	NO	BASIS2	Game	1	MALCUT(I)	1-40	10I4	Allowable annual cut in acres. May vary with PRIDIV(I).
13	NO	BASIS2	Game	1	FMRCHD(I)	1-80	10F8.3	Minimum cutting age. May vary with PRIDIV(I).
14	NO	BASIS2	Game	1	RATE	1-8	F8.3	Rate of annual increase in costs. Enter zero if constant costs are desired. Otherwise, enter percentage as a decimal.
					CPLT	9-16	F8.3	Cost of regenerating 1 acre by seeding or planting.
					CTHN	17-24	F8.3	Cost per acre of noncommercial thinning with stand conditions as specified for the simulation.
					CLOSS	25-32	F8.3	Cost per acre of cleanup after loss due to fire, wind, etc., when volume that can be salvaged is less than BFSALV.
					ACCST	33-40	F8.3	Total per acre for 1 year of the annual costs that can be assessed by area.
					CUCST	41-48	F8.3	Total of the costs that can be assessed against each 100 cubic feet harvested.
					BFCST	49-56	F8.3	Total of the costs that can be assessed against each M bd. ft. harvested.

Modification of MANGD2

The program can be adapted readily for simulations of species other than those represented in the listing of appendix 1. Replacement of, or additions to, statements in subroutines YIELD, VOLS, CUTS, HRVST, CLEAR, and SHWD are needed. The program listing (appendix 1) contains COMMENT statements that name the species-specific statements. Each statement is identified in YIELD because of the length of the subroutine. Elsewhere, the species-specific statements are named at the beginning of the routine.

As stated in the description of MANGD2, each species-specific statement can appear in several versions, one for each species of interest. In the listing of appendix 1, specific statements are given for two species. Space is provided for a third species in the form of dummy CONTINUE statements. The simplest modification for another species is, therefore, to replace the dummy statements with appropriate relationships applicable to the new species.

Species-specific relationships are described briefly below. Additional details on necessary field work and analysis are given elsewhere (Myers 1971).

1. Diameter increase from growth.

Regression analysis of data obtained on temporary and/or permanent plots provides the equation for DBHO in subroutine YIELD. Future average stand d.b.h. is predicted from present stand conditions. For ponderosa and lodgepole pines, present d.b.h., site index, and present basal area per acre are useful variables. The prediction period of the equation is determined by the number of rings measured on increment cores from temporary plots or from the interval between records on permanent plots.

2. **Diameter increase from thinning.**

Change in average stand diameter caused by intermediate cutting is determined by CUTS with the statements for DBHE and PDBHE. Regression analysis of data obtained during repeated trial marking of plots to numerous intensities of cutting is used to obtain the relationships. In CUTS, post-thinning d.b.h. (DBHE) is a function of prethinning d.b.h. and the percentage of trees to be retained. DBHE is computed directly if the percentage of trees to be retained is at least 50 percent. With fewer trees retained, the relationship is highly nonlinear, so PDBHE is computed and its antilogarithm becomes DBHE.

Simulation may be used to supplement the field data, if the results are checked before use (Myers 1971).

3. **Residuals of the DBHO equation.**

Optional computation of random elements to be added to each predicted DBHO is covered in the description of subroutine YIELD. Residuals used to compute the polynomial for RES come from the field data and related regression equation for DBHO described in item one, above (Evans et al. 1967).

4. **Average stand height.**

Heights, ages, and site indexes obtained on plots where height growth apparently has never been reduced by high stand density are used to obtain estimators of HTSO. Heights from good site index curves or tables may supplement or substitute for field data if based on the same crown classes used in the stand volume equation, described below. In MANGD2, average dominant and codominant heights are used wherever stand heights enter calculations.

5. **Increase in average height from thinning.**

Data to compute the relationships for ADDHT in YIELD are obtained the same way as those used to estimate changes in average d.b.h. Repeated trial markings of numerous stands to many reserve levels will provide: (1) initial average height, (2) postthinning average height, and (3) the percentage of trees retained. Relationships for ADDHT compute the amount of change in height, or the difference between prethinning and post-thinning averages, as a function of the percentage of trees retained. The crown classes measured must be the same as for other measures involving height, dominants and codominants in the case of MANGD2.

At each cutting, the current value of ADDHT is added to height before thinning, HTSO, to obtain height after thinning, HTST. It is also added to a cumulative sum of changes, HTCUM, so computed heights before thinning will show the effects of past treatments as well as of increased age.

6. **Noncatastrophic mortality.**

The number of trees that die in a given period is expressed as a percentage of the number of trees alive at the beginning of the period. This percentage, DIED, is estimated in YIELD from average stand d.b.h. and basal area, both at the beginning of the period. Data come from permanent plots and from temporary plots in areas where dead trees were removed a known number of years prior to measurement. Each percentage is converted to a decimal before regression analysis.

Subroutine YIELD produces yield tables for managed stands where density is kept at a reasonable level by repeated thinnings. Reduction in numbers of trees is, therefore, minor and erratic, just as it is in actual thinned stands of ponderosa and lodgepole pines. In fact, a prediction equation could not be found for such stands with an average d.b.h. of 10.0 inches or larger. Thus each mortality equation in YIELD is preceded by a logical IF statement with 10.0 in the comparison.

7. **Stand volume equation.**

The basic volume computation in MANGD2 is the determination of total cubic volume per acre (CUFT) by subroutine VOLS. This is the sum of the cubic-foot volumes from ground line to tip of all trees more than 4.5 feet tall. Volumes in other units are computed by multiplying total cubic-foot volumes by conversion factors.

Plot volumes are determined by appropriate methods in all units of interest, including total cubic feet. Other measurements are also obtained for use in regression analysis. Two forms of stand volume equation appear in subroutine VOLS. They are:

$$V = (a + b_1D^2H + b_2B) \times N$$

$$V = (a + b_1D^2H) \times N$$

Another form that has proven useful is:

$$V = a + b_1BH + b_2D$$

Where
V = gross total cubic volume per acre.
D = average stand d.b.h. in inches.
H = average height of dominant and codominant trees.
B = basal area per acre in square feet.
N = number of trees per acre.

Two statements are used for each species, because the relationships are not linear over the ranges of BH or D^2H needed for the yield tables. In data for regression analysis for the first two equations, the dependent variable is cubic volume per acre divided by number of trees.

8. Volume conversion factors.

Factors to convert total cubic feet to other units are computed by VOLS. Two factors are produced: (1) FCTR to obtain merchantable cubic feet from top of stump to minimum merchantable top, and (2)PROD to obtain volume in board feet. As mentioned previously, relationships for other units of measure or other utilization standards may replace those listed in appendix 1.

Volumes per acre in various units are obtained as described for the previous item. Ratios are then computed, such as: (1) merchantable cubic feet per total cubic foot, and (2) board feet per total cubic foot. These ratios are then used as dependent variables in regression analyses involving average stand d.b.h. and basal area. Several equations for each factor and species are shown in VOLS so the relationships can be expressed by simple linear functions over a wide range of d.b.h.

9. Cubic feet from saw-log cut.

The equations for ADD in subroutines HRVST, CLEAR, and SHWD estimate the merchantable cubic feet obtained in the board-foot portion of saw-log cuts. To obtain the basic data, cubic- and board-foot volumes of all trees above minimum size for saw-logs are summed to obtain equivalent volumes per acre. Tree data come from the same plots used for other volume items described above. Dependent variable for regression analysis is merchantable cubic feet per thousand board feet. Independent variables for the pines used as examples are average d.b.h. and thousands of board feet per acre.

The equation for ADD is used as follows:

1. Cubic volume contained in saw logs is computed.
2. This volume is subtracted from the entire amount of merchantable cubic feet in the cut.
3. The difference is used in computations as the cubic volume obtainable as a byproduct of the saw-log operation.

Possible modifications of MANGD2 for purposes other than changes of species are given in the description of the appropriate subroutine.

An Application of MANGD2

The test problem that follows, demonstrates most computations possible with MANGD2 and the printed results obtained. It may be used to verify accuracy of source decks and compatibility of the program with locally available compilers. The data deck is listed in figure 2. Although the growth projections use relationships applicable to Black Hills ponderosa pine, costs and prices are hypothetical. Results of the simulation are therefore examples only, and do not apply to any real forest area.

Assume an area of 885 acres of managed ponderosa pine stands that range from 0 (just harvested) to 139 years old at the end of a year of operations. Management is by 3-cut shelterwood, with controlling stand ages and intervals as shown in figure 1. Overstory stands range in age from 30 to 139 years old, with 8 acres in each 1-year age class. Understory stands range from 0 (understory absent) to 29 years old. There are 8 acres in each 1-year age class of the understory, including age 0, plus an additional 645 acres of age 0 where understory does not exist. Understories are established where overstory stands are 111 to 139 years old. There are 5 acres of old burn and windthrow that will be seeded or planted at the rate of one acre annually. Annual losses to fire, wind, and other agencies average 0.04 percent of the forested area. Site index of all acres is 70 feet (base age 100 years).

```
SHELTERWOOD TEST          1
BLACK HILLS PONDEROSA PINE                     1
MANAGED, THINNED AT AGE 30.                    2  30   2  10  40
   70   20   10  120  100   30  950   48      80
  110        50   20       130        50      10       140
   40  15    15  300  100  15    85  1       2222  0      25
   1450    1520    1780    1680    1340    1410    1740    1180    1110    1220
   1290    1010     830     900    1090    1390    1310    1190    1270    1570
   1360    1210    1520    1610    1670    1960    1850    1470    1550    1710
   1300    1220    1340    1420    1210    1010    1090    1300    1620    1520
   1510    1620    1960    1730    1770    1730    1560    1690    1810    1610
   1450    1570    1830    1730    1390    1460    1790    1230    1160    1270
   1340    1060     880     950    1140    1440    1360    1240    1320    1620
   1410    1260    1570    1660    1720    2010    1900    1520    1600    1760
   1350    1270    1390    1470    1260    1060    1140    1350    1670    1570
   1560    1670    2010    1780    1820    1780    1610    1740    1860    1660
   1550    1620    1880    1780    1440    1510    1840    1280    1210    1320
   1390    1110     930    1000    1190    1490    1410    1290    1370    1670
   1460    1310    1620    1710    1770    2060    1950    1570    1650    1810
   1400    1320    1440    1520    1310    1110    1190    1400    1720    1620
   1610    1720    2060    1830    1870    1830    1660    1790    1910    1710
EQUAL AREAS CUT ANNUALLY 885 139   5   8   1   0004  21
   99       0       0       0       0       0       0       0       0       0
   8   0   0   0   0   0   0   0   0   0
  110       0       0       0       0       0       0       0       0       0
     01      30      25      25       20      05     156
VARY CUT WITH PRICE       885 139   5   8   1   0004  21
   12      15      99       0       0       0       0       0       0       0
   5   8  12   0   0   0   0   0   0   0
  110     110     110       0       0       0       0       0       0       0
     01      30      25      25       20      05     156
```

Figure 2.--Data deck for test problems.

Stands will be regenerated by 3-cut shelterwood and will be thinned at 20-year intervals, beginning with a precommercial cut at age 30. Shelterwood after the first regeneration cut will have half the basal area that would be left if the operation were an intermediate cut. Basal area retained after the second regeneration cut will be half that left after the first cut. Stands 30 years old on land of site index 70 are expected to have 950 trees per acre that average 4.8 inches in diameter. Initial thinning will be to level 120 or 120/80 times the basal areas in table 1. Subsequent intermediate cuts will be to level 100, or 100/80 times tabulated basal areas.

Values in the first line of the yield table describe stand conditions just prior to initial thinning. To increase the realism of simulations, it is necessary to have some knowledge of what may be expected for various combinations of stand conditions. Actual unthinned, young stands can be examined to determine, for each site index class, the average d.b.h. resulting from various combinations of stand age and number of trees per acre. Influence of an overstory is included, as necessary, where shelterwood or seed tree systems are used. The combination of d.b.h., density, and site index selected for the first line of the table will be the one that best represents the regeneration goal for the working group.

Potential prices of two products have been estimated for each of the next 30 years. The stumpage price of 100 cubic feet of roundwood from mature trees or from thinnings is expected to be $2.50 throughout the period. Price of a thousand board feet of mature saw logs is expected to vary annually, as shown in column 28 of page type 5 of the printout of annual results (appendix 2). Saw logs from thinnings will sell for 85 percent of the price of logs from regeneration cuts. A minimum commercial cut of saw logs will be 1,500 board feet per acre. Minimum commercial cuts per acre of roundwood will be 300 cubic feet from roundwood sales and 100 cubic feet as a byproduct from saw-log operations.

Current value of the growing stock will be computed only for stands at least 40 years old.

Value will be computed for cubic volume for acres with less than 1,500 board feet. Otherwise board-foot volumes will be used.

Present costs of various operations are as follows:

Costs per acre—
- Seeding—$30.00
- Precommercial thinning—$25.00
- Cleanup where salvage is not possible—$25.00
- Annual costs—$0.20

Costs assessed against volume sold—
- Per 100 cubic feet—$0.05
- Per thousand board feet—$1.56

These costs are expected to increase at a rate of 1 percent annually. Resources are available to seed 1 acre each year.

Two possible means of setting the allowable annual cut are to be tested. One alternative is to harvest 8 acres annually, less any catastrophic losses, regardless of price fluctuations. A second possibility is to harvest: (1) 5 acres if stumpage price per thousand board feet is $12.00 or less, (2) 8 acres if the price is $12.01 to $15.00, and (3) 12 acres if price exceeds $15.00 per thousand. Regeneration will not be started in stands less than 110 years old.

Periodic production in board feet and total net worth will be compared. Values needed to obtain rates earned will be computed.

Data cards to enter the above values into computer memory must contain the alphameric characters shown in figure 2. Card types 7 and 10 are not included in the data deck because the options that require them will be bypassed.

Test conditions and results of the simulations are printed on seven types of pages (appendix 2). The first two types, (1) a yield table, and (2) tables of volumes per acre for each year of stand age, appear once because one test was run. Four types of pages are printed for each of the two games. The seventh type of page appears once at the end of the printout to summarize specified results of the two games.

The two sheets of "alternatives for this game" show the values used in the simulations, including the different allowable cuts and cutting ages tested.

Distributions of acres by age classes (page type 4) appear on two sets of pages, one set for each game. Pages for year zero show 8 acres of overstory in each 1-year age class from 30 to 139 years. Age class zero has an additional 5 acres of nonstocked area. At year zero, there are 8 acres of understory in each 1-year class from 0 to 29 years. Total acres of understory in the zero age class is 653 to account for the acres not in process of regeneration that have only one story (fig. 1). Acreages are the same for both games, because initial distributions were the same.

Type 4 pages are printed at the end of the first year of each game and at the end of each decade. For brevity, only the pages printed after the thirtieth year of each game are reproduced in appendix 2. After 30 years of simulation, losses and direct seeding have modified the pattern of 8-acre units. In addition, area distributions of the second game have been changed by the variable annual cuts.

The fifth type of page is a set of five pages for each game. Values in many of the 40 numbered columns differ between games. Volumes are unequal because of variations in annual cuts of mature timber during the second game. This caused money values to differ from those reported for the first game.

A page of discounted money values, the sixth type of page, is printed for each game. Rate of return was about the same for both games. Both operations were profitable. In addition, the forest would probably be in good condition to produce other products, especially recreation.

Last, specified values from each game were printed together for convenience in interpretation of results. Total volume in board feet of all cuts plus growing stock (column 10) was slightly higher after 30 years where equal areas were cut each year. After the second year, total net worth (column 40) was greater where annual cuts varied with price.

It must be emphasized that results of these or other simulations depend on: (1) duration of the games, (2) values entered for the various variables, (3) assumptions made, and (4) degree to which the system model represents reality.

The above information, additional data, and knowledge of local conditions would help the forest manager decide how he might best conduct his business. Money yields might encourage the manager to vary annual cuts in response to changes in stumpage price. Highly variable annual cuts and equally variable net incomes could suggest that additional simulations be run to test other alternatives. Cost of computer time need not restrict the manager in his search for information. The test problem was compiled and run on a CDC 6400 computer in 66 seconds of central processor time and 47 seconds of input-output time. Times for a similar problem with clearcutting were 63 and 47 seconds, respectively. Opportunities for cost reductions with repeat runs are great. Compilation, avoidable with use of a binary deck for the source program, took 50 seconds of the total central processor time.

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 PROGRAM MANGD2
 1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)

 SIMULATE MANAGEMENT OF EVEN-AGED TIMBER STANDS.
L STATEMENTS TO BE MODIFIED FOR OTHER SPECIES ARE IN SUBROUTINES
ELD, VOLS, CUTS, HRVST, CLEAR, SHWD.

FINITIONS OF VARIABLES.

 ACCST = ANNUAL COST PER ACRE.
 ADD = CUBIC FEET IN SUBSAWLOG TREES OBTAINABLE DURING SAWLOG CUT.
 ADDHT = CHANGE IN AVERAGE STAND HEIGHT BY THINNING.
 AGED = INITIAL AGE IN YIELD TABLE.
 AGEOS(I) = AGE OF OVERSTORY STAND ON ACRE I, AGE OF ENTIRE STAND
    FOR CLEARCUTTING.
 AGEUN(I) = AGE OF UNDERSTORY STAND ON ACRE I.
 AGMRCH = MINIMUM AGE FOR STAND TO BE INCLUDED IN GROWING STOCK.
 ANBDF(I) = M BD. FT. PER ACRE AT END OF YEAR I, IN YIELD TABLE.
 ANCUV(I) = CU. FT. PER ACRE AT END OF YEAR I, IN YIELD TABLE.
 ANNET = ANNUAL NET INCOME.
 ANUL = NUMBER BETWEEN 0 AND 127 USED TO START GENERATION OF
    PSEUDORANDOM NUMBERS.
 BASC = BASAL AREA REMOVED PER ACRE, IN YIELD TABLE.
 BASD = BASAL AREA PER ACRE BEFORE THINNING, IN YIELD TABLE.
 BAST = BASAL AREA PER ACRE AFTER THINNING, IN YIELD TABLE.
 BATCH(I) = JOB NAME.
 BDFC(I) = M BD. FT. REMOVED PER ACRE IN YEAR I, IN YIELD TABLE.
 BDFO(I) = M BD. FT. PER ACRE BEFORE THINNING IN YEAR I, IN YIELD
    TABLE.
 BDFT(I) = M BD. FT. PER ACRE AFTER THINNING IN YEAR I, IN YIELD
    TABLE.
 BDPRI = CONSTANT STUMPAGE PRICE PER M BD. FT.
 BFCST = COSTS PER M BD. FT. HARVESTED.
 BFMRCH = MINIMUM VOLUME TO BE INCLUDED IN BD. FT. GROWING STOCK.
 BFPCT = PCT. TO CONVERT BD. FT. PRICE FOR THINNINGS.
 BFSALV = MINIMUM M BD. FT. FOR COMMERCIAL SALVAGE.
 CFMC(I) = MERCHANTABLE CU. FT. REMOVED PER ACRE IN YEAR I, IN
    YIELD TABLE.
 CFMO(I) = MERCHANTABLE CU. FT. PER ACRE BEFORE THINNING IN YEAR I,
    IN YIELD TABLE.
 CFMT(I) = MERCHANTABLE CU. FT. PER ACRE AFTER THINNING IN YEAR I,
    IN YIELD TABLE.
 CFPCT = PCT. TO CONVERT CU. FT. PRICE FOR THINNINGS.
 CFPRI = CONSTANT STUMPAGE PRICE PER 100 CU. FT.
 CLOSS = COST OF CLEANUP OF ACRE NOT SALVAGED.
 COMBF = MINIMUM COMMERCIAL CUT IN M BD. FT.
 COMCU = MINIMUM COMMERCIAL CUT IN CU. FT.
 CPLT = PLANTING  COST PER ACRE.
 CRATE(I) = INTEREST RATES FOR DISCOUNTING.
 CSTAC = ANNUAL COSTS BASED ON AREA.
 CSTVL = ANNUAL COSTS FOR VOLUME HARVESTED.
 CTHN = COST PER ACRE OF PRECOMMERCIAL THINNING.
 CUCST = COSTS PER 100 CUBIC FEET HARVESTED.
 CUFT = TOTAL CUBIC FEET PER ACRE FROM STAND VOLUME EQUATION, IN
    YIELD TABLE.
 CUTAGE = MINIMUM CUTTING AGE.
 CYCL = INTERVAL BETWEEN INTERMEDIATE CUTS.
 CYCNW(I) = NEW CUTTING CYCLE AFTER REGENERATION CUT I.
 DBHE = AVERAGE STAND D.B.H. AFTER REMOVAL OF A PERCENTAGE OF THE
    LIVE TREES.
 DBHD = AVERAGE STAND D.B.H. BEFORE THINNING, IN YIELD TABLE.
 DBHT = AVERAGE STAND D.B.H. AFTER THINNING, IN YIELD TABLE.
 DEFOR = PERCENTAGE, AS A DECIMAL, OF NUMBER OF ACRES LOST ANNUALLY.
 DENC = TREES REMOVED PER ACRE, IN YIELD TABLE.
 DENO = TREES PER ACRE BEFORE THINNING, IN YIELD TABLE.
 DENT = TREES PER ACRE AFTER THINNING, IN YIELD TABLE.
 DESCR(I) = DESCRIPTION OF TEST CONDITIONS.
 DIAM(I) = AVERAGE D.B.H. BEFORE THINNING AT STAND AGE I.
 DIED = PERCENTAGE, AS A DECIMAL, OF TREES THAT DIE DURING PERIOD
    RINT.
 DISC(I) = DISCOUNTED VALUE OF FUTURE COSTS.
 DISG(I) = DISCOUNTED VALUE OF GROWING STOCK.
 DISI(I) = DISCOUNTED VALUE OF FUTURE INCOMES.
 DLEV = GROWING STOCK LEVEL FOR SECOND AND SUBSEQUENT THINNINGS.
 EXTCU = MINIMUM COMMERCIAL CUT IN CU. FT. FROM SAW LOG OPERATION.
 FCTR = MERCHANTABLE CU. FT. PER TOTAL CU. FT.
 FMRCHD(I) = MINIMUM CUTTING AGE BASED ON PRICE.
 GIDE = BASE FOR GROWING STOCK LEVELS, 80.0 IN EXAMPLE SHOWN.
 GMNAM(I) = NAME OF THE GAME.
 GNTR = PSEUDORANDOM NUMBER GENERATOR. VALUE 0 TO 1023.
 GSVALB = DOLLAR VALUE OF BD. FT. GROWING STOCK.
 GSVALC = DOLLAR VALUE OF CU. FT. GROWING STOCK.
 GVLBF = GROWING STOCK VOLUME, M BD. FT.
 GVLCU = GROWING STOCK VOLUME, CU. FT.
 HTSO = TREE HEIGHT BEFORE THINNING, IN YIELD TABLE.
 HTST = TREE HEIGHT AFTER THINNING, IN YIELD TABLE.
 IACRE(I) = ACRES OF WORKING CIRCLE IN EACH 1-YEAR AGE CLASS AT
    START OF GAME, BASED ON OVERSTORY.
 IALCUT = NUMBER OF ACRES ALLOWABLE ANNUAL CUT.
 IGAME = NUMBER OF GAME.
 IPLNT = NUMBER OF NON-STOCKED ACRES REGENERATED ANNUALLY.
 ISUM(I) = TOTAL ACRES IN OVERSTORY FOR EACH 10-YR AGE CLASS I.
 ITEST = NUMBER OF TEST.
 IVAR(I,J) = VARIABLES PRINTED BY REPRT2, ITEM I, YEAR J.
 IYEAR = YEAR WITHIN RUN OF A GAME.
 KAREA = EQUAL AREA OF OVERSTORY IN EACH 1-YEAR AGE CLASS.
 KOL(I) = COLUMN NUMBER (FROM REPRT2) PRINTED BY SUMRY.
 KOUNT = COUNT OF ACRES HARVESTED, PLUS ONE.
 LAND = TOTAL ACRES IN SIMULATED WORKING CIRCLE.
 LAST = NUMBER OF LAST ACRE HARVESTED.
 MALCUT(I) = ANNUAL ALLOWABLE CUT BASED ON PRICE.
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C       MOLD = AGE OF OLDEST ACRE IN WORKING CIRCLE AT START OF A GAME.
C       NACOS(I) = ACRES OF OVERSTORY IN EACH 1-YEAR AGE CLASS I.
C       NACUN(I) = ACRES OF UNDERSTORY IN EACH 1-YEAR AGE CLASS I.
C       NGAME = NUMBER OF GAMES PER TEST.
C       NKOLS = NUMBER OF COLUMNS OF REPRT2 TO BE PRINTED BY SUMRY.
C       NONSTK = NONSTOCKED AREA FROM FIRE OR OTHER CATASTROPHE.
C       NOYRS = NUMBER OF YEARS IN A GAME.
C       NSP = CODE NUMBER FOR SPECIES BEING RUN.  USED TO SELECT SPECIES-
C          SPECIFIC RELATIONSHIPS IN SUBROUTINES.
C       NSUM(I) = TOTAL ACRES IN UNDERSTORY FOR EACH 10-YEAR AGE CLASS I.
C       NTSTS = NUMBER OF TESTS IN BATCH.
C       PRET = PERCENTAGE OF TREES RETAINED AFTER THINNING.
C       PREV(I) = PRESENT VALUE OF GROWING STOCK AND INCOMES.
C       PRIBD(I) = STUMPAGE PRICE PER M BD. FT. IN YEAR I.
C       PRICF(I) = STUMPAGE PRICE PER 100 CU. FT. IN YEAR I.
C       PRIDIV(I) = PRICES USED TO SET POLICY.
C       PROD = BOARD FEET PER TOTAL CUBIC FOOT.
C       PWTH(I) = PRESENT WORTH.
C       RATE = RATE OF ANNUAL INCREASE IN COSTS.
C       REGN(I) = STAND AGE WHEN REGENERATION CUT I OCCURS.
C       RES = RANDOM VALUE FROM DISTRIBUTION OF RESIDUALS OF EQUATION FOR
C          DBHD.
C       RETHV = ANNUAL RETURN FROM FINAL HARVEST.
C       RETRN = ANNUAL INCOME FROM STUMPAGE.
C       RETTH = ANNUAL RETURN FROM THINNINGS.
C       RINT = NUMBER OF YEARS FOR WHICH GROWTH PROJECTION IS MADE.
C       ROTA = OLDEST STAND AGE TO BE GIVEN IN YIELD TABLE.
C       SALVB = TOTAL BOARD-FOOT VOLUME SALVAGED ANNUALLY.
C       SCLOSS = TOTAL ANNUAL COST OF SALVAGE AND CLEANUP.
C       SCPLT = TOTAL ANNUAL PLANTING COST.
C       SCTHN = SUM OF PRECOMMERCIAL THINNING COSTS.
C       SITE = SITE INDEX.
C       SPEC(I) = NAME OF SPECIES FOR WHICH RUN IS BEING MADE.
C       SQFT = BASAL AREA FOR SPECIFIED AVERAGE D.B.H. BASIS GROWING STOC
C          LEVEL STANDARDS.
C       SUMM(I,J,K) = ARRAY OF IVAR(I,J) AND VAR(I,J) FOR PRINTING BY
C          SUMRY - NUMBER I IN LIST OF COLUMNS, YEAR J, GAME K.
C       TCOST = TOTAL ANNUAL COSTS.
C       THIN = GROWING STOCK LEVEL FOR INITIAL THINNING.
C       TOTC = TOTAL CUBIC FEET REMOVED PER ACRE, IN YIELD TABLE.
C       TOTO = TOTAL CUBIC FEET PER ACRE BEFORE THINNING, IN YIELD TABLE.
C       TOTT = TOTAL CUBIC FEET PER ACRE AFTER THINNING, IN YIELD TABLE.
C       TRET(I) = INDEX TO SHOW CURRENT TREATMENT STATUS OF ACRE I IF
C          CLEARCUTTING NOT USED.
C       VAR(I,J) = VARIABLES PRINTED BY REPRT2, ITEM I, YEAR J.
C       VBHV = BOARD-FOOT VOLUME FROM HARVESTS.
C       VBTH = BOARD-FOOT VOLUME FROM THINNING.
C       VCHV = CUBIC-FOOT VOLUME FROM HARVESTS.
C       VCTH = CUBIC-FOOT VOLUME FROM THINNING.
C       VLBF = VOLUME HARVESTED, M BD. FT.
C       VLCU = VOLUME HARVESTED, CU. FT.
C       VLLV(I) = PERCENT OF PREVIOUS DLEV TO BE LEFT AT REGN(I), ENTEREC
C          AS A DECIMAL.
C       YRLOS = NUMBER OF ACRES LOST ANNUALLY.
C       YSDM(I) = AVERAGE D.B.H. AFTER THINNING AT STAND AGE I.
C
        COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
        COMMON AGED,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPC
       1,COMBF,COMCU,CYCL,CYCNW(3),DBHD,DENO,DESCR(5),DLEV,GIDE,GNTR,
       2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
       3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
        COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
       1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VDM,
       2YSDM(180)
        COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
       1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
       2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
       3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
        COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
       1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOS
       2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C  READ BATCH INFORMATION FROM CARD TYPE 1.
C
       READ (5,1) (BATCH(I),I=1,3),NTSTS
     1 FORMAT (3A9,I4)
       IF(NTSTS .GT. 0) GO TO 10
       WRITE (6,5)
     5 FORMAT (1H1,////,40X,46HNTSTS NOT A POSITIVE NUMBER GREATER THAN
      1ERO.)
       GO TO 100
C
C  OPERATE SYSTEM FOR DESIRED NUMBER OF TESTS.
C
    10 DO 50 ITEST=1,NTSTS
C
C  ENTER AND CHECK DATA FOR A TEST.
C
       CALL BASIS1
       CALL CHEK1
       IF(FLAG1 .GT. 0.0) GO TO 60
       IF(FLAG2 .GT. 0.0) GO TO 75
C
C  PRINT YIELD TABLE AND COMPUTE VOLUME FOR EACH YEAR OF STAND AGE.
C
       CALL YIELD
       CALL ANVOL
C
C  OPERATE SYSTEM FOR DESIRED NUMBER OF GAMES.
C
       DO 50 IGAME=1,NGAME
```

```
C
C ENTER AND CHECK DATA FOR A GAME.
C
      IYEAR = 0
      CALL BASIS2
      CALL CHEK2
      IF(FLAG1 .GT. 0.0) GO TO 60
      IF(FLAG2 .GT. 0.0) GO TO 75
C
C PRINT INITIAL CONDITIONS FOR EACH GAME.
C
      CALL START
C
C CREATE ACRES IN EACH AGE CLASS.
C
      CALL AREAS
      IF(FLAG1 .EQ. 2.0) GO TO 90
      CALL REPRT1
      IJK = 0
C
C OPERATE SYSTEM FOR DESIRED NUMBER OF YEARS.
C
      DO 40 IYEAR=1,NOYRS
      CALL COVER
      IF(FLAG1 .EQ. 2.0) GO TO 90
      CALL HRVST
      CALL SUMS
C
C PRINT ACRES IN EACH AGE CLASS FOR FIRST YEAR AND AT END OF EACH
C DECADE OF THE GAME.
C
      IF(IYEAR .LE. 1) GO TO 15
      IF(IJK .EQ. 10) GO TO 20
      GO TO 30
   15 IJK = 1
      GO TO 25
   20 IJK = 0
   25 CALL REPRT1
   30 IJK = IJK + 1
      CALL ANUAL
   40 CONTINUE
C
C PRINT VOLUMES AND VALUES FOR EACH YEAR.
C
      CALL REPRT2
      CALL WORTH
C
C SUMMARIZE DESIRED NUMBER OF COLUMNS OF REPRT2.
C
      IF(NKDLS .LE. 0) GO TO 50
      CALL SUMRY
   50 CONTINUE
      GO TO 100
C
C PRINT MESSAGE IF INPUT ERRORS PREVENT RUN.
C
   60 WRITE (6,65)
   65 FORMAT (1H1,////,20X,44HTHIS RUN CANNOT BE MADE WITH INPUT PROVIDE
     1D.)
      WRITE (6,70)
   70 FORMAT (1H0,10X,111HINCORRECT VALUE PROVIDED FOR A VARIABLE LATER
     1USED AS TERMINAL INDEX OF A DO LOOP OR COUNTER OF COMPUTED GO TO.)
      GO TO 80
   75 WRITE (6,65)
   80 IF(FLAG2 .EQ. 0.0) GO TO 100
      WRITE (6,85)
   85 FORMAT (1H0,30X,73HINCORRECT VALUE PROVIDED FOR A VARIABLE LATER U
     1SED IN MAJOR COMPUTATIONS.)
      GO TO 100
   90 WRITE (6,65)
      WRITE (6,95)
   95 FORMAT (1H0,//////,47X,39HYOU WENT BEYOND AGE LIMIT OF 179 YEARS.)
  100 CALL EXIT
      END
```

Subroutine BASIS1

```
      SUBROUTINE BASIS1
C
C TO ENTER VALUES THAT DO NOT CHANGE DURING A TEST.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGED,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHD,DEND,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKDLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BOFD(180),CFMC(180),CFMD(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGD,PRET,PROD,REST,RDTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MDLD,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C SET INITIAL VALUES OF ZERO.
C
      DO 1 I=1,6
    1 KOL(I) = 0
      DO 3 I =1,3
      CYCNW(I) = 0.0
      REGN(I) = 0.0
      VLLV(I) = 0.0
    3 CONTINUE
      DO 5 I=1,150
      PRIBD(I) = 0.0
    5 PRICF(I) = 0.0
      DO 10 I=1,181
      ANBDE(I) = 0.0
   10 ANCUV(I) = 0.0
      DO 15 I=1,6
      DO 15 J=1,25
      DO 15 K=1,10
   15 SUMM(I,J,K) = 0.0
      NSP = 0
C
C READ VALUES THAT DO NOT CHANGE DURING A TEST, FROM CARD TYPES 2 TO 6.
C
      READ (5,25) SPEC,NSP
   25 FORMAT (5A8,I3)
      READ (5,30) (DESCR(I),I=1,5),NGAME,NOYRS,NKDLS,(KOL(I),I=1,6)
   30 FORMAT (5A8,9I4)
      READ (5,35) SITE,CYCL,RINT,THIN,DLEV,AGED,DEND,DBHD,GIDE
   35 FORMAT (7F5.0,F5.2,F5.0)
      READ (5,40) REGN(1),VLLV(1),CYCNW(1),REGN(2),VLLV(2),CYCNW(2),REGN
     1(3)
   40 FORMAT (10F8.3)
      READ (5,45) AGMRCH,BFMRCH,BFSALV,COMCU,EXTCU,COMBF,BFPCT,CFPCT,
     1GNTR,BDPRI,CFPRI
   45 FORMAT (F5.0,2F5.2,2F5.0,F5.2,2F5.3,F5.0,2F5.2)
C
C CREATE ARRAYS OF CONSTANT PRICES OR READ VARIABLE PRICES FROM CARD
C TYPES 7 AND 8.
C
      IF(CFPRI .NE. 0.0) GO TO 50
      READ (5,40) (PRICF(I),I=1,150)
      GO TO 60
   50 DO 55 I=1,150
   55 PRICF(I) = CFPRI
   60 IF(BDPRI .NE. 0.0) GO TO 70
      READ (5,40) (PRIBD(I),I=1,150)
      GO TO 90
   70 DO 80 I=1,150
   80 PRIBD(I) = BDPRI
   90 RETURN
      END
```

Subroutine CHEK1

```
      SUBROUTINE CHEK1
C
C TO CHECK VALUES READ IN BY BASIS1.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGED,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHD,DEND,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKDLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BOFD(180),CFMC(180),CFMD(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGD,PRET,PROD,REST,RDTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MDLD,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      FLAG1 = 0.0
      FLAG2 = 0.0
      IF(NGAME .LT. 1) FLAG1 = 1.0
      IF(NKDLS .GT. 6) FLAG1 = 1.0
      IF(NOYRS .LT. 1) FLAG1 = 1.0
      IF(NOYRS .GT. 150) FLAG1 = 1.0
      IF(NSP .LT. 1) FLAG1 = 1.0
      IF(AGED .LE. 0.0) FLAG2 = 1.0
      IF(BFPCT .LE. 0.0) FLAG2 = 1.0
      IF(CFPCT .LE. 0.0) FLAG2 = 1.0
      IF(CYCL .LE. 0.0) FLAG2 = 1.0
      IF(DBHD .LE. 0.0) FLAG2 = 1.0
      IF(DEND .LE. 0.0) FLAG2 = 1.0
      IF(DLEV .LE. 0.0) FLAG2 = 1.0
      IF(GIDE .LE. 0.0) FLAG2 = 1.0
      IF(PRIBD(1) .LE. 0.0) FLAG2 = 1.0
      IF(PRICF(1) .LE. 0.0) FLAG2 = 1.0
      IF(REGN(1) .LE. 0.0) FLAG2 = 1.0
      IF(RINT .LE. 0.0) FLAG2 = 1.0
      IF(SITE .LE. 0.0) FLAG2 = 1.0
      IF(THIN .LE. 0.0) FLAG2 = 1.0
C
C CHECK THAT CYCL IS EQUAL TO OR A MULTIPLE OF RINT.
C
      IXN = CYCL / RINT
      IRINT = RINT
      JCYCL = CYCL
      TEM = JCYCL - IRINT * IXN
      IF(TEM .NE. 0.0) FLAG2 = 1.0
      RETURN
      END
```

routine YIELD

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  SUBROUTINE YIELD

 COMPUTE YIELDS OF MANAGED, EVEN-AGED STANDS.
NTAINS SIX SETS OF STATEMENTS THAT ARE SPECIES-SPECIFIC.
OTNOTE FORMATS WILL VARY WITH MERCHANTABILITY STANDARDS.

  COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
  COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
 1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDE,GNTR,
 2KOL(6),NGAME,NKOLS,NDYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
 3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
  COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
 1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VDM,
 2YSDM(180)
  COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
 1FMRCHD(10),GMNAM(3),IACRE(18D),IALCUT,IPLNT,IVAR(26,150),
 2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
 3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
  COMMON AGEOS(100D),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
 1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
 2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU

  ADDHT = D.D
  BDFT = D.D
  CFMT = 0.0
  HTCUM = D.D
  JBDFC = 0
  JBDFO = 0
  JBDFT = 0
  JCFMC = 0
  JCFMO = 0
  JCFMT = 0
  DO 1 I=1,180
  BDFC(I) = 0.0
  BDFO(I) = 0.D
  CFMC(I) = 0.0
  CFMO(I) = 0.0
  DIAM(I) = 0.0
  YSDM(I) = 0.0
1 CONTINUE
  NAGO = AGEO
  N = AGEO
  CHAC = CYCL
  DZIB = DLEV

TERMINE OLDEST STAND AGE TO APPEAR IN YIELD TABLES.

  DO 5 NA=1,3
  L = 4 - NA
  IF(REGN(L) .EQ. D.0) GD TO 5
  ROTA = REGN(L)
  GO TD 10
5 CONTINUE
0 DIAM(N) = DBHO

LOW FOR FELLING AGES OLDER THAN ROTATION WITH CLEARCUTTING.

  IF(REGN(2) .EQ. 0.D) ROTA = ROTA + 20.D
  IF(ROTA .GT. 18D.0) ROTA = 180.0

TAIN AVERAGE HEIGHT AND VOLUMES PER ACRE.
ATEMENTS FOR HTSO ARE SPECIES-SPECIFIC.

  BASD = DENO * 0.D054542 * DBHO * DBHO
  GO TO (15,25,35), NSP
  IF(AGEO .GT. 55.0) GO TO 20
  HTSO = 0.01441 * AGEO * SITE - 0.12162 * AGEO - 1.50953
  GO TO 60
  HTSO = D.59947 - 61.5019 / AGEO + 0.80522 * ALOGlD(SITE) + 20.5252
 1B * ALOG10(SITE) / AGEO
  HTSO = 10.0 ** HTSO
  GO TD 6D
  IF(AGEO .GT. 45.D) GO TO 30
  HTSO = 3.86111 - 0.05979 * AGEO + 0.01215 * AGEO * SITE
  GO TO 60
  HTSD = 0.33401 - 33.2866 / AGEO + 0.92341 * ALOG10(SITE) + 6.27811
 1 * ALOG10(SITE) / AGEO
  HTSO = 10.0 ** HTSO
  GO TO 6D
  CONTINUE
  GO TO 60
  CONTINUE
  BA = BASO
  HITE = HTSO
  STAND = DENO
  VDM = DBHO
  CALL VOLS
  TOTD = CUFT
  BDFO(N) = CUFT * PROD
  CFMO(N) = CUFT * FCTR
  REST = THIN

ER LOOP FDR ALL REMAINING COMPUTATIONS AND PRINTOUT.

  DO 500 I=1,100
6 IF(AGEO .GE. ROTA) GO TO 130

NGE STANDARDS IF A REGENERATION CUT IS DUE.

  IF(REGN(2) .EQ. 0.0) GO TD 8D
  IF(AGEO .LT. REGN(1)) GO TO 8D
  IF(AGEO .NE. REGN(1)) GO TO 70
  DLEV = DLEV * VLLV(1)
      REST = DLEV
      CYCL = CYCNW(1)
      GO TO 80
   70 IF(AGEO .NE. REGN(2)) GO TO 75
      DLEV = DLEV * VLLV(2)
      REST = DLEV
      CYCL = CYCNW(2)
      GO TO 80
   75 IF(AGEO .NE. REGN(3)) GO TO 80
      DLEV = DLEV * VLLV(3)
      REST = DLEV
      CYCL = CYCNW(3)
C
C INCREASE D.B.H. BY THINNING AND COMPUTE POST-THINNING VALUES.
C
   80 CALL CUTS
      IF(PRET .GE. 100.0) GO TO 83
      YSDM(N) = DBHT
      JDENT = (BAST / (0.0054542 * DBHT * DBHT)) + 0.5
      DENT = JDENT
      BAST = 0.0054542 * DBHT * DBHT * DENT
C
C SKIP THINNING IF BASAL AREA BELOW SPECIFIED RESIDUAL.
C
      IF(BAST .LT. BASO) GO TO 85
   83 BAST = BASO
      HTST = HTSO
      DENT = DENO
      JDENT = DENO + 0.5
      DBHT = DBHO
      YSDM(N) = DBHT
      TOTT = TOTO
      BDFT = BDFO(N)
      CFMT = CFMO(N)
      GO TO 130
C
C COMPUTE CHANGE IN AVERAGE HEIGHT FROM THINNING.
C STATEMENTS FOR ADDHT ARE SPECIES-SPECIFIC.
C
   85 GO TO (90,95,100), NSP
   90 ADDHT = 7.64833 - 3.82286 * ALOG10(PRET)
      GO TU 120
   95 ADDHT = 6.79950 - 3.41979 * ALOG10(PRET)
      GO TO 120
  100 CONTINUE
  120 HTCUM = HTCUM + ADDHT
      HTST = HTSO + ADDHT
      BA = BAST
      HITE = HTST
      STAND = DENT
      VDM = DBHT
      CALL VOLS
      TOTT = CUFT
      BDFT = CUFT * PROD
      CFMT = CUFT * FCTR
C
C CHANGE MODE AND ROUND OFF FOR PRINTING.
C
  130 JCYCL = CYCL
      JSITE = SITE
      JDENO = DENO + 0.5
      JHTSO = HTSO + 0.5
      JTOTO = TOTO + 0.5
      JBASO = BASO + 0.5
      JCFMO = CFMO(N) + 0.5
      JBDFO = (BDFO(N) * 0.1) + 0.5
      JBDFO = JBDFO * 10
      JHTST = HTST + 0.5
      JTOTT = TOTT + 0.5
      JCFMT = CFMT + 0.5
      CFMT = JCFMT
      IF(JCFMT .GT. JCFMO) JCFMO = JCFMT
      CFMO(N) = JCFMO
      JBDFT = (BDFT * 0.1) + 0.5
      JBDFT = JBDFT * 10
      BDFT = JBDFT
      BDFT = BDFT * 0.001
      IF(JBDFT .GT. JBDFO) JBDFO = JBDFT
      BDFO(N) = JBDFO
      BDFO(N) = BDFO(N) * 0.001
      JBAST = BAST + 0.5
      JDENC = JDENO - JDENT
      JBASC = JBASO - JBAST
      JTOTC = JTOTO - JTOTT
      JCFMC = JCFMO - JCFMT
      IF(JCFMC .LE. 0) JCFMC = 0
      CFMC(N) = JCFMC
      JBDFC = JBDFO - JBDFT
      IF(JBDFC .LE. 0) JBDFC = 0
      BDFC(N) = JBDFC
      BDFC(N) = BDFC(N) * 0.001
      IF(I .GE. 2) GO TO 180
C
C WRITE HEADINGS FOR YIELD TABLE ON PAGE TYPE 1.
C
      WRITE (6,150)
  150 FORMAT (1H1,//,63X,11HPAGE TYPE 1)
      WRITE (6,155) SPEC,JSITE,JCYCL,THIN,DLEV
  155 FORMAT (1H0,27X,48HYIELDS PER ACRE OF MANAGED, EVEN-AGED STANDS OF
     1 ,5A8/1H0,49X,11HSITE INDEX ,I3,1H,,I4,19H-YEAR CUTTING CYCLE/1H0
     242X,26HTHINNING LEVELS= INITIAL -,F6.0,14H, SUBSEQUENT -,F6.0,//)
      WRITE (6,160)
  160 FORMAT (1H0,25X,38HENTIRE STAND BEFORE AND AFTER THINNING,28X,26HP
     1ERIODIC INTERMEDIATE CUTS)
      WRITE (6,165)
```

```
165 FORMAT (1H0,9X,5HSTANO,10X,5HBASAL,3X,7HAVERAGE,2X,7HAVERAGE,3X,5H
   1TOTAL,3X,9HMERCHANT-,3X,9HSAWTIMBER,9X,5HBASAL,4X,5HTOTAL,3X,9HMER
   2CHANT-,3X,9HSAWTIMBER)
    WRITE (6,170)
170 FORMAT (1H ,10X,3HAGE,4X,5HTREES,3X,4HAREA,4X,6HO.B.H.,3X,6HHEIGHT
   1,2X,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME,3X,5HTREES,3X,4HAREA,3X
   2,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME)
    WRITE (6,175)
175 FORMAT (1H ,8X,7H(YEARS),3X,3HNO.,3X,6HSQ.FT.,4X,3HIN.,6X,3HFT.,4X
   1,6HCU.FT.,5X,6HCU.FT.,8X,3HMBF,5X,3HNO.,3X,6HSQ.FT.,2X,6HCU.FT.,5X
   2,6HCU.FT.,8X,3HMBF)

C WRITE TABLE ENTRIES OF OIAMETER, VOLUMES, ETC., ON PAGE TYPE 1.

180 WRITE (6,185) AGEO,JOENO,JBASO,OBHO,JHTSO,JTOTO,CFMO(N),BOFO(N)
185 FORMAT (1H0,9X,F4.0,4X,I5,2X,I4,5X,F5.1,5X,I3,4X,I5,5X,F6.0,5X,F7.
   13)
    IF(AGEO .GE. ROTA) GO TO 510
    WRITE (6,190) AGEO,JOENT,JBAST,OBHT,JHTST,JTOTT,CFMT,BOFT,JOENC,JB
   1ASC,JTOTC,CFMC(N),BOFC(N)
190 FORMAT (1H ,9X,F4.0,4X,I5,2X,I4,5X,F5.1,5X,I3,4X,I5,5X,F6.0,5X,F7.
   13,4X,I5,3X,I3,5X,I4,5X,F5.0,6X,F7.3)

C COMPUTE VALUES FOR EACH PERIOO. THIN AS SPECIFIED ON OATA CAROS.

    IK = CYCL / RINT
    OO 450 L=1,IK
    AGEO = AGEO + RINT
    N = AGEO
    IF(AGEO .GT. ROTA) GO TO 510

C COMPUTE NEW O.B.H. BEFORE THINNING AND ROUNO OFF TO 0.1 INCH.
C STATEMENTS FOR OBHO ARE SPECIES-SPECIFIC.

    GO TO (200,205,210), NSP
200 OBHO = 1.0097*OBHT + 0.0096*SITE - 1.5766*ALOG10(BAST) + 3.3021
    GO TO 240
205 OBHO = 1.0222*OBHT + 0.0151*SITE - 1.2417*ALOG10(BAST) + 2.1450
    GO TO 240
210 CONTINUE
240 IOBHO = OBHO * 10.0 + 0.5
    OBHO = IOBHO
    OBHO = OBHO * 0.1

C AOO RANOUM ELEMENT TO PREOICTEO OBHO, IF OESIREO.
C STATEMENT FOR RES IS SPECIES-SPECIFIC.

    IF(GNTR .GT. 1024.0) GO TO 300
250 IOIV = (17.0 * GNTR + 3.0) / 1024.0
    NGNTR = GNTR
    GNTR = (17 * NGNTR + 3) - 1024 * IOIV
    IF(GNTR .GT. 1000.0) GO TO 250
    IF(GNTR .LT. 0.0) GO TO 250
    A1 = GNTR * 0.01
    A2 = A1 * A1
    GO TO (255,260,265), NSP
255 RES = 0.9565 * A1 - 0.0523 * A2 - 0.0063 * A1 * A2 + 0.00084 * A2
   1* A2 - 3.3009
    GO TO 280
260 RES = 0.2527 * A1 - 0.0669 * A2 + 0.0079 * A1 * A2 - 0.0003 * A2
   1* A2 - 0.4282
    GO TO 280
265 CONTINUE
280 IRES = RES
    IF(RES .LT. 0.0) IRES = RES - 0.5
    IF(RES .GT. 0.0) IRES = RES + 0.5
    AOJ = IRES
    OBHO = OBHO + AOJ * 0.1
300 OIAM(N) = OBHO

C REOUCE OENSITY FOR NONCATASTROPHIC MORTALITY.
C STATEMENT FOR OIEO IS SPECIES-SPECIFIC.

    GO TO (310,315,320), NSP
310 IF(OBHT .GE. 10.0) GO TO 345
    OIEO = 0.00247 + 0.00124 * OBHT + 0.00028 * OBHT * OBHT + 0.000005
   121 * BAST * BAST - 0.0000905 * OBHT * BAST
    GO TO 340
315 IF(OBHT .GE. 10.0) GO TO 345
    OIEO = 0.05285 - 0.01346 * OBHT + 0.00226 * OBHT * OBHT + 0.000006
   16 * BAST * BAST - 0.0001931 * OBHT * BAST
    GO TO 340
320 CONTINUE
340 IF(OIEO .LT. 0.0) OIEO = 0.0
    OENO = OENT * (1.0 - OIEO)
    MNK = OENO + 0.5
    OENO = MNK
    GO TO 350
345 OENO = OENT
350 BASO = OENO * (0.0054542 * OBHO * OBHO)

C OBTAIN AVERAGE HEIGHT AND VOLUMES PER ACRE.
C STATEMENTS FOR HTSO ARE SPECIES-SPECIFIC.

    GO TO (370,380,390), NSP
370 IF(AGEO .GT. 55.0) GO TO 375
    HTSO = 0.01441 * AGEO * SITE - 0.12162 * AGEO - 1.50953
    GO TO 420
375 HTSO = 0.59947 - 61.5019 / AGEO + 0.80522 * ALOG10(SITE) + 20.5252
   18 * ALOG10(SITE) / AGEO
    HTSO = 10.0 ** HTSO
    GO TO 420
380 IF(AGEO .GT. 45.0) GO TO 385
    HTSO = 3.86111 - 0.05979 * AGEO + 0.01215 * AGEO * SITE
    GO TO 420
385 HTSO = 0.33401 - 33.2866 / AGEO + 0.92341 * ALOG10(SITE) + 6.278
   1 * ALOG10(SITE) / AGEO
    HTSO = 10.0 ** HTSO
    GO TO 420
390 CONTINUE
    GO TO 420
395 CONTINUE
420 HTSO = HTSO + HTCUM
    BA = BASO
    HITE = HTSO
    STANO = OENO
    VOM = OBHO
    CALL VOLS
    TOTO = CUFT
    BOFO(N) = CUFT * PROO
    CFMO(N) = CUFT * FCTR
C
C TEST IF REGENERATION CUT IS OUE.
C
    OO 430 KU=1,3
    IF(AGEO .EO. REGN(KU)) GO TO 65
430 CONTINUE
C
C CHANGE MUOE ANO ROUNO OFF FOR PRINTING.
C
    IF(L .EQ. IK) GO TO 460
    KOENO = OENO + 0.5
    KHTSO = HTSO + 0.5
    KBASO = BASO + 0.5
    KTOTO = TOTO + 0.5
    JCFMO = CFMO(N) + 0.5
    CFMO(N) = JCFMO
    JBOFO = (BOFO(N) * 0.1) + 0.5
    JBOFO = JBOFO * 10
    BOFO(N) = JBOFO
    BOFO(N) = BOFO(N) * 0.001
C
C WRITE VALUES FOR ENO OF PERIOO IF THINNING NOT OUE.
C
    WRITE (6,185) AGEO,KOENO,KBASO,OBHO,KHTSO,KTOTO,CFMO(N),BOFO(N)
    OBHT = OBHO
    BAST = BASO
    OENT = OENO
450 CONTINUE
460 REST = OLEV
500 CONTINUE
C
C WRITE TABLE FOOTNOTES.  CHANGE OR AOO TO FORMAT STATEMENTS FOR OTHER
C MERCHANTABLE LIMITS.
C
510 IF(REGN(2) .EO. 0.0) GO TO 530
    WRITE (6,520)
520 FORMAT (1H0,//,11X,106HTHIS TABLE SHOWS VALUES FOR SEEO TREE OR SH
   1ELTERWOOO CUTTING WITH TIMING ANO AMOUNTS SPECIFIED PREVIOUSLY.)
    GO TO 550
530 WRITE (6,540)
540 FORMAT (1H0,//,11X,85HTHIS TABLE SHOWS VALUES FOR CLEARCUTTING WIT
   1H ANY ROTATION UP TO A SPECIFIEO MAXIMUM.)
550 GO TO (560,575,590), NSP
560 WRITE (6,565)
565 FORMAT (1H0,10X,66HMERCH. CU. FT. - TREES 6.0 INCHES O.B.H. AND LA
   1RGER TO 4-INCH TOP.)
    WRITE (6,570)
570 FORMAT (1H0,10X,60HBO. FT. - TREES 10.0 INCHES O.B.H. ANO LARGER T
   1O 8-INCH TOP.)
    GO TO 650
575 WRITE (6,580)
580 FORMAT (1H0,10X,66HMERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LA
   1RGER TO 4-INCH TOP.)
    WRITE (6,585)
585 FORMAT (1H0,10X,59HBO. FT. - TREES 6.5 INCHES O.B.H. ANO LARGER TO
   1 6-INCH TOP.)
    GO TO 650
590 CONTINUE
650 CYCL = CHAC
    OLEV = OZIB
    AGEO = NAGO
    RETURN
    END
```

Subroutine VOLS

```
      SUBROUTINE VOLS
C
C TO COMPUTE VOLUMES PER ACRE IN VARIOUS UNITS.
C STATEMENTS FOR CUFT, FCTR, ANO PROO ARE SPECIES-SPECIFIC.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,OENO,OESCR(5),OLEV,GIOE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBO(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BOFO(180),CFMC(180),CFMO(180),CUFT,OBHT,
     1OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROO,REST,ROTA,STANO,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,PROIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TREE(1000),VRHV,VCHV,VLBF,VLCU
C
```

```
   FCTR = 0.0
   PROO = 0.0

MPUTE TOTAL CUBIC FEET PER ACRE.

   02H = VOM * VOM * HITE
   GO TO (5,15,25), NSP
5  IF(02H .GT. 6000.0) GO TO 10
   CUFT = (0.00225 * 02H - 0.00074 * BA + 0.03711) * STANO
   GO TO 70
0  CUFT = (0.00247 * 02H + 0.00130 * BA - 1.40286) * STAND
   GO TO 70
5  IF(02H .GT. 7000.0) GO TO 20
   CUFT = (0.00276 * 02H - 0.00059 * BA - 0.00577) * STAND
   GO TO 70
0  CUFT = (0.00248 * 02H + 1.96336) * STANO
   GO TO 70
5  CONTINUE
   GO TO 70
0  CONTINUE
0  IF(VOM .LT. 5.0) GO TO 200

TAIN CONVERSION FACTORS FOR MERCHANTABLE CUBIC FEET.

   GO TO (100,105,110), NSP
0  IF(VOM .GT. 6.7) GO TO 102
   FCTR = 0.26612 * VOM - 1.12689
   GO TO 140
2  IF(VOM .GT. 10.4) GO TO 104
   FCTR = 3.46993 - 0.12017 * VOM - 13.41984 / VOM
   GO TO 140
4  FCTR = 0.99666 - 0.66932 / VOM
   GO TO 140
5  IF(VOM .GT. 5.75) GO TO 107
   FCTR = 0.30711 * VOM - 1.11042
   GO TO 140
7  IF(VOM .GT. 9.8) GO TO 109
   FCTR = 2.32307 - 0.06419 * VOM - 7.47890 / VOM
   GO TO 140
9  FCTR = 0.99659 - 0.61056 / VOM
   GO TO 140
0  CONTINUE
   GO TO 140
2  CONTINUE
   GO TO 140
4  CONTINUE
0  IF(VOM .LT. 8.0) GO TO 200

TAIN CONVERSION FACTORS FOR BOARD FEET SCRIBNER.

   GO TO (150,155,160), NSP
0  IF(VOM .GT. 11.9) GO TO 153
   PROO = 0.87783 * VOM + 0.00660 * BA - 7.27957
   GO TO 200
3  PROO = 5.10752 + 0.10712 * VOM + 0.00185 * BA - 36.20229 / VOM
   GO TO 200
5  IF(VOM .GT. 10.0) GO TO 158
   PROO = 2.08874 + 0.18091 * VOM + 0.00045 * BA
   GO TO 200
8  PROO = 0.16583 + 3.74174 * ALOG10(VOM)
   GO TO 200
0  CONTINUE
   GO TO 200
3  CONTINUE
0  RETURN
   END
```

routine CUTS

```
   SUBROUTINE CUTS

 ESTIMATE INCREASE IN AVERAGE D.B.H. DUE TO THINNING.
ATEMENTS FOR OBHE AND POBHE ARE SPECIES-SPECIFIC.
ANGE STATEMENTS FOR DBHP AND SQFT IF OTHER GROWING STOCK SYSTEM IS
ED.

   COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
   COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
  1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,OENO,OESCR(5),OLEV,GIOE,GNTR,
  2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBO(150),PRICF(150),REGN(3),RINT,
  3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),FXTCU
   COMMON BA,BAST,BOFC(180),BOFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
  1OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROO,REST,ROTA,STANO,VOM,
  2YSOM(180)
   COMMON ACCST,ANUL,BECST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
  1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
  2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLD,NACOS(180),
  3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
   COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
  1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
  2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU

   IF(OBHO .LT. 9.4) GO TO 70

MPUTE O.B.H. IF OBHO IS LARGE ENOUGH FOR BASAL AREA TO REMAIN
NSTANT.

   PRET = 100.0
   00 60 KJ=1,100
   GO TO (1,10,20), NSP
1  IF(PRET .LT. 50.0) GO TO 5
   OBHE = 0.73365 + 1.02008 * OBHO - 0.01107 * (PRET - 50.0) - 0.0001
  14 * (PRET - 50.0) * (PRET - 50.0)
```

```
      GO TO 50
    5 POBHE = 0.49401 + 0.71890 * ALOG10(DBHO) - 0.22530 * ALOG10(PRET
     1 + 0.12616 * ALOG10(DBHO) * ALOG10(PRET)
      OBHE = 10.0 ** POBHE
      GO TO 50
   10 IF(PRET .LT. 50.0) GO TO 15
      DBHE = 0.44222 + 1.03170 * OBHO - 0.00816 * (PRET - 50.0) - 0.000
     19 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 50
   15 PDBHE = 0.37321 - 0.17274 * ALOG10(PRET) + 0.79921 * ALOG10(OBHO
     1+ 0.09315 * ALOG10(PRET) * ALOG10(DBHO)
      DBHE = 10.0 ** PDBHE
      GO TO 50
   20 CONTINUE
      GO TO 50
   25 CONTINUE
   50 IOBHE = DBHE  * 10.0 + 0.5
      OBHE = IOBHE
      DBHE = OBHE * 0.1
      OENE = DENO * PRET * 0.01
      NOENE = DENE + 0.5
      DENE = NOENE
      BASE = 0.0054542 * OBHE * DBHE * OENE
      NBASE = BASE * 10.0 + 0.5
      BASE = NBASE
      BASE = BASE * 0.1
      TMPY = 0.0054542 * DBHE * OBHE
      TEM = BASE - REST
      IF(KJ .EQ. 1 .AND. TEM .LT. 0.0) GO TO 220
      IF(TEM .LE. TMPY) GO TO 180
      IF(TEM .LT. 4.0) GO TO 55
      PRET = PRET - 1.0
      GO TO 60
   55 PRET = PRET - 0.3
   60 CONTINUE
      GO TO 180
C
C COMPUTE O.B.H. IF BASAL AREA INCREASES WITH O.B.H.
C
   70 PRET = 40.0
      IF(DBHO .GT. 7.0) PRET = 70.0
      DO 175 J=1,100
      GO TO (75,85,95), NSP
   75 IF(PRET .GE. 50.0) GO TO 80
      PDBHE = 0.49401 + 0.71890 * ALOG10(DBHO) - 0.22530 * ALOG10(PRET)
     1 + 0.12616 * ALOG10(DBHO) * ALOG10(PRET)
      DBHE = 10.0 ** PDBHE
      GO TO 145
   80 DBHE = 0.73365 + 1.02008 * OBHO - 0.01107 * (PRET - 50.0) - 0.000
     14 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 145
   85 IF(PRET .GE. 50.0) GO TO 90
      PDBHE = 0.37321 - 0.17274 * ALOG10(PRET) + 0.79921 * ALOG10(OBHO)
     1+ 0.09315 * ALOG10(PRET) * ALOG10(DBHO)
      OBHE = 10.0 ** POBHE
      GO TO 145
   90 DBHE = 0.44222 + 1.03170 * OBHO - 0.00816 * (PRET - 50.0) - 0.000
     19 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 145
   95 CONTINUE
      GO TO 145
  100 CONTINUE
  145 IDBHE = OBHE * 10.0 + 0.5
      DBHE = IOBHE
      DBHE = OBHE * 0.1
      OENE = OENO * (PRET * 0.01)
      NOENE = OENE + 0.5
      OENE = NOENE
      BASE = 0.0054542 * DBHE * OBHE * DENE
      NBASE = BASE * 10.0 + 0.5
      BASE = NBASE
      BASE = BASE * 0.1
      BREAK = 49.9 * REST / GIOE
      IF(BASE .GT. BREAK) GO TO 150
      OBHP = (GIOE / REST) * (0.08682 * BASE) + 0.94636
      GO TO 160
  150 BUST = 66.2 * (REST / GIOE)
      IF(BASE .GT. BUST) GO TO 155
      OBHP = (GIDE / REST) * (0.10938 * BASE) - 0.17858
      GO TO 160
  155 TMPY = BASE * (GIOE / REST)
      TEM = TMPY * TMPY
      OBHP = 19.04740 * TMPY - 0.26673 * TEM + 0.0012539 * TEM * TMPY
     1 - 448.76833
      IF(TMPY .GT. GIDE) DBHP = OBHO + 0.8
  160 IOBHP = OBHP * 10.0 + 0.5
      DBHP = IOBHP
      OBHP = OBHP * 0.1
      IF(OBHP - OBHE) 165,180,170
  165 PRET = PRET * 1.02
      IF(PRET .GT. 100.0) GO TO 220
      GO TO 175
  170 PRET = PRET * 0.98
  175 CONTINUE
  180 DBHT = OBHE
C
C COMPUTE POST-THINNING BASAL AREA.
C
      IF(OBHT .GT. 5.0) GO TO 200
      SOFT = 11.58495 * DBHT - 11.09724
      GO TO 205
  200 IF(DBHT .GE. 10.0) GO TO 210
      TEM = DBHT * OBHT
      SQFT = 7.76226 * DBHT +0.85289 * TEM -0.07952 * TEM * DBHT-3.4562
  205 BAST = (REST / GIDE) * SOFT
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      GO TO 215
  210 BAST = REST
  215 RETURN
  220 PRET = 100.0
      RETURN
      END
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Subroutine ANVOL

```
      SUBROUTINE ANVOL
C
C TO COMPUTE VOLUMES FOR EACH YEAR OF STAND AGE.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      IROT = ROTA
      INT = RINT
      NVOL = ((IROT - NAGO) / INT) + 1
      K = NVOL - 1
C
C INTERPOLATE BETWEEN VOLUMES IN YIELD TABLE.
C
      DO 1 L=1,K
      DO 1 J=1,INT
      NN = J + NAGO + (L - 1) * INT
      RJ = J - 1
      N = NAGO + (L - 1) * INT
      ANCUV(NN) =CFMO(N)-CFMC(N)+(RJ/RINT)*(CFMO(N+INT)-CFMO(N)+CFMC(N))
      ANBDF(NN) =BDFO(N)-BDFC(N)+(RJ/RINT)*(BDFO(N+INT)-BDFO(N)+BDFC(N))
    1 CONTINUE
C
C WRITE TABLE HEADINGS FOR PAGE TYPE 2.
C
      WRITE (6,5)
    5 FORMAT (1H1,//,61X,11HPAGE TYPE 2)
      WRITE (6,10) SPEC,SITE,CYCL,THIN,DLEV
   10 FORMAT (1H0,40X,25HGROWING STOCK OF MANAGED ,5A8/1H ,46X,10HSITE I
     1NDEX,F5.0,1H,,F5.0,19H-YEAR CUTTING CYCLE/1H ,52X,14HDENSITY LEVEL
     2-,F5.0,1X,3HAND,F5.0)
      WRITE (6,15)
   15 FORMAT (1H0,43X,44HVOLUMES PRESENT PER ACRE AT END OF EACH YEAR)
      WRITE (6,20)
   20 FORMAT (1H ,54X,23HMERCHANTABLE CUBIC FEET/1H0,64X,4HYEAR/1H ,14X,
     16HDECADE,9X,1H0,9X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9
     2X,1H8,9X,1H9,//)
      K = 0
C
C WRITE CUBIC FEET PER ACRE FOR EACH YEAR ON PAGE TYPE 2.
C
      WRITE (6,40) K,(ANCUV(NN),NN=1,10)
   40 FORMAT (1H ,I20,F13.1,9F10.1)
      IJ = (ROTA * 0.1 + 0.5) - 1.0
      DO 45 J=1,IJ
      NN = 10 * J + 1
      WRITE (6,40) J,ANCUV(NN),ANCUV(NN+1),ANCUV(NN+2),ANCUV(NN+3),ANCUV
     1(NN+4),ANCUV(NN+5),ANCUV(NN+6),ANCUV(NN+7),ANCUV(NN+8),ANCUV(NN+9)
   45 CONTINUE
      J = ROTA * 0.1 + 0.5
      ANCUV(IROT+1) = CFMO(IROT)
      WRITE (6,40) J,ANCUV(IROT+1)
C
C WRITE BOARD FEET PER ACRE FOR EACH YEAR ON PAGE TYPE 2.
C
      WRITE (6,60)
   60 FORMAT (1H0,///,55X,23HTHOUSANDS OF BOARD FEET,//)
      WRITE (6,65) K,(ANBDF(NN),NN=1,10)
   65 FORMAT (1H ,I20,F13.3,9F10.3)
      DO 70 J=1,IJ
      NN = 10 * J + 1
      WRITE (6,65) J,ANBDF(NN),ANBDF(NN+1),ANBDF(NN+2),ANBDF(NN+3),ANBDF
     1(NN+4),ANBDF(NN+5),ANBDF(NN+6),ANBDF(NN+7),ANBDF(NN+8),ANBDF(NN+9)
   70 CONTINUE
      J = ROTA * 0.1 + 0.5
      ANBDF(IROT+1) = BDFO(IROT)
      WRITE (6,65) J,ANBDF(IROT+1)
C
C INTERPOLATE BETWEEN COMPUTED DIAM(N) FOR USE BY OTHER ROUTINES.
C
      K = NAGO
      DO 85 J=1,NVOL
      TEM = K
      INT = TEM + RINT
      TEM = INT
      IF(TEM .GT. ROTA) GO TO 87
      DBHO = YSOM(K)
      IF(DIAM(K) .GT. YSOM(K)) DBHO = DIAM(K)
      TMPY = (DIAM(INT) - DBHO) / RINT
      AKTR = 0.0
      KK = K + 1
      DO 80 I=KK,INT
      AKTR = AKTR + 1.0
      DIAM(I) = DBHO + TMPY * AKTR
   80 CONTINUE
      K = INT
   85 CONTINUE
   87 IF(REGN(2) .GT. 0.0) GO TO 90
      NIC = REGN(1) + 1.0
      KU = REGN(1)
      DO 88 I=NIC,IROT
      DIAM(I) = DIAM(KU)
   88 CONTINUE
C
C PROVIDE FOR ANY ACRES BEYOND CUTAGE LEFT UNTHINNED A FEW YEARS.
C
   90 JCYCL = CYCL
      IMI = JCYCL - 1
      DO 95 I=NAGO,IROT,JCYCL
      DO 95 J=1,IMI
      NX = I + J
      IF(NX .GE. 180) GO TO 100
      BDFC(NX) = BDFC(I)
   95 CFMC(NX) = CFMC(I)
  100 RETURN
      END
```

Subroutine BASIS2

```
      SUBROUTINE BASIS2
C
C TO ENTER OR COMPUTE VALUES USED FOR A SINGLE GAME.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CF
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBH
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAP(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCL
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C SET INITIAL VALUES OF ZERO.
C
      CSTAC = 0.0
      CSTVL = 0.0
      IALCUT = 0
      KOUNT = 1
      LAST = 0
      MIX = 0
      PETPN = 0.0
      YRLOS = 0.0
      DO 1 I=1,180
      IACRE(I) = 0
      NACOS(I) = 0
    1 NACUN(I) = 0
      DO 5 I=1,10
      FMRCHD(I) = 0.0
      MALCUT(I) = 0
    5 PRIDIV(I) = 0.0
      DO 10 I=1,15
      DO 10 J=1,150
      JVAP(I,J) = 0
   10 CONTINUE
      DO 15 I=1,26
      DO 15 J=1,150
   15 IVAR(I,J) = 0
      DO 20 I=1,14
      DO 20 J=1,150
   20 VAR(I,J) = 0.0
C
C READ VALUES THAT DO NOT CHANGE DURING A GAME, FROM CARD TYPE 9.
C
      READ(5,25)(GMNAM(I),I=1,3),LAND,MOLD,NONSTK,KAREA,IPLNT,DEFOR,AN
   25 FORMAT (3A3,5I4,2F8.5)
      IF(KAREA .EQ. 0) GO TO 35
C
C ENTER EQUAL AREA FOR EACH OVERSTORY AGE CLASS, IF DESIRED.
C
      MOX = CYCNW(1) + CYCNW(2) + 1.0
      NOX = MOLD + 1
      DO 30 I=MOX,NOX
   30 IACRE(I) = KAREA
C
C ADJUST NUMBER OF ACRES IN OLDEST CLASS IF TOTAL AREA NOT MULTIPLE
C OF KAREA.
C
      KDIFF = LAND - (NOX - MOX + 1) * KAREA - NONSTK
      IACRE(NOX) = IACRE(NOX) + KDIFF
      IACRE(1) = IACRE(1) + NONSTK
      GO TO 45
C
C READ UNEQUAL AREAS FROM CARD TYPE 10, IF DESIRED.
C
   35 READ (5,40) (IACRE(I),I=1,180)
```

```
 FORMAT (18I4)

) COSTS AND LIMITATIONS ON CUT FROM CARD TYPES 11 TO 14.

 READ (5,50) (PRIDIV(I),I=1,10)
 FORMAT (10F8.3)
 READ (5,40) (MALCUT(I),I=1,10)
 READ (5,50) (FMRCHO(I),I=1,10)
 READ (5,50) RATE,CPLT,CTHN,CLOSS,ACCST,CUCST,BFCST
 RETURN
 END
```

outine CHEK2

```
 SUBROUTINE CHEK2

CHECK VALUES ENTERED BY BASIS2.
TAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.

 COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
 COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,OENO,OESCR(5),OLEV,GIDE,GNTR,
2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
 COMMON BA,BAST,BOFC(180),BDFD(180),CFMC(180),CFMO(180),CUFT,OBHT,
1OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROO,REST,ROTA,STANO,VOM,
2YSOM(180)
 COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLO,NACOS(180),
3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
 COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU

 FLAG1 = 0.0
 FLAG2 = 0.0
 IF(LANO .LT. 1) FLAG1 = 1.0
 IF(LANO .GT. 1000) FLAG1 = 1.0
 IF(MOLO .LT. 1) FLAG1 = 1.0
 IF(MOLO .GT. 179) FLAG1 = 1.0
 IF(ACCST .LE. 0.0) FLAG2 = 1.0
 IF(BFCST .LE. 0.0) FLAG2 = 1.0
 IF(CTHN .LE. 0.0) FLAG2 = 1.0
 IF(CUCST .LE. 0.0) FLAG2 = 1.0
 IF(FMRCHO(1) .LE. 0.0) FLAG2 = 1.0
 IF(MALCUT(1) .LE. 0) FLAG2 = 1.0
 IF(PRIDIV(1) .LE. 0.0) FLAG2 = 1.0
 RETURN
 END
```

outine START

```
 SUBROUTINE START

PRINT CONDITIONS OF SIMULATIONS ON PAGE TYPE 3.
TAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.

 COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
 COMMON AGED,AGMRCH,ANBOF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
,COMBF,COMCU,CYCL,CYCNW(3),OBHO,OENO,OESCR(5),OLEV,GIDE,GNTR,
KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
 COMMON BA,BAST,BDFC(180),BOFO(180),CFMC(180),CFMO(180),CUFT,OBHT,
OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROO,REST,ROTA,STANO,VOM,
YSDM(180)
 COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
 COMMON AGEDS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU

 OEFOR1 = OEFOR * 100.0
 WRITE (6,5)
 FORMAT (1H1,//,54X,11HPAGE TYPE 3/1H0,45X,26HALTERNATIVES FOR THIS
  GAME)
 WRITE (6,10) (BATCH(I),I=1,3)
 FORMAT (1H ,45X,7HBATCH  ,3A8)
 WRITE (6,15) ITEST
 FORMAT (1H ,45X,4HTEST,I4)
 WRITE (6,20) (GMNAM(I),I=1,3)
 FORMAT (1H ,45X,6HGAME  ,3A8)
 WRITE (6,25) (OESCR(I),I=1,5)
 FORMAT (1H ,45X,5A8,////)
 WRITE (6,30) NOYRS
 FORMAT (1H ,45X,24HNUMBER OF YEARS PER GAME,I4,////)
 WRITE (6,35) (PRIOIV(I),I=1,10)
 FORMAT (1H ,15HCRITICAL PRICES,12X,10F9.2)
 WRITE (6,40) (MALCUT(I),I=1,10)
 FORMAT (1H ,13HALLOWABLE CUT,11X,10I9)
 WRITE (6,45) (FMRCHO(I),I=1,10)
 FORMAT (1H ,19HMINIMUM CUTTING AGE,6X,10F9.0,////)
 WRITE (6,50) LAND
 FORMAT (1H ,23HACRES IN WORKING CIRCLE,13X,I4,25X,27HCOSTS IN FIRS
T YEAR OF GAME)
 WRITE (6,55) ACCST
 FORMAT (1H ,69X,17HPER ACRE (ANNUAL),8X,F9.2)
 WRITE (6,60) CUCST
 FORMAT (1H ,38HMINIMUM VALUES FOR INCLUSION IN TOTALS,31X,25HPER 1
  100 CU. FT. HARVESTED,F9.2)
   WRITE (6,65) AGMRCH,BFCST
65 FORMAT (1H ,4X,22HAGE, FOR GROWING STOCK,11X,F4.0,28X,13HPER M BD.
  1 FT.,12X,F9.2)
   WRITE (6,70) BFMRCH,CTHN
70 FORMAT (1H ,4X,28HM BD. FT., FOR GROWING STOCK,5X,F5.1,27X,13HTHIN
  1 ONE ACRE,12X,F9.2)
   WRITE (6,75) COMCU,CPLT
75 FORMAT (1H ,4X,27HCU. FT., FOR COMMERCIAL CUT,5X,F5.0,28X,14HPLANT
  1 ONE ACRE,11X,F9.2)
   WRITE (6,80) COMBF,CLOSS
80 FORMAT (1H ,4X,29HM BD. FT., FOR COMMERCIAL CUT,4X,F5.1,27X,19HCLE
  1ANUP OF ONE ACRE,6X,F9.2)
   WRITE (6,85) BFSALV,RATE
85 FORMAT (1H ,4X,22HM BD. FT., FOR SALVAGE,11X,F5.1,23X,25HRATE OF I
  1NCREASE IN COSTS,4X,F9.2)
   WRITE (6,88) EXTCU
88 FORMAT (1H ,4X,22HCU. FT. IN SAW LOG CUT,10X,F5.0,//)
   WRITE (6,90) IPLNT
90 FORMAT (1H ,22HACRES PLANTED ANNUALLY,14X,I4,25X,35HRELATIVE VALUE
  1 OF INTERMEDIATE CUTS)
   WRITE (6,95) OEFOR1,CFPCT
95 FORMAT (1H ,30HPERCENT OF ACRES LOST ANNUALLY,6X,F8.3,25X,23HSTUMP
  1AGE PRICE, CU. FT.,2X,F9.2)
   WRITE (6,100) BFPCT
100 FORMAT (1H ,69X,23HSTUMPAGE PRICE, BD. FT.,2X,F9.2)
   WRITE (6,105) ANUL
105 FORMAT (1H ,29HPSEUDORANDOM NUMBER GENERATOR,5X,F8.1)
   WRITE (6,110) GNTR
110 FORMAT (1H ,34X,F8.1)
   RETURN
   END
```

Subroutine AREAS

```
      SUBROUTINE AREAS
C
C TO CREATE AND CHECK ARRAY OF ACRES BY STAND AGE AND TO COMPUTE VOLUME
C AND VALUE OF INITIAL GROWING STOCK.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,OENO,OESCR(5),OLEV,GIOE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,OBHT,
     1OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROO,REST,ROTA,STANO,VOM,
     2YSDM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      GSVALB = 0.0
      GSVALC = 0.0
      GVLBF = 0.0
      GVLCU = 0.0
      DO 5 I=1,18
      ISUM(I) = 0
    5 NSUM(I) = 0
      DO 10 I=1,1000
      AGEOS(I) = 0.0
      AGEUN(I) = 0.0
      TRET(I) = 0.0
   10 CONTINUE
C
C CONVERT OVERSTORY ACRES IN EACH IACRE(I) TO INDIVIDUAL ACRES.
C ASSIGN UNDERSTORY ACRES IF USING SEED TREES OR SHELTERWOOD.
C
      JK = 0
      DO 20 J=1,180
      IF(JK .GE. LAND) GO TO 25
      IF(IACRE(J) .LE. 0) GO TO 20
      KL = JK + 1
      JK = JK + IACRE(J)
      DO 15 I=KL,JK
      NAC = LANO + 1 - I
      AGEOS(NAC) = J - 1
      IF(REGN(2) .EQ. 0.0) GO TO 15
      IF(AGEOS(NAC) .LE. REGN(1)) GO TO 15
      AGEUN(NAC) = AGEOS(NAC) - REGN(1)
   15 CONTINUE
   20 CONTINUE
C
C ASSIGN TREATMENT STATUS CODE IF SEED TREES OR SHELTERWOOD USED.
C
   25 IF(REGN(2) .EQ. 0.0) GO TO 35
      TEM = REGN(1) - 1.0
      DO 30 I=1,LAND
      IF(AGEOS(I) .LE. TEM) GO TO 30
      LAST = LAST + 1
      IF(AGEOS(I) .LT. REGN(1)) GO TO 30
      TRET(I) = AGEOS(I) - REGN(1) + 1.0
   30 CONTINUE
C
C GET DISTRIBUTION OF ACRES BY AGE. CHECK THAT NO ACRE IS OLDER THAN
C 179 YEARS UNLESS APPROPRIATE DIMENSIONS ARE CHANGED.
C
   35 DO 50 K=1,LAND
```

```
      IF(AGEOS(K) .LE. 179.0) GO TO 40
      FLAG1 = 2.0
      RETURN
   40 LM = AGEOS(K) + 1.0
      NACOS(LM) = NACOS(LM) + 1
      ML = AGEUN(K) + 1.0
      NACUN(ML) = NACUN(ML) + 1
   50 CONTINUE
C
C COMPUTE TOTAL ACRES BY 10-YEAR AGE CLASSES.
C
      DO 60 I=1,18
      DO 60 J=1,10
      NS = 10 * (I - 1) + J
      ISUM(I) = ISUM(I) + NACOS(NS)
      NSUM(I) = NSUM(I) + NACUN(NS)
   60 CONTINUE
C
C COMPUTE VOLUME OF GROWING STOCK. USE CU. FT. IF VOLUME IS LESS
C THAN BFMRCH.
C
      DO 100 M=1,LANO
      IF(REGN(2) .EQ. 0.0) GO TO 80
C
C ADD VOLUME OF UNDERSTORY IF SYSTEM IS SEED TREE OR SHELTERWOOD.
C
      IF(AGEUN(M) .LT. AGMRCH) GO TO 80
      IL = AGEUN(M) + 1.0
      IF(ANBDF(IL) .GE. BFMRCH) GO TO 70
      GVLCU = GVLCU + ANCUV(IL)
      GO TO 80
   70 GVLBF = GVLBF + ANBDF(IL)
C
C ADD IN VOLUME OF MAIN STAND.  IS OVERSTORY IF SYSTEM IS SEED TREE OR
C SHELTERWOOD.
C
   80 IF(AGEOS(M) .LT. AGMRCH) GO TO 100
      IAG = AGEOS(M) + 1.0
      IF(ANBDF(IAG) .GE. BFMRCH) GO TO 90
      GVLCU = GVLCU + ANCUV(IAG)
      GO TO 100
   90 GVLBF = GVLBF + ANBDF(IAG)
  100 CONTINUE
C
C COMPUTE INITIAL NON-ZERO VALUES FOR REPRT2.
C
      IVAR(7,1) = GVLCU + 0.5
      IVAR(8,1) = GVLBF + 0.5
      IVAR(9,1) = IVAR(5,1) + IVAR(7,1)
      IVAR(10,1) = IVAR(6,1) + IVAR(8,1)
      IVAR(11,1) = NONSTK
      VAR(1,1) = PRICF(1)
      VAR(2,1) = PRIBD(1)
      GSVALB = GVLBF * (PRIBD(1) - BFCST)
      GSVALC = (GVLCU * 0.01) * (PRICF(1) - CUCST)
      VAR(13,1) = GSVALC + GSVALB
      VAR(14,1) = VAR(13,1) + VAR(12,1)
      DO 110 I=1,14
      N = I + 11
      JVAR(I,1) = NSUM(I)
  110 IVAR(N,1) = ISUM(I)
      DO 120 I=15,18
      JVAR(15,1) = JVAR(15,1) + NSUM(I)
  120 IVAR(26,1) = IVAR(26,1) + ISUM(I)
      RETURN
      END
```

Subroutine REPRT1

```
      SUBROUTINE REPRT1
C
C TO REPORT DISTRIBUTION OF ACRES BY AGE CLASSES.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,DENO,DESCR(5),OLEV,GIOE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,OBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C WRITE TABLE HEADINGS FOR PAGE TYPE 4.
C
      DO 120 KU=1,2
      IF(KU .EQ. 2 .AND. REGN(2) .EQ. 0.0) GO TO 120
      WRITE (6,5)
    5 FORMAT (1H1,//,55X,11HPAGE TYPE 4)
      IF(KU .EQ. 2) GO TO 15
      WRITE (6,10)
   10 FORMAT (1H0,40X,38HDISTRIBUTION OF OVERSTORY ACRES BY AGE)
      GO TO 30
   15 WRITE (6,20)
   20 FORMAT (1H0,40X,39HDISTRIBUTION OF UNDERSTORY ACRES BY AGE)
   30 WRITE (6,35) (BATCH(I),I=1,3)
   35 FORMAT (1H ,45X,7HBATCH  ,3A8)
      WRITE (6,40) ITEST
   40 FORMAT (1H ,45X,4HTEST,I4)
      WRITE (6,45) (GMNAM(I),I=1,3)
   45 FORMAT (1H ,45X,6HGAME  ,3A8)
      WRITE (6,50) (DESCR(I),I=1,5)
   50 FORMAT (1H ,45X,5A8)
      WRITE (6,55) IYEAR
   55 FORMAT (1H ,45X,16HYEAR WITHIN GAME,I4,//)
      WRITE (6,60)
   60 FORMAT (1H ,55X,9HAGE(YEAR))
      WRITE (6,70)
   70 FORMAT (1H ,4X,11HAGE(DECADE),8X,1H0,7X,1H1,7X,1H2,7X,1H3,7X,
     1X,1H5,7X,1H6,7X,1H7,7X,1H8,7X,1H9,10X,5HTOTAL,//)
C
C WRITE NUMBER OF ACRES IN EACH 1-YEAR AGE CLASS AND THE TOTALS OF
C 10-YEAR CLASSES ON PAGE TYPE 4.
C
      DO 100 J=1,18
      IK = J - 1
      NN = 10 * IK + 1
      IF(KU .EQ. 2) GO TO 90
      WRITE (6,80) IK,NACOS(NN),NACOS(NN+1),NACOS(NN+2),NACOS(NN+3),
     1S(NN+4),NACOS(NN+5),NACOS(NN+6),NACOS(NN+7),NACOS(NN+8),NACOS(
     2),ISUM(J)
   80 FORMAT (1H ,I11,5X,10(8,I15,/)
      GO TO 100
   90 WRITE (6,80) IK,NACUN(NN),NACUN(NN+1),NACUN(NN+2),NACUN(NN+3),
     1N(NN+4),NACUN(NN+5),NACUN(NN+6),NACUN(NN+7),NACUN(NN+8),NACUN(
     2),NSUM(J)
  100 CONTINUE
  120 CONTINUE
      RETURN
      END
```

Subroutine COVER

```
      SUBROUTINE COVER
C
C TO SIMULATE ANNUAL CHANGES DUE TO PLANTING OR FIRES.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181),BEMRCH,BFPCT,BESALV,C
     1,COMBF,COMCU,CYCL,CYCNW(3),OBHO,DENO,DESCR(5),OLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RIN
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BOFO(180),CFMC(180),CFMO(180),CUFT,OB
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFO
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLB
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SC
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      GVLBF = 0.0
      GVLCU = 0.0
      LOSS = 0
      NPLNT = 0
      RETHV = 0.0
      RETTH = 0.0
      SCLOSS = 0.0
      SCPLT = 0.0
      SCTHN = 0.0
      VLBF = 0.0
      VLCU = 0.0
      JCYCL = CYCL
      IYRM = IYEAR + 1
C
C MAKE ANY SCHEDULED ANNUAL SEEDING OR PLANTING.
C
      IF(NONSTK .EQ. 0) GO TO 5
      NPLNT = IPLNT
      IF(NPLNT .GT. NONSTK) NPLNT = NONSTK
      NONSTK = NONSTK - NPLNT
      APLT = NPLNT
      SCPLT = APLT * CPLT
      IF(NONSTK .EQ. 0) GO TO 5
      IF(REGN(2) .GT. 0.0) GO TO 1
      KIM = LANO - NONSTK + 1 + LAST
      IF(KIM .GT. LANO) KIM = KIM - LANO
      GO TO 3
    1 KIM = LAND - NONSTK + 1
    3 ICH = KIM + NONSTK - 1
C
C INCREASE STAND AGES ONE YEAR TO OBTAIN AGES FOR CURRENT YEAR.
C
    5 DO 10 I=1,LAND
      AGEOS(I) = AGEOS(I) + 1.0
   10 CONTINUE
      DO 13 I=1,LANO
      IF(TRET(I) .EQ. 0.0) GO TO 13
      AGEUN(I) = AGEUN(I) + 1.0
      TRET(I) = TRET(I) + 1.0
   13 CONTINUE
      IF(NONSTK .EQ. 0) GO TO 20
C
C SUPPRESS AGE INCREASE FOR NONSTOCKED ACRES.
C
      DO 15 I=KIM,ICH
```

```
 AGEOS(I) = 0.0
 AGEUN(I) = 0.0
5 CONTINUE
) IF(DEFOR .EQ. 0.0) GO TO 100

MPUTE AREA DEFORESTED ANNUALLY.

 AKDX = LAND - NONSTK
 YRLOS = (AKDX * DEFOR) + YRLOS
 IF(YRLOS .LT. 1.0) GO TO 100

NERATE PSEUDORANDOM NUMBER FOR AGE OF ACRE DESTROYED.
TH SEED TREES OR SHELTERWOOD, ALL COMPUTATIONS BASED ON AGE OF
ERSTORY.

5 NDIV = (17.0 * ANUL + 3.0) / 128.0
 NULL = ANUL
 NULL = (17 * NULL + 3) - 128 * NDIV
 ANUL = NULL

ECK THAT AGE EXISTS AND IS BETWEEN ONE AND OLDEST CURRENT AGE.

 IF(REGN(2) .EQ. 0.0) GO TO 28
 IF(ANUL .LE. AGEO ) GO TO 25
 GO TO 29
3 IF(ANUL .LE. 0.0) GO TO 25
 IF(ANUL .GT. AGEOS(KOUNT)) GO TO 25
9 DO 30 M=1,LAND
 KACR = M
 IF(AGEOS(M) .EQ. ANUL) GO TO 35
) CONTINUE
 GO TO 25

T LOSS TO REDUCE CURRENT ALLOWABLE CUT.

5 LOSS = LOSS + 1
 NONSTK = NONSTK + 1
 YRLOS = YRLOS - 1.0
 IF(REGN(2) .GT. 0.0) GO TO 38
 IF(IYEAR .EQ. 1) LAST = KACR

LVAGE BOARD-FOOT VOLUME IF NOT LESS THAN BFSALV AND IF AGE IS
EATER THAN AGEO.

 IF(NULL .LE. NAGO) GO TO 50
 IF(IYEAR .EQ. 1) MTHN = FMRCHD(1)
 NULL = NULL + 1
 KULL = NULL - 1
 IF(REGN(2) .EQ. 0.0) GO TO 39
 IF(AGEOS(KACR) .GT. REGN(1) .AND. AGEOS(KACR) .NE. REGN(2)) GO TO
1 40
) IF(KULL .LT. MTHN) GO TO 40
 SALVB = ANBOF(NULL) + BOFC(KULL)
 GO TO 45
) SALVB = ANBOF(NULL)
5 IF(SALVB .GE. BFSALV) GO TO 48
 SCLOSS = SCLOSS + CLOSS
 GO TO 50
 VLBF = VLBF + SALVB
 RETTH = RETTH + SALVB * (PRIBD(IYRM) * BFPCT)

UMBER ACRES. PUT ACRE LOST AT END OF AGE SEQUENCE WITH AGE ZERO.

) IF(REGN(2) .GT. 0.0) GO TO 80
 IF(KACR .NE. KOUNT) GO TO 55
 LAST = LAST + 1
 KOUNT = KOUNT + 1
 AGEOS(LAST) = 0.0
 GO TO 100
 LUB = LAST - 1
 IF(KACR .LT. LAST) GO TO 70
 MNO = LAND - KACR
 DO 60 J=1,MNO
 JSUB = KACR + J
 ISUB = JSUB - 1
 AGEOS(ISUB) = AGEOS(JSUB)
 CONTINUE
 AGEOS(LAND) = AGEOS(1)
 DO 65 K=1,LUB
 KAN = K + 1
 AGEOS(K) = AGEOS(KAN)
 CONTINUE
 AGEOS(LAST) = 0.0
 GO TO 100
 DO 75 M=KACR,LUB
 MOL = M + 1
 AGEOS(M) = AGEOS(MOL)
 CONTINUE
 AGEOS(LAST) = 0.0
 GO TO 90
 MNO = LAND - 1
 DO 85 M=KACR,MNO
 MOL = M + 1
 AGEOS(M) = AGEOS(MOL)
 AGEUN(M) = AGEUN(MOL)
 TRET(M) = TRET(MOL)
 CONTINUE
 AGEOS(LAND) = 0.0
 AGEUN(LAND) = 0.0
 TRET(LAND) = 0.0
 IF(KACR .LE. LAST) LAST = LAST - 1

OVE ANOTHER ACRE IF FIRE LOSS TOTAL STILL ONE ACRE OR MORE.

 IF(YRLOS .GE. 1.0) GO TO 25
```

```
      IF(REGN(2) .GT. 0.0) GO TO 100
      IF(IYEAR .EQ. 1) LAST = 0
C
C PREPARE SUBTOTALS FOR CURRENT YEAR AND CHECK THAT NO ACRE IS OLDER
C THAN 179 YEARS.
C
  100 DO 110 K=1,180
      NACOS(K) = 0
      NACUN(K) = 0
  110 CONTINUE
      DO 130 K=1,LAND
      IF(AGEOS(K) .LE. 179.0) GO TO 120
      FLAGI = 2.0
      GO TO 140
  120 LM = AGEOS(K) + 1.0
      NACOS(LM) = NACOS(LM) + 1
      ML = AGEUN(K) + 1.0
      NACUN(ML) = NACUN(ML) + 1
  130 CONTINUE
  140 RETURN
      END
```

Subroutine HRVST

```
      SUBROUTINE HRVST
C
C TO SIMULATE ANNUAL CHANGES DUE TO THINNINGS AND REGENERATION CUTS.
C STATEMENTS FOR ADD ARE SPECIES-SPECIFIC.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST IYEAR
      COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181 ,BFMRCH,BFPCT,BFSALV,CFPC
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DEND,DESCR(5),DLFV,GIDF,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1DIAM(190),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VDM,
     2YSDM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,'PLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,JSUM(18),RETHV,RETTH,SCLOS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C DETERMINE ALLOWABLE CUT ON BASIS OF BD. FT. STUMPAGE PRICE.
C
      DO 5 J=1,10
      NSUB = J
      IF(PRIBD(IYRM) .LE. PRIDIV(J)) GO TO 10
    5 CONTINUE
   10 IALCUT = MALCUT(NSU8) - LOSS
      CUTAGE = FMRCHD(NSUB)
C
C COMPUTE THINNINGS FOR ANNUAL CUT.
C
      MXY = 0
      MAC = CUTAGE
      DO 70 I=NAGO,MAC,JCYCL
C
C COMPUTE BD. FT. FROM THINNINGS.
C
      VBTH = 0.0
      VCTH = 0.0
      VLBF1 = 0.0
      VLBF3 = 0.0
      VLCU1 = 0.0
      VLCU3 = 0.0
      IF(I .GE. MAC) GO TO 80
      MR = I + 1
      IF(BDFC(I) .LT. COMBF) GO TO 60
      VLBFI = NACOS(MR) * BDFC(I)
      VLBF3 = NACUN(MR) * BDFC(I)
      VLBF = VLBF + VLBF1 + VLBF3
      VBTH = VLBF1 + VLBF3
      RETTH = RETTH + VBTH * (PRIBD((YRM) * BFPCT)
      MXY = MXY + 1
C
C CU. FT. NOT IN SAWLOGS INCLUDED IN CU. FT. CUT, IF COMMERCIAL.
C
      GO TO (15,20,25), NSP
   15 ADD = BOFC(I) * (61.79999 + 2677.97761 / DIAM(I) - 4.03445 * BDFC
     II))
      GO TO 50
   20 ADD = BDFC(I) * (209.34226 + 298.06217 / OIAM(I) - 0.54225 *
     1 BDFC(I))
      GO TO 50
   25 CONTINUE
   50 ADD = CFMC(I) - AOD
      IF(ADO .LT. EXTCU) GO TO 70
      VLCUI = NACOS(MR) * ADD
      VLCU3 = NACUN(MR) * ADD
      VLCU = VLCU + VLCU1 + VLCU3
      VCTH = VLCU1 + VLCU3
      RETTH = RETTH + (VCTH * 0.01) * (PRICF(IYRM) * CFPCT)
      GO TO 70
C
C COMPUTE CU. FT. FROM THINNINGS IF 8D. FT. CUT IS NONCOMMERCIAL.
C
   60 IF(CFMC(I) .LT. COMCU) GO TO 65
      VLCUI = NACOS(MR) * CFMC(I)
      VLCU3 = NACUN(MR) * CFMC(I)
      VLCU = VLCU + VLCU1 + VLCU3
```

```
      VCTH = VLCU1 + VLCU3
      RETTH = RETTH + VCTH * 0.01 * (PRICF(IYRM) * CFPCT)
      MXY = MXY + 1
      GO TO 70
   65 MXY = MXY + 1
      SCTHN = NACOS(MR) * CTHN + SCTHN
      SCTHN = NACUN(MR) * CTHN + SCTHN
   70 CONTINUE
   80 MTHN = NAGO + MXY * JCYCL
C
C SELECT APPROPRIATE SUBROUTINE FOR SILVICULTURAL SYSTEM SPECIFIEO.
C
      IF(IALCUT .LE. 0) GO TO 100
      IF(REGN(2) .GT. 0.0) GO TO 90
      CALL CLEAR
      GO TO 100
   90 CALL SHWD
  100 RETURN
      END
```

Subroutine CLEAR

```
      SUBROUTINE CLEAR
C
C TO COMPUTE VOLUMES FROM HARVEST BY CLEARCUTTING.
C STATEMENTS FOR ADO ARE SPECIES-SRECIFIC.
C
      COMMUN BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      CCMMON AGED,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFRCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHD,OENO,DESCR(5),OLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBO(150),PRICF(150),REGN(3),RINT,
     3SITE,SREC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMUN BA,BAST,BOFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1OIAM(180),FCTR,HITE,JCYCL,NAGD,PRET,RROO,REST,ROTA,STANO,VOM,
     2YSDM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFOR,
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATF,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      KAI = 0
      DO 140 I=1,IALCUT
      VBHV = 0.0
      VCHV = 0.0
      VLBF2 = 0.0
      VLCU2 = 0.0
      IF(LAST .LT. LANO) GO TO 10
      LAST = 0
   10 LAST = LAST + 1
      IF(AGEOS(LAST) .GE. CUTAGE) GO TO 20
      LAST = LAST - 1
      GO TO 150
   20 M = AGEOS(LAST)
      KAI = KAI + 1
      K = M + 1
      KOUNT = KOUNT + 1
      ISAFE = LANO + 1
      IF(KOUNT .GE. ISAFE) KOUNT = 1
C
C COMRUTE BD. FT. FROM HARVEST CUTS.
C
      IF(M .LT. MTHN) GO TO 30
      VLBF2 = ANBOF(K) + BOFC(M)
      TEM = ANCUV(K) + CFMC(M)
      GO TO 40
   30 VLBF2 = ANBOF(K)
      TEM = ANCUV(K)
   40 IF(VLBF2 .LT. COMBF) GO TO 100
      VLBF = VLBF + VLBF2
      VBHV = VLBF2
      RETHV = RETHV + VBHV * PRIBD(IYRM)
C
C CU. FT. NOT IN SAWLOGS INCLUDEO IN CU. FT. CUT, IF COMMERCIAL.
C
      GO TO (50,55,60), NSP
   50 ADD = VLBF2 * (61.79999 + 2677.97761 / DIAM(M) - 4.03445 * VLBF2)
      GO TO 90
   55 ADD = VLBF2 * (209.34226 + 298.06217 / DIAM(M) - 0.54225 * VLBF2)
      GO TO 90
   60 CONTINUE
   90 VCHV = TEM - ADD
      IF(VCHV .LT. EXTCU) GO TO 130
      VLCU = VLCU + VCHV
      RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)
      GO TO 130
C
C COMPUTE CU. FT. FROM HARVEST CUTS IF BO. FT. CUT IS NONCOMMERCIAL.
C
  100 IF(M .LT. MTHN) GO TO 110
      VLCU2 = ANCUV(K) + CFMC(M)
      GO TO 120
  110 VLCU2 = ANCUV(K)
  120 IF(VLCU2 .LT. COMCU) GO TO 140
      VLCU = VLCU + VLCU2
      VCHV = VLCU2
      RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)
  130 AGEOS(LAST) = 0.0
  140 CONTINUE
  150 IF(KAI .LT. IALCUT) IALCUT = KAI
      RETURN
      END
```

Subroutine SHWD

```
      SUBROUTINE SHWD
C
C TO COMPUTE VOLUMES FROM HARVEST BY SEEO TREES OR SHELTERWOOO.
C STATEMENTS FOR ADO ARE SPECIES-SPECIFIC.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBOF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,C
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,OENO,OESCR(5),OLEV,GIOE,GNTR,
     2KOL(6),NGAME,NKDLS,NDYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RIN
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BOFC(180),BOFO(180),CFMC(180),CFMO(180),CUFT,OB
     1OIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STANO,VDM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,OEFO
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,RRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLB
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SC
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      JK = REGN(1) + 1.0
      KJ = REGN(1)
      KAI = 0
      INT = CYCNW(1) + CYCNW(2) - 1.0
      MIX = MIX + 1
      IF(MIX .GT. INT) MIX = 1
C
C MAKE ALLOWABLE CUT OF INITIAL CUTTINGS BY SHELTERWOOO OR SEEO TREE
C SYSTEM.
C
      DO 130 I=1,IALCUT
      ADD = 0.0
      VBHV = 0.0
      VCHV = 0.0
      VLBF2 = 0.0
      VLCU2 = 0.0
      IF(LAST .LT. LANO) GO TO 10
      LAST = 0
   10 LAST = LAST + 1
      IF(AGEOS(LAST) .GE. CUTAGE) GO TO 20
      LAST = LAST - 1
      GO TO 140
   20 M = AGEOS(LAST)
C
C COMPUTE BD. FT. FROM INITIAL HARVEST CUTS.
C
      IF(AGEOS(LAST) .GT. REGN(1)) GO TO 30
      VLBF2 = BOFC(KJ)
      VLCU2 = CFMC(KJ)
      GO TO 40
   30 TEM = AGEOS(LAST) - REGN(1)
      IT = REGN(1) + TEM + 1.0
      EXO = ANBOF(IT) - ANBOF(JK)
      VLBF2 = BOFC(KJ) + EXO
      EXT = ANCUV(IT) - ANCUV(JK)
      VLCU2 = CFMC(KJ) + EXT
   40 IF(VLBF2 .LT. COMBF) GO TO 110
      VLBF = VLBF + VLBF2
      VBHV = VLBF2
      RETHV = RETHV + VBHV * PRIBD(IYRM)
      TRET(LAST) = 1.0
      KAI = KAI + 1
C
C CU. FT. NOT IN SAWLOGS INCLUOEO IN CU. FT. CUT, IF COMMERCIAL.
C
      IF(M .GT. KJ) M = KJ
      GO TO (50,60,70), NSP
   50 ADD = VLBF2 * (61.79999 + 2677.97761 / OIAM(M) - 4.03445 * VLBF
      GO TO 100
   60 ADD = VLBF2 * (209.34226 + 298.06217 / DIAM(M) - 0.54225 * VLBF
      GO TO 100
   70 CONTINUE
  100 TEM = VLCU2
      VCHV = TEM - ADD
      IF(VCHV .LT. EXTCU) GO TO 130
      VLCU = VLCU + VCHV
      RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)
      GO TO 130
C
C COMPUTE CU. FT. FROM HARVEST CUTS IF BD. FT. CUT IS NONCOMMERCIAL.
C
  110 IF(VLCU2 .LT. COMCU) GO TO 130
      VLCU = VLCU + VLCU2
      VCHV = VLCU2
      RETHV = RETHV + VCHV * 0.01 * RRICF(IYRM)
      TRET(LAST) = 1.0
      KAI = KAI + 1
  130 CONTINUE
C
C ADD VOLUME AND VALUE OF SECOND CUT OF SHELTERWOOD OR SEED TREES TO
C APPROPRIATE YEAR TOTAL.
C
  140 K = REGN(2)
      KK = K + 1
      TMPY = CYCNW(1) + 1.0
      DO 230 I=1,LANO
      IF(TRET(I) .NE. TMPY) GO TO 230
      ADD = 0.0
      VBHV = 0.0
      VCHV = 0.0
      VLBF2 = 0.0
      VLCU2 = 0.0
      M = AGEOS(I)
```

```
  IF(REGN(3) .EQ. 0.0) GO TO 150
  VLBF2 = BDFC(K)
  VLCU2 = CFMC(K)
  GO TO 160
0 VLBF2 = ANBDF(KK)
  VLCU2 = ANCUV(KK)

MPUTE BD. FT. FROM SECOND CUTS.

0 IF(VLBF2 .LT. COMBF) GO TO 210
  VLBF = VLBF + VLBF2
  VBHV = VLBF2
  RETHV = RETHV + VBHV * PRIBD(IYRM)

. FT. NOT IN SAWLOGS INCLUDED IN CU. FT. CUT, IF COMMERCIAL.

  IF(M .GT. K) M = K
  IF(M .EQ. 0) GO TO 220
  IF(DIAM(M) .EQ. 0.0) GO TO 220
  GO TO (170,175,180), NSP
0 ADD = VLBF2 * (61.79999 + 2677.97761 / DIAM(M) - 4.03445 * VLBF2)
  GO TO 200
5 ADD = VLBF2 * (209.34226 + 298.06217 / DIAM(M) - 0.54225 * VLBF2)
  GO TO 200
0 CONTINUE
0 TEM = VLCU2
  VCHV = TEM - ADD
  IF(VCHV .LT. EXTCU) GO TO 220
  VLCU = VLCU + VCHV
  RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)
  GO TO 220

MPUTE CU. FT. IF BD. FT. VOLUME NOT COMMERCIAL.

0 IF(VLCU2 .LT. COMCU) GO TO 230
  VLCU = VLCU + VLCU2
  VCHV = VLCU2
  RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)

ANGE STAND AGE AND STORY DESIGNATION TO MATCH CUT.

0 IF(REGN(3) .GT. 0.0) GO TO 230
  TRET(I) = 0.0
  AGEOS(I) = AGEUN(I)
  AGEUN(I) = 0.0
0 CONTINUE

D VOLUME AND VALUE OF THIRD CUT OF SHELTERWOOD TO APPROPRIATE YEAR
TAL.

  IF(REGN(3) .EQ. 0.0) GO TO 340
  K = REGN(3)
  KK = K + 1
  TMPY = CYCNW(1) + CYCNW(2) + 1.0
  DO 330 I=1,LANO
  IF(TRET(I) .LT. TMPY) GO TO 330
  ADD = 0.0
  VBHV = 0.0
  VCHV = 0.0
  VLBF2 = 0.0
  VLCU2 = 0.0
  M = AGEOS(I)
  VLBF2 = ANBDF(KK)
  VLCU2 = ANCUV(KK)

MPUTE BD. FT. FROM THIRD CUTS.

  IF(VLBF2 .LT. COMBF) GO TO 310
  VLBF = VLBF + VLBF2
  VBHV = VLBF2
  RETHV = RETHV + VBHV * PRIBD(IYRM)

 FT. NOT IN SAWLOGS INCLUDED IN CU. FT. CUT, IF COMMERCIAL.

  IF(M .GT. K) M = K
  IF(M .EQ. 0) GO TO 320
  IF(DIAM(M) .EQ. 0.0) GO TO 320
  GO TO (270,275,280), NSP
  ADD = VLBF2 * (61.79999 + 2677.97761 / DIAM(M) - 4.03445 * VLBF2)
  GO TO 300
  ADD = VLBF2 * (209.34226 + 298.06217 / DIAM(M) - 0.54225 * VLBF2)
  GO TO 300
  CONTINUE
  TEM = VLCU2
  VCHV = TEM - AOD
  IF(VCHV .LT. EXTCU) GO TO 320
  VLCU = VLCU + VCHV
  RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)
  GO TO 320

PUTE CU. FT. IF BD. FT. VOLUME NOT COMMERCIAL.

  IF(VLCU2 .LT. COMCU) GO TO 330
  VLCU = VLCU + VLCU2
  VCHV = VLCU2
  RETHV = RETHV + VCHV * 0.01 * PRICF(IYRM)

NGE STANO AGE AND STORY DESIGNATION TO MATCH CUT.

  TRET(I) = 0.0
  AGEOS(I) = AGEUN(I)
  AGEUN(I) = 0.0
  CONTINUE
  IF(KAI .LT. IALCUT) IALCUT = KAI
  IF(MIX .GE. INT) GO TO 350
```

```
      RETURN
  350 CALL ARNG
      RETURN
      END
```

Subroutine ARNG

```
      SUBROUTINE ARNG
C
C TO REARRANGE ACRES FOR SIMULATION PERIODS LONGER THAN REGENERATION
C PERIOD.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPC
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,OESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STANO,VOM,
     2YSDM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     IFMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      DO 5 I=1,180
    5 NACOS(I) = 0
C
C PRESERVE VALUES OF TRET(I) GREATER THAN ZERO.
C
      KU = 0
      LAB = 0
      DO 10 I=1,LANO
      LAB = I - 1
      IF(TRET(I) .GT. 0.0) GO TO 15
   10 CONTINUE
   15 DO 20 I=I,LAND
      KU = KU + I
      KDX = LAB + I
      IF(KDX .GT. LAND) GO TO 25
      TRET(I) = TRET(KDX)
   20 CONTINUE
   25 DO 30 I=KU,LAND
   30 TRET(I) = 0.0
C
C SUM ACRES BY 1-YEAR AGE CLASSES.
C
      DO 40 I=1,LAND
      LM = AGEOS(I) + 1.0
      NACOS(LM) = NACOS(LM) + 1
   40 CONTINUE
      DO 50 I=1,LAND
      AGEOS(I) = 0.0
      AGEUN(I) = 0.0
   50 CONTINUF
C
C CONVERT OVERSTORY ACRES IN EACH NACOS(I) TO INDIVIOUAL ACRES.
C ASSIGN UNDERSTORY ACRES TO APPROPRIATE OVERSTORY.
C
      JK = 0
      DO 70 J=1,180
      IF(JK .GT. LAND) GO TO 80
      IF(NACOS(J) .LE. 0) GO TO 70
      KL = JK + 1
      JK = JK + NACOS(J)
      DO 60 I=KL,JK
      NAC = LAND + I - I
      AGEOS(NAC) = J - 1
      IF(TRET(NAC) .LE. 1.0) GO TO 60
      AGEUN(NAC) = TRET(NAC) - 1.0
   60 CONTINUE
   70 CONTINUE
C
C COMPUTE INOEX TO LOCATE NEXT ACRE FOR INITIAL HARVEST.
C
   80 LAST = 0
      DO 90 I=1,LAND
      IF(TRET(I) .EQ. 0.0) GO TO 100
      LAST = LAST + 1
   90 CONTINUE
  100 RETURN
      END
```

Subroutine SUMS

```
      SUBROUTINE SUMS
C
C TO SUMMARIZE RESULTS OF ANNUAL CHANGES.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAGI,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMPCH,BFPCT,BFSALV,CFPC
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDF,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),RLGN(3),RINT,
     3SITF,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(190),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VDM,
     2YSDM(180)
```

```
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C COMPUTE GROWING STOCK VOLUME. USE CU. FT. IF VOLUME IS LESS THAN
C BFMRCH BOARD FEET.
C
      DO 50 MU=1,2
      AMU = MU
      IF(AMU .EQ. 2.0 .AND. REGN(2) .EQ. 0.0) GO TO 60
      DO 40 I=1,LANO
      IF(AMU .EQ. 2.0) GO TO 5
      IF(AGEOS(I) .LT. AGMRCH) GO TO 40
      IAG = AGEOS(I) + 1.0
      IF(REGN(2) .EQ. 0.0) GO TO 10
      IF(AGEOS(I) .LE. REGN(1)) GO TO 10
      TEM = AGEOS(I) - REGN(1) + 1.0
      IF(TRET(I) .LT. TEM) IAG = IAG - (TEM - TRET(I))
      GO TO 10
    5 IF(AGEUN(I) .LT. AGMRCH) GO TO 40
      IAG = AGEUN(I) + 1.0
   10 IBG = IAG - 1
      IF(TRET(I) .GT. 0.0) GO TO 15
      IF(IBG .LT. MTHN) GO TO 15
      GBL1 = ANBDF(IAG) + BDFC(IBG)
      IF(GBL1 .LT. BFMRCH) GO TO 20
      GVLBF = GVLBF + GBL1
      GO TO 40
   15 GBL1 = ANBDF(IAG)
      IF(GBL1 .LT. BFMRCH) GO TO 20
      GVLBF = GVLBF + GBL1
      GO TO 40
   20 IF(IBG .LT. MTHN) GO TO 30
      GCL1 = ANCUV(IAG) + CFMC(IBG)
      GVLCU = GVLCU + GCL1
      GO TO 40
   30 GCL1 = ANCUV(IAG)
      GVLCU = GVLCU + GCL1
   40 CONTINUE
   50 CONTINUE
C
C PREPARE FOR NEW TOTALS AND SUBTOTALS.
C
   60 DO 70 K=1,180
      NACOS(K) = 0
   70 NACUN(K) = 0
      DO 80 I=1,18
      ISUM(I) = 0
   80 NSUM(I) = 0
      DO 90 K=1,LANO
      LM = AGEOS(K) + 1.0
      NACOS(LM) = NACOS(LM) + 1
      ML = AGEUN(K) + 1.0
      NACUN(ML) = NACUN(ML) + 1
   90 CONTINUE
C
C COMPUTE TOTAL ACREAGE BY 10-YEAR AGE CLASSES.
C
      DO 100 I=1,18
      DO 100 J=1,10
      NS = 10 * (I - 1) + J
      ISUM(I) = ISUM(I) + NACOS(NS)
      NSUM(I) = NSUM(I) + NACUN(NS)
  100 CONTINUE
C
C COMPUTE VOLUMES AND VALUES AT END OF CURRENT YEAR FOR USE BY ANUAL.
C
      RETRN = RETTH + RETHV
      CSTAC = LAND * ACCST + SCPLT + SCTHN + SCLOSS
      CSTVL = CUCST * (VLCU * 0.01) + BFCST * VLBF
      TCOST = CSTAC + CSTVL
      ANNET = RETRN - TCOST
      GSVALB = GVLBF * (PRIBD(IYRM) - BFCST)
      GSVALC = (GVLCU * 0.01) * (PRICF(IYRM) - CUCST)
C
C INCREASE COSTS ANNUALLY, IF DESIRED.
C
      ACCST = ACCST + (ACCST * RATE)
      BFCST = BFCST + (BFCST * RATE)
      CLOSS = CLOSS + (CLOSS * RATE)
      CPLT = CPLT + (CPLT * RATE)
      CTHN = CTHN + (CTHN * RATE)
      CUCST = CUCST + (CUCST * RATE)
      RETURN
      END
```

Subroutine ANUAL

```
      SUBROUTINE ANUAL
C
C TO STORE ANNUAL VALUES FOR PRINTING LATER.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFO
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLD,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLB
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SC
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C CONVERT VOLUMES AND AREAS TO SUBSCRIPTED VALUES FOR FUTURE USE.
C
      K = IYEAR
      J = IYEAR + 1
      IVAR(1,J) = IALCUT
      IVAR(2,J) = CUTAGE
      IVAR(3,J) = VLCU + 0.5
      IBFT = VLBF + 0.5
      IVAR(4,J) = IVAR(4,J) + IBFT
      IVAR(5,J) = IVAR(5,K) + IVAR(3,J)
      IVAR(6,J) = IVAR(6,K) + IVAR(4,J)
      IVAR(7,J) = GVLCU + 0.5
      IVAR(8,J) = GVLBF + 0.5
      IVAR(9,J) = IVAR(5,J) + IVAR(7,J)
      IVAR(10,J) = IVAR(6,J) + IVAR(8,J)
      IVAR(11,J) = NONSTK
      DO 1 I=1,14
      N = I + 11
      JVAR(I,J) = NSUM(I)
    1 IVAR(N,J) = ISUM(I)
      DO 5 I=15,18
      JVAR(15,J) = JVAR(15,J) + NSUM(I)
    5 IVAR(26,J) = IVAR(26,J) + ISUM(I)
C
C STORE MONEY VALUES IN ARRAYS FOR REMAINING ROUTINES.
C
      VAR(1,J) = PRICF(J)
      VAR(2,J) = PRIBD(J)
      VAR(3,J) = VAR(3,J) + RETRN
      VAR(4,J) = VAR(4,K) + VAR(3,J)
      VAR(5,J) = CSTAC
      VAR(6,J) = VAR(6,K) + VAR(5,J)
      VAR(7,J) = VAR(7,J) + CSTVL
      VAR(8,J) = VAR(8,K) + VAR(7,J)
      VAR(9,J) = VAR(5,J) + VAR(7,J)
      VAR(10,J) = VAR(10,K) + VAR(9,J)
      VAR(11,J) = VAR(3,J) - VAR(9,J)
      VAR(12,J) = VAR(12,K) + VAR(11,J)
      VAR(13,J) = GSVALC + GSVALB
      VAR(14,J) = VAR(12,J) + VAR(13,J)
      RETURN
      END
```

Subroutine REPRT2

```
      SUBROUTINE REPRT2
C
C TO REPORT VALUES COMPUTED EACH YEAR OF THE SIMULATION.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGEO,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CF
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHO,DENO,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFO(180),CFMC(180),CFMO(180),CUFT,DBH
     1DIAM(180),FCTR,HITE,JCYCL,NAGO,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSOM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR
     1FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LANO,LAST,MALCUT(10),MOLO,NACOS(180),
     3NACUN(180),NONSTK,PRIOIV(10),RATE,RETRN,VAR(14,150),YRLOS
      COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCL
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
      N = NOYRS + 1
      DO 180 MAC=1,5
      IF(MAC .EQ. 3 .AND. REGN(2) .EQ. 0.0) GO TO 180
      M = 40
      DO 175 J=1,N
      LINE = J - 1
      IF(M .LT. 40) GO TO 110
      M = 0
      WRITE (6,1)
    1 FORMAT (1H1,//,48X,11HPAGE TYPE 5)
      WRITE (6,2)
    2 FORMAT (1H0,35X,36HSTATUS OF FOREST AT END OF EACH YEAR)
      WRITE (6,5) (BATCH(I),I=1,3)
    5 FORMAT (1H ,45X,7HBATCH  ,3A8)
      WRITE (6,10) ITEST
   10 FORMAT (1H ,45X,4HTEST,I4)
      WRITE (6,15) (GMNAM(I),I=1,3)
   15 FORMAT (1H ,45X,6HGAME  ,3A8)
      WRITE (6,20) (DESCR(I),I=1,5)
   20 FORMAT (1H ,45X,5A8)
      WRITE (6,25)
   25 FORMAT (1H )
      GO TO (30,50,67,70,90), MAC
C
C PRINT FIRST PAGE OF ANNUAL RESULTS ON PAGE TYPE 5.
C
   30 WRITE (6,35)
```

```
 FORMAT (1H ,12X,9HALLOWABLE,5X,7HCUTTING,8X,10HACTUAL CUT,10X,9HCU
1MUL CUT,10X,9HGRSTK VOL,12X,9HTOTAL VOL)
 WRITE (6,40)
 FORMAT (1H ,2X,4HYEAR,9X,3HCUT,10X,3HAGE,7X,6HCU.FT.,5X,3HMBF,6X,6
1HCU.FT.,5X,3HMBF,6X,6HCU.FT.,5X,3HMBF,6X,6HCU.FT.,5X,3HMBF)
 WRITE (6,45)
 FORMAT (1H ,15X,3H(1),10X,3H(2),8X,3H(3),7X,3H(4),7X,3H(5),7X,3H(6
1),7X,3H(7),7X,3H(8),7X,3H(9),6X,4H(10),//)
 GO TO 110

NT SECOND PAGE OF ANNUAL RESULTS OF PAGE TYPE 5.

 WRITE (6,55)
 FORMAT (1H ,11X,3HNON,41X,22HAGE CLASSES, OVERSTORY)
 WRITE (6,60)
 FORMAT (1H ,2X,4HYEAR,5X,3HSTK,114H    0-9  10-19  20-29  30-39  40
1-49  50-59  60-69  70-79  80-89  90-99  100-109  110-119  120-129
2 130-139  140-179)
 WRITE (6,65)
 FORMAT (1H ,10X,117H(11)    (12)  (13)    (14)    (15)    (16)    (17)
1  (18)     (19)    (20)    (21)     (22)      (23)       (24)       (25)
2 (26),//)
 GO TO 110

NT THIRD PAGE OF ANNUAL RESULTS OF PAGE TYPE 5.

 WRITE (6,68)
 FORMAT(1H ,11X,3HNON,40X,23HAGE CLASSES, UNDERSTORY)
 WRITE (6,60)
 WRITE (6,65)
 GO TO 110

NT FOURTH PAGE OF ANNUAL RESULTS OF PAGE TYPE 5.

 WRITE (6,75)
 FORMAT (1H ,18X,14HSTUMPAGE PRICE,9X,15HSTUMPAGE INCOME,13X,10HARE
1A COSTS,15X,12HVOLUME COSTS)
 WRITE (6,80)
 FORMAT (1H ,2X,4HYEAR,9X,10H100 CU.FT.,5X,3HMBF,6X,6HANNUAL,5X,9HC
1UMULATED,6X,6HANNUAL,5X,9HCUMULATED,6X,6HANNUAL,5X,9HCUMULATED)
 WRITE (6,85)
 FORMAT (1H ,18X,4H(27),8X,4H(28),6X,4H(29),9X,4H(30),9X,4H(31),9X,
14H(32),9X,4H(33),9X,4H(34),//)
 GO TO 110

NT FIFTH PAGE OF ANNUAL RESULTS OF PAGE TYPE 5.

 WRITE (6,95)
 FORMAT (1H ,18X,10HTOTAL COST,17X,10HNET INCOME,13X,13HCURRENT VAL
1UE,9X,5HTOTAL)
 WRITE (6,100)
 FORMAT (1H ,2X,4HYEAR,8X,6HANNUAL,5X,9HCUMULATED,7X,6HANNUAL,5X,9H
1CUMULATED,7X,13HGROWING STOCK,7X,9HNET WORTH)
 WRITE (6,105)
 FORMAT (1H ,15X,4H(35),9X,4H(36),10X,4H(37),9X,4H(38),13X,4H(39),1
14X,4H(40),//)

TE BODY OF EACH TABLE.

 GO TO (115,125,133,135,145), MAC
 WRITE (6,120) LINE,(IVAR(I,J),I=1,10)
 FORMAT (1H ,I6,I12,I13,I12,I9,3(I11,I9))
 GO TO 160
 WRITE (6,130) LINE,(IVAR(I,J),I=11,26)
 FORMAT (1H ,I6,2I7,I6,8I7,I8,4I9)
 GO TO 160
 WRITE (6,130) LINE,IVAR(11,J),(JVAR(I,J),I=1,15)
 GO TO 160
 WRITE (6,140) LINE,IVAR(I,J),I=1,8)
 FORMAT (1H ,I6,F16.2,F11.2,F12.0,F11.0,2(F15.0,F11.0))
 GO TO 160
 WRITE (6,150) LINE,(VAR(I,J),I=9,14)
 FORMAT (1H ,I6,F14.0,F12.0,F15.0,F12.0,2F18.0)
 IF(J .LE. 1) GO TO 165
 M = M + 1
 IF(LL .LT. 10) GO TO 170
 WRITE (6,25)
 LL = 0
 LL = LL + 1
 CONTINUE
 CONTINUE
 RETURN
 END
```

outine WORTH

```
 SUBROUTINE WORTH

COMPUTE PRESENT VALUES AND RATES EARNED.
CAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.

 COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
 COMMON AGED,AGMRCH,ANBOF(181),ANCUV(181),BEMRCH,BFPCT,BESALV,CFPCT
,COMBF,COMCU,CYCL,CYCNW(3),DBHD,DENO,DESCR(5),DLFV,GIOE,GNTR,
KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBO(150),PRICF(150),REGN(3),RINT,
SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
 COMMON BA,BAST,BOFC(180),BOFD(180),CFMC(180),CFMO(180),CUFT,DBHT,
DIAM(180),FCTR,HITE,JCYCL,NAGD,PRET,PROD,REST,ROTA,STAND,VDM,
YSDM(180)
 COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
FMRCHO(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACOS(180),
3NACUN(180),NONSTK,PRDIV(10),RATE,RETRN,VAR(14,150),YRLUS
 COMMON AGEOS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBE,
1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
 DIMENSION CRATE(20),DISC(20),DISG(20),DISI(20),PREV(20),PWTH(20),R
1ATIO(20,150)
C
 DO 1 I=1,20
 CRATE(I) = 0.0
 DISC(I) = 0.0
 DISG(I) = 0.0
 DISI(I) = 0.0
 PREV(I) = 0.0
 1 PWTH(I) = 0.0
 DO 5 I=1,20
 DO 5 J=1,150
 5 RATIO(I,J) = 0.0
C
C COMPUTE A SERIES OF ALTERNATIVE RATES.
C
 CRATE(1) = 0.010
 DO 10 I=1,19
 K = I + 1
 10 CRATE(K) = CRATE(I) + 0.005
C
C COMPUTE AN INTEREST TABLE FOR THE PERIOD NOYRS.
C
 DO 15 J=1,20
 FACTR = 1.0 + CRATE(J)
 DO 15 K=1,NOYRS
 YRS = K
 PRPN = ALOG(FACTR) * YRS
 RATIO(J,K) = EXP(PRPN)
 15 CONTINUE
C
C DISCOUNT GROWING STOCK VALUE AT NOYRS.
C
 DO 20 L=1,20
 KL = NOYRS + 1
 DISG(L) = VAR(13,KL) / RATIO(L,NOYRS)
 20 CONTINUE
C
C DISCOUNT ANNUAL COSTS AND RETURNS.
C
 DO 30 M=1,20
 PRESC = 0.0
 PRESI = 0.0
 SPRSC = 0.0
 SPRSI = 0.0
 DO 25 N=1,NOYRS
 I = N + 1
 PRESC = VAR(9,I) / RATIO(M,N)
 PRESI = VAR(3,I) / RATIO(M,N)
 SPRSC = SPRSC + PRESC
 SPRSI = SPRSI + PRESI
 25 CONTINUE
 DISI(M) = SPRSI
 DISC(M) = SPRSC
 30 CONTINUE
C
C COMPUTE PRESENT WORTH AT EACH RATE.
C
 DO 35 IJ=1,20
 PREV(IJ) = DISI(IJ) + DISG(IJ)
 PWTH(IJ) = PREV(IJ) - DISC(IJ) - VAR(13,1)
 CRATE(IJ) = CRATE(IJ) * 100.0
 35 CONTINUE
C
C SUMMARIZE COMPUTATIONS ON PAGE TYPE 6.
C
 WRITE (6,40)
 40 FORMAT (1H1,//,62X,11HPAGE TYPE 6/1H0,52X,29HPRESENT WORTH AND RAT
 1E EARNED)
 WRITE (6,45) (BATCH(I),I=1,3)
 45 FORMAT (1H ,52X,7HBATCH  ,3A8)
 WRITE (6,50) ITEST
 50 FORMAT (1H ,52X,4HTEST,I4)
 WRITE (6,55) (GMNAM(I),I=1,3)
 55 FORMAT (1H ,52X,6HGAME  ,3A8)
 WRITE (6,60) (DESCR(I),I=1,5)
 60 FORMAT (1H ,52X,5A8)
 WRITE (6,65) NOYRS
 65 FORMAT (1H ,52X,15HYEARS IN PERIOD,I5,//)
 WRITE (6,75) VAR(13,1)
 75 FORMAT (1H ,11X,33HVALUE OF INITIAL GROWING STOCK--$,F10.2,//)
 WRITE (6,80)
 80 FORMAT (1H ,57X,38HVALUES DISCOUNTED TO PRESENT (DOLLARS),/)
 WRITE (6,90)
 90 FORMAT (1H ,11X,8HCOMPOUND,14X,6HFUTURE,34X,5HSTOCK,36X,3HNET)
 WRITE (6,100)
100 FORMAT (1H ,13X,4HRATE,15X,7HGROWING,15X,3HALL,17X,4HPLUS,16X,3HAL
 1L,15X,7HPRESENT)
 WRITE (6,110)
110 FORMAT (1H ,11X,9H(PERCENT),13X,5HSTOCK,14X,7HINCOMES,13X,7HINCOME
 1S,14X,5HCOSTS,15X,5HWORTH,/)
 DO 130 I=1,20
 WRITE (6,120) CRATE(I),DISG(I),DISI(I),PREV(I),DISC(I),PWTH(I)
120 FORMAT (1H ,12X,F5.1,12X,5(F10.2,10X),/)
130 CONTINUE
 RETURN
 END
```

Subroutine SUMRY

```
      SUBROUTINE SUMRY
C
C TO PRINT SPECIFIED COLUMNS OF PAGE TYPE 5 AS SUMMARY OF RESULTS.
C CONTAINS NO STATEMENTS TO BE MODIFIED TO ADAPT TO OTHER SPECIES.
C
      COMMON BATCH(3),FLAG1,FLAG2,IGAME,ITEST,IYEAR
      COMMON AGED,AGMRCH,ANBDF(181),ANCUV(181),BFMRCH,BFPCT,BFSALV,CFPCT
     1,COMBF,COMCU,CYCL,CYCNW(3),DBHD,DEND,DESCR(5),DLEV,GIDE,GNTR,
     2KOL(6),NGAME,NKOLS,NOYRS,NSP,PRIBD(150),PRICF(150),REGN(3),RINT,
     3SITE,SPEC(5),SUMM(6,25,10),THIN,VLLV(3),EXTCU
      COMMON BA,BAST,BDFC(180),BDFD(180),CFMC(180),CFMD(180),CUFT,DBHT,
     1DIAM(180),FCTR,HITE,JCYCL,NAGD,PRET,PROD,REST,ROTA,STAND,VOM,
     2YSDM(180)
      COMMON ACCST,ANUL,BFCST,CLOSS,CPLT,CSTAC,CSTVL,CTHN,CUCST,DEFOR,
     1FMRCHD(10),GMNAM(3),IACRE(180),IALCUT,IPLNT,IVAR(26,150),
     2JVAR(15,150),KOUNT,LAND,LAST,MALCUT(10),MOLD,NACDS(180),
     3NACUN(180),NONSTK,PRIDIV(10),RATE,RETRN,VAR(14,150),YRLDS
      COMMON AGEDS(1000),AGEUN(1000),ANNET,CUTAGE,GSVALB,GSVALC,GVLBF,
     1GVLCU,ISUM(18),IYRM,KACR,LOSS,MIX,MTHN,NSUM(18),RETHV,RETTH,SCLOSS
     2,SCPLT,SCTHN,TCOST,TRET(1000),VBHV,VCHV,VLBF,VLCU
C
C CONVERT IVAR(I,J) AND VAR(I,J) TO SUMM(I,J,K) AT END OF EACH GAME.
C
      LIM = 10 + NOYRS / 10
      DO 20 I=1,NKOLS
      DO 20 J=1,LIM
      K = KOL(I)
      IF(J .GT. 10) GO TO 5
      JJ = J + 1
      GO TO 10
    5 JJ = 10 * (J - 10) + 1
   10 IF(K .GT. 26) GO TO 15
      SUMM(I,J,IGAME) = IVAR(K,JJ)
      GO TO 20
   15 K = K - 26
      SUMM(I,J,IGAME) = VAR(K,JJ)
   20 CONTINUE
C
C WRITE SUMMARY TABLES ON PAGE TYPE 7 WHEN ALL GAMES ARE FINISHED.
C
      IF(IGAME .LT. NGAME) GO TO 150
C
C WRITE PAGE HEADINGS WITH SEPARATE PAGE FOR EACH COLUMN OF REPRT2
C IDENTIFIED IN BASIS1.
C
      DO 120 I=1,NKOLS
      WRITE (6,30)
   30 FORMAT (1H1,//,54X,11HPAGE TYPE 7/1H0,45X,26HCOMPARISON OF ALTER
     1TIVES)
      WRITE (6,35) (BATCH(N),N=1,3)
   35 FORMAT (1H ,45X,7HBATCH  ,3A8)
      WRITE (6,40) ITEST
   40 FORMAT (1H ,45X,4HTEST,I4)
      WRITE (6,45) (DESCR(N),N=1,5)
   45 FORMAT (1H ,45X,5A8)
      K = KOL(I)
      WRITE (6,50) K
   50 FORMAT (1H ,45X,8HCOLUMN  ,I3,///)
      WRITE (6,60)
   60 FORMAT (1H ,5X,4HYEAR,6X,6HGAME 1,6X,6HGAME 2,6X,6HGAME 3,6X,6HG
     1E 4,6X,6HGAME 5,6X,6HGAME 6,6X,6HGAME 7,6X,6HGAME 8,6X,6HGAME 9,
     2,7HGAME 10,//)
      M = 0
C
C WRITE SUMM(I,J,K) FOR EACH OF FIRST 10 YEARS AND FOR END EACH DECADE
C
      DO 120 J=1,25
      IF(J .GT. 10) GO TO 70
      JJ = J
      GO TO 80
   70 JJ = 10 * (J - 10)
   80 IF(M .LT. 5) GO TO 100
      WRITE (6,90)
   90 FORMAT (1H ,//)
      M = 0
  100 WRITE (6,110) JJ,(SUMM(I,J,L),L=1,10)
  110 FORMAT (1H ,I9,F11.0,9F12.0)
  120 M = M + 1
  150 RETURN
      END
```

Appendix 2: Output of MANGD2

PAGE TYPE 1

YIELDS PER ACRE OF MANAGEO, EVEN-AGED STANOS OF BLACK HILLS PONDEROSA PINE

SITE INOEX 70, 20-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 120., SUBSEQUENT - 100.

	ENTIRE STANO BEFORE ANO AFTER THINNING							PERIODIC INTERMEOIATE CUTS				
STANO AGE (YEARS)	TREES NO.	BASAL AREA SQ.FT.	AVERAGE D.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME MBF	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME MBF
30.	950	119	4.8	25	1188	309.	0.000					
30.	463	79	5.6	26	849	309.	0.000	487	40	339	0.	0.000
40.	458	109	6.6	35	1559	981.	0.000					
50.	449	134	7.4	44	2408	1848.	.900					
50.	251	92	8.2	45	1701	1443.	.900	198	42	707	405.	0.000
60.	249	115	9.2	51	2420	2192.	3.760					
70.	246	134	10.0	58	3200	2964.	7.630					
70.	160	100	10.7	59	2456	2294.	6.810	86	34	744	670.	.820
80.	160	117	11.6	64	3230	3033.	11.880					
90.	160	134	12.4	69	4017	3786.	15.120					
90.	105	100	13.2	70	3030	2867.	12.010	55	34	987	919.	3.110
100.	105	115	14.2	74	3747	3558.	16.080					
110.	105	131	15.1	78	4468	4255.	20.410					
110.	32	49	16.8	80	1734	1659.	8.400	73	82	2734	2596.	12.010
120.	32	58	18.3	83	2148	2063.	11.170					
130.	32	68	19.7	86	2581	2485.	14.210					
130.	10	25	21.3	87	964	931.	5.530	22	43	1617	1554.	8.680
140.	10	30	23.3	90	1189	1151.	7.260					

THIS TABLE SHOWS VALUES FOR SEEO TREE OR SHELTERWOOO CUTTING WITH TIMING ANO AMOUNTS SPECIFIEO PREVIOUSLY.

MERCH. CU. FT. - TREES 6.0 INCHES D.B.H. ANO LARGER TO 4-INCH TOP.

BD. FT. - TREES 10.0 INCHES D.B.H. AND LARGER TO 8-INCH TOP.

PAGE TYPE 2

GROWING STOCK OF MANAGEO BLACK HILLS PONDEROSA PINE
SITE INOEX 70., 20.-YEAR CUTTING CYCLE
OENSITY LEVEL- 120. AND 100.

VOLUMES PRESENT PER ACRE AT END OF EACH YEAR
MERCHANTABLE CUBIC FEET

	YEAR									
OECAOE	0	1	2	3	4	5	6	7	8	9
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	309.0	376.2	443.4	510.6	577.8	645.0	712.2	779.4	846.6	913.8
4	981.0	1067.7	1154.4	1241.1	1327.8	1414.5	1501.2	1587.9	1674.6	1761.3
5	1443.0	1517.9	1592.8	1667.7	1742.6	1817.5	1892.4	1967.3	2042.2	2117.1
6	2192.0	2269.2	2346.4	2423.6	2500.8	2578.0	2655.2	2732.4	2809.6	2886.8
7	2294.0	2367.9	2441.8	2515.7	2589.6	2663.5	2737.4	2811.3	2885.2	2959.1
8	3033.0	3108.3	3183.6	3258.9	3334.2	3409.5	3484.8	3560.1	3635.4	3710.7
9	2867.0	2936.1	3005.2	3074.3	3143.4	3212.5	3281.6	3350.7	3419.8	3488.9
10	3558.0	3627.7	3697.4	3767.1	3836.8	3906.5	3976.2	4045.9	4115.6	4185.3
11	1659.0	1699.4	1739.8	1780.2	1820.6	1861.0	1901.4	1941.8	1982.2	2022.6
12	2063.0	2105.2	2147.4	2189.6	2231.8	2274.0	2316.2	2358.4	2400.6	2442.8
13	931.0	953.0	975.0	997.0	1019.0	1041.0	1063.0	1085.0	1107.0	1129.0
14	1151.0									

THOUSANDS OF BOARO FEET

0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	.090	.180	.270	.360	.450	.540	.630	.720	.810
5	.900	1.186	1.472	1.758	2.044	2.330	2.616	2.902	3.188	3.474
6	3.760	4.147	4.534	4.921	5.308	5.695	6.082	6.469	6.856	7.243
7	6.810	7.317	7.824	8.331	8.838	9.345	9.852	10.359	10.866	11.373
8	11.880	12.204	12.528	12.852	13.176	13.500	13.824	14.148	14.472	14.796
9	12.010	12.417	12.824	13.231	13.638	14.045	14.452	14.859	15.266	15.673
10	16.080	16.513	16.946	17.379	17.812	18.245	18.678	19.111	19.544	19.977
11	8.400	8.677	8.954	9.231	9.508	9.785	10.062	10.339	10.616	10.893
12	11.170	11.474	11.778	12.082	12.386	12.690	12.994	13.298	13.602	13.906
13	5.530	5.703	5.876	6.049	6.222	6.395	6.568	6.741	6.914	7.087
14	7.260									

PAGE TYPE 3

ALTERNATIVES FOR THIS GAME
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

NUMBER OF YEARS PER GAME 30

CRITICAL PRICES	99.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALLOWABLE CUT	8	0	0	0	0	0	0	0	0	0
MINIMUM CUTTING AGE	110.	0.	0.	0.	0.	0.	0.	0.	0.	0.

ACRES IN WORKING CIRCLE	885
MINIMUM VALUES FOR INCLUSION IN TOTALS	
AGE, FOR GROWING STOCK	40.
M BD. FT., FOR GROWING STOCK	1.5
CU. FT., FOR COMMERCIAL CUT	300.
M BD. FT., FOR COMMERCIAL CUT	1.5
M BD. FT., FOR SALVAGE	1.5
CU. FT. IN SAW LOG CUT	100.
ACRES PLANTED ANNUALLY	1
PERCENT OF ACRES LOST ANNUALLY	.040
PSEUDORANDOM NUMBER GENERATOR	21.0
	2222.0

COSTS IN FIRST YEAR OF GAME	
PER ACRE (ANNUAL)	.20
PER 100 CU. FT. HARVESTED	.05
PER M BD. FT.	1.56
THIN ONE ACRE	25.00
PLANT ONE ACRE	30.00
CLEANUP OF ONE ACRE	25.00
RATE OF INCREASE IN COSTS	.01
RELATIVE VALUE OF INTERMEDIATE CUTS	
STUMPAGE PRICE, CU. FT.	1.00
STUMPAGE PRICE, BD. FT.	.85

PAGE TYPE 4

DISTRIBUTION OF OVERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.
YEAR WITHIN GAME 0

AGE(DECADE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	5	0	0	0	0	0	0	0	0	0	5
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	8	8	8	8	8	8	8	8	8	8	80
4	8	8	8	8	8	8	8	8	8	8	80
5	8	8	8	8	8	8	8	8	8	8	80
6	8	8	8	8	8	8	8	8	8	8	80
7	8	8	8	8	8	8	8	8	8	8	80
8	8	8	8	8	8	8	8	8	8	8	80
9	8	8	8	8	8	8	8	8	8	8	80
10	8	8	8	8	8	8	8	8	8	8	80
11	8	8	8	8	8	8	8	8	8	8	80
12	8	8	8	8	8	8	8	8	8	8	80
13	8	8	8	8	8	8	8	8	8	8	80
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

OISTRIBUTION OF UNDERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 0

AGE(OECAOE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	653	8	8	8	8	8	8	8	8	8	725
1	8	8	8	8	8	8	8	8	8	8	80
2	8	8	8	8	8	8	8	8	8	8	80
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

OISTRIBUTION OF OVERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 30

AGE(OECAOE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	0	1	0	0	1	0	0	1	0	0	3
1	1	0	0	1	0	1	0	0	1	0	4
2	0	1	0	0	1	1	1	1	1	1	7
3	9	8	8	8	8	8	8	8	8	8	81
4	8	8	8	8	8	8	8	8	8	8	80
5	8	8	8	8	8	8	8	8	8	8	80
6	8	8	8	8	8	8	8	8	8	8	80
7	8	8	8	8	8	8	8	6	8	8	78
8	8	8	8	8	8	8	8	8	8	8	80
9	8	8	7	7	8	8	8	8	8	8	78
10	8	8	8	8	8	8	8	8	7	7	78
11	8	8	8	8	8	8	8	8	8	8	80
12	8	8	8	8	7	7	8	8	8	8	78
13	8	6	8	8	8	8	8	8	8	8	78
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

DISTRIBUTION OF UNDERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.
YEAR WITHIN GAME 30

AGE(DECADE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	664	7	8	8	7	8	8	7	8	8	733
1	7	8	8	7	8	6	8	8	7	8	75
2	8	7	8	8	7	8	8	7	8	8	77
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

YEAR	ALLOWABLE CUT (1)	CUTTING AGE (2)	ACTUAL CUT CU.FT. (3)	ACTUAL CUT MBF (4)	CUMUL CUT CU.FT. (5)	CUMUL CUT MBF (6)	GRSTK VOL CU.FT. (7)	GRSTK VOL MBF (8)	TOTAL VOL CU.FT. (9)	TOTAL VOL MBF (10)
0	0	0	0	0	0	0	146122	7210	146122	7210
1	8	110	12179	248	12179	248	146122	7210	158301	7458
2	8	110	12179	248	24358	496	146122	7210	170480	7706
3	7	110	11873	254	36231	750	146122	7204	182353	7954
4	8	110	12180	249	48411	999	146122	7204	194533	8203
5	8	110	12180	249	60591	1248	146122	7203	206713	8451
6	7	110	11874	256	72465	1504	146122	7195	218587	8699
7	8	110	12181	249	84646	1753	146122	7194	230768	8947
8	8	110	12181	249	96827	2002	146122	7192	242949	9194
9	7	110	11876	251	108703	2253	146122	7189	254825	9442
10	8	110	12180	249	120883	2502	146122	7187	267005	9689
11	8	110	12180	249	133063	2751	146122	7186	279185	9937
12	7	110	11874	242	144937	2993	146122	7191	291059	10184
13	8	110	12181	249	157118	3242	146122	7189	303240	10431
14	8	110	12181	249	169299	3491	146122	7187	315421	10678
15	7	110	11876	257	181175	3748	146122	7177	327297	10925
16	8	110	12183	249	193358	3997	146122	7175	339480	11172
17	7	110	11876	242	205234	4239	146122	7179	351356	11418
18	8	110	12183	249	217417	4488	146122	7176	363539	11664
19	8	110	12183	249	229600	4737	146122	7173	375722	11910
20	7	110	11877	244	241477	4981	146122	7176	387599	12157
21	8	110	12184	250	253661	5231	146122	7172	399783	12403
22	8	110	12184	250	265845	5481	146122	7169	411967	12650
23	7	110	10397	240	276242	5721	146122	7177	422364	12898
24	8	110	12185	250	288427	5971	146122	7173	434549	13144
25	8	110	12185	250	300612	6221	146122	7168	446734	13389
26	7	110	11738	244	312350	6465	146122	7170	458472	13635
27	8	110	12187	247	324537	6712	146122	7168	470659	13880
28	8	110	12187	247	336724	6959	146122	7167	482846	14126
29	7	110	11739	249	348463	7208	146122	7163	494585	14371
30	8	110	12188	250	360651	7458	146122	7157	506773	14615

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

YEAR	NON STK (11)	AGE CLASSES, OVERSTORY 0-9 (12)	10-19 (13)	20-29 (14)	30-39 (15)	40-49 (16)	50-59 (17)	60-69 (18)	70-79 (19)	80-89 (20)	90-99 (21)	100-109 (22)	110-119 (23)	120-129 (24)	130-139 (25)	140-179 (26)
0	5	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
1	4	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
2	3	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
3	3	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
4	2	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
5	1	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
6	1	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
7	0	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
8	0	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
9	1	8	0	0	80	80	80	80	80	79	80	80	78	80	80	0
10	0	7	1	0	80	80	80	80	80	79	80	80	78	80	80	0
11	0	6	2	0	80	80	80	80	80	79	80	80	78	80	80	0
12	1	6	3	0	80	80	80	80	79	80	79	80	78	80	80	0
13	0	5	4	0	80	80	80	80	79	80	79	80	78	80	80	0
14	0	4	5	0	80	80	80	80	79	80	79	80	78	80	80	0
15	1	4	6	0	80	80	80	80	79	80	79	79	78	80	80	0
16	0	3	7	0	80	80	80	80	79	80	79	80	77	80	80	0
17	1	4	7	0	80	80	80	79	79	80	79	80	77	80	80	0
18	0	4	7	0	80	80	80	79	80	79	79	80	77	80	80	0
19	0	3	8	0	80	80	80	79	80	79	79	80	79	78	80	0
20	1	4	7	1	80	80	80	78	80	79	79	80	79	78	80	0
21	0	4	6	2	80	80	80	78	80	79	79	80	79	78	80	0
22	0	3	6	3	80	80	80	78	80	79	80	79	79	78	80	0
23	1	4	5	4	80	80	80	80	78	79	80	79	78	78	80	0
24	0	4	4	5	80	80	80	80	78	79	80	79	78	78	80	0
25	0	3	4	6	80	80	80	80	78	79	80	79	79	77	80	0
26	1	4	3	7	80	80	80	80	78	78	80	79	80	76	80	0
27	0	3	4	7	80	80	80	80	78	79	79	79	80	76	80	0
28	0	3	4	7	80	80	80	80	78	80	78	79	80	76	80	0
29	1	4	3	8	80	80	80	80	78	80	78	78	80	78	78	0
30	0	3	4	7	81	80	80	80	78	80	78	78	80	78	78	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

YEAR	NON STK (11)	AGE CLASSES, UNDERSTORY 0-9 (12)	10-19 (13)	20-29 (14)	30-39 (15)	40-49 (16)	50-59 (17)	60-69 (18)	70-79 (19)	80-89 (20)	90-99 (21)	100-109 (22)	110-119 (23)	120-129 (24)	130-139 (25)	140-179 (26)
0	5	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
1	4	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
2	3	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
3	3	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
4	2	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
5	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
6	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
7	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
8	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
9	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
10	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
11	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
12	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
13	0	726	79	80	0	0	0	0	0	0	0	0	0	0	0	0
14	0	726	79	80	0	0	0	0	0	0	0	0	0	0	0	0
15	1	726	79	80	0	0	0	0	0	0	0	0	0	0	0	0
16	0	727	78	80	0	0	0	0	0	0	0	0	0	0	0	0
17	1	727	78	80	0	0	0	0	0	0	0	0	0	0	0	0
18	0	727	78	80	0	0	0	0	0	0	0	0	0	0	0	0
19	0	728	77	80	0	0	0	0	0	0	0	0	0	0	0	0
20	1	728	77	80	0	0	0	0	0	0	0	0	0	0	0	0
21	0	728	77	80	0	0	0	0	0	0	0	0	0	0	0	0
22	0	729	76	80	0	0	0	0	0	0	0	0	0	0	0	0
23	1	729	77	79	0	0	0	0	0	0	0	0	0	0	0	0
24	0	729	77	79	0	0	0	0	0	0	0	0	0	0	0	0
25	0	731	75	79	0	0	0	0	0	0	0	0	0	0	0	0
26	1	731	76	78	0	0	0	0	0	0	0	0	0	0	0	0
27	0	732	75	78	0	0	0	0	0	0	0	0	0	0	0	0
28	0	732	75	78	0	0	0	0	0	0	0	0	0	0	0	0
29	1	732	76	77	0	0	0	0	0	0	0	0	0	0	0	0
30	0	733	75	77	0	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

YEAR	STUMPAGE PRICE 100 CU.FT. (27)	STUMPAGE PRICE MBF (28)	STUMPAGE INCOME ANNUAL (29)	STUMPAGE INCOME CUMULATED (30)	AREA COSTS ANNUAL (31)	AREA COSTS CUMULATED (32)	VOLUME COSTS ANNUAL (33)	VOLUME COSTS CUMULATED (34)
0	2.50	14.50	0.	0.	0.	0.	0.	0.
1	2.50	15.20	4025.	4025.	407.	407.	394.	394.
2	2.50	17.80	4661.	8686.	411.	818.	398.	791.
3	2.50	16.80	4461.	13147.	415.	1233.	411.	1202.
4	2.50	13.40	3588.	16735.	419.	1653.	406.	1608.
5	2.50	14.10	3759.	20494.	424.	2076.	410.	2018.
6	2.50	17.40	4634.	25128.	428.	2504.	426.	2444.
7	2.50	11.80	3199.	28327.	432.	2936.	419.	2863.
8	2.50	11.10	3027.	31354.	404.	3340.	423.	3286.
9	2.50	12.20	3290.	34644.	408.	3748.	431.	3717.
10	2.50	12.90	3465.	38110.	445.	4193.	431.	4148.
11	2.50	10.10	2779.	40889.	416.	4610.	435.	4583.
12	2.50	8.30	2271.	43160.	421.	5031.	429.	5012.
13	2.50	9.00	2512.	45672.	459.	5489.	445.	5456.
14	2.50	10.90	2978.	48651.	429.	5918.	449.	5906.
15	2.50	13.90	3776.	52426.	433.	6352.	468.	6373.
16	2.50	13.10	3522.	55948.	473.	6824.	459.	6832.
17	2.50	11.90	3127.	59075.	442.	7266.	450.	7282.
18	2.50	12.70	3423.	62498.	482.	7748.	468.	7750.
19	2.50	15.70	4160.	66658.	451.	8199.	472.	8222.
20	2.50	13.60	3548.	70207.	455.	8655.	467.	8689.
21	2.50	12.10	3279.	73486.	497.	9151.	483.	9171.
22	2.50	15.20	4042.	77528.	465.	9616.	487.	9659.
23	2.50	16.10	4030.	81558.	469.	10085.	472.	10130.
24	2.50	16.70	4415.	85973.	512.	10597.	498.	10628.
25	2.50	19.60	5129.	91102.	479.	11075.	503.	11131.
26	2.50	18.50	4697.	95799.	483.	11559.	496.	11626.
27	2.50	14.70	3888.	99687.	527.	12086.	507.	12133.
28	2.50	15.50	4083.	103770.	493.	12579.	512.	12645.
29	2.50	17.10	4437.	108207.	498.	13077.	521.	13166.
30	2.50	13.00	3512.	111719.	577.	13654.	529.	13696.

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.

YEAR	TOTAL COST ANNUAL (35)	TOTAL COST CUMULATED (36)	NET INCOME ANNUAL (37)	NET INCOME CUMULATED (38)	CURRENT VALUE GROWING STOCK (39)	TOTAL NET WORTH (40)
0	0.	0.	0.	0.	96878.	96878.
1	801.	801.	3224.	3224.	101925.	105149.
2	809.	1609.	3852.	7076.	120557.	127634.
3	826.	2435.	3635.	10711.	113145.	123856.
4	825.	3261.	2762.	13474.	88527.	102001.
5	834.	4094.	2926.	16400.	93444.	109843.
6	853.	4948.	3780.	20180.	116972.	137152.
7	851.	5799.	2348.	22528.	76547.	99075.
8	827.	6626.	2200.	24728.	71378.	96107.
9	839.	7465.	2451.	27179.	79131.	106310.
10	876.	8341.	2589.	29768.	84028.	113796.
11	852.	9193.	1927.	31696.	63770.	95466.
12	849.	10042.	1422.	33118.	50744.	83862.
13	903.	10946.	1609.	34727.	55637.	90364.
14	878.	11824.	2100.	36827.	69151.	105978.
15	901.	12725.	2875.	39702.	90464.	130165.
16	931.	13656.	2591.	42292.	84561.	126853.
17	892.	14548.	2234.	44527.	75865.	120391.
18	950.	15498.	2474.	47000.	81443.	128443.
19	923.	16421.	3237.	50237.	102798.	153035.
20	922.	17343.	2626.	52863.	87631.	140494.
21	979.	18323.	2300.	55163.	76695.	131859.
22	952.	19275.	3090.	58253.	98745.	156998.
23	941.	20215.	3090.	61343.	105173.	166516.
24	1009.	21225.	3406.	64748.	109277.	174025.
25	981.	22206.	4147.	68896.	129861.	198757.
26	979.	23185.	3718.	72614.	121859.	194473.
27	1034.	24219.	2854.	75467.	94448.	169915.
28	1005.	25225.	3078.	78545.	100013.	178558.
29	1019.	26244.	3419.	81963.	111275.	193238.
30	1106.	27350.	2406.	84369.	81699.	166068.

PAGE TYPE 6

PRESENT WORTH AND RATE EARNED
BATCH SHELTERWOOD TEST
TEST 1
GAME EQUAL AREAS CUT ANNUALLY
MANAGED, THINNED AT AGE 30.
YEARS IN PERIOD 30

VALUE OF INITIAL GROWING STOCK--$ 96877.59

VALUES DISCOUNTED TO PRESENT (DOLLARS)

COMPOUND RATE (PERCENT)	FUTURE GROWING STOCK	ALL INCOMES	STOCK PLUS INCOMES	ALL COSTS	NET PRESENT WORTH
1.0	60614.17	95822.44	156436.61	23367.41	36191.62
1.5	52267.79	89061.09	141328.88	21671.91	22779.39
2.0	45103.50	82970.09	128073.59	20143.59	11052.40
2.5	38949.28	77472.88	116422.16	18763.50	781.07
3.0	33658.80	72502.45	106161.26	17515.01	-8231.34
3.5	29107.50	68000.03	97107.53	16383.54	-16153.59
4.0	25189.25	63914.01	89103.26	15356.29	-23130.61
4.5	21813.57	60199.03	82012.60	14421.98	-29286.97
5.0	18903.25	56815.16	75718.41	13570.71	-34729.89
5.5	16392.36	53727.21	70119.57	12793.71	-39551.73
6.0	14224.58	50904.11	65128.69	12083.26	-43832.16
6.5	12351.71	48318.42	60670.13	11432.53	-47639.98
7.0	10732.53	45945.87	56678.40	10835.45	-51034.63
7.5	9331.71	43764.95	53096.67	10286.67	-54067.59
8.0	8119.00	41756.58	49875.58	9781.43	-56783.43
8.5	7068.43	39903.81	46972.24	9315.48	-59220.82
9.0	6157.73	38191.57	44349.30	8885.06	-61413.34
9.5	5367.74	36606.46	41974.20	8486.81	-63390.19
10.0	4682.04	35136.49	39818.53	8117.72	-65176.78
10.5	4086.46	33771.00	37857.46	7775.12	-66795.25

PAGE TYPE 3

ALTERNATIVES FOR THIS GAME
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

NUMBER OF YEARS PER GAME 30

CRITICAL PRICES	12.00	15.00	99.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ALLOWABLE CUT	5	8	12	0	0	0	0	0	0	0
MINIMUM CUTTING AGE	110.	110.	110.	0.	0.	0.	0.	0.	0.	0.

ACRES IN WORKING CIRCLE	885
MINIMUM VALUES FOR INCLUSION IN TOTALS	
AGE, FOR GROWING STOCK	40.
M BD. FT., FOR GROWING STOCK	1.5
CU. FT., FOR COMMERCIAL CUT	300.
M BD. FT., FOR COMMERCIAL CUT	1.5
M BD. FT., FOR SALVAGE	1.5
CU. FT. IN SAW LOG CUT	100.
ACRES PLANTED ANNUALLY	1
PERCENT OF ACRES LOST ANNUALLY	.040
PSEUDORANDOM NUMBER GENERATOR	21.0 2222.0

COSTS IN FIRST YEAR OF GAME	
PER ACRE (ANNUAL)	.20
PER 100 CU. FT. HARVESTED	.05
PER M BD. FT.	1.56
THIN ONE ACRE	25.00
PLANT ONE ACRE	30.00
CLEANUP OF ONE ACRE	25.00
RATE OF INCREASE IN COSTS	.01
RELATIVE VALUE OF INTERMEDIATE CUTS	
STUMPAGE PRICE, CU. FT.	1.00
STUMPAGE PRICE, BD. FT.	.85

PAGE TYPE 4

OISTRIBUTION OF OVERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST I
GAME VARY CUT WITH PRICE
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 0

	AGE(YEAR)										
AGE(OECAOE)	0	1	2	3	4	5	6	7	8	9	TOTAL
0	5	0	0	0	0	0	0	0	0	0	5
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	8	8	8	8	8	8	8	8	8	8	80
4	8	8	8	8	8	8	8	8	8	8	80
5	8	8	8	8	8	8	8	8	8	8	80
6	8	8	8	8	8	8	8	8	8	8	80
7	8	8	8	8	8	8	8	8	8	8	80
8	8	8	8	8	8	8	8	8	8	8	80
9	8	8	8	8	8	8	8	8	8	8	80
10	8	8	8	8	8	8	8	8	8	8	80
11	8	8	8	8	8	8	8	8	8	8	80
12	8	8	8	8	8	8	8	8	8	8	80
13	8	8	8	8	8	8	8	8	8	8	80
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

OISTRIBUTION OF UNOERSTORY ACRES BY AGE
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 0

	AGE(YEAR)										
AGE(OECAOE)	0	1	2	3	4	5	6	7	8	9	TOTAL
0	653	8	8	8	8	8	8	8	8	8	725
1	8	8	8	8	8	8	8	8	8	8	80
2	8	8	8	8	8	8	8	8	8	8	80
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

OISTRIBUTION OF OVERSTORY ACRES BY AGE
BATCH SHELTERWOOO TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 30

AGE(OECAOE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	0	1	0	0	1	0	0	1	0	0	3
1	1	0	0	1	0	1	0	0	1	0	4
2	0	1	0	0	1	1	1	1	1	1	7
3	9	8	8	8	8	8	8	8	8	8	81
4	8	8	8	8	8	8	8	8	8	8	80
5	8	8	8	8	8	8	8	8	8	8	80
6	8	8	8	8	8	8	8	8	8	8	80
7	8	8	8	8	8	8	8	6	8	8	78
8	8	8	8	8	8	8	8	8	8	8	80
9	8	8	7	7	8	8	8	8	8	8	78
10	8	8	8	8	8	8	8	8	7	7	78
11	8	8	8	8	8	8	8	8	8	8	80
12	8	8	8	8	7	7	8	8	8	8	78
13	8	6	8	8	8	8	8	8	8	8	78
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 4

OISTRIBUTION OF UNOERSTORY ACRES BY AGE
BATCH SHELTERWOOO TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGEO, THINNEO AT AGE 30.
YEAR WITHIN GAME 30

AGE(OECAOE)	AGE(YEAR) 0	1	2	3	4	5	6	7	8	9	TOTAL
0	657	8	9	8	11	12	12	11	12	8	748
1	7	12	8	3	8	7	5	5	4	5	64
2	8	7	5	5	8	8	8	8	8	8	73
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

YEAR	ALLOWABLE CUT (1)	CUTTING AGE (2)	ACTUAL CUT CU.FT. (3)	ACTUAL CUT MBF (4)	CUMUL CUT CU.FT. (5)	CUMUL CUT MBF (6)	GRSTK VOL CU.FT. (7)	GRSTK VOL MBF (8)	TOTAL VOL CU.FT. (9)	TOTAL VOL MBF (10)
0	0	0	0	0	0	0	146122	7210	146122	7210
1	8	110	12179	248	12179	248	146122	7210	158301	7458
2	8	110	12179	248	24358	496	146122	7210	170480	7706
3	8	110	12179	266	36537	762	146122	7192	182659	7954
4	8	110	12179	248	48716	1010	146122	7192	194838	8202
5	8	110	12179	248	60895	1258	146122	7191	207017	8449
6	8	110	12179	268	73074	1526	146122	7172	219196	8698
7	5	110	11262	212	84336	1738	146122	7207	230458	8945
8	5	110	11265	213	95601	1951	146122	7241	241723	9192
9	7	110	11881	252	107482	2203	146122	7237	253604	9440
10	8	110	12185	250	119667	2453	146122	7234	265789	9687
11	5	110	11268	214	130935	2667	146122	7268	277057	9935
12	4	110	10961	207	141896	2874	146122	7306	288018	10180
13	5	110	11276	215	153172	3089	146122	7336	299294	10425
14	5	110	11278	215	164450	3304	146122	7365	310572	10669
15	7	110	11901	261	176351	3565	146122	7350	322473	10915
16	8	110	12212	254	188563	3819	146122	7343	334685	11162
17	4	110	10976	209	199539	4028	146122	7377	345661	11405
18	8	110	12222	255	211761	4283	146122	7369	357883	11652
19	12	110	13456	305	225217	4588	146122	7315	371339	11903
20	7	110	11901	247	237118	4835	146122	7313	383240	12148
21	8	110	12212	254	249330	5089	146122	7305	395452	12394
22	12	110	13446	304	262776	5393	146122	7251	408898	12644
23	11	110	11784	300	274560	5693	146122	7200	420682	12893
24	12	110	13425	301	287985	5994	146122	7148	434107	13142
25	12	110	13412	299	301397	6293	146122	7094	447519	13387
26	11	110	13101	300	314498	6593	146122	7038	460620	13631
27	8	110	11755	220	326253	6813	146122	7064	472375	13877
28	9	110	12061	232	338314	7045	146122	7077	484436	14122
29	8	110	12037	259	350351	7304	146122	7063	496473	14367
30	8	110	12179	248	362530	7552	146122	7059	508652	14611

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

YEAR	NON STK (11)	0-9 (12)	10-19 (13)	20-29 (14)	30-39 (15)	40-49 (16)	50-59 (17)	60-69 (18)	70-79 (19)	80-89 (20)	90-99 (21)	100-109 (22)	110-119 (23)	120-129 (24)	130-139 (25)	140-179 (26)
		AGE CLASSES, OVERSTORY														
0	5	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
1	4	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
2	3	5	0	0	80	80	80	80	80	80	80	80	80	80	80	0
3	3	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
4	2	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
5	1	6	0	0	80	80	80	80	80	80	80	79	80	80	80	0
6	1	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
7	0	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
8	0	7	0	0	80	80	80	80	80	80	80	78	80	80	80	0
9	1	8	0	0	80	80	80	80	80	79	80	80	78	80	80	0
10	0	7	1	0	80	80	80	80	80	79	80	80	78	80	80	0
11	0	6	2	0	80	80	80	80	80	79	80	80	78	80	80	0
12	1	6	3	0	80	80	80	80	79	80	79	80	78	80	80	0
13	0	5	4	0	80	80	80	80	79	80	79	80	78	80	80	0
14	0	4	5	0	80	80	80	80	79	80	79	80	78	80	80	0
15	1	4	6	0	80	80	80	80	79	80	79	79	78	80	80	0
16	0	3	7	0	80	80	80	80	79	80	79	80	77	80	80	0
17	1	4	7	0	80	80	80	79	79	80	79	80	77	80	80	0
18	0	4	7	0	80	80	80	79	80	79	79	80	77	80	80	0
19	0	3	8	0	80	80	80	79	80	79	79	80	79	78	80	0
20	1	4	7	1	80	80	80	78	80	79	79	80	79	78	80	0
21	0	4	6	2	80	80	80	78	80	79	79	80	79	78	80	0
22	0	3	6	3	80	80	80	78	80	79	80	79	79	78	80	0
23	1	4	5	4	80	80	80	80	78	79	80	79	78	78	80	0
24	0	4	4	5	80	80	80	80	78	79	80	79	78	78	80	0
25	0	3	4	6	80	80	80	80	78	79	80	79	79	77	80	0
26	1	4	3	7	80	80	80	80	78	78	80	79	80	76	80	0
27	0	3	4	7	80	80	80	80	78	79	79	79	80	76	80	0
28	0	3	4	7	80	80	80	80	78	80	78	79	80	76	80	0
29	1	4	3	8	80	80	80	80	78	80	78	78	80	78	78	0
30	0	3	4	7	81	80	80	80	78	80	78	78	80	78	78	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

YEAR	NON STK (11)	0-9 (12)	10-19 (13)	20-29 (14)	30-39 (15)	40-49 (16)	50-59 (17)	60-69 (18)	70-79 (19)	80-89 (20)	90-99 (21)	100-109 (22)	110-119 (23)	120-129 (24)	130-139 (25)	140-179 (26)
		AGE CLASSES, UNDERSTORY														
0	5	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
1	4	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
2	3	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
3	3	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
4	2	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
5	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
6	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
7	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
8	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
9	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
10	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
11	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
12	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
13	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
14	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
15	1	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
16	0	725	80	80	0	0	0	0	0	0	0	0	0	0	0	0
17	1	728	77	80	0	0	0	0	0	0	0	0	0	0	0	0
18	0	731	74	80	0	0	0	0	0	0	0	0	0	0	0	0
19	0	732	73	80	0	0	0	0	0	0	0	0	0	0	0	0
20	1	732	73	80	0	0	0	0	0	0	0	0	0	0	0	0
21	0	735	70	80	0	0	0	0	0	0	0	0	0	0	0	0
22	0	739	66	80	0	0	0	0	0	0	0	0	0	0	0	0
23	1	742	63	80	0	0	0	0	0	0	0	0	0	0	0	0
24	0	745	60	80	0	0	0	0	0	0	0	0	0	0	0	0
25	0	746	59	80	0	0	0	0	0	0	0	0	0	0	0	0
26	1	746	59	80	0	0	0	0	0	0	0	0	0	0	0	0
27	0	751	57	77	0	0	0	0	0	0	0	0	0	0	0	0
28	0	751	60	74	0	0	0	0	0	0	0	0	0	0	0	0
29	1	747	65	73	0	0	0	0	0	0	0	0	0	0	0	0
30	0	748	64	73	0	0	0	0	0	0	0	0	0	0	0	0

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

YEAR	STUMPAGE PRICE 100 CU.FT. (27)	MBF (28)	STUMPAGE INCOME ANNUAL (29)	CUMULATED (30)	AREA COSTS ANNUAL (31)	CUMULATED (32)	VOLUME COSTS ANNUAL (33)	CUMULATED (34)
0	2.50	14.50	0.	0.	0.	0.	0.	0.
1	2.50	15.20	4025.	4025.	407.	407.	394.	394.
2	2.50	17.80	4661.	8686.	411.	818.	398.	791.
3	2.50	16.80	4671.	13356.	415.	1233.	430.	1221.
4	2.50	13.40	3584.	16940.	419.	1653.	406.	1627.
5	2.50	14.10	3755.	20696.	424.	2076.	410.	2037.
6	2.50	17.40	4846.	25541.	428.	2504.	445.	2482.
7	2.50	11.80	2744.	28286.	432.	2936.	358.	2840.
8	2.50	11.10	2608.	30893.	404.	3340.	363.	3202.
9	2.50	12.20	3303.	34197.	408.	3748.	433.	3635.
10	2.50	12.90	3480.	37677.	445.	4193.	433.	4068.
11	2.50	10.10	2404.	40080.	416.	4610.	375.	4443.
12	2.50	8.30	1956.	42037.	421.	5031.	367.	4810.
13	2.50	9.00	2183.	44220.	459.	5489.	384.	5194.
14	2.50	10.90	2587.	46807.	429.	5918.	389.	5582.
15	2.50	13.90	3830.	50637.	433.	6352.	475.	6057.
16	2.50	13.10	3580.	54217.	473.	6824.	467.	6524.
17	2.50	11.90	2705.	56923.	442.	7266.	388.	6912.
18	2.50	12.70	3495.	60417.	482.	7748.	478.	7390.
19	2.50	15.70	5064.	65481.	451.	8199.	577.	7967.
20	2.50	13.60	3598.	69079.	455.	8655.	473.	8440.
21	2.50	12.10	3330.	72409.	497.	9151.	490.	8931.
22	2.50	15.20	4896.	77305.	465.	9616.	592.	9523.
23	2.50	16.10	5041.	82346.	469.	10085.	590.	10113.
24	2.50	16.70	5299.	87645.	512.	10597.	599.	10712.
25	2.50	19.60	6117.	93762.	479.	11075.	600.	11312.
26	2.50	18.50	5775.	99538.	483.	11559.	609.	11921.
27	2.50	14.70	3474.	103012.	527.	12086.	451.	12373.
28	2.50	15.50	3841.	106853.	493.	12579.	481.	12853.
29	2.50	17.10	4622.	111474.	498.	13077.	543.	13396.
30	2.50	13.00	3486.	114961.	577.	13654.	525.	13921.

PAGE TYPE 5

STATUS OF FOREST AT END OF EACH YEAR
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.

YEAR	TOTAL COST ANNUAL (35)	TOTAL COST CUMULATED (36)	NET INCOME ANNUAL (37)	NET INCOME CUMULATED (38)	CURRENT VALUE GROWING STOCK (39)	TOTAL NET WORTH (40)
0	0.	0.	0.	0.	96878.	96878.
1	801.	801.	3224.	3224.	101925.	105149.
2	809.	1609.	3852.	7076.	120557.	127634.
3	845.	2455.	3825.	10902.	112962.	123864.
4	825.	3280.	2759.	13661.	88388.	102049.
5	833.	4113.	2922.	16583.	93301.	109884.
6	873.	4986.	3973.	20556.	116607.	137163.
7	790.	5776.	1955.	22510.	76683.	99193.
8	767.	6542.	1841.	24351.	71842.	96193.
9	841.	7383.	2463.	26814.	79636.	106450.
10	878.	8261.	2602.	29415.	84554.	113969.
11	791.	9053.	1613.	31028.	64456.	95484.
12	787.	9840.	1169.	32197.	51493.	83690.
13	843.	10683.	1340.	33537.	56696.	90233.
14	818.	11500.	1770.	35306.	70769.	106076.
15	908.	12408.	2922.	38228.	92552.	130780.
16	939.	13348.	2641.	40870.	86459.	127328.
17	830.	14178.	1875.	42744.	77863.	120607.
18	960.	15138.	2535.	45279.	83539.	128818.
19	1028.	16166.	4036.	49315.	104755.	154070.
20	929.	17095.	2669.	51984.	89233.	141217.
21	987.	18082.	2343.	54327.	78047.	132374.
22	1057.	19139.	3839.	58167.	99832.	157998.
23	1059.	20198.	3981.	62148.	105508.	167656.
24	1110.	21308.	4189.	66337.	108907.	175244.
25	1079.	22387.	5038.	71375.	128548.	199924.
26	1093.	23480.	4682.	76057.	119690.	195747.
27	979.	24459.	2496.	78553.	93120.	171673.
28	974.	25432.	2867.	81420.	98806.	180226.
29	1041.	26473.	3581.	85001.	109771.	194772.
30	1102.	27575.	2384.	87386.	80629.	168015.

PAGE TYPE 6

PRESENT WORTH AND RATE EARNED
BATCH SHELTERWOOD TEST
TEST 1
GAME VARY CUT WITH PRICE
MANAGED, THINNED AT AGE 30.
YEARS IN PERIOD 30

VALUE OF INITIAL GROWING STOCK--$ 96877.59

VALUES DISCOUNTED TO PRESENT (DOLLARS)

COMPOUND RATE (PERCENT)	FUTURE GROWING STOCK	ALL INCOMES	STOCK PLUS INCOMES	ALL COSTS	NET PRESENT WORTH
1.0	59820.71	98225.77	158046.48	23515.58	37653.31
1.5	51583.58	91122.91	142706.49	21789.26	24039.64
2.0	44513.08	84733.69	129246.77	20234.40	12134.78
2.5	38439.42	78976.23	117415.64	18831.48	1706.58
3.0	33218.19	73778.79	106996.99	17563.40	-7444.00
3.5	28726.47	69078.51	97804.98	16415.18	-15487.79
4.0	24859.51	64820.17	89679.69	15373.64	-22571.54
4.5	21528.02	60955.27	82483.29	14427.20	-28821.50
5.0	18655.80	57441.11	76096.91	13565.67	-34346.35
5.5	16177.78	54240.08	70417.86	12780.03	-39239.76
6.0	14038.37	51318.98	65357.36	12062.37	-43582.60
6.5	12190.02	48648.53	60838.55	11405.64	-47444.68
7.0	10592.04	46202.80	56794.84	10803.65	-50886.40
7.5	9209.56	43958.86	53168.42	10250.88	-53960.05
8.0	8012.72	41896.36	49909.08	9742.44	-56710.95
8.5	6975.91	39997.24	46973.15	9274.00	-59178.43
9.0	6077.12	38245.48	44322.60	8841.68	-61396.66
9.5	5297.48	36626.80	41924.28	8442.04	-63395.35
10.0	4620.75	35128.48	39749.23	8072.00	-65200.36
10.5	4032.96	33739.18	37772.15	7728.84	-66834.28

PAGE TYPE 7

COMPARISON OF ALTERNATIVES
BATCH SHELTERWOOD TEST
TEST 1
MANAGED, THINNED AT AGE 30.
COLUMN 10

YEAR	GAME 1	GAME 2	GAME 3	GAME 4	GAME 5	GAME 6	GAME 7	GAME 8	GAME 9	GAME 10
1	7458.	7458.	0.	0.	0.	0.	0.	0.	0.	0.
2	7706.	7706.	0.	0.	0.	0.	0.	0.	0.	0.
3	7954.	7954.	0.	0.	0.	0.	0.	0.	0.	0.
4	8203.	8202.	0.	0.	0.	0.	0.	0.	0.	0.
5	8451.	8449.	0.	0.	0.	0.	0.	0.	0.	0.
6	8699.	8698.	0.	0.	0.	0.	0.	0.	0.	0.
7	8947.	8945.	0.	0.	0.	0.	0.	0.	0.	0.
8	9194.	9192.	0.	0.	0.	0.	0.	0.	0.	0.
9	9442.	9440.	0.	0.	0.	0.	0.	0.	0.	0.
10	9689.	9687.	0.	0.	0.	0.	0.	0.	0.	0.
10	9689.	9687.	0.	0.	0.	0.	0.	0.	0.	0.
20	12157.	12148.	0.	0.	0.	0.	0.	0.	0.	0.
30	14615.	14611.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
70	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
110	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
120	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
130	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
140	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
150	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

PAGE TYPE 7

COMPARISON OF ALTERNATIVES
BATCH SHELTERWOOD TEST
TEST 1
MANAGED, THINNED AT AGE 30.
COLUMN 40

YEAR	GAME 1	GAME 2	GAME 3	GAME 4	GAME 5	GAME 6	GAME 7	GAME 8	GAME 9	GAME 10
1	105149.	105149.	0.	0.	0.	0.	0.	0.	0.	0.
2	127634.	127634.	0.	0.	0.	0.	0.	0.	0.	0.
3	123856.	123864.	0.	0.	0.	0.	0.	0.	0.	0.
4	102001.	102049.	0.	0.	0.	0.	0.	0.	0.	0.
5	109843.	109884.	0.	0.	0.	0.	0.	0.	0.	0.
6	137152.	137163.	0.	0.	0.	0.	0.	0.	0.	0.
7	99075.	99193.	0.	0.	0.	0.	0.	0.	0.	0.
8	96107.	96193.	0.	0.	0.	0.	0.	0.	0.	0.
9	106310.	106450.	0.	0.	0.	0.	0.	0.	0.	0.
10	113796.	113969.	0.	0.	0.	0.	0.	0.	0.	0.
10	113796.	113969.	0.	0.	0.	0.	0.	0.	0.	0.
20	140494.	141217.	0.	0.	0.	0.	0.	0.	0.	0.
30	166068.	168015.	0.	0.	0.	0.	0.	0.	0.	0.
40	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
50	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
60	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
70	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
100	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
110	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
120	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
130	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
140	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
150	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

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Myers, Clifford A.
1973. Simulating changes in even-aged timber stands. USDA For. Serv. Res. Pap. RM-109, **47** p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Growth and volume relationships are assembled in a computer program, written in FORTRAN IV, that simulates timber management by shelterwood, seed tree, or clearcutting systems. Tree growth, intermediate and regeneration cuts, planting, and catastrophic losses are among the changes computed. Annual and periodic costs and returns, analysis of rate earned, and other statements of volume and value are printed. Supersedes USDA For. Serv. Res. Pap. RM-42.

Oxford: 524.37:U681.3. **Keywords:** Stand yield tables, timber management, forest management, simulation, *Pinus ponderosa, Pinus contorta.*

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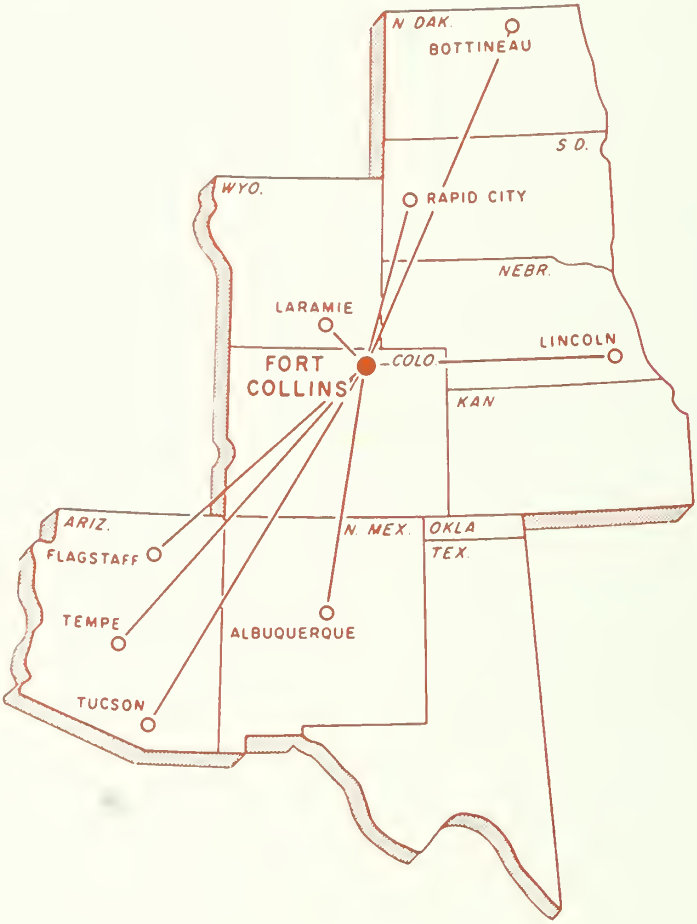
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PARTIAL CUTTING IN OLD-GROWTH SPRUCE-FIR

by Robert R. Alexander

Abstract

Guidelines are provided to aid the forest manager in developing partial cutting practices needed to convert old-growth spruce-fir forests into managed stands, while maintaining continuous forest cover in travel influence zones and areas of high recreational values or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk, and insect susceptibility. The cutting practices can be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, to improve wildlife habitat, and to integrate timber production with other uses. They can also be used on areas that are difficult to regenerate where timber production is the primary objective.

Oxford: 221.42:421.1. **Keywords:** Partial cutting, windthrow, multiple use (forest resources), *Picea engelmannii, Abies lasiocarpa.*

About the cover:

Group selection cutting in spruce-fir on the Fraser Experimental Forest. About half the volume was removed from a third of the area in group cuttings about one tree height in diameter. Subsequent blowdown losses were light.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

USDA Forest Service
Research Paper RM-110

July 1973

Partial Cutting in Old-Growth Spruce-Fir

by

Robert R. Alexander
Principal Silviculturist

Rocky Mountain Forest and Range Experiment Station[1]

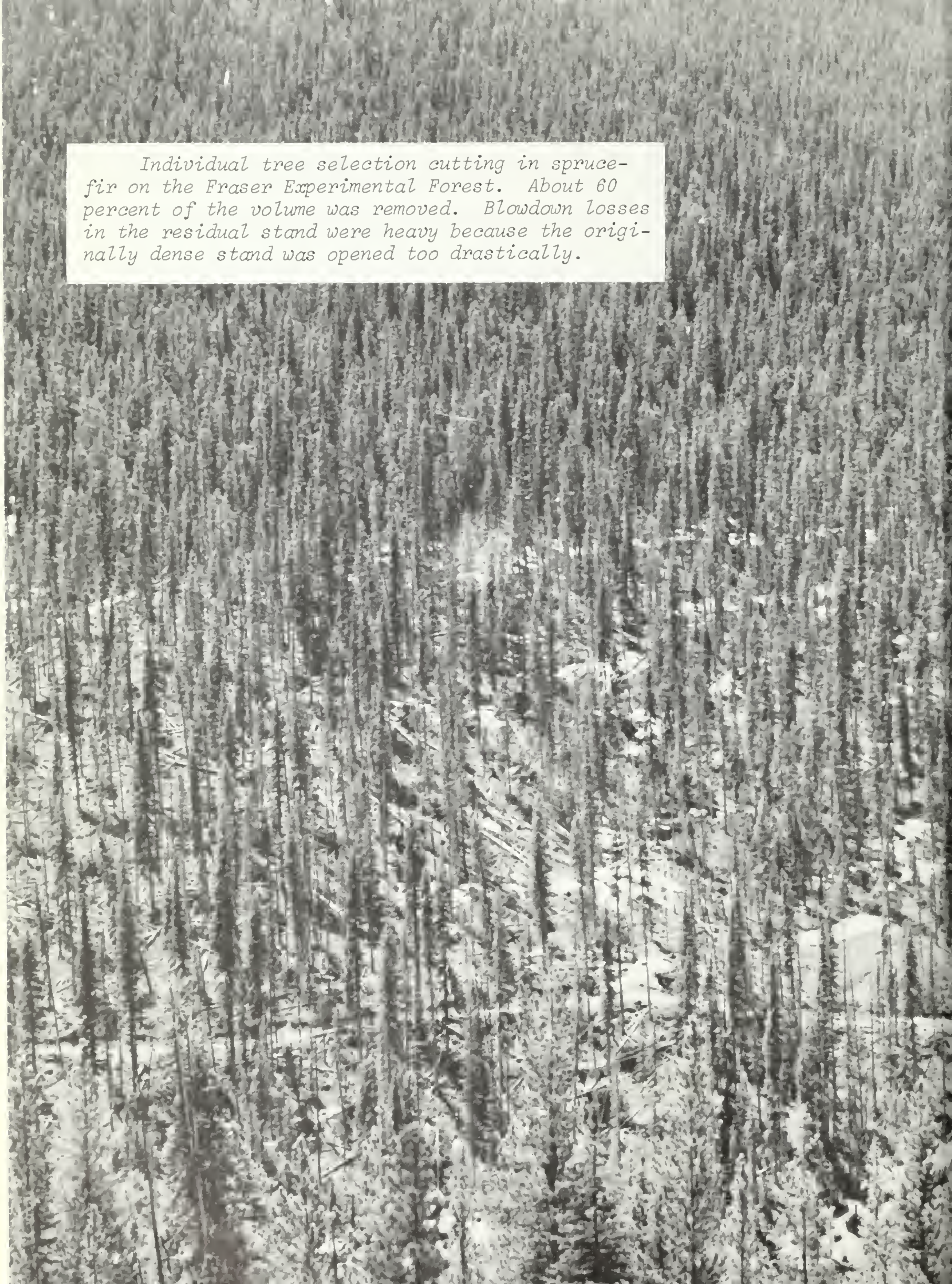
[1]*Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

Contents

Author's Preface

This publication supersedes Research Paper RM-76, "Initial partial cutting in old-growth spruce-fir," in which I provided guidelines for initial cutting only. The revisions and improvements to the original are in response to requests by users for information on how stands should be handled after the initial harvest, and for practices needed to obtain natural regeneration after partial cutting. Other changes are the result of greater insight obtained by applying those original guidelines in field studies.

For convenient field use, the stand descriptions and cutting guides in this Research Paper were published separately in a smaller format as USDA Forest Service Research Paper RM-76A, "Initial Partial Cutting in Old-Growth Spruce-Fir — Field Guide to Stand Descriptions and Cutting Practices." Although it contains suggested practices only for initial entry, information in this original Field Guide is still appropriate, and can be used in conjunction with the newer guidelines published here. Copies of RM-76A are available from the Rocky Mountain Forest and Range Experiment Station, 240 West Prospect Street, Fort Collins, Colorado 80521.



Individual tree selection cutting in spruce-fir on the Fraser Experimental Forest. About 60 percent of the volume was removed. Blowdown losses in the residual stand were heavy because the originally dense stand was opened too drastically.

Partial Cutting in Old-Growth Spruce-Fir

Robert R. Alexander

INTRODUCTION

The Engelmann spruce (Picea engelmannii
'arry) — subalpine fir (Abies lasiocarpa (Hook.)
Nutt.) type is the largest and most productive imber resource in the central Rocky Mountains Choate 1963, Miller and Choate 1964). A large roportion of the spruce-fir type is in overmature awtimber stands that offer little opportunity or management, however, because of their dvanced age, relatively slow growth, and suseptibility to wind and insects. Also, many of hese natural stands developed after fires or ther disturbances and do not have an all-aged tructure. Therefore, forest managers concerned vith timber production have most often elected o convert this old-growth to managed evenged stands.[2] Harvesting and regeneration ractices developed in the central Rocky Mounains have therefore been directed toward learcutting.

In addition to being the most productive imber type in the central Rocky Mountains, owever, spruce-fir forests are also the highest 'ater yielding, and are valuable wildlife, recretion, and scenic areas. Because of increasing emands on forest lands from a rapidly xpanding population and the limited resource vailable, management must consider all key nd uses. The visual and environmental impacts f clearcutting for timber production are not ways compatible with the objectives of other ey uses. Furthermore, many areas have been ifficult to regenerate after clearcutting.

The next section describes the form, strucre, and arrangement of stands that are esirable for increased water yields, improveent of wildlife habitat, preservation of the forest landscape, and maintenance of scenic values. Silvicultural practices are later developed that can be used alone or in combination with small cleared openings to maintain forest cover while gradually replacing the old stand with a healthy, vigorous new one.

[2] *Considerable literature is available on the silvical aracteristics of spruce, and spruce regeneration requireents and practices for timber production, but that work ill not be reviewed here. Good discussions are esented by Alexander (1958), Roe et al. (1970), and in manuscript Alexander is preparing on "Silviculture of balpine forests in the central and southern Rocky ountains: The state of the art," to be published in e Research Paper RM- series.*

MULTIPLE-USE SILVICULTURE

Water

Water-yield studies have indicated that the increase in snow depth in openings cut in spruce-fir forests is not additional snow but a change in deposition pattern (Hoover and Leaf 1967). Snow blows off adjacent standing trees and settles in the openings. The increased snow in the openings means that more water is available for streamflow. Research and experience suggest that a round or patch-shaped opening, about five to eight times (in diameter) the height of surrounding trees, is the most effective for trapping snow (Hoover 1969). In larger openings, wind dips to the ground and scours and blows snow out of the opening.

About one-third of the forest area should be in openings, which would be periodically recut when tree height reaches one-half the height of surrounding trees. The remaining two-thirds of the area would be retained as continuous high forest; trees would be periodically harvested on an individual tree basis. Ultimately the reserve stand would approach an all-aged structure with the overstory canopy remaining at about the same height, although the original overstory could not be maintained indefinitely.

An alternative would be to make a light cut distributed over the entire watershed, removing about 20 to 30 percent of the basal area on an individual-tree basis or in small groups. The objective would be to open up the stand enough to develop windfirmness, and salvage low-vigor and poor-risk trees. Openings five to eight times tree height could then be cut on about one-third of the area. The remaining two-thirds of the area would be retained as permanent high forest, with trees periodically removed on an individual-tree basis or in small groups.

Another alternative that would integrate water and timber production would be to harvest all the old-growth in a cutting block in a series of cuts spread over a period of 120 to 160 years. Each cutting block would contain at least 300 acres, subdivided into round or patch-shaped units approximately 2 acres in size or four to five times (in diameter) the height of a general canopy level. At periodic intervals, some of these units, distributed over the cutting block, would be harvested and the openings regenerated. The interval between cuttings could vary from as often as every 10 years to as infrequently as every 30 to 40 years. The percentage of units cut at each interval would be determined by Cutting cycle/Rotation age times 100. At the end of one rotation, each cutting block would be composed of groups of trees in several age classes ranging from reproduction to trees ready for harvest. The height of the tallest trees would be somewhat less than the original overstory, but any adverse effect on snow deposition should be minimized by keeping the openings small and widely spaced.

Wildlife

Big game use of spruce-fir forests can be improved by certain timber cutting practices.

Openings of less than 20 acres cut in the canopy of spruce-fir forests in Arizona were heavily used by desert mule deer (Odocoileus hemionus Rafinesque) and American elk (Cervus canadensis (Erxleben) Reynolds), but use decreased considerably in larger openings (Reynolds 1966). Openings created by harvesting were preferred to natural openings because the vegetation that initially comes in on cutovers is more palatable to deer and elk. Reynolds suggested that openings be maintained by cleaning up the logging slash and debris, removing new tree reproduction, and seeding the area to forage species palatable to big game. However, since the more palatable species are likely to be replaced during natural succession on the cutover areas, a more desirable alternative would be to cut new openings periodically while allowing the older cuttings to regenerate. That would provide a constant source of palatable forage and the edge effect desired, while creating an all-aged forest by even-aged groups. The openings created should be widely spaced, with the stand between openings maintained as high forest.

On the Fraser Experimental Forest in Colorado, Rocky Mountain mule deer use in spruce-fir forests was greater and forage more abundant on cleared openings than in the uncut forest (Wallmo 1969). Clearcut openings 3 chains wide were used more than wider or narrower openings. Forage production appears to decline about 10 years after cutting, however, as tree reproduction replaces forage species (Wallmo et al. 1972). While no recommendations were made as to optimum size or arrangement of openings, the Fraser study suggests that they be kept small and interspersed with standing trees that could be periodically harvested on an individual tree basis.

One alternative that would integrate wildlife habitat improvement with timber production would be to cut about one-sixth of a cutting block every 20 years in openings about four to five times tree height. Each Working Circle would be subdivided into a number of cutting blocks (of at least 300 acres) so that not all periodic cuts would be made in a single year on a Working Circle. Such periodic cutting would provide a good combination of numbers and species of palatable forage plants and the edge effect desired, while creating a several-aged forest of even-aged groups.

Wildlife other than big game is also influenced by the way forests are handled. For example, with the curtailment of wildfires, some reduction in stand density by logging is probably necessary to create or maintain drumming grounds for male blue grouse (Dendragapus obscurus Say). Partial cutting that opens up the canopy enough to allow tree regeneration to become established in scattered thickets appears to provide the most desirable habitat. Cutting small, irregularly shaped openings (up to 10 acres) in the canopy may also be beneficial to blue grouse, if thickets of new reproduction become established in the cleared openings (Martinka 1972).

Recreation and Esthetics

Permanent forest cover at least in part is preferred in recreation areas, travel influence zones, and scenic view areas. Since old-growth spruce-fir forests will not maintain themselves in an esthetically pleasing or sound condition indefinitely, some form of partial cutting can help retain forest cover while at the same time replacing the old with a new stand. However, the visual impact of logging operations — haul roads, damage to residual trees, and slash and debris — must be minimized. In situations where there is no harvesting alternative to clearcutting, and the environmental impact of clearcutting is unacceptable, there is no choice but to leave the stands uncut.

To reduce the sudden and severe visual mpact on the landscape, openings cut in stands or timber and water production, wildlife habitat mprovement, and recreation (ski runs) should e a repetition of natural shapes, visually tied ogether to create a balanced, unified pattern hat will complement the natural landscape Barnes 1971). This is especially important for hose openings in the middle and background hat can be seen from a distance. The oreground should be maintained in high forests nder some partial cutting system.

PARTIAL CUTTING HISTORY

Most cuttings in spruce-fir forests on the ational Forests before 1950 in the central and outhern Rocky Mountains were of a type that ould be collectively called "partial cuttings." hey ranged from removal of a few individual rees to removal of all of the larger, more aluable trees in the stand. Seedbed preparation as usually limited to the disturbance created y logging, and slash was untreated or lopped. lost skidding was done with horses.

In general, heavy partial cutting — usually onsidered necessary to make logging profitable -was not successful as a means of arresting and deterioration or increasing net increment n residual trees. For example, residual stands f spruce-fir in Colorado suffered heavy ortality when 60 percent of the original volume as removed by individual tree selection (Alexnder 1963). Net increment was only about oneird of that in uncut stands. Similar results ollowed heavy partial cutting elsewhere in the entral Rocky Mountains (USDA Forest Service 933), and in the Northern Rockies (Roe and eJarnette 1965). Even when mortality was not problem, heavy partial cutting left the older, ecadent stands in a shabby condition, with ttle appearance of permanent forest cover.

Windfall, the principal cause of mortality, icreased as the intensity of cutting increased. ow stumpage values and the generally cattered pattern of windfall usually prevented alvage of blowdown after partial cutting. Not nly was the volume of windthrown trees lost, ut the combination of down spruce and overory shade provided breeding grounds for oruce beetles (Dendroctonus rufipennis Kirby).

Partial cutting was successful — in the sense hat the residual stand did not suffer heavy ortality — in some spruce-fir stands where rge reserve volumes were left in protected ocations. In one study in northern Idaho, windll losses were light after a partial cutting that ft 6,000 board feet per acre in spruce-fir stands in a sheltered location on deep, well-drained soil (Roe and DeJarnette 1965). On the Grand Mesa National Forest in Colorado, where spruce trees are relatively short and no serious wind problems are associated with topography, few trees blew down when about 40 percent of the original volume was removed from two-storied stands. In single-storied stands, however, only about 30 percent of the original volume could be safely removed. On the other hand, heavier partial cutting that removed 50 percent or more of the original volumes per acre from spruce-fir forests in the dry "rain shadow" of the Continental Divide on the Rio Grande National Forest did not result in blowdown to the residual stand. However, these two-storied stands were growing on sites where productivity was very low. Individual trees were short, widely spaced, and therefore relatively windfirm before cutting.

There are also numerous examples of early cuttings — between 1910 and 1930 — on many National Forests in Colorado where very light partial cutting — removal of 10 to 15 percent of the stand — did not result in substantial windthrow of residual trees.

Although an overstory tends to favor fir reproduction over spruce, regeneration success of spruce has been acceptable under a wide variety of partial cutting treatments (Alexander 1963, Roe and DeJarnette 1965).

SUSCEPTIBILITY TO WIND AND INSECTS

Windfall

Windfall is a common cause of mortality after any kind of initial cutting in old-growth spruce-fir forests, but partial cutting increases the risk because the entire stand is opening up and therefore vulnerable. While the tendency of spruce to windthrow is usually attributed to a shallow root system, the development of the root system varies with soil and stand conditions. On medium to deep, well-drained soils, trees have a better root system than on shallow, poorly drained soils. Trees that have developed together in dense stands over long periods of time mutually protect each other, and do not have the roots, boles, or crowns to withstand sudden exposure to wind if opened up too drastically. If the roots and boles are defective, the risk of windthrow is increased. The presence of old windfalls in a stand is another good indicator of lack of windfirmness. Furthermore, regardless of the kind or intensity of cutting, or soil and stand conditions, windthrow is greater on some exposures than others (Alexander 1964, 1967). Exposures where windfall risk is below average, above average, or very high have been identified as follows:

Below Average

1. Valley bottoms, except where parallel to the direction of prevailing winds, and flat areas.
2. All lower, and gentle middle north- and east-facing slopes.
3. All lower, and gentle middle, south- and west-facing slopes that are protected from the wind by considerably higher ground not far to windward.

Above Average

1. Valley bottoms parallel to the direction of prevailing winds.
2. Gentle middle south and west slopes not protected to the windward.
3. Moderate to steep middle, and all upper north- and east-facing slopes.
4. Moderate to steep middle, south- and west-facing slopes protected by considerably higher ground not far to windward.

Very High

1. Ridgetops.
2. Saddles in ridges.
3. Moderate to steep middle south- and west-facing slopes not protected to the windward.
4. All upper south- and west-facing slopes.

The risk of windfall in these situations is increased at least one category by such factors as poor drainage, shallow soils, defective roots and boles, or overly dense stands. Conversely, the risk of windfall is reduced if the stand is open-grown or composed of young, vigorous, sound trees. All situations become **very high risk** if exposed to special topographic situations such as gaps or saddles in ridges at higher elevations to the windward that can funnel winds into the area.

Insects

A large number of insect pests infest Engelmann spruce (Keen 1952). The spruce beetle is the most serious in mature to overmature stands, and epidemics have occurred throughout recorded history (Hopkins 1909, Massey and Wygant 1954). The most damaging outbreak was in Colorado from 1939-51, when beetles killed nearly 4 billion board feet of standing spruce. Most attacks have been associated with extensive windthrow, where down trees provided an ample food supply for a rapid buildup of beetle populations (Massey and Wygant 1954, Wygant 1958).

Cull material left after logging has also started outbreaks, and there are examples where heavy spruce beetle populations have developed in scattered trees windthrown after heavy partial cutting. The beetle progeny have then emerged to attack living trees, sometimes seriously damaging the residual stand. Occasionally heavy spruce beetle outbreaks have developed in overmature stands with no recent history of cutting or windfall, but losses in uncut stands that have not been subjected to catastrophic windstorms have usually been no greater than normal mortality in old growth.

Overmature trees are attacked first, but if an infestation persists, beetles will attack and kill smaller diameter trees after the larger trees in the stand are killed. In the central Rocky Mountains, susceptibility of spruce stands in relation to location, increases in the following order: (1) immature stands, (2) mixed stands, (3) poorer stands on benches and high ridges, (4) better stands on benches and high ridges, (5) trees in creek bottoms (Schmid and Beckwith 1971). For individual stands, analysis of past infestations suggests the following characteristics are potentially associated with outbreaks: (1) single- or two-storied stands, (2) high proportions of spruce in the overstory, (3) basal area of 150 square feet per acre or more in the older and larger trees, and (4) an average 10-year periodic diameter growth of 0.4 inch or less.[3]

In infested stands, or those with potential beetle problems, felling and salvaging attacked or susceptible trees, and disposing of green cull material, is the most effective silvicultural control. However, partial cutting that removes the larger overmature trees and releases the younger trees also reduces potential insect problems in stands with a good stocking of trees in the smaller diameter classes. "Trap trees" intentionally felled prior to beetle flight, are highly attractive and often provide an effective way of concentrating and trapping spruce beetles (Nagel et al. 1957). After the beetles enter the downed logs, they are usually

[3] *Schmid, J.M., and T.E. Hinds. "Spruce beetle outbreak areas." (Manuscript in preparation at Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.)*

alvaged, but may be chemically treated or urned (Schmid and Beckwith 1971). Lethal raps in which cacodylic acid is used to prevent rood development appears to be a potentially seful refinement to the regular trap tree pproach (Buffam et al. 1973).

STAND CONDITIONS

Old-growth spruce-fir forests grow on a vide range of sites, with a great diversity of tand conditions and characteristics. This liversity complicates the development of silvi-ultural systems needed to convert old-growth o managed stands for a variety of uses. For xample, spruce-fir forests are the dominant lements in a number of near-climax vegetation ssociations throughout the central and outhern Rocky Mountains, but frequently they lo not have the age-class structure of true limax forests. Some stands are clearly single-toried, indicating that desirable spruce forests an be grown under even-aged management. Others are two- or three-storied, and multi-toried stands are not uncommon (LeBarron and ameson 1953, Miller 1970). This structure may e the result of either past disturbances such s fire, insect epidemics, or cutting, or the radual deterioration of old-growth stands ssociated with normal mortality from wind, nsects, and diseases. Gradual deterioration is specially evident in the formation of some nulti-storied stands. On the other hand, some nulti-storied stands appear to have originated s uneven-aged stands and are successfully erpetuating this stand structure.

The composition of spruce and fir varies onsiderably with elevation. At middle levations (10,000 to 11,000 feet) on north slopes, orests are frequently pure spruce in the over-tory with fir predominating in the understory. n the central Rocky Mountains, for example, pruce commonly makes up 70 percent or more f the overstory basal area, and fir from two-hirds to three-fourths of the understory and dvanced reproduction (Alexander 1957, 1963; osting and Reed 1952). This composition in elation to structure has developed under atural conditions because spruce is more xacting in its seedbed requirements and less ble to compete with fir under low light intensi-ies common to dense forests. Once established, owever, spruce lives longer than fir and is less usceptible to disease (Alexander 1958). xceptions are stands attacked by spruce beetles, here fir is the dominant element in both the verstory and understory.[3]

At higher elevations (above 11,000 feet levation), spruce may form essentially pure stands, while at lower elevations where sites are usually drier, the density of spruce relative to fir may be low. In these latter situations, and at middle elevations on south and west slopes, lodgepole pine (Pinus contorta Dougl.) is frequently more numerous in the overstory than spruce. Aspen (Populus tremuloides Michx.) and Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco) also grow with spruce at middle and low elevations.

Advanced spruce and fir reproduction is likely to be older than it appears because the early growth of both is slow. Spruce commonly takes from 20 to 40 years to reach a height of 4 to 5 feet, even under favorable conditions; under a dense canopy, spruces 4 to 6 feet tall may be 75 years or more old (Oosting and Reed 1952). Spruce and fir reproduction suppressed for long periods of time will respond to release, however, and make acceptable growth.

PARTIAL CUTTING PRACTICES

Partial cutting here includes both shelter-wood and selection cuts and their modifications. They are regeneration systems that harvest the timber on an area in more than one step. From a silvicultural point of view these are acceptable harvesting methods in old-growth spruce-fir. They are, in fact, the only options open to the manager where (1) multiple-use considerations preclude clearcutting, (2) combinations of cleared openings and high forests are needed to meet various resource use requirements, or (3) areas are difficult to regenerate after clearcutting. However, windfall, insects, and stand conditions impose limitations on how stands can be handled. Cutting to bring old-growth under management is likely to be a compromise between what is desirable and what is possible. Management may involve a combination of several partial cutting treat-ments, continuous sanitation salvage cutting, clearcutting, and no cutting on many areas.

A **careful appraisal** of the capabilities and limitations of each stand is necessary to deter-mine cutting practices. Furthermore, partial cutting requires **careful marking** of individual trees or groups of trees to be removed, and **close supervision** of logging. The following partial cutting recommendations are keyed to broad stand descriptions, windfall risk situa-tions, and insect problems with the objective of maintaining permanent forest cover to meet the needs of different resource uses.

SINGLE – STORY

Single-Storied Stands[4]

Description

1. May appear to be even-aged, but usually contain more than one age class. In some instances, the canopy may not appear to be of uniform height because of changes in topography, stand density, or stocking.
2. Codominant trees form the general level of the overstory canopy. Dominants may be 5 to 10 feet taller, and occasionally predominants may reach 15 to 20 feet above the general canopy level. Taller intermediates extend into the general canopy; shorter intermediates are below the general canopy level but do not form a second story.
3. Small range in diameters and crown length of dominants and codominants.
4. Few coarse-limbed trees in the stand: if two-aged or more, younger trees usually have finer branches and may not have diameters equal to the older trees.
5. Trees more often uniformly spaced than clumpy.
6. Usually does not have a manageable stand of advanced reproduction.[5]
7. If lodgepole pine is present in the overstor[y] it is not a major stand component. Lodgepol[e] pine reproduction is absent or sparse.[6]

Recommended Cutting Treatments

These stands are usually the least windfirm because trees have developed together over a long period of time and mutually protect each other from the wind.

1. If the windfall risk is below average, and the trees are uniformly spaced —

a. The first cut should be light, removing about 30 percent of the basal area of the stand on an individual tree basis.[7] This type of cutting resembles the first or **preparatory cut** of a three-step shelterwood. Since all overstory trees are about equally susceptible to windthrow, the general level of the canopy should be maintained by removing some trees from each overstory crown class. Those trees with known indicators of defect should be removed first, but avoid creating openings in the canopy with a diameter larger than one tree height by distributing the cut over the entire area. Do not remove dominants in the interior of the stand that are protecting other trees to their

[4]*Reproduction less than 4.5 feet tall is not considered a stand story in these descriptions.*

[5]*Since any kind of cutting in spruce-fir forests may destroy as much as half of the advanced reproduction, even with careful logging, at least 600 seedlings and saplings per acre, of good form and vigor and free of defect, must be present to be considered a manageable stand (Roe et al. 1970). Needless destruction of a manageable stand of advanced reproduction because the composition is largely fir is not justified when one of the management objectives is to establish and maintain forest cover.*

[6]*Where mixed stands of spruce, fir, and lodgepole pine occur, pine, relative to its position in the canopy, should be handled the same as spruce.*

[7]*As a practical matter, small saplings that do not represent significant competition to the remainder of the stand may be excluded from the computation of basal area.*

leeward if these latter trees are to be reserved for the next cut. In these, and all other stands containing natural openings one to several tree heights in diameter, leave the trees around the perimeter for a distance of about one tree height until the final entry. These trees have been exposed to the wind and are usually windfirm, and protect the trees in the interior of the stand.

). The second entry into the stand should not be made for at least 5 to 10 years after the first cut, to determine if the remaining trees are windfirm. This cut should also remove about 30 percent of the original basal area on an individual tree basis. Any windfall salvaged after the first cut should be included in the computation of basal area to be removed. This cut simulates the second or **seed cut** of a three-step shelterwood. The largest and most vigorous dominants and codominants should be reserved as a seed source, but avoid cutting openings in the canopy larger than one tree height in diameter by distributing the cut over the entire area, even if it means leaving trees with poor seed production potential.

. The last entry is the **final harvest** and should remove all of the remaining original overstory. It should not be made until a manageable stand of reproduction has become established, but the cut should not be delayed beyond this point if timber production is one of the primary concerns because the overwood hampers the later growth of seedlings.

l. The manager also has the option of removing less than 30 percent of the basal area at any entry and making more entries, but they cannot be made more often than every 5 to 10 years. This will spread the cut out and maintain a continuous forest cover for a longer period of time.

f the windfall risk is below average, and he trees are clumpy —

. The first cut should be a modified **group selection** that removes about 30 percent of the basal area. Harvesting timber in groups will take advantage of the natural arrangement of trees in clumps. Group openings should be kept small — not more than one to two tree heights in diameter — and not more than one-third of the area should be cut over. However, all trees in a clump should be either cut or left since they mutually support each other, and removing only part of a clump is likely to result in windthrow of the remaining trees.

b. The second entry into the stand should not be made until the first group of openings has been regenerated. This cut can also remove about 30 percent of the original basal area, but without cutting over more than an additional one-third of the area. Openings should be no closer than about one to two tree heights to the openings created by the previous cut.

c. The final entry should remove the remaining groups of merchantable trees. The timing of this cut depends upon how the manager elects to regenerate the openings. If he chooses to use natural regeneration, the final harvest must be delayed until the regeneration in the openings cut earlier are large enough to provide a seed source.

d. The manager may choose to remove less than 30 percent of the basal area and cut over less than one-third of the area at any one time. This will require more entries, but no new cut should be made until the openings cut the previous entry have regenerated. The last groups cannot be cut until there is a seed source unless the manager elects to plant these openings.

3. If the windfall risk is above average, and the trees are uniformly spaced —

a. The first cut should be restricted to a very light **preparatory** cutting that removes about 10 percent of the basal area on an individual tree basis. The objective is to open up the stand but at the same time minimize the windfall risk to the remaining trees. This type of cutting resembles a **sanitation cut** in that the poorest risk trees — those of low vigor and with known indicators of defect — and predominants should be removed, but it is important that the general level of the overstory canopy be maintained intact. Provision should be made to salvage windfalls after spruce beetle flight at the end of July.

b. The second entry can be made in about 10 years after the first cut. This entry should remove about 15 to 20 percent of the original basal area on an individual tree basis. Any windfall salvaged after the first cut should be included in the computation of the basal area to be removed. The objective of this **preparatory cut** is to continue to open up the stand gradually while preparing the stand for the seed cut. Most of the trees marked for removal should come from the intermediates and small codominants, but maintain the general level of the canopy intact.

c. It will require another 5 to 10 years to determine if the stand is windfirm enough to make another entry. This will be the **seed cut** and should remove about 20 to 25 percent of the original basal area, including any windfalls salvaged after the last cutting. The largest and most vigorous dominants and codominants should be reserved as a seed source, but it is more important to distribute the cut over the entire area.

d. The last entry is the **final harvest**, which should remove the remaining original overstory. It cannot be made until a manageable stand of reproduction has been established. About 50 percent of the original basal area will be removed in this cut. If this harvest is more than 10,000 board feet per acre, it is probably too heavy to be removed in one cut without undue damage to the reproduction. The manager must then plan on a final harvest in two steps. The second step can begin as soon as the skidding is finished in the first step, providing that a manageable stand of reproduction still remains.

4. **If the windfall risk is above average and the trees are clumpy —**

a. The first cut should be light, removing about 15 to 20 percent of the basal area in a modified **group selection**. Group openings should be no larger than one tree height in diameter, and not more than one-fifth of the area should be cut over at any one time. All trees in a clump should be cut or left. In stands with small natural openings — about one tree height in diameter — the openings can be enlarged one tree height by removing clumps of trees to the windward.

b. Four additional entries into the stand can be made at periodic intervals, but no new entry should be made until the openings cut the previous entry have regenerated. The last groups to be removed should be retained until trees in the original openings are large enough to provide a seed source. About 20 percent of the basal area should be removed over about one-fifth of the area at each entry. Group openings should be no larger than one tree height in diameter.

5. **If the windfall hazard is very high —**

The choice is limited to removing all the trees or leaving the area uncut. Cleared openings should not be larger than regeneration requirements dictate, and they should be interspersed with uncut areas of at least equal size. Not more than one-third of the total area in this wind risk situation should be cut at one time.

TWO-STORY

Two-Storied Stands

Description

1. May appear to be two-aged, but usually contains more than two age classes.
2. Top story (dominants, codominants, and intermediates) is usually spruce; resembles a single-storied stand.
3. Second story is often fir, and the trees are younger and smaller in diameter than the overstory. May consist of small saw logs, poles, or large saplings, but is always below the top story and clearly distinguishable from the overstory. Trees in the second story are overtopped, but not suppressed.
4. May contain a manageable stand of advanced reproduction.
5. Arrangement of individual trees varies from uniform to clumpy.
6. If lodgepole pine is present in the stand it is usually a scattered component of the overstory. Lodgepole pine reproduction is absent or sparse.

Recommended Cutting Treatments

Same as for three-storied stands.

THREE-STORY

Three-Storied Stands

Description

1. May appear to be three-aged, but usually contains more than three age classes. Occasionally two-aged, but is never all-aged.
2. If three-aged or more, top story usually predominantly spruce and resembles a single-storied stand except that there are fewer trees. Second and third stories usually consist of younger, smaller diameter trees (that is, small saw logs, poles, and large saplings), usually fir. In a typical stand, the second story will be 10 to 30 feet below the top story and consist of small saw logs or large poles. Third story will be 10 to 30 feet below the second story and consist of small poles or large saplings. Although the second and third stories are overtopped, the trees are usually not suppressed.
3. If two-aged, first two stories are old-growth with spruce in the top story and fir in the second story. The third story will be younger trees, largely fir, of smaller diameter.
4. Frequently contains a manageable stand of advanced reproduction.
5. More often clumpy than single- or two-storied stands.
6. If lodgepole pine is present in the stand, it is usually a scattered component of the top story, but may occur in the second story. Lodgepole pine reproduction is usually absent or sparse.

Recommended Cutting Treatments

Trees in the overstory of two- and three-storied stands are usually more windfirm than those in single-storied stands. The second and third stories are likely to be less windfirm than the top story.

1. **If the windfall risk is below average, and the trees are uniformly spaced—**

   a. Where there is **not** a manageable stand of advanced reproduction:
   (1) The first cut can remove about 40 percent of the basal area. This type of cutting is heavy enough to resemble the first step or **seed cut** of a two-cut shelterwood, but the marking follows the rules for individual tree selection — mature trees are removed from each story. Since the overstory is likely to be more windfirm, selected dominants and codominants of good vigor and free of defect should be left. These trees are also the most desirable seed source. Avoid cutting holes in the canopy larger than one tree height in diameter by distributing the cut over the entire area. Do not remove dominant trees in the interior of the stand that are protecting other trees to their leeward if these latter trees are to be reserved for the next cut.
   (2) The second entry should be the **final harvest** to remove the remaining original

stand and release the reproduction. It cannot be made until the new stand of reproduction is established. If the residual volume is greater than about 10,000 board feet per acre, the final harvest should be made in two steps to avoid undue damage to newly established reproduction. The second step can begin as soon as skidding is finished in the first step, providing that a manageable stand of reproduction still remains.

b. If there is a manageable stand of advanced reproduction, the first cut can be an overstory removal if the volume is not too heavy. Otherwise, the first cut can remove 40 percent of the basal area on an individual tree basis as long as the more windfirm dominants and codominants are left. The timing of the second cut is not critical from a regeneration standpoint, providing a manageable stand of reproduction still remains after the first cut and can be saved.

c. The manager has other options to choose from. He may elect to cut less than the recommended basal area, make more entries, and spread the cut out over a longer period of time by delaying the final harvest until the new stand is tall enough to create a continuous high forest. He may also elect to convert these stands to an uneven-aged structure by making a series of light cuts — 10 to 20 percent of the basal area — at frequent intervals — 10 to 20 years. Ultimately the stand will contain a series of age classes.

2. If the windfall risk is below average, and the trees are clumpy—

a. The first cut should remove about 40 percent of the basal area in a modified **group selection** cutting. The group openings can be larger (two to three times tree height) than for single-storied stands, but the area cut over should be not more than one-third of the total. The group openings should be irregular in shape but without dangerous, windcatching indentations in the edges. All trees in a clump should either be cut or left.

b. Two additional entries can be made in the stand. They should each remove about 30 percent of the original basal area in group openings up to two to three times tree height, but not more than one-third of the area should be cut over at any one time. If there is not a manageable stand of advanced reproduction, the manager must wait until the first group openings are regenerated before cutting the second series. Furthermore, he must either delay the cutting of the final groups until there is a seed source or plan on planting these openings. If there is a manageable stand of advanced reproduction, the timing between cuts is not critical from a regeneration standpoint.

c. The manager has the option of removing less than the recommended basal area and cutting less than the recommended area at any one time. This will require more entries and spread the cut out over a longer period of time.

3. If the windfall risk is above average, and the trees are uniformly spaced—

a. The first cut should be a light **preparatory** cut that removes not more than 20 percent of the basal area, on an individual tree basis, where there is not a manageable stand of advanced reproduction. Predominants, intermediates with long, dense crowns, and trees with known indicators of defect should be removed first, but maintain the general level of the canopy. The objective of this cut is to open up the stand but at the same time minimize the windfall risk to the residual stand. Provision should be made to salvage windfalls after spruce beetle flight.

b. The second entry into the stand should not be made within 10 years. This cut should remove about 30 percent of the original basal area, including the salvage of any windfalls that occur between the first and second cuts. Because the second entry is the **seed cut** the best dominants and codominants should be reserved as a seed source, but it is important that the cut be distributed over the entire area.

c. The next entry is the **harvest cut** to remove the remaining merchantable volume and release the established new reproduction. However, if volume of the residual stand is too heavy, the final harvest should be made in two steps.

d. If these stands contain a manageable stand of reproduction and the volume per acre is not too heavy, the first cut can be an **overwood removal**. If the volume is too heavy for a one-step removal, the manager should follow the recommendations 3a-c because the wind hazard is too great to permit a two-step removal in a stand that has not been previously opened up.

4. **If the windfall risk is above average, and the trees are clumpy—**

   a. The first cut should be a **modified group selection** that removes about 25 percent of the basal area. Group openings should be kept small — not more than one to two tree heights in diameter — and not more than one-fourth of the area should be cut over at any one time. All trees in a clump should either be cut or left. Small natural openings can be enlarged one to two tree heights by removing trees in clumps to the windward of the opening.
   b. Three additional entries should be made in the stand. About 25 percent of the original basal area should be removed on about one-fourth of the area each entry.

   If there is not a manageable stand of advanced reproduction, the interval between cuts will depend upon the time required to regenerate each series of openings. The manager must either delay the removal of the final groups until a seed source is available or plant the openings. If there is a manageable stand of advanced reproduction, the timing between cuts is not critical from a regeneration standpoint.

5. **If the windfall hazards are very high—**

   The choice is usually limited to removing all the trees or leaving the area uncut. Cleared openings should not be larger than regeneration requirements dictate, and should be interspersed with uncut areas. Not more than one-third of the total area in this windfall risk situation should be cut over at any one time.

MULTI - STORY

Multi-Storied Stands

Description

1. Generally uneven-aged with a wide range in diameters.
2. If the stand developed from a relatively few individuals, overstory trees are coarse limbed, fill-in trees are finer limbed. Overstory trees may be relatively vigorous.
3. If the stand developed from the deterioration of a single- or two-storied stand, overstory may be no limbier than fill-in trees. Much of the vigorous growing stock is below saw log size.
4. Almost always contains a manageable stand of reproduction as a ground story.
5. Fill-in trees may be clumpy, but usually not the overstory.
6. Lodgepole pine may occur as a scattered component of the stand, usually in the overstory, but may occur in all stories including reproduction.

Recommended Cutting Treatments

These stands are usually the most windfirm, even where they have developed from the deterioration of single- and two-storied stands, because by the time they have reached their present condition, the remaining overstory trees are usually windfirm.

1. **If the windfall risk is below average—**

   There is considerable flexibility in harvesting these stands. All size classes can be cut with emphasis on either the largest or smallest trees in the stand. For example, the first cut can range from removal of all large trees in the overstory to release the younger growing stock, to a thinning from below to improve the spacing of the larger trees. If the manager elects to make an overwood removal and the volume is too heavy, it should be harvested in two steps. Thereafter, cutting can be directed toward either even- or uneven-aged management, with entries made as often as growth and regeneration needs dictate.

2. **If the windfall risk is above average or very high—**

   The safest first cut is an overwood removal with a thinning from below to obtain a wide-spaced, open-grown stand that will develop windfirmness. Thereafter, cutting can be directed toward either even- or uneven-aged management.

Modifications to Cutting Treatments Imposed by Spruce Beetles

1. If spruce beetles are present in the stand at an endemic level, or in adjacent stands in sufficient numbers to make successful attacks, and:

   a. Less than the recommended percentage of basal area to be removed is in susceptible trees, any attacked and all susceptible trees should be removed in the first cut. This will include most of the larger spruce trees and is therefore a calculated risk, especially in above-average wind risk situations. Furthermore, the percentage of fir in the stand will increase. Provision should be made to salvage attacked trees. The remaining cuts should be scheduled in accordance with windfall risk, insect susceptibility, and regeneration needs.

b. More than the recommended percentage of basal area to be removed is in susceptible trees, the manager has three options: (1) remove all the susceptible trees, (2) remove the recommended basal area in attacked and susceptible trees and accept the risk of future losses, or (3) leave the stand uncut. If the stand is partially cut or left uncut, probably less than half of the residual basal area would be lost, but most of the surviving merchantable spruce would be small-diameter trees.

2. If an infestation is building up and the manager chooses to either partially cut or leave the stand uncut because clearcutting is unacceptable, he must accept the risk of an outbreak that will destroy most of the merchantable spruce in the stand and spread to adjacent stands.

Cutting to Save the Residual

Before any cutting begins, the manager must determine whether he has an acceptable stand of advanced reproduction and if he is going to manage it. Furthermore, he must reevaluate the stand after the final harvest and slash disposal to determine the need for supplemental stocking. The same criteria used to evaluate advanced reproduction on clearcut areas applies here (Roe et al. 1970).

In partial cutting, protection of the residual from logging damage is of primary concern. The residual includes merchantable trees left after shelterwood cutting, and advanced reproduction in both shelterwood and group selection cutting where an acceptable stand is to be managed. Protection begins with a well-designed logging plan at the time of the first cut. To minimize damage, skid roads must be layed out — about 200 feet apart depending on the topography — and marked on the ground. These skid roads should be located so that they can be used to move logs out of the woods at each cut. Close supervision of logging will be required to restrict travel of skidding and other logging equipment to the skid roads.

In shelterwood cuttings, trees should be felled into openings as much as possible, using a herringbone pattern that will permit logs to be pulled onto the skid roads with a minimum of disturbance. It may be necessary to deviate from the herringbone felling angle to drop trees into openings. If this is the case, the logs should be bucked into short lengths to reduce skidding damage. Trees damaged in felling and skidding should not be removed if they are still windfirm. In group selection cutting, the felling pattern should be similar where there is a manageable stand of advanced reproduction. Otherwise all trees should be felled into the openings. Both shelterwood and group selection cuttings require close coordination between felling and skidding because it may be necessary to skid one tree before another tree is felled.

REGENERATION PRACTICES

Some slash disposal will probably be needed after each cut but it should be confined to concentrations and that needed to reduce visual impact; most equipment now available for slash disposal is not readily adaptable to working in shelterwood cuttings. Furthermore, burning slash will cause additional damage to the residual. Skid out as much of the down sound dead and green cull material as possible for disposal at the landings or at the mill. Some hand piling or scattering may be needed where slash disposal equipment cannot be used. In group-selection cutting, if there is not a manageable stand of advanced reproduction, dozers equipped with brush blades can be used to concentrate slash for burning in the openings cut. Piles should be kept small to reduce the amount of heat generated. Leave some of the larger pieces of slash and other debris in place to provide shade for new seedlings, but cut green spruce material over 8 inches in diameter should be removed or treated to reduce the buildup of spruce beetle populations.

On areas to be regenerated by new reproduction, a partial overstory canopy or trees standing around the margins of small openings provide two of the basic elements necessary for regeneration success — a seed source within effective seeding distance, and an environment compatible with germination, initial survival, and seedling establishment. The manager must make sure that the third element — a suitable seedbed — is provided after the seed cut where shelterwood cutting is used, and after each cut where group selection is used. Unless at least 40 percent of the available ground surface is exposed mineral soil after logging and slash disposal, additional seedbed preparation is needed. Until special equipment is developed, the same problem exists in shelterwood cuttings as with slash disposal. The equipment available today is too large to work well around standing trees. The smaller machines equipped with suitable attachments will have to be used, but they must be closely supervised to minimize damage to the residual.

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Guidelines are provided to aid the forest manager in developing partial cutting practices needed to convert old-growth spruce-fir forests into managed stands, while maintaining continuous forest cover in travel influence zones and areas of high recreational values or outstanding scenic beauty. These guidelines consider stand conditions, windfall risk, and insect susceptibility. The cutting practices can be used in combination with small cleared openings to create the kinds of stands desirable for increased water yields, to improve wildlife habitat, and to integrate timber production with other uses. They can also be used on areas that are difficult to regenerate where timber production is the primary objective.

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Rocky Mountain Forest and
Range Experiment Station

Colorado Division of Wildlife —
Department of Natural Resources

FOODS OF THE ROCKY MOUNTAIN MULE DEER

by Roland C. Kufeld, O. C. Wallmo
and Charles Feddema

NOV 19

Forest Service
U.S. Department of Agriculture

Fort Collins, Colorado

Abstract

Literature on food habits of the Rocky Mountain mule deer *(Odocoileus hemionus hemionus)* was reviewed to compile listings of reported foods of this species throughout its range. Plant species are classified as to relative importance on the basis of their contribution to the diet in 99 studies where quantitative data were provided. A total of 202 shrubs and trees, 484 forbs, 84 grasses, sedges and rushes, and 18 lower plants are listed.

Oxford: 156.2. **Keywords:** Wildlife food plants, *Odocoileus hemionus hemionus.*

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July 1973

Foods of the Rocky Mountain Mule Deer[1]

by

Roland C. Kufeld, O. C. Wallmo, and Charles Feddema[2]

[1]*This study is a contribution of Federal Aid in Wildlife Restoration Project W-101-R. Personnel of the Library Reference Service, Federal Aid in Wildlife Restoration, Denver, Colorado, assisted in assembling deer food habits references.*

[2]*Kufeld is Wildlife Researcher, Colorado Division of Wildlife, Fort Collins, Colorado. Wallmo is Principal Wildlife Biologist and Feddema is Research Botanist, Forest Service Herbarium, Rocky Mountain Forest and Range Experiment Station, U. S. Department of Agriculture, Forest Service. The Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.*

Contents

Foods of the Rocky Mountain Mule Deer

Roland C. Kufeld, O. C. Wallmo, and Charles Feddema

Knowledge of the relative degree to which mule deer consume various species of plants is basic to deer range appraisal and to planning and evaluating habitat improvement programs. Although numerous mule deer food habits studies have been conducted, individual studies are limited to a specific area, and relatively few plant species are found in the diet compared to the number of plants eaten by deer throughout their range. The amount of a particular species found in a given study may or may not be indicative of its true importance as deer forage. In preparing this report, we have evaluated all available food habits studies to determine which plants are eaten by mule deer, and their relative importance as reflected by the degree to which they are consumed. Relative importance of plants in this report does not infer nutritional quality or the status of a species in relationship to a desired stage of ecological succession.

Methods

Only those studies which pertain to food habits of the Rocky Mountain mule deer *(Odocoileus hemionus hemionus)* in the Western United States and Canada were included. Studies of Rocky Mountain mule deer transplanted to areas outside their normal range were excluded. Locations of food habits studies evaluated are mapped in figure 1.

Only studies meeting the following criteria were incorporated: (1) Data must have been original and derived from a specific effort to collect food habits information. References containing statements of what deer eat based on general knowledge, or those which summarized previous food habits studies were excluded. (2) Data must have been listed by species and reported quantitatively in terms that would permit the categorization used in this report. (3) Season of use must have been shown. (4) Data must have been listed separately for mule deer. Studies which referred to combined deer and elk use, or mule deer and white-tailed deer use or "game use" were excluded. (5) Studies with a very limited sample (for example only two or three stomachs) were excluded. (6) Deer must have had free choice of available forage. This excluded some pen feeding studies. (7) Study animals must not have been starving. (8) Routine management surveys of browse use, involving fall and spring measurements of tagged twigs, were excluded. In such surveys not all available species were measured, and it is not possible to be sure what animal ate the plant. Ninety-nine studies were incorporated in this summary.

Methods of data collection were divided into five categories: stomach analysis; feeding observations on wild deer; feeding observations on tame, trained deer; ocular judgments of plant use; and pen feeding studies designed to determine relative preferences for natural forage.

Food habits studies differ widely in methods of collecting and presenting data; in number, relative abundance, and availability of plant species encountered; and in number of animals using the study area. Thus, firm guidelines cannot be established for comparing results of different studies in terms of relative forage preference. In every study, however, some plants comprised a greater portion of the sample than others. It is impossible to equate the various kinds of quantification used: volume of stomach contents measured by different methods, weight of stomach contents, instances of amount of apparent use on plants, bites taken by tame deer, or weight consumed in "cafeteria" feeding. Therefore, we categorized the quantities recorded, regardless of the measurements used, in three broad

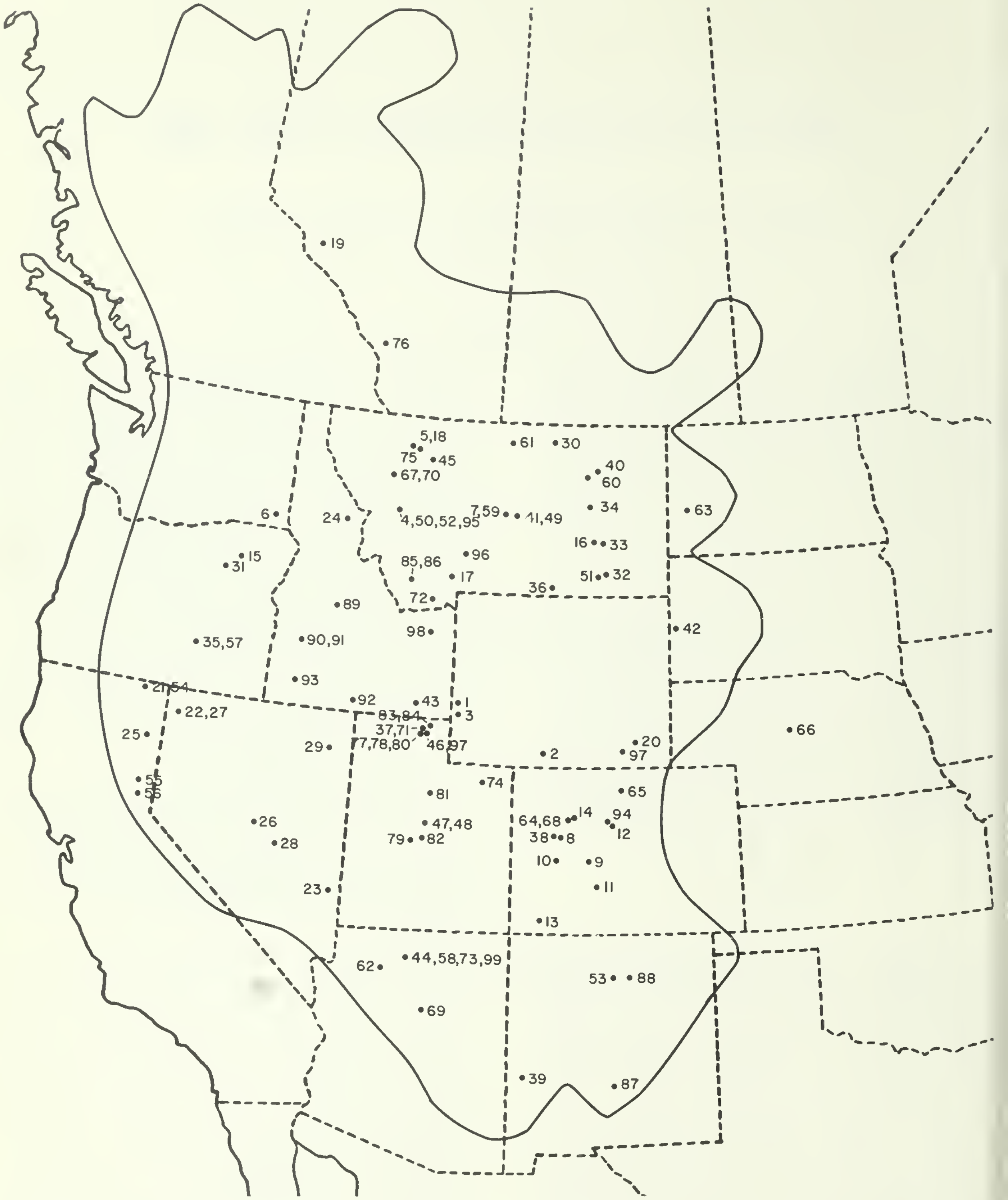

Figure 1.—Locations of Rocky Mountain mule deer food habits studies summarized in this paper. Numbers indica literature citations. The enclosing line is the distribution boundary of the Rocky Mountain mule deer as reporte by Taylor (Taylor, Walter P. 1956. The deer of North America. 668 p. The Stackpole Co., Harrisburg, Pa.). Th portion of the boundary within Arizona and New Mexico, however, was modified to conform with that reporte by Hoffmeister (Hoffmeister, Donald F. 1962. The kinds of deer, *Odocoileus,* in Arizona. Am. Midl. Na 67:45-64.).

groups: heavily, moderately, or lightly eaten. Heavily eaten plants, by definition, comprised a major part of a food sample (usually at least 20 percent). In a few cases, plants which comprised less than a major portion of the food sample were classified as heavily eaten if their reported contribution to the diet was far in excess of their reported vegetative composition. Moderately eaten plants usually comprised between 5 and 20 percent of the food sample, and lightly eaten plants comprised less than 5 but more than 1 percent. Plants which contributed less than 1 percent of the total or were reported as trace amounts were excluded from the above system and were cited separately in the summary tables.

Light use was then given a value of 1, moderate use 2, and heavy use 3. These rankings were then summed for each species by season, and the sums divided by the number of citations involved to obtain a mean rank. Mean ranks were then categorized by symbols: - for mean ranks of 1.00 to 1.49, + for 1.50 to 2.24, and * for 2.25 to 3.00. This arbitrary procedure obviously cannot provide accurate summary quantification of the studies involved, but the mean rank of a species, along with the number of times it was cited, suggests its relative importance in deer diets over the range.

Data were separated by the following seasons of use: **Winter** —December, January, February; **Spring**—March, April, May; **Summer**—June, July, August; **Fall**—September, October, November.

Some plants, identified as to species in the original food habits reference, have been listed here only by genus because the identity of the species is questionable. A number of names have been changed from those used in the original studies to reflect current usage in wildlife management and in recent plant manuals, especially those covering large portions of the Rocky Mountain mule deer range. These changes are appropriately keyed in the summary tables.

Results

Seasonal Use of Major Forage Groups

Percent composition of shrubs and trees, forbs, and grasses and grasslike plants (sedges and rushes) in Rocky Mountain mule deer diets, as reported from selected references (Literature Citation numbers) for each season of the year, is presented in table 1. We used only those references in which information was presented in such a manner that percent composition of major plant groups in the diet could be easily retrieved by season. Shrubs and trees contributed the bulk of the forage consumed during all seasons of the year in most of these references, although there is a great deal of variation among references in composition of forage eaten.

During winter, shrubs and trees averaged 74 percent of the diet in these selected references, forbs comprised an average of 15 percent, and grasses, sedges, and rushes 11 percent. Consumption of grass and grasslike plants was quite variable in winter data, ranging from 0 to 53 percent of the diet.

During spring, average reported consumption of shrubs and trees dropped to 49 percent, and forb and grass-grasslike dietary consumption rose to 25 and 26 percent, respectively. Reported use of grasses, sedges, and rushes was highest during spring, but ranged from 4 to 64 percent of the diet among the selected references.

In summer studies, average shrub and tree dietary consumption remained at 49 percent, while forbs rose to an average of 46 percent and grasses-grasslikes dropped to 3 percent. Consumption of forbs was highest in summer, ranging from 3 to 77 percent among the selected references. Use of grasses, sedges, and rushes as a class was lowest during summer, ranging between 0 and 22 percent of the diet. Lower plant forms became important food in some areas during summer. Hungerford (*44*) found that mushrooms comprised 66 percent of the mule deer diet on the North Kaibab National Forest in Arizona between August 1 and 15.

In fall data, use of shrubs and trees rose to 60 percent of the diet while forbs declined to 30 percent, and grasses-grasslikes climbed to 9 percent. Fall forb dietary composition was extremely variable, ranging from a low of 2 percent to 78 percent of the total forage reported. In the grass-sedge-rush category, composition varied from 0 to 24 percent in fall data.

Seasonal Importance of Individual Plant Species

Plant species eaten by deer, and their relative importance rankings for each season, are listed by shrubs and trees in table 2, forbs in table 3, grasses and grasslike plants in table 4, and lower plants in table 5. Validity of these rankings can be assumed to increase with the number of references on which a ranking is based.

Tables 2 through 5 also show the references in which a species was recorded as a trace amount or comprising less than 1 percent of the diet. A plant that has been reported as comprising less than 1 percent of the diet in only a few food habits studies can probably be attributed little importance in management considerations. However, one that has appeared in numerous studies, even though never contributing more than 1 percent, may have some significance as deer food. It may contain some nutrient that deer need only in small quantities, or even though palatable the plant may not be abundant enough on the range to contribute substantially to the overall deer diet. Numerous references to trace amounts of use, in addition to a quantitative ranking, would no doubt lend additional significance to consideration of a plant as deer food.

Plant names in tables 2 through 5 which were changed in this publication from those appearing in the original deer food habits references are listed and explained in table 6.

Shrubs and trees most often ranked as heavily eaten were *Artemisia tridentata, Cercocarpus ledifolius, Cercocarpus montanus, Cowania mexicana, Populus tremuloides, Purshia tridentata, Quercus gambellii* and *Rhus trilobata*. Most of these were heavily consumed only during certain seasons of the year. Other shrubs and trees frequently reported, but with rankings ranging between light and heavy depending upon the season, were *Amelanchier alnifolia, Arctostaphylos uva-ursi, Artemisia cana, Berberis repens, Ceanothus velutinus, Chrysothamnus* sp., *Chrysothamnus nauseosus, Chrysothamnus viscidiflorus, Juniperus* spp., *Pachystima myrsinites, Pinus edulis, Pinus ponderosa, Prunus virginiana, Pseudotsuga menziesii, Ribes* sp., *Rosa* sp., *Salix* spp., *Shepherdia canadensis, Symphoricarpos* spp., and *Yucca glauca*.

Relatively few individual forb species were reported heavily eaten in a large number of references, although many forbs were frequently reported to be consumed in moderate quantities. In studies reporting forbs, a large variety of species were usually involved. Thus, rarely did one particular species consistently constitute a major portion of the diet.

The most frequently reported forbs, taken in various amounts, were *Achillea millefolium, Antennaria* sp., *Artemisia frigida, Artemisia ludoviciana, Aster* spp., *Astragalus* sp., *Balsamorhiza sagittata, Cirsium* sp., *Erigeron* spp., *Eriogonum* spp., *Geranium* sp., *Lactuca serriola, Lupinus* spp., *Medicago sativa, Penstemon* spp., *Phlox* sp., *Phlox hoodii, Polygonum* sp., *Potentilla* spp., *Taraxacum officinale, Tragopogon dubius, Trifolium* sp., and *Vicia americana*.

While grasses, sedges, and rushes appear to be important mule deer foods, particularly in spring, most authors simply lumped them into a "grass and grasslike" category, and did not attempt to list quantities eaten by individual species. Thus the actual list of grasses, sedges, and rushes eaten by mule deer is probably much more extensive than presented in table 4. Also, the number of references upon which importance rankings for individual grass and grasslike species are based in table 4 would undoubtedly be much greater had it not been for lumping by most authors. Where species were identified, the most commonly reported were *Agropyron* sp., *Agropyron spicatum, Bromus tectorum, Carex* spp., *Festuca idahoensis, Poa fendleriana, Poa pratensis*, and *Poa* spp. These ranged from light to heavy in quantity consumed, depending upon season of the year. No sedges or rushes ranked higher than light in any season.

Little information is available on the importance of individual lower plant species as deer food. Most of the species in table 5 appeared in only one food habits study. Authors usually lumped lower plants into a mushroom, lichen, moss, or fungus category.

The Compositae, Gramineae, Rosaceae, and Leguminoseae with 50, 30, 26, and 21 genera, respectively, and 110, 55, 53, and 51 named species were the most abundantly represented plant families. They are also among the largest families of vascular plants.

Discussion

All methods used in studies of deer food habits contain problems, either in identification, quantification, or both. The possibility of bias toward large, conspicuous plants or, in stomach analyses, slowly digested plants or those with distinctive morphological features is obvious. Furthermore, relative abundance, availability, and palatability of plants on the ranges where the individual studies were made influence their presence in the diet. This summary cannot take such factors into account. Nevertheless, we feel that the relative rankings and the number of citations for the various species can offer managers some general guidelines for recognizing species of conspicuous importance as foods for Rocky Mountain mule deer.

Since rankings contained here are averages, some deer managers working where food habits have been studied extensively may feel that certain ratings are too high or low for their particular area, which may very well be true. However, the real benefits from these rankings should be realized by managers who lack sufficient data to determine the relative importance of plants in their area, and by managers who want to revegetate ranges with plant species known to be good deer forage.

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Table 1. Seasonal composition of shrubs and trees, forbs, and grass and grasslike plants in data from selected references

State	Literature citation	Kind of data [1]	Percent composition: Shrubs & trees	Forbs	Grasses & grasslikes	Other[2]	Total
			Winter[3]				
Montana	17	U	62	29	7		98
"	19	0	79	6	15		100
"	30	S	60	40	0		100
"	49	U	71	27	2		100
"	51	U & S	96	4	0		100
"	59	S	78	20	1		99
"	60	U	87	10	2		99
"	61	S	75	24	1		100
"	67	S	27	20	53		100
"	70	S	48	37	15		100
"	72	S	37	43	20		100
"	75	U	73	22	5		100
"	86	S	90	9	0		99
"	96	S	66	18	14		98
Idaho	91	S	62	2	32	3	99
Montana, Idaho & N.E. Washington	24	S	89	5	5	1	100
Wyoming	97	U	77	17	6		100
Colorado	8	S	98	2	0		100
"	9	S	94	4	2		100
"	10	S	100	0	0		100
"	14	S	97	2	1		100
California	54	S	61	7	32		100
"	55	S	72	5	23		100
"	56	S	84	0	16		100
Arizona	[4]69	T	67	22	11		100
"	[5]69	T	51	21	28		100
			Spring[3]				
Montana	30	S	59	24	17		100
"	53	S	41	21	38		100
"	60	U	52	35	13		100
"	61	S	37	30	33		100
"	67	S	6	30	64		100
"	70	S	29	39	31		99
"	72	S	37	43	20		100
"	86	S	61	27	11		99
"	96	S	24	40	37		101
Colorado	8	S	92	4	4		100
"	13	S	58	0	42		100
"	14	S	79	9	12		100
California	54	S	29	36	35		100
"	55	S	67	8	25		100
"	56	S	86	1	13		100
Arizona	[4]69	T	46	32	22		100
"	[5]69	T	29	40	31		100
			Summer[3]				
Montana	30	S	42	57	1		100
"	49	U	60	40	0		100
"	51	U & S	51	47	0		98
"	59	S	20	66	2	12	100
"	60	U	43	56	0		99
"	61	S	12	66	22		100

See footnotes at end of table, p. 12.

Table 1. Seasonal composition of shrubs and trees, forbs, and grass and grasslike plants in data from selected references (continued)

State	Literature citation	Kind of data [1]	Percent composition: Shrubs & trees	Forbs	Grasses & grasslikes	Other [2]	Total
			Summer (continued) [3]				
Montana	67	S	36	62	2		100
"	70	S	95	3	2		100
"	86	S	22	75	2		99
"	95	S	64	34	0	2	100
"	96	S	19	77	3		99
Colorado	14	S	94	6	0		100
California	54	S	54	35	11		100
"	55	S	80	20	0		100
Arizona	44	O				[6]66	
"	[4]69	T	42	54	4		100
"	[5]69	T	52	45	3		100
			Fall [3]				
Montana	51	U & S	58	39	2		99
"	59	S	44	53	3		100
"	61	S	44	53	3		100
"	67	S	3	78	19		100
"	70	S	46	35	19		100
"	86	S	73	21	6		100
"	96	S	73	24	3		100
Wyoming	2	S	60	34	6		100
"	3	S	5	73	22		100
North Oakota	63	S	86	7	5	2	100
So. Oakota & Wyoming	42	S	76	14	6	4	100
Colorado	14	S	97	3	0		100
Utah	47	S	83	10	7		100
Oregon	35	S	70	5	12	12	99
California	54	S	71	5	24		100
"	55	S	86	9	5		100
"	56	S	86	2	12		100
Arizona	62	S	60	33	7		100
"	[4]69	T	23	65	12		100
"	[5]69	T	58	40	2		100

[1] S = Stomachs; O = Feeding observations of wild deer; T = Feeding observations of tame deer; U = Ocular judgments of plant use.

[2] Lichens, mushrooms, unidentified material, or crops.

[3] Winter = December, January, February; Spring = March, April, May; Summer = June, July, August; Fall = September, October, November.

[4] Oata from the pinyon-juniper type.

[5] Oata from the ponderosa pine type.

[6] Sixty-six percent of the diet between August 1 and 15 was comprised of mushrooms.

Table 2. Shrubs and trees reported as foods of Rocky Mountain mule deer

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Abies				1	3
Abies concolor	- 3	- 3, 1	* 4, 2	- 1, 2	44,55,62,73,87,88,89,35,54,55,87
Abies lasiocarpa	1		3	1	65,94,95
Acacia greggii	1	1	1		69
Acer	- 1	- 1		1	83,45
Acer glabrum	* 1, 5	1	+ 2, 1	3	49,75,78, 5,11,15,52,88,94,97
Acer grandidentatum	- 2, 2		+ 1		71,77,78,37,80
Acer negundo	1	+ 1		+ 1	33,34,34
Alnus	2	1		+ 1	52,15,52,88
Alnus sinuata	2		- 1		96,91,96
Alnus tenuifolia	+ 2, 1		+ 1, 1	1	7,65,95,11,25,94
Amelanchier	+ 1, 1		+ 2	+ 2, 2	42,74,82,93,15,93,99
Amelanchier alnifolia	+ 21, 3	+ 12, 3	+ 13, 2	+ 9, 4	4, 8, 9,10,11,12,14,18,22,23,26, 27,28,30,38,46,48,49,50,52,54,61, 75,77,78,79,80,83,94,97,98, 5,29, 35,54,55,56,61,63,82,91
Amelanchier utahensis	+ 1, 2	- 1, 2	1	1	64,68,69,99
Arceuthobium		1	- 1	- 1	99,99
Arceuthobium campylopodum	1		1	1	54,55,56
Arceuthobium vaginatum		1	1		69
Arctostaphylos			- 1	1	54,99
Arctostaphylos patula	+ 2	+ 2	+ 1, 1	+ 4, 1	35,47,54,55,56,54,88
Arctostaphylos pungens	1	2	1		69,99
Arctostaphylos uva-ursi	+ 5, 6	+ 7, 1	5	+ 3, 5	7,18,19,42,49,59,75,86,88,94, 2, 5,11,15,49,52,59,65,86,88,94
Artemisia	* 7, 1	+ 7	+ 4, 1	+ 7, 3	22,23,26,27,28,29,33,39,47,65,72, 74,99,16,32,52,94
Artemisia arbuscula #	+ 4, 1	+ 2		+ 2	37,58,77,93,25
Artemisia cana	* 7, 1	+ 6, 1	+ 2, 1	+ 11, 2	3,16,30,32,33,34,40,47,51,57,60, 63,82, 2, 7,33,35,51
Artemisia tridentata	* 47, 3	* 30, 1	- 2, 5	+ 17, 5	1, 3, 5, 7, 8, 9,10,11,12,13,14, 15,17,18,21,25,30,31,34,35,37,40, 43,45,48,49,51,54,55,56,57,58,60, 62,64,68,71,72,73,77,80,82,83,84, 85,86,89,90,91,92,93,94,96,97,98, 99, 2,16,33,34,54,55,63,65,86,94, 99
Artemisia tripartita	+ 3	+ 2		- 1	85,86,89
Atriplex	- 1, 1	1	+ 1	1	40,73, 1, 2,39
Atriplex canescens	- 1, 1	1	+ 1, 1	- 2, 2	54,62,99, 3,28,39,99
Atriplex confertifolia	+ 2	- 3		- 1, 1	8,14,51,68,22
Atriplex nuttallii	- 2	1	- 1, 1		30,60,60
Berberis #	1		- 1	1	55,15,54
Berberis fremontii	1	1		1	99
Berberis haematocarpa		1			87
Berberis repens #	+ 15, 8	+ 8, 8	- 5, 9	+ 12, 7	7, 9,10,11,12,14,23,33,42,46,47, 49,50,52,59,64,70,72,78,79,82,89, 92,93, 1, 2, 3, 8,14,16,33,35,37, 40,44,59,65,68,69,70,83,84,89,93, 94,97,99
Betula		1		1	45
Betula glandulosa	+ 1		- 1	- 1	61,65,75
Betula occidentalis #	- 1, 2		+ 1, 1		78,86,85,91,97
Calliandra			1	1	87
Calliandra eriophylla	+ 1		+ 1	1	39,39
Caragana arborescens			* 1		53
Ceanothus				1	35
Ceanothus diversifolius				- 1	25
Ceanothus fendleri	+ 1, 1	+ 2, 1	+ 3, 1	- 2, 1	44,69,87,99,69,94,99
Ceanothus gregii	+ 1	- 1	+ 1	1	69,39
Ceanothus martinii			1	1	23
Ceanothus ovatus	1	1		* 1	66,66
Ceanothus prostratus	+ 4	+ 2, 1	- 2	+ 3	25,54,55,56,54
Ceanothus velutinus	+ 14	+ 7, 1	* 6, 1	+ 14, 1	2, 4,15,22,25,26,27,31,35,42,49, 50,52,54,55,56,71,75,77,78,90,92, 93,52,84,94
Cercocarpus	+ 6	1	* 2	* 1	8, 9,10,11,12,14,54,14

See footnotes at end of table, p. 17.

Table 2. Shrubs and trees reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Cercocarpus betuloides		* 1	- 1	+ 1	23
Cercocarpus breviflorus	* 1	* 1	+ 1	+ 1	69
Cercocarpus intricatus	1				99
Cercocarpus ledifolius	* 22	* 6, 6	+ 8, 2	* 13, 1	15,22,23,25,26,27,28,29,31,37,43, 47,48,54,55,56,58,71,74,77,78,80, 82,83,84,85,86,89,92,93,23,35,48, 54,55,56,86,89,93
Cercocarpus montanus	* 13	+ 2, 2	* 3, 1	+ 5, 2	3,20,37,39,47,48,64,65,71,74,77, 78,80,82,83,87,88,97, 2,39,68,87, 88
Chrysothamnus	+ 14, 2	- 7, 7	- 1, 3	+ 11, 2	2, 8, 9,11,12,14,21,22,23,33,34, 39,40,47,60,65,68,72,73,89,99, 1, 8,22,23,33,34,45,88,99
Chrysothamnus depressus	+ 1, 1			1	64,99
Chrysothamnus nauseosus	+ 23, 1	- 6, 4	- 3, 1	+ 4, 5	7,15,16,18,30,31,33,37,46,51,54, 55,57,58,60,64,71,77,80,82,83,85, 86,88,91,97,98,18,32,54,55,56,60, 84,86,90,94
Chrysothamnus parryi	1				94
Chrysothamnus pulchellus				1	99
Chrysothamnus viscidiflorus	+ 10, 1	+ 3, 4	1	+ 2, 3	17,35,48,55,57,58,60,64,86,94,98, 54,55,56,60,85,94
Coleogyne ramosissima				1	23
Cornus stolonifera	+ 3, 2	1	* 3	+ 3	5,17,30,75,78,82,15,17,18
Cotoneaster acutifolia			* 1		54
Cowania mexicana #	* 8, 1	* 2, 2	+ 4, 1	* 4, 1	23,29,39,48,62,69,73,77,78,80,82, 99,23,69
Crataegus			+ 1		49
Crataegus douglasii			2	- 1	96,49,96
Dalea formosa			1		87
Elaeagnus angustifolia			* 1		53
Elaeagnus commutata	1		+ 1	- 1	30,30
Ephedra	- 2, 1	+ 1		- 1	64,73,82,82
Ephedra nevadensis	- 1, 1	1			29,22,28
Ephedra viridis	* 1, 1	- 1	1	+ 1, 1	8,14,99,99
Eurotia lanata	- 1, 2	+ 1	+ 2	1	13,40,53,64,97,99
Fallugia paradoxa	+ 1, 1	2	- 1, 2	2	53,99,39,87,99
Fendlera rupicola #		1		1	69,99
Fendlerella utahensis				1	99
Forestiera neomexicana		1	1	1	69
Forsellesia = Glossopetalon	- 1, 1				59,99
Forsellesia nevadensis = Glossopetalon nevadensis	1			1	99
Fraxinus pennsylvanica #				1	42
Garrya wrightii	1	1	* 1, 1	+ 1	39,69
Glossopetalon = Forsellesia	- 1, 1				59,99
Glossopetalon nevadensis = Forsellesia nevadensis	1			1	99
Holodiscus #	2	- 1			83,11
Holodiscus dumosus	- 1	- 1	- 1	+ 1	37,88
Jamesia americana	- 1	- 1	- 1		88
Juglans major				1	84
Juniperus	+ 14, 2	+ 9, 1	- 2, 2	+ 4, 6	8, 9,10,13,14,30,33,39,40,41,66, 68,71,74,83,84,87,99, 1, 2,11,16, 30,33,39,66,87,99
Juniperus communis	+ 8, 6	+ 6, 2	2	+ 3, 5	7,17,30,34,40,42,49,59,75,86, 3, 11,12,19,30,40,63,65,85,94,97,99
Juniperus deppeana	+ 2	+ 1, 1	2	- 1	69,87,69,87
Juniperus horizontalis	* 7	* 4		+ 2, 1	7,30,34,49,59,61,63,75,16
Juniperus occidentalis	+ 7, 1	+ 3, 1	- 1	+ 4, 1	15,21,31,35,54,55,57,93,25,55
Juniperus osteosperma #	+ 11, 3	* 4, 3	- 1, 2	+ 4, 1	22,23,28,29,37,43,48,62,64,73,77, 82,99,22,69,80,99
Juniperus scopulorum	+ 16, 3	+ 8, 3	- 1, 1	+ 4, 4	5,17,18,19,30,33,37,45,49,60,65, 72,77,80,85,86,88,96,98,16,17,60, 84,86,88,94,96,97

See footnotes at end of table, p. 17.

Table 2. Shrubs and trees reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Libocedrus decurrens	- 1	1	2	2	56,54,55,56
Linnaea borealis #				1	42
Lonicera	1		* 1		53,11
Lonicera arizonica			1		44
Lonicera involucrata			+ 1, 1	1	78,94
Menziesia ferruginea #			+ 1	+ 1	52,95
Pachystima myrsinites #	* 2, 3	- 1, 3	+ 3, 2	+ 5, 1	3, 8,14,47,54,74,78,92,94,10,11, 15,87,88,94,99
Petrophytum caespitosum	- 1				37
Philadelphus lewisii	- 1, 3	+ 1	- 1, 1	* 1	70,96,15,70,91,96
Phoradendron			1	1	39
Phoradendron juniperinum #	1	- 1, 1	1	- 1, 1	15,62,87
Phoradendron villosum		- 1			69
Physocarpus malvaceus		- 1	+ 2, 1	+ 2, 1	52,78,81,82,52,82
Physocarpus monogynus				1	88
Picea			- 1, 1	1	73,65,99
Picea engelmannii			1		94
Pinus	1		2	2	16,32,39,65,99
Pinus albicaulis			1		95
Pinus banksiana	+ 1	+ 1			66
Pinus contorta	- 1, 2	+ 2, 1	- 1, 4	- 1, 3	7,19,65,76,94, 3,17,25,35,76,91, 94,95,97
Pinus edulis	+ 8, 1	+ 6, 2	3	- 3, 1	8, 9,10,13,14,62,64,73,87,88,99, 14,68,69,87
Pinus flexilis	- 2	3	1	1	17,86, 3, 7,85,87
Pinus monophylla	+ 3	+ 3	+ 1		23,28,29
Pinus ponderosa	+ 17, 1	+ 10, 3	- 3, 5	+ 5,10	5, 7,15,18,33,34,39,40,44,51,59, 54,55,65,66,69,70,73,87,88,89,34, 35,42,45,54,55,56,59,69,70,87
Pinus sylvestris	1				66
Populus	1	+ 2	+ 1	+ 2	16,33,45,72,65
Populus acuminata	1		- 1		88,88
Populus angustifolia	- 1, 1			+ 1	12,88,11
Populus deltoides				- 1	63
Populus sargentii				+ 1	61
Populus tremuloides	+ 12, 3	+ 5, 2	+ 18, 4	* 16, 4	1, 7,10,11,12,14,17,26,27,30,35, 37,39,44,46,47,48,49,52,59,61,65, 71,73,75,76,78,79,82,86,88,92,93, 94,97,99, 3,15,27,42,54,55,56,61, 63,65,69,87,94
Populus trichocarpa	- 1, 1		- 1	- 1	96,91
Potentilla fruticosa	- 1, 1	1	1		86,11,69,94
Prosopis juliflora			1	1	69
Prunus	1	+ 1, 1	- 2, 2	- 3, 4	33,63,66,81, 3,32,35,55,69
Prunus americana				+ 1	33
Prunus andersonii	- 1, 1	+ 2		- 1	28,55,56,55
Prunus emarginata	3	+ 1, 1	+ 4	+ 3, 1	22,27,55,93,15,27,91,92,93
Prunus fasciculata			* 1		54
Prunus virginiana #	+ 20, 6	+ 15, 9	+ 24, 2	+ 20, 2	4, 7, 8,11,12,14,16,17,20,22,23, 26,27,30,34,37,46,48,49,50,51,52, 54,55,56,60,61,64,65,67,70,75,76, 77,78,79,80,82,86,88,90,91,92,93, 94,96,98, 9,14,15,18,27,30,49,54, 55,60,61,70,83,84,87,93,94
Pseudotsuga menziesii #	+ 23, 3	+ 15, 2	- 2, 2	+ 9, 4	1, 5, 7,11,14,15,17,18,19,34,37, 39,41,44,45,49,58,59,60,65,67,70, 72,75,86,88,89,96,97,99, 5,14,34, 59,70,71,86,94,96,99
Ptelea		1	1		69
Purshia glandulosa	* 2	+ 2	* 1	* 1	23,28
Purshia tridentata	* 35	+ 14, 4	* 10, 1	* 14, 2	1, 2, 8,11,12,13,14,15,20,21,22, 25,27,29,31,35,37,43,47,48,53,54, 55,56,57,58,64,65,71,74,77,78,79, 80,82,83,89,90,91,92,93,94,96,97, 98,26,54,68,84,92,94,99

See footnotes at end of table, p. 17.

Table 2. Shrubs and trees reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Quercus	* 1		* 1	* 1	39
Quercus chrysolepis	- 1				73
Quercus gambellii	+ 13, 1	+ 5, 2	* 9	* 10	8, 9,10,11,14,38,47,48,62,64,69, 73,77,78,80,82,87,88,99,88,99
Quercus kelloggii	1	1	1	+ 1	55,55
Quercus macrocarpa				- 1	42
Quercus turbinella	+ 1	+ 1	- 1	1	69,69
Quercus undulata	+ 2	+ 1, 1	* 1, 1	* 1, 1	69,87,69
Quercus vacciniifolia				* 1	25
Rhamnus crocea	+ 1	- 1	- 1		69
Rhus			* 1		33
Rhus glabra #	- 1, 1	1	* 1	1	78,83,42,71,83
Rhus radicans #	1	1	1		66,69
Rhus trilobata	+ 9, 5	+ 4, 1	* 8, 2	* 10, 5	11,16,23,30,32,33,34,39,40,51,53, 60,63,64,65,75,82, 2,28,34,39,69, 87,88
Ribes	- 3, 7	- 1, 7	+ 7, 6	- 5, 3	17,18,35,36,44,52,56,64,78,79,85, 88,93, 5, 7,11,12,15,16,17,20,33, 45,65,69,86,87,88,93,95,97,99
Ribes aureum			+ 2	- 1, 1	25,30,78,30
Ribes cereum	- 1, 1	2		1	65,52,94
Ribes coloradense				1	94
Ribes lacustre				1	94
Ribes leptanthum			1	1	94
Ribes nevadensis				- 1	25
Ribes setosum			- 2	- 1	30,96
Robinia	1				91
Robinia neomexicana		1	- 1, 3	2	44,69,87,99
Robinia pseudoacacia			* 1		53
Rosa	- 6,14	+ 8, 3	+ 17, 7	+ 17, 7	4,14,23,26,30,32,33,34,36,40,42 46,49,59,60,61,63,64,65,66,76,78, 79,81,82,85,88,93,97, 2, 3, 7,11, 12,14,15,16,22,27,33,34,49,52,59, 60,65,69,75,83,86,88,91,99
Rosa acicularis #	- 2, 1	3	- 2	- 2	17,94,96,17,94,96
Rosa arkansana			+ 1	- 1	51
Rosa californica	1	- 1	1	+ 1	55,55
Rosa woodsii #	- 1, 1		- 1, 1	1	37,44, 5, 7,99
Rubus		- 1	+ 2, 2	1	76,96,44,94,99
Rubus neomexicanus			1		44
Rubus parviflorus		1	+ 1, 1	1	78,14,94
Rubus strigosus			1		44
Salix	- 8, 8	- 6, 3	+ 9, 3	+ 9, 5	3,12,17,22,30,42,52,55,56,63,65, 66,72,75,76,82,83,86,88,93,94,95, 2, 7,11,15,16,27,35,55,65,66,69, 87,88,91,92,93
Salix anglorum			1		94
Salix bebbiana			* 1		78
Salix brachycarpa			+ 1		94
Salix exigua	- 2		* 1		77,78,80
Salix scouleriana			* 1		78
Sambucus	- 1		- 2, 2	- 3, 1	52,81,83,93,27,65,92
Sambucus coerulea #	- 2, 1		* 2	* 1, 1	77,78,80,82,15,23
Sambucus racemosa #			+ 1, 2	1	78,44,94
Sarcobatus vermiculatus	+ 2, 2	- 1, 1		1	30,60,15,60,94
Shepherdia		- 1	- 1		40
Shepherdia argentea	1	1	* 2	+ 2, 1	30,53,63,16,30
Shepherdia canadensis	- 3, 4	- 3, 1	- 4	- 2, 1	2,17,19,49,65,75,86,88,94,15,52 85,97
Sorbus			+ 1	+ 1	52
Sorbus scopulina			* 2		78,95
Spiraea	2				15,83
Spiraea betulifolia	- 2, 1		+ 1, 1	+ 1	5,49,49,75
Spiraea densiflora			1		95
Symphoricarpos	+ 7, 7	* 5, 2	+ 12, 4	+ 10, 6	3, 8,11,14,16,30,33,40,45,51,58, 59,60,65,75,78,79,87,92,95, 2, 9, 14,15,20,30,35,54,59,61,88,97,99

See footnotes at end of table, p. 17

Table 2. Shrubs and trees reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Symphoricarpos albus	- 3, 3	+ 3, 1	+ 3	+ 5, 1	5,16,17,30,32,34,36,52, 5, 7,17, 36,86
Symphoricarpos longiflorus		- 3	- 1, 2	- 4	22,23,26,27,23,27
Symphoricarpos occidentalis	+ 3	* 2	+ 2	+ 5	30,42,63,66,67,96
Symphoricarpos oreophilus #	- 4, 1	1	+ 3	+ 3, 1	37,47,48,64,82,93,94,98,93,94
Symphoricarpos parishii			- 1		44
Tetradymia canescens	+ 4, 1	- 2, 1		1	17,59,64,85,86,69,86,94
Vaccinium	+ 1, 1		+ 1		65,78,15
Vaccinium membranaceum		1	* 3	* 1	52,95,96,52
Vaccinium myrtillus			* 1	* 1	94
Vaccinium scoparium		1	+ 2, 1	* 1, 4	86,94,35,42,59,88
Vitis arizonica			1		69
Yucca	+ 3	2	- 1	- 3, 1	33,39,40,51,40,88,99
Yucca baccata	1				99
Yucca elata		1			87
Yucca glauca	* 4, 2	* 3, 2	- 3	+ 4, 1	16,30,33,40,51,60,63,66,11,32,40, 60

1
Some plants are listed by two names. Example: Species A = Species 8. These are plants with synonymous scientific names which are both used commonly. Those plants marked with # were listed by another less common name or archaic synonymy in some of the original food habits studies. See Table 6 for synonymy.

2
Entries consist of three parts. The first is a symbol which reflects the amount consumed relative to all species reported in those studies where it comprised at least 1 percent of the diet. It is based on an average of the amounts reported, but avoids precise numerical quantification: - = Light; + = Moderate; * = Heavy. The second part (underlined) is the number of literature citations upon which the ranking is based. The third part is the number of citations in which the plant was recorded as a trace amount or comprising less than 1 percent of the diet.

3
Underlined numbers indicate literature citations on which value rankings are based. Those not underlined denote literature where a plant was reported as a trace amount or comprising less than 1 percent of the diet. In many cases a number may appear once underlined and again not underlined for an individual species. This would indicate a plant comprised more than 1 percent of the diet during one or more seasons of the year, and contributed a trace or less than 1 percent during another season in the same report.

Table 3. Forbs reported as foods of Rocky Mountain mule deer

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Achillea millefolium #	- 2, 6	- 5, 6	- 4, 7	- 1, 8	17,44,48,49,79,83,88,90,96, 5,15, 18,33,40,42,46,49,52,54,65,69,86, 87,91,94,96,99
Actaea arguta			+ 1	+ 1	82
Agastache urticifolia			+ 2		46,78,23
Agave	1		1		69
Agoseris	3	- 3, 1	- 1, 2	1	69,76,86,99,33,69,86,91,99
Agoseris glauca			+ 4	1	36,44,78,96,94
Allium		- 1, 1	2		22,54,69
Allium cernuum		+ 1			76
Allium textile		+ 1			60
Alyssum alyssoides	- 1		1		49,49
Amaranthus	1	1	2	4	3,32,54,69,87
Ambrosia psilostachya	1		1	1	69
Anaphalis margaritacea		1	2	1	94,99
Androsace septentrionalis			- 1		44
Anemone			- 1		87
Anemone patens = *Pulsatilla ludoviciana* #	1	- 3, 1	+ 2, 3		34,36,61,76,65,88,94
Angelica arguta			1		96
Angelica grayi			1	1	94
Antennaria	- 2, 3	+ 4, 1	4	- 3, 2	7,18,33,42,45,49,72,99,16,49,53, 65,69,99
Antennaria aprica		- 1			88
Antennaria microphylla		- 1		- 1	96
Antennaria parvifolia	- 2, 1	1	- 1	1	19,49,94
Antennaria racemosa		1	+ 2		59,17
Antennaria rosea	+ 2			1	5, 7,94
Apocynum			* 1		78
Apocynum medium	1				75
Aquilegia		1	+ 2	- 1	78,88,88
Aquilegia caerulea			1	1	94
Arabis				1	94
Arabis drummondii	1		1	1	94
Arabis perennans		- 1			69
Arenaria			2	1	99
Arenaria confusa			1		94
Arenaria congesta	- 2		1	1	5,49,18,49
Arenaria fendleri		1			99
Arenaria hookeri	1				7
Arenaria nuttallii		1			86
Arenaria obtusiloba			1		94
Arenaria saxosa			- 1		44
Arnica			+ 2, 1		59,78,99
Arnica cordifolia			+ 4	- 3	36,82,86,94
Arnica foliosa = *A. chamissonis*			- 1		44
Arnica latifolia			1		95
Arnica mollis			1	1	94
Arnica sororia		1			5
Artemisia	1	1	1	1	99
Artemisia biennis	- 1				52
Artemisia campestris #	- 1				96
Artemisia carruthii	1	2	2	1	69,87,99
Artemisia dracunculus #	- 2	- 1	- 1, 1		30,75,69
Artemisia frigida	+ 12, 5	- 6, 5		- 6, 3	5, 7,17,18,30,33,34,40,49,51,59, 60,65,67,70,72,75,11,16,18,19,20, 45,60,86,88,94
Artemisia longifolia	+ 2	1	1	* 1	30,60,60
Artemisia ludoviciana #	- 4, 3	- 1, 3	5	- 3, 6	20,33,34,49,60,87,96, 7,16,33,49, 60,69,87,94,95,96,99
Artemisia michauxiana	+ 1	- 1			17
Artemisia scopulorum			1		94
Aster	+ 5, 3	- 1, 4	+ 9, 1	+ 3, 2	7,40,48,51,52,59,60,75,78,81,86, 88,90, 7,59,69,90,94,99

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Aster campestris				1	94
Aster canescens				1	69
Aster chilensis	- 1		* 2		46,48,79
Aster conspicuous			- 1		76
Aster engelmannii			+ 1	+ 1	81
Aster falcatus #	- 3, 1	4	- 1, 2	- 3	30,49,60,69,30,49,60,69
Aster foliaceus	1	1	+ 1		49,49
Aster laevis			+ 1		95
Aster modestus			+ 1		96
Aster occidentalis			- 1		51
Astragalus	3	3	+ 5, 2	- 2, 2	30,44,51,62,76,99, 7,16,30,65,69, 99
Astragalus cibarius			+ 1		78
Astragalus convallarius	1	1		1	82,94
Astragalus drummondii	- 2		- 2		30,51,75,96
Astragalus flexuosus #		1			99
Astragalus gilviflorus			- 1	- 1	30
Astragalus missouriensis	- 1				75
Astragalus pectinatus	- 1				30
Astragalus recurvus		+ 1	+ 1		69
Astragalus straturensis			+ 1		48
Astragalus tephrodes	1	- 1	1	1	69,69
Astragalus vexilliflexus			- 1		86
Atriplex	1		1	1	99
Bahia				1	87
Bahia dissecta			1		69
Balsamorhiza			- 1	+ 1, 1	3,54, 2
Balsamorhiza sagittata	+ 11, 5	+ 6, 5	+ 6, 2	+ 13, 2	17,18,26,27,36,48,49,51,52,54,55, 59,67,70,75,78,82,90,92,93,94,96, 15,22,26,27,28,49,54,59,86,90,94
Besseya wyomingensis		+ 1			49
Brassica campestris			1		94
Brickellia			1	1	99
Brodiaea pulchella #		1			69
Calochortus		1			99
Calochortus gunnisonii			- 1		49
Calochortus nuttallii			1		23
Caltha leptosepala			- 1, 1	1	65,94
Campanula		1			88
Campanula rotundifolia			- 2		36,88
Capsella bursa-pastoris	1				69
Castilleja	1	1	+ 4, 2	- 1, 2	48,76,79,93,25,69,92,94
Castilleja flava	1				94
Castilleja linariaefolia	- 1		* 1	+ 1	48,82
Castilleja miniata #			- 2		44,96
Castilleja occidentalis			1		94
Castilleja rhexifolia				1	94
Castilleja septentrionalis #			1		94
Cerastium arvense	- 2	- 1, 1	1	1	49,96,49,96
Chaenactis douglasii	+ 1, 1				48,91
Chenopodium		1	1	6	2,20,32,65,87,99
Chenopodium album #	1		2	3	23,35,69,99
Chenopodium capitatum			- 1		44
Chrysopsis	1				65
Chrysopsis villosa	- 2, 1	- 2	* 1	* 2	17,30,67,70,75
Cirsium	+ 2, 7	6	+ 2, 3	+ 8, 5	34,54,59,60,62,67,70,82, 1,29,33, 40,54,56,59,65,69,75,87,94,99
Cirsium arvense	1	1			86
Cirsium drummondii				1	94
Cirsium undulatum				+ 1	51
Cirsium wheeleri			1		44
Claytonia lanceolata		- 2			49,96
Clematis	2	- 1, 1	- 1	1	49,83,49,65,83,94
Clematis columbiana			- 1		49
Clematis hirsutissima			- 1	1	49,94
Clematis ligusticifolia	1	1	+ 1		78,91,99
Clematis pseudoalpina	- 1			1	88,88

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Collinsia			2		54,55
Collinsia parviflora	1				91
Collomia			2		35,56
Collomia linearis		1	- 1		51,99
Comandra umbellata #	1	+ 2, 2	+ 2, 1	2	40,60,23,60,69,94,99
Commelina dianthifolia	1				69
Conringia orientalis			- 1		30
Convolvulus	1				65
Conyza canadensis = Erigeron canadensis	1		1		69
Cordylanthus	+ 1		1	1	99,54,99
Cordylanthus ramosus	- 1	1		1	86,86,92
Cordylanthus tenuifolius	- 1	1	1		69,69
Crepis			+ 1		96
Crepis accuminata	- 1	- 2, 1	1		22,26,23,27
Cryptantha				2	2,56
Cuscuta				1	35
Cymopterus	1	2	1		69,99
Cymopterus bipinnatus	1	+ 1			86,86
Cymopterus purpurascens		1			99
Cynoglossum officinale	- 1				49
Dalea albiflora	1	1	- 1	1	69,69
Delphinium		+ 1, 2	1		76,69,99
Delphinium barbeyi				* 1	47
Delphinium bicolor		- 2	+ 1		36,49,96
Delphinium occidentale			- 1	1	96,94
Descurainia		1	+ 1		78,69
Descurainia californica				1	99
Descurainia pinnata #	1	+ 1	2	2	23,23,96
Desmanthus cooleyi			- 1	- 1	69
Douglasia montana		1			86
Draba		1			99
Draba cuneifolia		1			69
Draba oligosperma		1			86
Draba verna		1			54
Dryas octopetala			1		94
Dyssodia papposa			1		87
Epilobium			+ 3, 1		52,65,86,54
Epilobium angustifolium		+ 1	+ 3	- 1, 1	76,94,95,76
Epilobium hornemannii			1		94
Epilobium lactiflorum			1	1	94
Epilobium paniculatum	1	1	- 1	- 1	69,69
Erigeron	- 2, 5	+ 2, 4	- 6, 4	- 1, 3	17,59,62,69,79,86,87,93, 5,18,65, 69,87,93,94,99
Erigeron caespitosus	- 1				49
Erigeron canadensis = Conyza canadensis	1		1		69
Erigeron compositus	2	2		2	5,18
Erigeron concinnus	1	1			82,99
Erigeron engelmannii	1				94
Erigeron flagellaris		1	+ 1	+ 1	44,99,99
Erigeron formosissimus #		1			99
Erigeron glabellus			- 1		96
Erigeron peregrinus			2	1	95,99
Erigeron pumilus		- 1			96
Erigeron simplex			1		94
Erigeron speciosus #	1		+ 2		36,49,69
Eriogonum	+ 5,14	- 10, 7	+ 7, 6	- 8, 7	7,22,23,26,27,28,29,34,40,55,59, 62,72,78,79,89,90,92,93,99, 1, 2, 3, 5, 7,15,22,23,29,34,35,45,54, 56,59,65,69,87,88,91,92,93,99
Eriogonum alatum		1			99
Eriogonum cernuum		1			99
Eriogonum flavum			+ 1		44
Eriogonum heracleoides	* 1				37
Eriogonum mearnsii	1	1		- 1	99,99

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Eriogonum multiceps	+ 2	1			7,30,30
Eriogonum ovalifolium		1			86
Eriogonum racemosum	- 1	- 1	+ 1	+ 1, 1	69,99
Eriogonum umbellatum #	- 2, 1	* 1, 2	- 2, 1	+ 1, 1	36,69,94,17,69,86
Eriogonum wrightii	+ 1	+ 1	- 1	* 1	69
Erodium	2	1		1	35,56,99
Erodium cicutarium	- 1, 1	2	+ 1, 1	1	78,91,54,69,99
Erysimum capitatum		1			69
Erysimum repandum		1			69
Erythronium grandiflorum		- 1			52
Euphorbia	1		2	6	2,16,32,35,69,87,99
Euphorbia albomarginata			1		69
Euphorbia capitellata			- 1	- 1	69
Euphorbia chamaesula		1	1	1	69
Euphorbia dentata			1		69
Euphorbia fendleri			1	1	69
Fragaria		2	- 1, 2	- 1, 3	35,54,18,52,54,65,99
Fragaria americana			1	1	94
Fragaria vesca #			+ 1		48
Fragaria virginiana #	- 1	2	- 1, 4	+ 1, 1	5,86,76,87,88,94
Frasera albicaulis		+ 1	- 1		86
Frasera speciosa = *Swertia radiata*	1	1	1	+ 2	42,92,65,69,99
Fritillaria atropurpurea		1			99
Fritillaria pudica		+ 2			60,96
Gaillardia aristata			- 1	1	96,96
Galium	2	3	2		69,87,99
Galium boreale	- 2		- 1		49,75
Galium wrightii			1		10
Gaura suffulta #		1	1		69
Gayophytum		1			99
Geranium	+ 1, 1	+ 3, 1	- 5, 3	+ 1, 1	34,59,61,69,76,78,92,65,76,99
Geranium fremontii			* 2, 1		46,79,44
Geranium richardsonii			+ 1, 1	1	48,94
Geranium viscossissimum		+ 2	+ 4		36,49,86,96
Geum rossii			- 1		94
Geum triflorum	2	- 4, 1	- 1, 1		18,34,36,49,59, 5,59,69
Gilia	- 1	1		- 1, 1	88, 2,99
Gilia candida	1				94
Gilia multiflora	1	1	1	1	69
Glycyrrhiza lepidota	- 1	- 1	* 2	+ 4, 1	30,33,51,60,16
Grindelia	1		1	1	16,65,69
Grindelia squarrosa	1	- 1			51,51
Gutierrezia	1	1	1	2	69,99
Gutierrezia sarothrae	6	+ 1	1	- 1, 1	62,87, 7,65,71,82,87,94
Hackelia			- 1		46
Haplopappus	1				99
Haplopappus acaulis	- 1	+ 1	+ 1		86,96
Haplopappus nuttallii	1			+ 1	33, 7
Haplopappus spinulosus				- 1	32
Hedeoma oblongifolium	1	1	1	1	69
Hedysarum		+ 1	* 1	1	76,76
Hedysarum sulphurescens			- 1		36
Helianthella uniflora	1		+ 2		79,86,86
Helianthus	+ 3	+ 2		2	30,65,66,83,42,99
Helianthus annuus	1	1	1	1	69
Helianthus nuttallii			+ 2		36,49
Heracleum lanatum	- 1	+ 1	- 2, 1		76,88,96,94
Hesperochiron			1		54
Heuchera		- 1		1	72,20
Heuchera cylindrica	1		- 1		49,49
Hieracium		1	- 1, 2		79,65,69
Hieracium gracile			1		94
Hieracium greenei				1	35
Houstonia wrightii		1	1		69
Hydrophyllum capitatum		- 1	* 1		48,83
Hymenopappus lugens	1	1	1	- 1	62,69
Hymenothrix wrightii	1		1		69

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Hymenoxys #		1		1	99
Hymenoxys acaulis	- 1				49
Hymenoxys richardsonii			- 1		44
Hypericum			+ 1	1	54,56
Hypericum formosum #			- 1		95
Idahoa scapigera = *Platyspermum scapigerum*		1		1	55,57
Ipomoea	1		1		69
Ipomoea coccinea				1	69
Ipomoea costellata				1	69
Iris			- 1		88
Iris missouriensis			- 1, 2		96,69,88
Lactuca	1		- 1	- 1	32,40,91
Lactuca pulchella			- 1		49
Lactuca serriola	3	- 1	+ 7	- 2	30,34,51,69,78,81,96,30,69,96
Lappula	1	1	2		94,99
Lappula redowskii		1			69
Lathyrus		- 1, 1	- 1	- 1	69,99
Lathyrus eucosmus		1			99
Lathyrus leucanthus		1	+ 1	- 1	46,94,94
Lathyrus ochroleucus		* 1	* 1		76
Lepidium		1	1	1	69,99
Leptodactylon pungens	1				65
Lesquerella	1	- 1, 1			99,65
Lesquerella alpina	1	1			86
Lesquerella arizonica	1				99
Lesquerella fendleri		1			87
Lesquerella gordonii		1			99
Lesquerella rectipes			1		44
Leucocrinum montanum #	1				65
Lewisia pygmaea			2		94,99
Lewisia rediviva		1			18
Liatris punctata	- 1				75
Ligusticum		1			86
Ligusticum porteri			* 1	+ 1	82
Linnaea borealis	- 1			+ 1	59
Lithophragma tenella #		1	1		99
Lithospermum ruderale	- 1		+ 2		75,78,79
Lomatium	2	* 2, 2	- 2	1	30,54,55,79,65,69,91,99
Lomatium foeniculaceum		+ 1			60
Lomatium nevadense		- 2			22,23
Lotus				- 1, 3	62, 2,87,99
Lotus humistratus		1			69
Lotus utahensis			- 1		44
Lotus wrightii	- 1, 1	- 1	+ 1, 1	- 1, 1	44,48,69,69,99
Lupinus	+ 5, 4	- 5, 6	+ 5, 4	+ 8, 6	2,17,22,27,29,35,45,47,48,52,62, 73,78,79,86,90,92,99, 3, 7,15,18, 22,26,33,42,45,52,55,65,69,86,87, 90,99
Lupinus argenteus	- 1	- 1	+ 3, 1	* 1, 1	48,82,96,96,99
Lupinus caudatus		- 1		1	5, 5
Lupinus greenei	1	1		1	94
Lupinus kingii		1	1		69
Lupinus palmeri			+ 1		44
Lupinus polyphyllus			- 1		36
Lupinus sericeus	- 1, 1	1	- 1	+ 1	5,49,75, 5
Marrubium vulgare	1			1	99
Medicago	+ 2, 2		* 1	* 3	16,33,60,65,60,91
Medicago lupulina	+ 1	- 1	+ 1		49,78
Medicago sativa	- 1, 3	+ 2, 1	* 6, 1	* 10, 1	2,16,30,32,38,49,51,55,61,63,69, 78,96,30,54,61,69,96
Melilotus	- 1, 1		* 2	+ 1, 1	39,55,65,78,42,91
Melilotus alba		+ 1	+ 1	- 1	1,32,44
Melilotus officinalis	+ 2, 1	+ 2, 1	* 3	* 1, 2	30,60,69, 2,30,69
Menodora	1	1	1	- 1	69,69
Mentha				+ 1	88

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Mertensia	1	- 1	+ 1, 1		88,65
Mertensia arizonica #			+ 1		82
Mertensia ciliata			1	1	94
Mertensia franciscana		1			99
Mertensia lanceolata	1	- 1			88,94
Micoseris nutans		- 1	1	1	60,60
Microsteris gracilis		1			69
Mirabilis linearis #			1		69
Mitella pentandra			1		94
Monarda			- 1		88
Monarda fistulosa	- 1				49
Monardella odoratissima #	1		1	2	3,69,99
Monoptilon bellioides		1			99
Montia perfoliata			1		56
Musineon divaricatum		+ 1			60
Myosurus aristatus		1			99
Nepeta cataria			+ 1		78
Nicotiana attenuata	- 1				22
Nolina microcarpa			1		69
Oenothera	1	1	1		69
Opuntia	5	1		- 1	66,28,65,66,94,99
Orthocarpus	1				69
Osmorhiza			- 1	- 1	36
Osmorhiza depauperata #			- 1, 1	- 1, 1	81,94
Oxalis		1			69
Oxalis grayi			1		69
Oxypolis fendleri			1	1	94
Oxyria digyna			1	1	94
Oxytropis	- 3	- 1	- 1, 1	1	5, 7,30,30,65
Oxytropis campestris			+ 1		76
Oxytropis lambertii			+ 1		30
Oxytropis sericea			+ 1		30
Paeonia brownii			1		55
Parnassia fimbriata			- 1		96
Pectis	1				87
Pedicularis		1	2		65,69
Pedicularis bracteosa			1	1	94
Pedicularis contorta			1		86
Pedicularis groenlandica		1	1		94,99
Pedicularis racemosa			+ 2, 2	1	78,79,94,95
Penstemon	+ 3, 6	+ 3, 6	- 4, 8	- 5, 5	22,23,26,40,52,65,70,78,82,92,95, 15,22,23,28,52,55,56,65,69,70,87, 94,99
Penstemon caespitosus	1	- 1		1	94,94
Penstemon cyaneus				1	5
Penstemon cyathophorus	1	1			94
Penstemon deustus			1		55
Penstemon linarioides	1	2	2	* 1, 2	62,69,99
Penstemon procerus			- 1		86
Penstemon thompsoniae	1	1		1	99
Penstemon virgatus			1		99
Penstemon watsonii	1		+ 1	- 1	82,94
Penstemon whippleanus			1		94
Pericome caudata				1	88
Perideridia gairdneri			+ 1		36
Petalostemon purpureum			- 1		30
Phacelia	1				65
Phacelia cryptantha	1			1	69
Phacelia hastata #	- 1, 1		1		96,91,96
Phacelia heterophylla #			- 1		44
Phacelia linearis				- 1	5
Phaseolus angustissimus		1	1	1	69
Phlox	- 4, 3	+ 8, 5	+ 4, 3	- 3, 7	22,23,26,28,29,34,35,40,45,55,72, 90,93, 2, 3,16,22,23,27,29,54,55, 87,92,99

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2]: Winter	Spring	Summer	Fall	Literature citations[3]
Phlox albomarginata	+ 1	+ 1			49
Phlox amabilis		1			99
Phlox austromontana #	1	1		1	99
Phlox bryoides = *P. muscoides*	+ 2	+ 2			86,94
Phlox douglasii	- 1			- 1	55
Phlox hoodii	- 5	+ 4, 3		+ 2, 1	7,17,30,33,51,59,60,18,30,59,60
Phlox kelseyi		1			88
Phlox multiflora	1	- 1		1	94,94
Phlox woodhousei		1	1		69
Physalis			2	- 1, 1	69,69,87
Plantago		1	1		88,99
Plantago major			1		99
Plantago purshii		2	- 1, 1		88,69,88
Platyspermum scapigerum = *Idahoa scapigera*		1		1	54,56
Polemonium			1		65
Polemonium albiflorum			+ 2		46,78
Polemonium viscosum			1		94
Polygonum	2	+ 2, 3	- 3, 6	- 3, 7	22,23,27,69,93, 2,16,22,23,26,27, 54,55,65,69,92,99
Polygonum aviculare	1	1	- 2		69,44,69
Polygonum bistortoides			- 1, 1		36,94
Portulaca oleracea			1	1	69
Potentilla	- 1, 1	- 1, 4	+ 6, 4	- 1, 1	46,49,59,65,78,79,86,99,45,52,59, 65,69,94,99
Potentilla concinna			1		94
Potentilla crinita			1		69
Potentilla diversifolia			2	- 1	88,86,94
Potentilla glandulosa				1	5
Potentilla gracilis = *P. pulcherrima*	2			2	7,18,88,94
Potentilla hippiana		1	1		88,94
Potentilla newberryi	* 1	* 1		+ 2	57
Potentilla norvegica			1		95
Potentilla subviscosa			1		44
Primula parryi			1		94
Pseudocymopterus		1	1		99
Pseudocymopterus montanus		1	+ 2		44,48,69
Psoralea				1	16
Psoralea lanceolata	1				94
Psoralea tenuiflora			1		69
Pterospora andromedea		1	1		69
Pulsatilla ludoviciana = *Anemone patens*	1	- 3, 1	+ 2, 3		34,36,61,76,65,88,94
Pyrola				- 1	94
Pyrola asarifolia				1	94
Pyrola minor				1	94
Ranunculus	1	1	5	1	22,54,55,65,69,87,99
Ranunculus californicus			- 1		55
Ranunculus cymbalaria			- 1		44
Ranunculus glaberrimus		- 2			49,96
Ranunculus orthorhinchus			+ 1		78
Ratibida columnifera			- 1		30
Rorippa nasturtium-aquaticum			+ 1		78
Rudbeckia				1	3
Rudbeckia occidentalis			+ 2		46,79
Rumex	+ 1, 1	2	- 3, 2	- 1, 2	26,33,57,78,79,27,54,69,94,99
Salsola kali #	- 1, 3	- 1, 1	1		74,83,54,69,91,99
Sanguisorba minor			1		44
Sanvitalia				1	87
Saxifraga arguta			1	1	94
Saxifraga bronchialis			1		94
Schoenocrambe linifolia #			1	1	87
Scrophularia lanceolata #			+ 1		78

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Sedum		1	1	2	7,35,52,65
Sedum stenopetalum #	- 1, 1	- 1, 1	1	1	49,42,86,65,95
Senecio		3	+ 1, 2	1	78,52,65,94,99
Senecio amplectens			1		94
Senecio canus	- 1		+ 1		49,51
Senecio crassulus			+ 1, 1	1	86,94
Senecio integerrimus	1				91
Senecio multilobatus	1			1	94
Senecio neomexicanus	1	- 1	1	- 1	69,69
Senecio serra			- 2		46,79
Senecio triangularis			1	1	94
Sibbaldia procumbens			1		94
Sidalcea			* 1		79
Sidalcea oregana			+ 1		78
Silene acaulis			1		94
Sisymbrium				1	32
Sisymbrium altissimum	+ 1		1	1	54,56,69
Smilacina			+ 1		78
Smilacina racemosa			* 1	* 1	81
Smilacina stellata		+ 1	- 1	1	76,94
Smilax herbacea #				1	42
Solanum				1	16
Solanum elaeagnifolium	1			1	87
Solidago	- 1, 2	2	+ 2, 4		49,78,65,69,94,99
Solidago missouriensis	+ 1	+ 1		- 1	17,30
Solidago petradoria	1	- 1			82,99
Solidago rigida	1			- 1	88,88
Sphaeralcea	2	2	2	+ 1, 2	62,69,87,99
Sphaeralcea coccinea				+ 1	60
Sphaeralcea grossulariaefolia		1	1	- 1	69,69
Streptopus amplexifolius			1	1	94
Swertia radiata = *Frasera speciosa*	1	1	1	+ 2	42,92,65,69,99
Taraxacum		+ 3, 2	+ 4, 4	+ 2, 2	51,69,76,88,93,16,54,55,65,69,88, 99
Taraxacum ceratophorum		- 1	* 1		86
Taraxacum laevigatum			+ 1	- 1	36
Taraxacum officinale #	1	+ 2, 2	+ 9	- 1, 1	5,38,44,48,59,78,79,82,94,96,59, 82,87,94
Tauschia	1				22
Thalictrum fendleri		2	+ 4, 2	1	46,48,78,79,44,69,94,99
Thalictrum occidentale				- 1	92
Thalictrum sparsiflorum			- 1		96
Thelypodium				1	69
Thermopsis divaricarpa #	1	1	1	1	69,87
Thermopsis montana #			1		54
Thlaspi	1	3	2		1,87,99
Thalaspi alpestre = *T. fendleri*			- 1, 1		44,94
Thlaspi arvense				1	32
Townsendia			1		99
Townsendia exscapa				1	69
Townsendia parryi			- 1		96
Tragia stylaris = *T. ramosa*			1		69
Tragopogon	1	+ 1, 1	* 2, 1	3	34,46,16,34,69
Tragopogon dubius	- 5, 2	- 1, 1	+ 8	+ 5, 1	17,30,36,49,51,60,61,81,96, 7,17, 61
Tragopogon pratensis	1			1	5,32
Trifolium	2	- 3	* 3, 5	+ 2, 3	17,49,69,73,82,90,16,17,35,54,65, 69,86,94,99
Trifolium andinum			+ 1		44

See footnotes at end of table, p. 26.

Table 3. Forbs reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Trifolium dasyphyllum			1		94
Trifolium longipes #			+ 2		48,86
Trifolium repens		+ 1	- 2	- 2	42,76,94
Trifolium wormskjoldii #			+ 1		44
Trollius laxus			2	1	65,94
Urtica dioica #			2		22,86
Valeriana			+ 1, 1		52,65
Valeriana dioica			- 1		36
Valeriana occidentalis			1		96
Valeriana sitchensis			+ 1		95
Veratrum				+ 1	52
Veratrum viride			- 1		95
Verbascum				1	35
Verbascum thapsus	1	1	1		69
Verbena macdougalii				1	99
Veronica americana		- 1			96
Vicia		- 1	2	4	69,33,65,69,92,94,99
Vicia americana	1	- 2	- 5, 2	- 3, 2	30,48,69,76,78,81,87,88,30,69,87,88
Vicia cracca			+ 2		52,95
Vicia pulchella		1	1		69
Viguiera	- 1	1	- 1, 1	1	69,88,69
Viguiera multiflora	- 1		+ 1		48
Viola			- 2, 1		40,46,54
Viola canadensis			- 1		49
Viola nuttallii #		1	- 1		36,99
Viola purpurea #				1	22
Wyethia			- 1		55
Wyethia amplexicaulis	- 1	- 1	* 3	- 1	48,78,79,81,83
Wyethia mollis	- 1, 1	1		- 1, 1	55,56,22,55,56
Xanthium				1	32
Zigadenus elegans		* 1	1	1	76,94
Zigadenus paniculatus		- 1			82
Zigadenus venenosus	1	1			86

1 Some plants are listed by two names. Example: Species A = Species B. These are plants with synonymous scientific names which are both used commonly. Those plants marked with # were listed by another less common name or archaic synonymy in some of the original food habits studies. See Table 6 for synonymy.

2 Entries consist of three parts. The first is a symbol which reflects the amount consumed relative to all species reported in those studies where it comprised at least 1 percent of the diet. It is based on an average of the amounts reported, but avoids precise numerical quantification: - = Light; + = Moderate; * = Heavy. The second part (underlined) is the number of literature citations upon which the ranking is based. The third part is the number of citations in which the plant was recorded as a trace amount or comprising less than 1 percent of the diet.

3 Underlined numbers indicate literature citations on which value rankings are based. Those not underlined denote literature where a plant was reported as a trace amount or comprising less than 1 percent of the diet. In many cases a number may appear once underlined and again not underlined for an individual species. This would indicate a plant comprised more than 1 percent of the diet during one or more seasons of the year, and contributed a trace or less than 1 percent during another season in the same report.

Table 4. Grasses, sedges and rushes reported as foods of Rocky Mountain mule deer

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Agropyron	+ 3, 1	+ 2, 1	2	* 2, 2	21,57,62,76,90, 1,15,69,94
Agropyron cristatum #	* 2	* 1, 2	- 1, 1	+ 2	44,57,69,69,94
Agropyron intermedium	- 1		- 1, 1	1	44,69,69
Agropyron saundersii				1	94
Agropyron smithii	- 1, 1	- 1	1	1	60,94,60
Agropyron spicatum	+ 5	- 2	1	- 1, 1	6,17,75,82,94,97,82,94
Agropyron subsecundum	1	1			17
Agrostis	1			1	35,65
Andropogon barbinodis		1			69
Aristida	1				69
Blepharoneuron tricholepis		- 1			88
Bouteloua curtipendula	1	1	- 1	1	69,69
Bouteloua gracilis	- 1, 1	1	1	1	94,69,94
Bromus		* 1, 1	1	1	76, 1,32,55
Bromus anomalus				1	94
Bromus carinatus			- 1		46
Bromus ciliatus			1	1	94
Bromus inermis			+ 1		44
Bromus rubens		- 1			69
Bromus tectorum	+ 3, 5	+ 2, 3	2	+ 1, 3	6,17,57,62,65,15,28,48,54,55,56, 69,99
Calamagrostis canadensis			1	1	94
Calamagrostis rubescens		- 1			17
Carex	- 2, 2	- 1, 4	+ 2, 4	+ 1, 3	19,21,76,79,82, 2,17,32,44,54,56, 83,87,94,95
Carex arapahoensis			1		94
Carex brevipes			1	1	94
Carex foenea			1	1	94
Carex geyeri	1	- 1		- 1	94,15
Carex nebraskensis			1		94
Carex nova				1	94
Cyperus		1			87
Dactylis glomerata		+ 1	+ 2		44,69
Danthonia parryi		+ 1			76
Deschampsia caespitosa			1		94
Echinochloa crusgalli				1	69
Elymus	1				17
Elymus cinereus #	1				97
Elymus glaucus			- 1		79
Eragrostis	2	1	1	- 1	69,65,69
Festuca		+ 1			76
Festuca arizonica		2	2		44,69,88
Festuca idahoensis	+ 3, 1	+ 1			6,17,21,75,17
Festuca ovina			1		44
Festuca scabrella	- 1				75
Festuca thurberi		1	- 1	1	38,94
Hesperochloa kingii #	- 1		1		97,65
Hordeum	1			+ 1, 1	33,16,99
Hordeum jubatum			1		69
Juncus			1		94
Juncus balticus			1	1	94
Juncus drummondii			1		94
Juncus mertensianus				1	94
Juncus regelii			+ 1		96
Koeleria cristata	4	+ 2	+ 1, 1	1	44,69,76,17,69,94,97
Leptochloa filiformis			1	- 1	69,69
Luzula glabrata			1		95
Luzula parviflora	+ 1		1	1	88,94
Muhlenbergia minutissima		1	1		69
Muhlenbergia montana			1		69
Muhlenbergia rigens	1				69
Oryzopsis hymenoides	2	1			82,94,97
Panicum obtusum				1	69
Panicum virgatum				1	69

See footnotes at end of table, p. 28.

Table 4. Grasses, sedges and rushes reported as foods of Rocky Mountain mule deer (continued)

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Phleum			1		69
Phleum alpinum			1		69
Phleum pratense	+ 1	+ 1	2	1	75,76,44,94
Poa	- 2, 4	+ 3, 3	6	2	17,21,69,76, 1,15,49,55,56,65,69, 87,94
Poa compressa		- 1			57
Poa fendleriana	- 1	* 1, 1	- 2	+ 2, 1	44,62,82,94,94
Poa juncifolia	1				94
Poa palustris	1				94
Poa pratensis		2	- 4, 1		38,44,46,79,88,94
Poa secunda = *Poa sandbergii*	+ 1, 1	* 2	1	+ 2, 1	57,60,60,94
Scirpus			1		56
Sitanion	- 1		1		21,94
Sitanion hystrix	- 2, 1	- 3	2	2	57,69,82,44,69,94
Sorghum halepense	1				69
Sporobolus		1			69
Stipa	- 1, 1		1	1	21,94
Stipa columbiana			- 1	+ 1	82
Stipa comata	1	* 1		1	82,94
Stipa lettermanii			- 2		46,82
Stipa pinetorum	- 1	1		1	94,94
Stipa viridula			1		44
Trisetum spicatum			1		94

1 Some plants are listed by two names. Example: Species A = Species B. These are plants with synonymous scientific names which are both used commonly. Those plants marked with # were listed by another less common name or archaic synonymy in some of the original food habits studies. See Table 6 for synonymy.

2 Entries consist of three parts. The first is a symbol which reflects the amount consumed relative to all species reported in those studies where it comprised at least 1 percent of the diet. It is based on an average of the amounts reported, but avoids precise numerical quantification: - = Light; + = Moderate; * = Heavy. The second part (underlined) is the number of literature citations upon which the ranking is based. The third part is the number of citations in which the plant was recorded as a trace amount or comprising less than 1 percent of the diet.

3 Underlined numbers indicate literature citations on which value rankings are based. Those not underlined denote literature where a plant was reported as a trace amount or comprising less than 1 percent of the diet. In many cases a number may appear once underlined and again not underlined for an individual species. This would indicate a plant comprised more than 1 percent of the diet during one or more seasons of the year, and contributed a trace or less than 1 percent during another season in the same report.

Table 5. Lower plants reported as foods of Rocky Mountain mule deer

Plant name[1]	Consumption rankings[2] Winter	Spring	Summer	Fall	Literature citations[3]
Alectoria fremontii	- 1				15
Amanita			+ 1		17
Amanita muscaria			- 1		44
Boletus granulatus			+ 1		44
Boletus aurantiacus			+ 1		44
Clavaria formosa			+ 1		25
Cortinarius			* 1		44
Equisetum				1	33
Equisetum arvense			1	1	94
Equisetum laevigatum			1		96
Letharia vulpina #	1				15
Parmelia chlorochloa	1				94
Pellaea	1	1			69
Pteridium aquilinum		1	+ 1, 1		78,69
Russula emetica			+ 1		44
Selaginella densa	1				7
Usnea			1	- 1, 1	42,94
Usnea sorediifera	1				94

1 Some plants are listed by two names. Example: Species A = Species B. These are plants with synonymous scientific names which are both used commonly. Those plants marked with # were listed by another less common name or archaic synonymy in some of the original food habits studies. See Table 6 for synonymy.

2 Entries consist of three parts. The first is a symbol which reflects the amount consumed relative to all species reported in those studies where it comprised at least 1 percent of the diet. It is based on an average of the amounts reported, but avoids precise numerical quantification: - = Light; + = Moderate; * = Heavy. The second part (underlined) is the number of literature citations upon which the ranking is based. The third part is the number of citations in which the plant was recorded as a trace amount or comprising less than 1 percent of the diet.

3 Underlined numbers indicate literature citations on which value rankings are based. Those not underlined denote literature where a plant was reported as a trace amount or comprising less than 1 percent of the diet. In many cases a number may appear once underlined and again not underlined for an individual species. This would indicate a plant comprised more than 1 percent of the diet during one or more seasons of the year, and contributed a trace or less than 1 percent during another season in the same report.

Table 6. Plant names which were changed in this publication from those appearing in the original deer food habits references [1]

Plant name in tables 2-5	Name shown in original reference	Literature citations
	Shrubs and Trees	
Artemisia arbuscula	*Artemisia nova*	37,77
Berberis	*Odostemon*	15
Berberis repens	*Mahonia repens*	3,37,47,50,68,70,78,79,82,92,97,99
Berberis repens	*Odostemon repens*	8, 9,10,11,12,14,42,84,85
Betula occidentalis	*Betula fontinalis*	78,91,97
Cowania mexicana	*Cowania stansburiana*	23,29,39,48,73,77,78,80,82,99
Fendlera rupicola	*Fendlera*	99
Fraxinus pennsylvanica	*Fraxinus lanceolata*	42
Holodiscus	*Sericotheca*	11,84
Juniperus osteosperma	*Juniperus utahensis*	37,43,64,73,77,80,82,99
Linnaea borealis	*Linnaea americana*	42
Menziesia ferruginea	*Menziesia glabella*	95
Pachystima myrsinites	*Pachystima*	99
Phoradendron villosum	*Phoradendron coryae*	69
Prunus virginiana	*Prunus demissa*	4,15,54,55,56,67,70,98
Prunus virginiana	*Prunus melanocarpa*	8, 9,11,12,14,77,78,79,84,85
Pseudotsuga menziesii	*Pseudotsuga taxifolia*	1,11,14,15,19,37,39,49,59,65,71,83,84,96,97,99
Rhus glabra	*Rhus cismontana*	42,71,84
Rhus radicans	*Rhus toxicodendron*	66
Rosa acicularis	*Rosa engelmannii*	96
Rosa woodsii	*Rosa fendleri*	99
Rosa woodsii	*Rosa neomexicana*	44
Sambucus coerulea	*Sambucus glauca*	15,82
Sambucus racemosa	*Sambucus melanocarpa*	44
Sambucus racemosa	*Sambucus microbotrys*	78,94
Sambucus racemosa	*Sambucus pubens*	94
Shepherdia canadensis	*Lepargyrea canadensis*	15
Symphoricarpos oreophilus	*Symphoricarpos tetonensis*	64
Symphoricarpos oreophilus	*Symphoricarpos vaccinoides*	37,93,98
	Forbs	
Achillea millefolium	*Achillea*	33,52
Achillea millefolium	*Achillea lanulosa*	15,40,42,44,46,48,65,69,79,83,84,87,88,91,94,96,99
Anemone patens	*Pulsatilla hirsutissima*	88
Artemisia campestris	*Artemisia canadensis*	96
Artemisia dracunculus	*Artemisia dracunculoides*	69
Artemisia ludoviciana	*Artemisia gnaphalodes*	99
Aster falcatus	*Aster commutatus*	60,69
Astragalus flexuosus	*Astragalus greenei*	99
Brodiaea pulchella	*Dichelostemma pulchella*	69
Castilleja miniata	*Castilleja confusa*	44
Castilleja septentrionalis	*Castilleja sulphurea*	94
Chenopodium album	*Chenopodium berlandieri*	99
Commandra umbellata	*Commandra pallida*	23,69,99
Descurainia pinnata	*Descurainia brachycarpa*	23
Erigeron formosissimus	*Erigeron pecosensis*	99
Erigeron speciosus	*Erigeron macranthus*	69
Eriogonum umbellatum	*Eriogonum cognatum*	69
Fragaria vesca	*Fragaria bracteosa*	48
Fragaria virginiana	*Fragaria glauca*	76
Fragaria virginiana	*Fragaria ovalis*	87,88,94
Gaura suffulta	*Gaura gracilis*	69
Hymenoxys	*Actinaea*	99
Hypericum formosum	*Hypericum scouleri*	95
Leucocrinum montanum	*Leucocrinum*	65
Lithophragma tenella	*Lithophragma*	99
Mertensia arizonica	*Mertensia leonardi*	82
Mirabilis linearis	*Oxybaphus linearis*	69
Monardella odoratissima	*Monardella*	3

Table 6. Plant names which were changed in this publication from those appearing in the original deer food habits references (continued) [1]

Plant name in tables 2-5	Name shown in original reference	Literature citations
	Forbs (continued)	
Osmorhiza depauperata	*Osmorhiza obtusa*	81,94
Phacelia hastata	*Phacelia leucophylla*	91,96
Phacelia heterophylla	*Phacelia magellanica*	44
Phlox austromontana	*Phlox densa*	99
Pulsatilla ludoviciana	*Pulsatilla hirsutissima*	88
Salsola kali	*Salsola pestifer*	84
Schoenocrambe linifolia	*Sedum douglasia*	87
Scophularia lanceolata	*Scrophularia occidentalis*	78
Sedum stenopetalum	*Sedum douglasii*	95
Smilax herbacea	*Smilax lasioneuron*	42
Taraxacum officinale	*Taracacum vulgare*	87
Thermopsis divaricarpa	*Thermopsis pinetorum*	69,87
Thermopsis montana	*Thermopsis gracilis*	54
Trifolium longipes	*Trifolium rydbergii*	48
Trifolium wormskjoldii	*Trifolium pinetorum*	44
Urtica dioica	*Urtica holosericea*	22
Viola nuttallii	*Viola praemorsa*	36
Viola purpurea	*Viola venosa*	22
	Grasses and Grasslikes	
Agropyron cristatum	*Agropyron desertorum*	57,94
Elymus cinereus	*Elymus condensatus*	42
Hesperochloa kingii	*Festuca kingii*	97
	Lower Plants	
Letharia vulpina	*Evernia vulpina*	15

[1] Some names were changed from those appearing in the original references to correspond to usage in most modern plant manuals. Several plants listed only by genus in the original food habits reference are shown by species if only one species of that genus is known to occur in the state where the food habits work was done.

griculture—CSU, Ft. Collins

Kufeld, Roland C., O. C. Wallmo, and Charles Feddema.
1973. Foods of the Rocky Mountain mule deer. USDA For. Serv. Res. Pap. RM-111, 31 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Literature on food habits of the Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) was reviewed to compile listings of reported foods of this species throughout its range. Plant species are classified as to relative importance on the basis of their contribution to the diet in 99 studies where quantitative data were provided. A total of 202 shrubs and trees, 484 forbs, 84 grasses, sedges and rushes, and 18 lower plants are listed.

Oxford: 156.2. **Keywords:** Wildlife food plants, *Odocoileus hemionus hemionus.*

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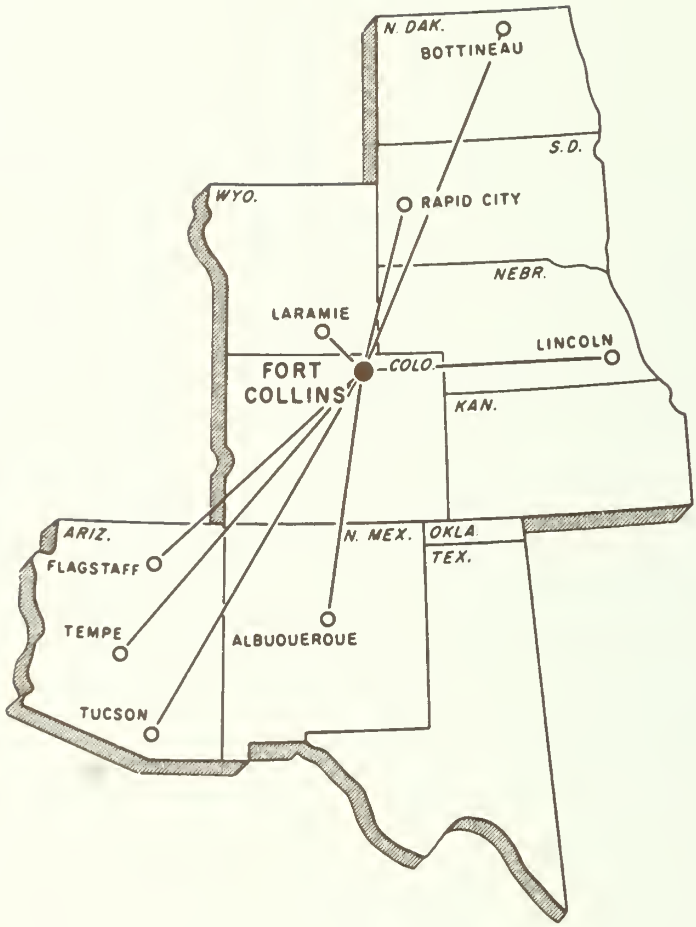
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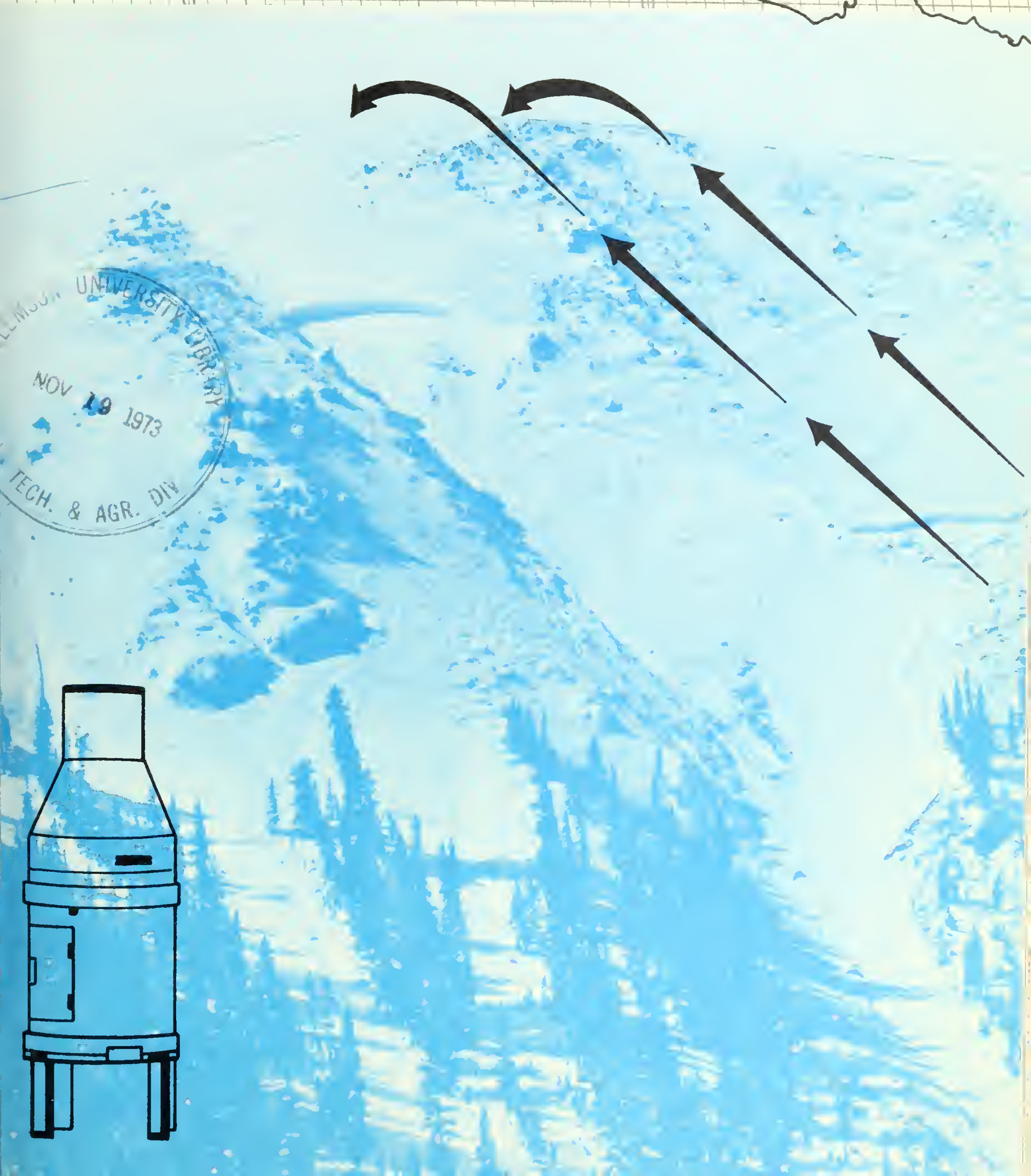
Predicting Avalanche Intensity from Weather Data: A Statistical Analysis

by Arthur Judson
and Bernard J. Erickson



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Abstract

Nineteen weather factors were analyzed to determine which have the highest correlation with avalanche activity. A simple two-parameter storm index and a discriminant function model were found to predict the likelihood of avalanches in Colorado's Front Range. The storm index utilizes precipitation intensity modified by windspeed to predict the number of avalanches expected on 23 paths. The discriminant function model was used in conjunction with a multiple regression program to classify snow as stable or unstable on eight avalanche paths. This analysis shows that a linear combination of the maximum 3-hour precipitation intensities, windspeed resolved to an optimum direction for each path, and the sum of the negative temperature departures from 20° F could be used to determine whether a slope will avalanche 70 to 80 percent of the time.

Oxford: 384.1:423.5. **Keywords:** Avalanches, weather, snow, statistical analysis, statistical methods.

ALL PHOTOS,

SEVEN SISTER AVALANCHE PATHS,

MAY 3, 1973:

This slab avalanche released at 4 a.m., following intense snowfall, strong winds, and cold temperatures. All seven of the north-facing Seven Sister paths discharged their snow cover simultaneously.

The fracture line, estimated as 10 feet high in the smooth curved section, extended across gullies and straight slopes for half a mile beyond the area shown at right edge of the centerfold photo.

The tongue-shaped snow layer, barely discernible left of the debris blocks (near center of centerfold photo), probably was the bed surface of a previous avalanche.

The snow that ran down the No. 6 2,000-foot track was 12 feet deep on U.S. Highway 6.

Traffic was minimal, and no injuries or damage resulted.

An event of this magnitude rarely occurs in the Seven Sister area.

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

USDA Forest Service
Research Paper RM-112

August 1973

Predicting Avalanche Intensity from Weather Data: A Statistical Analysis

by

Arthur Judson, Meteorologist,

and

Bernard J. Erickson, Computer Programer

Rocky Mountain Forest and Range Experiment Station [1]

[1] Central headquarters maintained in cooperation with Colorado State University at Fort Collins.

Contents

Predicting Avalanche Intensity from Weather Data: A Statistical Analysis

Arthur Judson and Bernard J. Erickson

Avalanche personnel know that certain weather factors contribute to avalanching, but determining the relative contribution of various factors is difficult for several reasons. For one thing, most statistical analyses are complicated by the high correlations between factors. Also, good weather and avalanche data are rare because they must be continuously monitored in a severe environment, and the complexity of the relationship between weather and avalanches requires a long, continuous record. Finally, even though avalanche researchers agree that precipitation, wind, and temperature influence snow stability, they do not agree on the best methods of quantifying these and other factors for forecasting purposes. The objectives of this study were to select weather factors that dominate avalanche response, evaluate their relative contribution, and develop a predictive model.

Weather data for the study were collected at Berthoud Pass in Colorado's Front Range from 1951 to 1972. Avalanche records were collected for the same time period. Weather records were taken by the Forest Service; avalanche data were collected by the Forest Service, Colorado Department of Highways, and American Metals Urad-Henderson Mines. The following weather data were put on magnetic tape to facilitate analysis and to insure a convenient permanent file: maximum 3-hour precipitation intensity, 6-hour average windspeed and direction, temperature and temperature trends, 24-hour new snowfall, water equivalent, total snow depth on the ground, and temperature extremes. Data format for both weather and avalanches is identical to that used by stations on the Forest Service weather and avalanche reporting network (Judson 1970).

For a first approximation, weather and avalanche data from 23 avalanche paths were analyzed by univariate techniques similar to Perla's (1970) analysis of contributing factors in avalanche hazard evaluation. This univariate analysis resulted in a relatively simple two-parameter storm index that effectively predicts the number of avalanches expected on the 23 paths. Thirteen factors isolated in the univariate analysis were subsequently subjected to a multivariate discriminant function analysis to produce a more refined three-variable model to predict the likelihood of avalanches on eight paths. This model will be thoroughly evaluated and further refined in the coming avalanche season.

The Univariate Analysis

Seven winters of data (1963-70) were used in this phase of the study. Twenty-three avalanche paths located in the Central Rockies near Berthoud Pass, the Urad Mine, and Loveland Pass were selected for analysis (table 1). Avalanche records for these paths were uniformly good, and the group had terrain features representative of most paths in the Front Range. Nineteen paths in this group were controlled by explosives. The group included moderate- and high-frequency paths which produced an average total of 93 avalanches per winter during the 8 winters, 1963-71.

Scatter diagrams and linear regression proved useful in delineating important weather factors. The number of avalanches from the 23 paths was plotted as a function of single weather factors or simple combinations of them during 42 storms. Storms were defined on the basis of precipitation episodes during the months of December through March. The beginning of a storm was defined as a time when measurable precipitation fell in two consecutive 6-hour periods. A storm was considered over when precipitation ceased for three or more consecutive 6-hour periods.

Table 1.--Some features of the 23 avalanche paths (19 controlled) used in the univariate analysis, 7 winters of data (1963-70)

Path name	Location	Starting zone aspect	Vertical drop	Events recorded, 1963-71: Path frequency per winter	Events recorded, 1963-71: Controlled during period
		Degrees	*Feet*	*Number*	*Percent*
Lift Gully	Berthoud Pass Ski Area	100	360	16	94
Seven Sister 1	U.S. 6	05	600	6	56
Seven Sister 3	U.S. 6	360	640	7	64
Seven Sister 7	U.S. 6	360	750	2	81
Four B	Urad Mine	105	1,840	4	89
Northwest Red	Urad Mine	350	1,840	5	74
Roll	Berthoud Pass Ski Area	80	350	4	66
Five A	Urad Mine	125	1,600	4	68
Five B	Urad Mine	165	1,810	3	75
Current Creek	Berthoud Pass Ski Area	85	500	8	0
Stanley	U.S. 40	160	2,760	3	54
Four A	Urad Mine	90	1,840	4	90
South Chute Roll	Berthoud Pass Ski Area	30	350	3	74
One C	Urad Mine	160	2,120	2	72
One E	Urad Mine	170	1,900	4	81
Bethel	U.S. 6	160	2,200	3	14
Dam	U.S. 40	70	2,600	3	0
Five C	Urad Mine	360	1,840	2	71
Five Car	U.S. 6	75	400	2	33
Little Professor	U.S. 6	140	1,360	2	27
Floral Park	U.S. 40	290	920	2	8
Black Widow	U.S. 6	160	1,640	2	17
Berthoud Falls	U.S. 40	05	2,440	2	0

Some weather factors, such as total water equivalent (fig. 1), showed definite trends while others showed little or no relation to avalanche activity (fig. 2). Several factors were eliminated on this basis. Weather factors tested against avalanche occurrence by scatter diagrams and linear regression during 42 storms were:

Factors kept for further analysis

1. 24-hour water equivalent.
2. 24-hour snowfall.
3. Maximum precipitation intensity.
4. Maximum precipitation intensity modified for excessive wind.

Factors rejected from further analysis

1. Average windspeed.
2. Sums and cross products of maximum precipitation intensity and windspeed (several combinations).
3. Temperature change during storms.
4. New snow density.
5. Settlement.

Wind direction was not analyzed during this part of the study because the paths had many aspects, and wind direction varied considerably during single storms. Much of this variation was due to the approach and passage of upper level troughs. The usual sequence was from SW to W to NW.

The Storm Index

Factors kept for further analysis were subjected to regression analysis using data from 81 storms during 1963-70. The factor best correlated with avalanche activity was the sum of the maximum precipitation intensities multiplied by a constant for excessive windspeed. This factor ($\Sigma\dot{P}k$), termed the **storm index**, predicts the total number of avalanches (controlled or natural) expected on the 23 paths as the result of a storm. For existing data, the

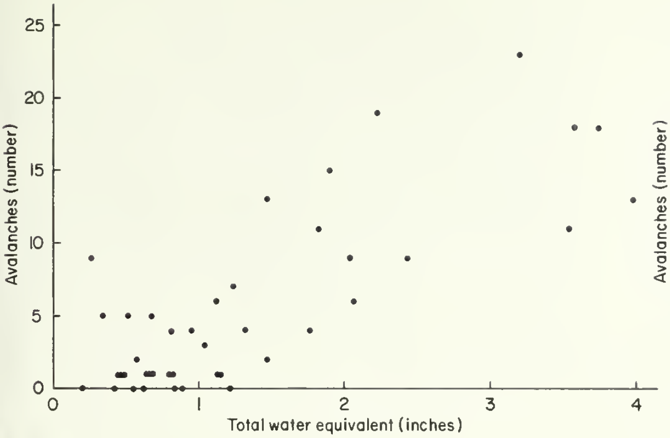


Figure 1.--Number of avalanches from 23 paths as a function of the 24-hour water equivalent of newly fallen snow, 7 winters, 1963-70.

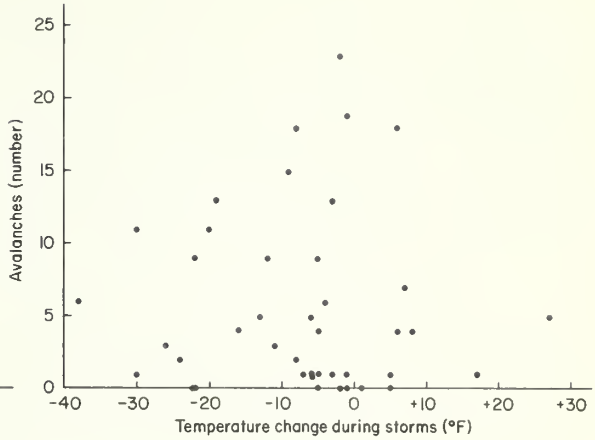


Figure 2.--Number of avalanches from 23 paths as a function of the temperature change during storms, 7 winters, 1963-70.

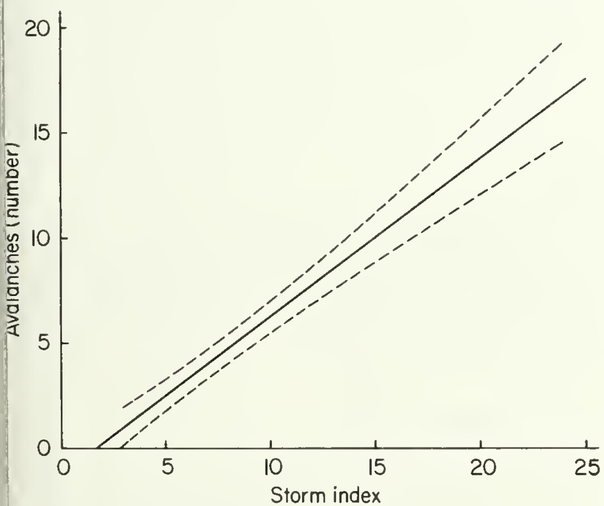


Figure 3.--The storm index, with 95 percent continuous confidence intervals for the mean of all future observations. The number of avalanches expected, based on 7 winters' data, 1963-70, on the 23 paths =

$\hat{Y} = -1.31 + 0.76\ [\Sigma_1^n \dot{P}k]$

where:

n = number of 6-hour periods in a storm;

$\dot{P}$ = maximum 3-hour precipitation intensity within each 6-hour period;

k = a constant.

k = 1 with windspeeds < 27 m.p.h.

k = 0.3 with windspeeds ≥ 27 m.p.h.

The correlation coefficient r = 0.86.

index has a correlation r of 0.86 and a standard error of ± 2.7 (fig. 3).

The storm index is computed every 6 hours and requires minimum instrumentation—a recording precipitation gage and a continuous windspeed record give the required data. This index was developed with avalanche data from paths that have been reliable indicators of avalanche activity in the Loveland-Berthoud Pass areas west of Denver.

The storm index was tested on 20 storms during 1971-72 (fig. 4) with satisfactory results.

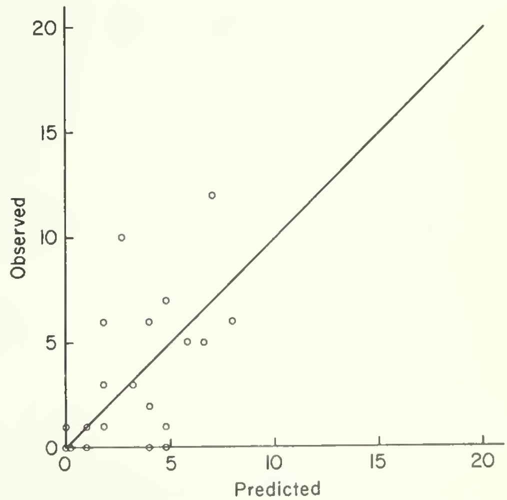


Figure 4.--Scatter diagram of observed versus predicted avalanches for 20 storms during 1971-72. Predictions based on the storm index derived from 1963-70 data.

The predicted numbers of avalanches fell within the confidence intervals shown in figure 3. Observed values were not consistently above or below the predicted, and scatter about the regression line appears to be random. Much of the scatter is attributed to nonuniform control efforts due to other operational considerations confronted by highway and mine personnel.

It was interesting to note that another storm index, developed with avalanche data from 23 uncontrolled avalanche paths, had a much lower correlation coefficient and a greater degree of scatter than the one we finally developed. This difference implies that forecasting indices based on avalanche data from uncontrolled paths are difficult to interpret and are less reliable as forecast guides.

The main drawback with the storm index is that the index is highest near the end of storms, even though hazard may be decreasing because some avalanches have already fallen and the snow is stabilizing. A way of reducing the index toward the end of the storm (a decay function) is badly needed and is now under study.

Applications

The storm index should have some application in other mountain areas. It utilizes precipitation intensity and windspeed during storms to predict the expected intensity of avalanching on an area basis. Because this index was developed using avalanche data from 23 paths that have a wide variety of physical features, we believe it will work, with some modifications, at most avalanche areas. The two weather factors comprising the storm index are directly related to the rate of loading on avalanche slopes. The rate of loading is a prime factor contributing to avalanche release at any area. Plans are being developed for testing the storm index at other avalanche areas.

The Multivariate Analysis

Weather factors other than precipitation intensity and windspeed affect avalanche formation. Moreover, because it is the combined effect of several factors which determines snow stability, it appeared logical to try a multivariate approach to predicting avalanche potential. Also, factors affect individual paths in different ways, so a single path analysis was indicated. A discriminant function analysis was selected for the second phase of the study.

A group of 10 well-defined, controlled paths (table 2) were selected for this analysis. Data from 1952-71 were analyzed. Like those in the first phase of this study, these paths run frequently, and data on their occurrence and control were uniformly good. They are representative of many moderate- to high-frequency paths in the Front Range because of their location, physical features, and wide variety of starting zone aspects. Eight paths threaten highways or roads, and two are in a ski area. None are skied.

The Discriminant Function

The discriminant function is a multivariate statistical technique of assigning data into two or more groups based on prior knowledge. More specifically, it is the linear component of p variables which maximizes the ratio of the between-groups variance to the within-groups variance.

In general form, the discriminant function is written as

$$L = \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p \qquad [1]$$

The discriminant coefficients $\beta_1, \beta_2 \ldots \beta_p$ are computed using the Fisher method discussed by Rao (1952). The multivariate mean of group 1 is given by

$$R_1 = \beta_1 \bar{X}_{11} + \beta_2 \bar{X}_{21} + \ldots + \beta_p \bar{X}_{p_1} \qquad [2]$$

and of group 2 by

$$R_2 = \beta_1 \bar{X}_{12} + \beta_2 \bar{X}_{22} + \ldots + \beta_p \bar{X}_{p_2} \qquad [3]$$

The generalized distance between the group means, called Mahalanobis' D^2, is the difference between the group means. Hence

$$D^2 = R_1 - R_2 \qquad [4]$$

The discriminant function is tested for significance using the F ratio involving D^2. When the function is significant, there is a real difference between groups. The discriminant index R_O, which determines the group classification of future data, is a weighted average of the group means:

$$R_o = \frac{n_1 R_1 + n_2 R_2}{n_1 + n_2} \qquad [5]$$

Table 2.--Pertinent features of the 10 avalanche paths (controlled) used in the multivariate analysis, 1952-71 data

Path name	Location	Starting zone			Vertical drop	Events recorded, 1963-71	
		Area	Aspect	Shape		Path frequency per winter	Controlled during period
		Acres	*Degrees*		*Feet*	*Number*	*Percent*
Lift Gully	Berthoud Pass Ski Area	0.2	100	Bowl-shaped depression	360	16	94
Cliff	Berthoud Pass Ski Area	0.4	90	Straight ramp	350	9	89
Floral Park	U.S. 40	10	290	Poorly defined, slight depressions with a midway bench	920	2	8
Stanley	U.S. 40	20	160	Broad bowl-shaped depressions and shallow gullies	2,760	3	54
Northwest Red	Urad Mine	22	350	Steep bowl-shaped depression with gullies	1,840	5	74
Four A	Urad Mine	10	90	Shallow gullies topped by a cliff	1,840	4	90
Four B	Urad Mine	15	105	Bowl-shaped depression with central gully	1,840	4	89
Bethel	U.S. 6	15	160	Straight slope feeding a gully from the side	2,200	3	14
Seven Sister 3	U.S. 6	0.5	360	Broad and shallow gully	640	8	64
Seven Sister 6	U.S. 6	4	360	Shallow depression flanked by a prominent rock rib	1,050	7	56

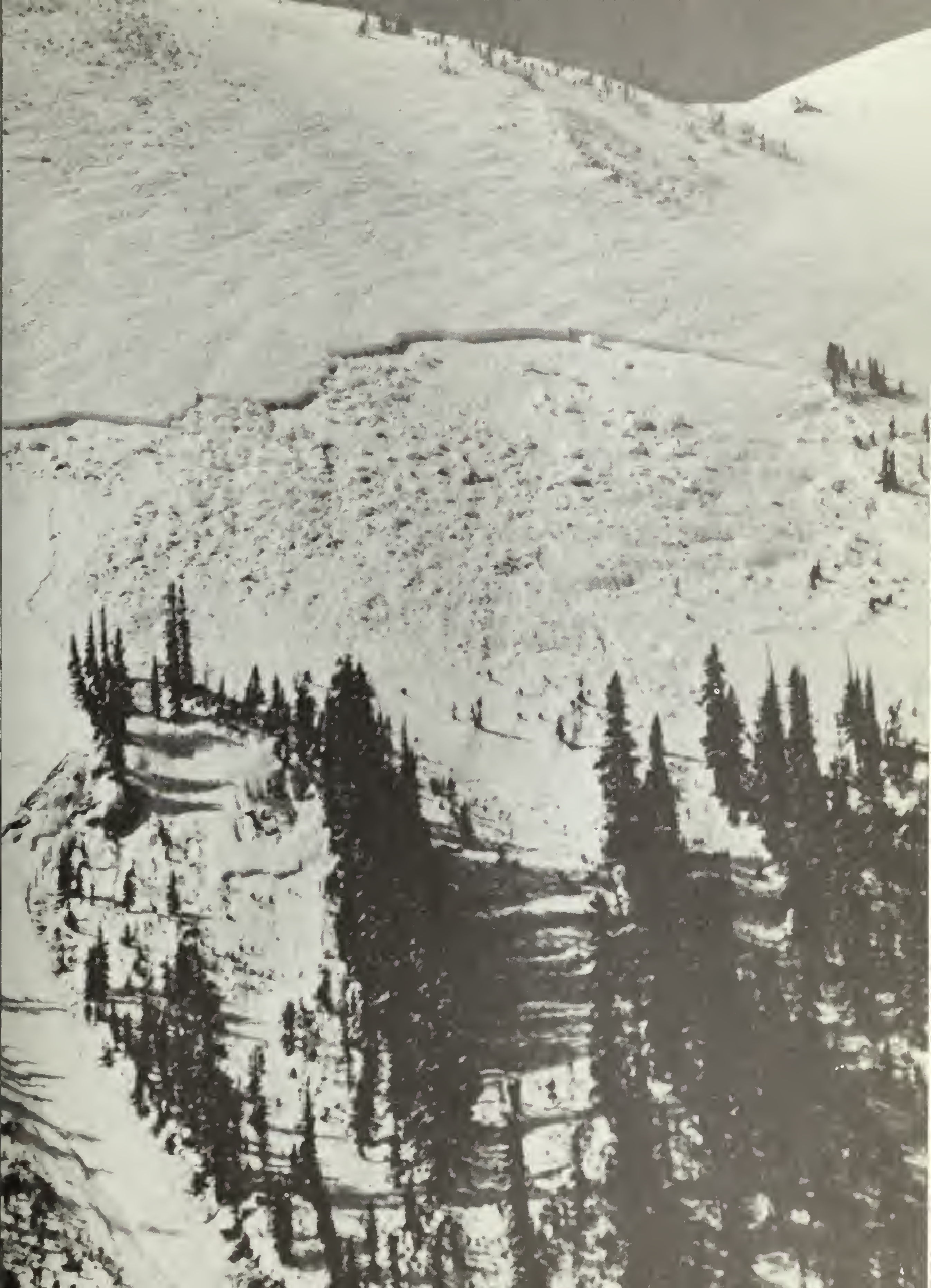
When $L > R_O$, the event is classified in group 1. The validity of R_O is attained by computing the probability of misclassification. This is done by entering D/2 in a cumulative normal frequency distribution table of the normal deviate.

The discriminant function was introduced by Fisher in 1938. It has since been used in medicine, psychology, engineering, biology, economics, anthropology, and geology. Weeks[2] was first to use the technique on weather and avalanche data. Bois and Obled [1972] recently began work with the discriminant function on data from Switzerland.

[2] *Unpublished data [1967], U. S. Army Materiel Command, Cold Regions Res. and Eng. Lab., Hanover, N. H.*

Analysis of Data

This study was confined to the period, November 15 to April 15, which limits the analysis to dry snow at this site. A 20-inch snow depth threshold at the Berthoud Pass weather and snow study site was required before analysis began. Data from 1952 through 1971 were used. Group classifications were based on control results. Snow was defined as unstable (group 1) when control efforts produced a slide or when a natural avalanche occurred. Snow was classified stable (group 2) when control efforts failed to initiate an avalanche. Weather data for both groups were limited to the interval between control applications and/or to the time between natural avalanches on each path. These intervals varied from 1 day to 6 weeks.




A preprocessing program (WXDAT) was
ritten to select weather data for both groups rom a master file of Berthoud Pass raw eather data on magnetic tape. WXDAT pre- ares an input file of selected weather variables or the discriminant function program. The rogram written by Davis and Sampson (1966) or the IBM 1620 was used in our analysis. This rogram was converted for use on a CDC 6400 omputer at Colorado State University. The rogram avoids complex matrix inversion and omputes the discriminant function coefficients or two groups with a maximum of 20 variables. rogram outputs include the discriminant index $_o$, the multivariate group means R_1 and R_2, e F ratio, and Mahalanobis' D^2. Additional utputs were added as analytical aids. The umber of cases in each group does not have be equal, but must exceed the number of ariables.

Variates used with the program must not highly interrelated, a constraint which resented an immediate problem since weather riables are correlated. Fortunately, a linear epwise program could be applied to the dis- iminant problem due to the mathematical uivalence between the models. The correla- on matrix provided by the stepwise program as used to delete highly interrelated variates hich add little to the analysis.

For computational convenience, the step- ise program was given a dummied predictand follows: Taking n_1 cases in group 1 and n_2 ses in group 2, we compute a predictand $_2$ / $n_1 + n_2$ for all cases in group 1 and $_1$ / $n_1 + n_2$ for all cases in group 2. The erage value of the predictand is zero since

$$n_1 \left[\frac{n_2}{n_1 + n_2}\right] + n_2 \left[\frac{-n_1}{n_1 + n_2}\right] = 0 \qquad [6]$$

sed in this manner, the stepwise or screening ogram provides a ranking of variates based the increase in explained variance. The first riate is selected on the basis of having the ghest F value at a given level. Once selected, is held aside, and the program selects the riate with the highest F value of the maining parameters, and so on. The screening ogram provides an unbiased selection of riates which are then run through the dis- iminant function program. The screening ogram is terminated when the additional riables entered are not significant.

The following 13 variables were selected r analysis on the basis of field experience d the earlier univariate analysis:

1. Sum of 24-hour water equivalents.
2. Sum of the maximum 3-hour precipitation intensities in each 6-hour period decayed over the interval.
3. Same as No. 2 without the decay function.
4. Sum of maximum precipitation intensities decreased for excessive windspeeds.
5. Count of 6-hour windspeeds < 15 m.p.h.
6. Count of 6-hour windspeeds between 15 and 27 m.p.h.
7. Count of 6-hour windspeeds > 27 m.p.h.
8. Count of 6-hour temperatures < 20° F.
9. Sum of the negative temperature departures from 20° F.
10. Average precipitation intensity.
11. Sum of windspeeds during precipitation periods, resolved to an optimum direction for each path.
12. Sum of windspeeds resolved to an optimum direction for each path.
13. Sum of squares of windspeeds resolved to an optimum direction for each path.

Results and Discussion

The discriminant function on 8 of the 10 paths was significant at either the 1- or 5-per- cent level. The avalanche records for the two paths failing the significance test were found to be incomplete because control teams failed to enter negative control results. Such data are critical since they define the time interval for weather data used in the analysis. Neither path provided a meaningful discriminant function.

Results of the study are summarized in table 3. The most important variates are:

No.	Designation	Variable
2	$\Sigma\dot{P}I^*D$	Sum of the maximum consecutive 3-hour precipitation intensities within each 6-hour period decayed over the interval.
9	ΣNeg TT	Sum of the 6-hour negative temperature departures from 20° F.
12	ΣVV_R	Sum of the windspeeds ≥ 15 m.p.h. resolved to an optimum direction for each path.

Maximum precipitation rates with a decay function ($\Sigma\dot{P}I^*D$) dominated avalanche response on five of the eight paths, while windspeed resolved to an optimum direction for each path

Table 3.--Composite summary of statistical data, multivariate analysis, 1952-71 data

Path (1)	Significance level (2)	Coefficient (3)	Variable symbol[1] (4)	Variable number[1] (5)	D^2 (6)	Probability of misclassification (7)	Increase in explained variance[2] (8)	R_o (9
	Percent							
Lift Gully	1	0.011	ΣVV_{NW}	12	1.68	0.26	0.1907	2.2
		.280	$\Sigma \dot{P}I{*}D$	2			.0967	
		.000	ΣNeg TT	9			.0001	
Cliff	1	.416	$\Sigma \dot{P}I{*}D$	2	2.06	.24	.2904	3.3
		.004	ΣVV_{NW}	12			.0446	
Floral Park	5	.495	$\Sigma \dot{P}I{*}D$	2	2.50	.21	.3909	4.6
		.001	ΣNeg TT	12			.0126	
		.000	ΣVV_{NW}	9			.0021	
Stanley	1	.294	$\Sigma \dot{P}I{*}D$	2	1.60	.26	.1863	2.6
		.004	ΣNeg TT	9			.0640	
		- .004	ΣVV_{NW}	12			.0438	
Northwest Red	1	.005	ΣVV_{W}	12	1.07	.30	.1671	1.6
		.141	$\Sigma \dot{P}I{*}D$	2			.0440	
		.000	ΣNeg TT	9			.0053	
Four A	5	.288	$\Sigma \dot{P}I{*}D$	2	1.06	.29	.1655	2.7
		.003	ΣNeg TT	9			.0530	
		.000	$\Sigma VV_{W}P$	12			.0005	
Four B	1	.011	ΣVV_{W}	12	2.10	.24	.3095	2.[illegible]
		.004	ΣNeg TT	9			.0295	
		.084	$\Sigma \dot{P}I{*}D$	2			.0119	
Bethel	1	.325	$\Sigma \dot{P}I{*}D$	2	2.23	.23	.3048	4.[illegible]
		.003	ΣVV_{NW}	12			.0407	
		.000	ΣNeg TT	9			.0141	

[1]Variable symbols and numbers are explained on page 9.

[2]Numbers in this column were provided by the screening program; they determine the <u>relative</u> order of importance of the variables.

(ΣVV_R) was the primary factor on three paths. An arbitrary decay function was used to decrease the sum of the precipitation intensities with time. The function is held at one for the first 2 days, reaches 0.5 on the 5th day, and levels off at 0.2 from the 9th day on. This function, used to simulate stabilization with time, decreased the probability of misclassification on seven of eight paths. This parameter is currently being refined for both wind and precipitation. Temperature appears to be an important secondary factor. It was the second most important variate on three paths.

The stepwise program is affected by correlation between independent variables. Therefore, the order of importance (table 3) relative. The primary validity of the variabl selected is given by the probability of misclas ification in column 7 of table 3. Variabl contributing the least toward the explain variance have coefficients near zero. Becau there is some correlation between variable coefficients may be negative in a few case even though the physical effect of the variab is assumed to be positive.

The multivariate analysis indicates that (precipitation intensity, (2) windspeed resolv to an optimum direction for each path, and (temperature can be used to predict the likeliho of avalanches. Even more important, these ariables predict avalanche activity on the test aths more accurately than do all 13 variables ombined.

The variables and order of importance are lifferent for different paths. Paths with a high requency of occurrence are less affected by low emperatures than are paths that run less often, vhich is no surprise since it takes time to hange snow structure. The effects of rapid emperature changes on avalanche release were ıot examined due to insufficient data. In this egard, one must realize that rapidly falling emperatures occur almost every afternoon, ut avalanches do not.

Applications

The technique and analysis developed in he second phase of this study can be applied o weather and avalanche data anywhere. Veather factors dominating avalanche activity at the Colorado study area will probably be key actors in other areas where dry snow avalanches are the main problem. The specific coefficients lerived in this study will be different at other ocations, but the magnitude of these differences s not presently known.

Current plans call for testing the three-variable model by using the eight avalanche paths used in the second phase of this study as an index of avalanche activity in the 100-square-mile area between Arapaho Basin and Berthoud Pass. The response from the index group resembles the occurrence pattern of avalanches from 40 other paths in the area (fig. 5). The probability of misclassification (column 7, table 3) indicates activity from the index group can be correctly predicted 70 to 80 percent of the time. If an independent set of data confirm this accuracy the discriminant function coefficients and variables for the index group could serve as a basis for regional avalanche warnings as well as a guide for avalanche control on the eight index paths.

The L values, or discriminant scores, could be calculated and pooled for the index paths every 6 hours to simulate avalanche activity on a real-time basis. When L exceeds the discriminant index R_O for a given path, the function predicts the path will avalanche either naturally or artificially. For example, the discriminant function for the Lift Gully in table 3 is:

$$L = 0.011(\Sigma VV_{NW}) + 0.28(\Sigma \dot{P}I*D).$$

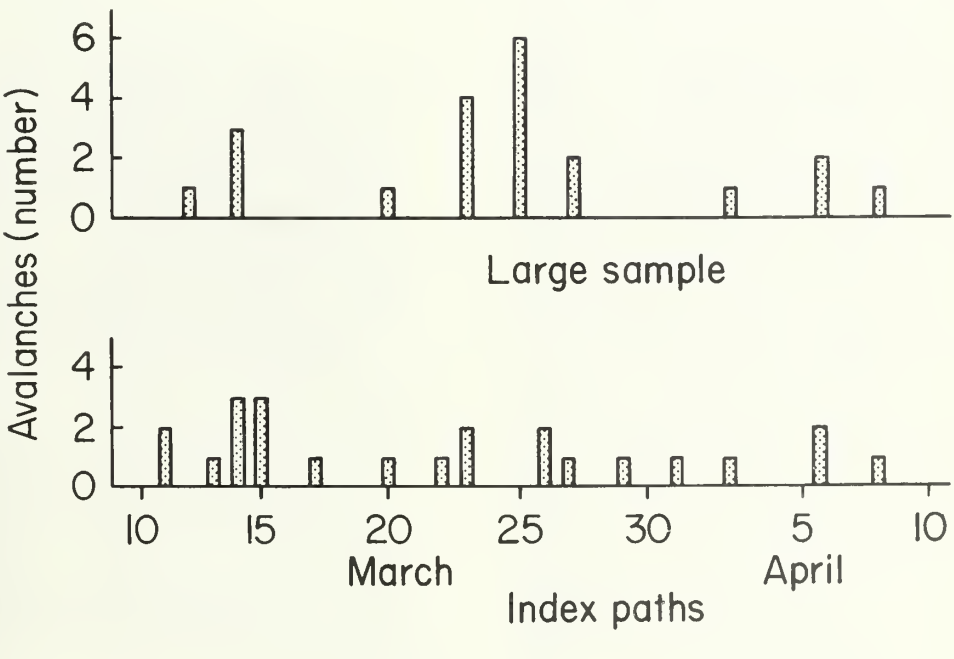


Figure 5.--Relationship between daily avalanche response from the 8 index paths and 40 other paths in the same general area, March 10 to April 10, 1965.

During one 42-hour period in December 1964, the values for the variables were 65.9 and 8.5, respectively. Substituting in the formula:

$$L = 0.011(65.9) + 0.28(8.5) = 3.1$$

R_O for this path is 2.26, the discriminant index was exceeded, and the slope avalanched. Similar calculations can be made for all index paths.

At present, individual L values are reset to zero when a slope avalanches or when it is shot with no results. The decay function reduces the sum of the maximum precipitation intensities ($\Sigma\dot{P}I$) with time. Wind and temperature could be treated in the same manner, so that L for all paths and therefore $L - R_O$, which represents the likelihood of avalanching, would fluctuate through periodic cycles simulating avalanche activity in the region.

Summary and Implications

The storm index developed and tested in the first phase of the study consists of the sum of the maximum 3-hour precipitation intensities multiplied by a constant for excessive windspeed ($\Sigma\dot{P}k$). It predicts the number of avalanches expected on 23 paths in Colorado's Front Range during storms. It could be used as an objective guide for issuing regional avalanche warnings. Its main limitations are: (1) it can be used only during precipitation periods, and (2) it contains no provision for a decrease in avalanche hazard during and following storms. With modifications, it can probably be used at other mountain locations where dry snow avalanches are the primary problem. An identical model made with the same weather data but based on avalanche activity from 23 uncontrolled paths yielded poor results. It is therefore recommended that similar models developed at other mountain areas be based on avalanche activity from paths which are controlled.

The three-variable model developed in the second phase uses maximum precipitation intensity, windspeed and direction, and temperature to predict the likelihood of avalanches on eight controlled paths in the Berthoud-Loveland Pass area. The model is untested. If planned test results are satisfactory, this model will serve as a guide for control decisions on the eight paths. It could also provide the means for issuing a regional avalanche warning and for lifting that warning. The three-variable model is more flexible than the storm index because the calculation of L, or the likelihood of avalanching, begins when snow depth on the ground reaches a threshold depth in early winter, and continues uninterrupted until spring. The L values increase and decrease with time and avalanche activity. This model could provide a daily rating of avalanche hazard which is independent of any subjective definition of storms. The main contribution from this second phase is the technique which can be used to evaluate weather and avalanche data from any mountain area. The weather factors which were found to dominate avalanche activity in this study will probably be key weather factors affecting avalanche response at other mountain locations where dry snow is common.

Although much work remains, an objective basis for issuing regional avalanche warnings is now possible. Additional variables that would give an indication of stress conditions within the snow cover, if they can be isolated and measured, would enhance the reliability of such warnings. Until we learn more about how to isolate and measure the snow-cover features pertinent to avalanche release, any objective avalanche warning scheme will be primarily dependent on weather factors.

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Nineteen weather factors were analyzed to determine which have the highest correlation with avalanche activity. A simple two-parameter storm index and a discriminant function model were found to predict the likelihood of avalanches in Colorado's Front Range. The storm index utilizes precipitation intensity modified by windspeed to predict the number of avalanches expected on 23 paths. The discriminant function model was used in conjunction with a multiple regression program to classify snow as stable or unstable on eight avalanche paths. This analysis shows that a linear combination of the maximum 3-hour precipitation intensities, windspeed resolved to an optimum direction for each path, and the sum of the negative temperature departures from 20° F could be used to determine whether a slope will avalanche 70 to 80 percent of the time.

Oxford: 384.1:423.5. **Keywords:** Avalanches, weather, snow, statistical analysis, statistical methods.

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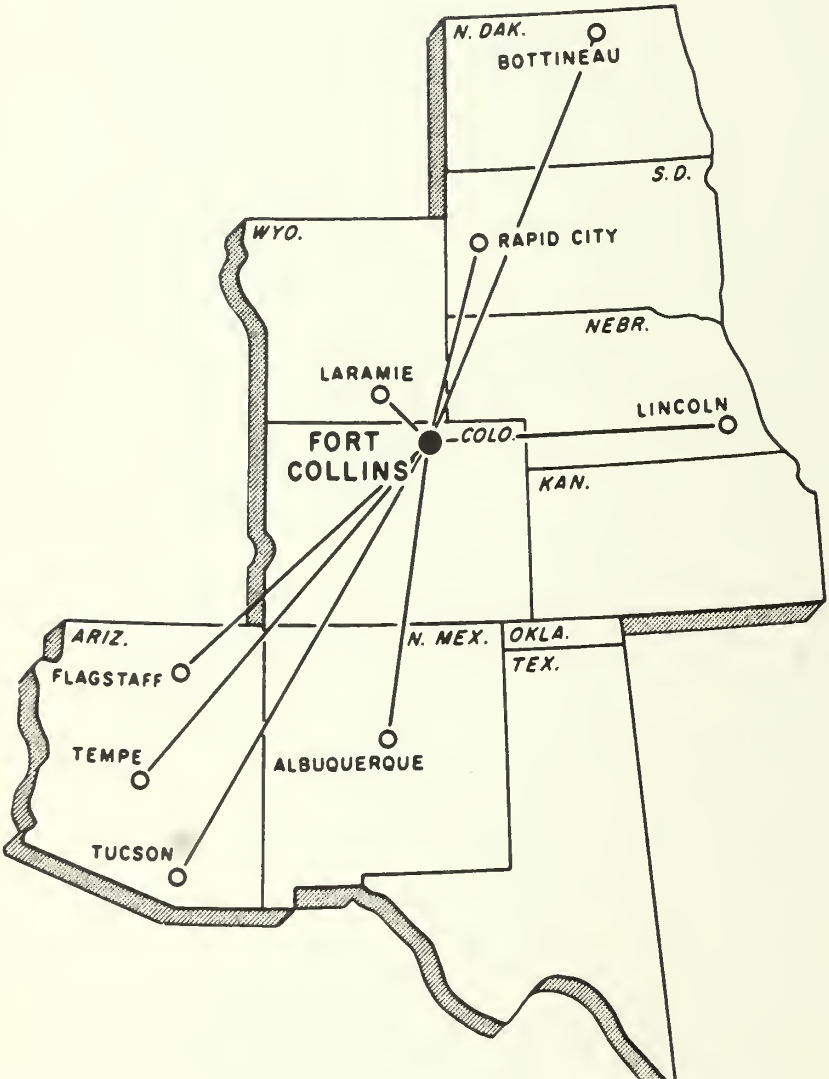
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EOLOGY OF THE MONTANE ZONE OF ENTRAL COLORADO — ith Emphasis on Manitou Park

USDA Forest Service
Research Paper RM-113
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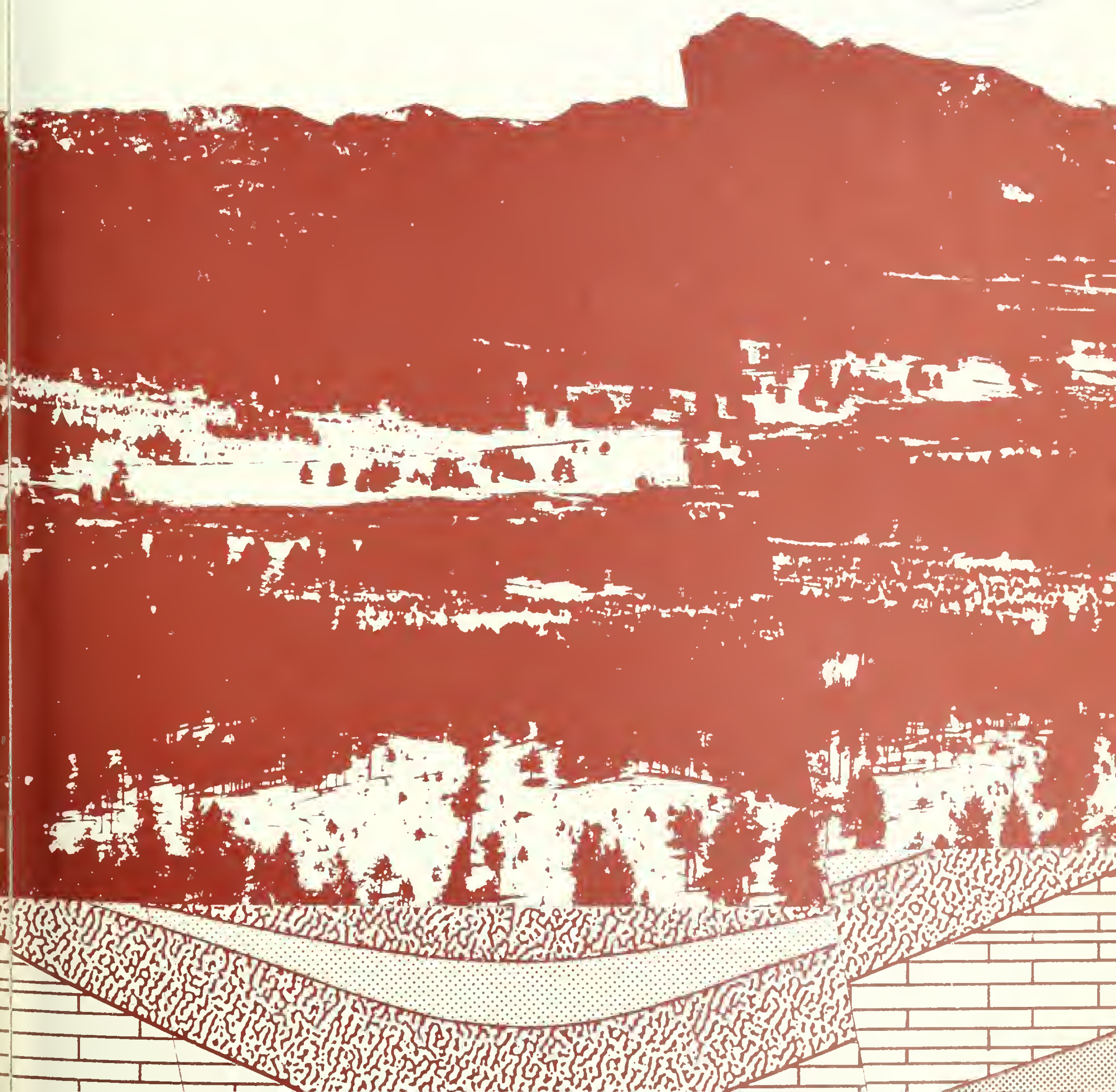
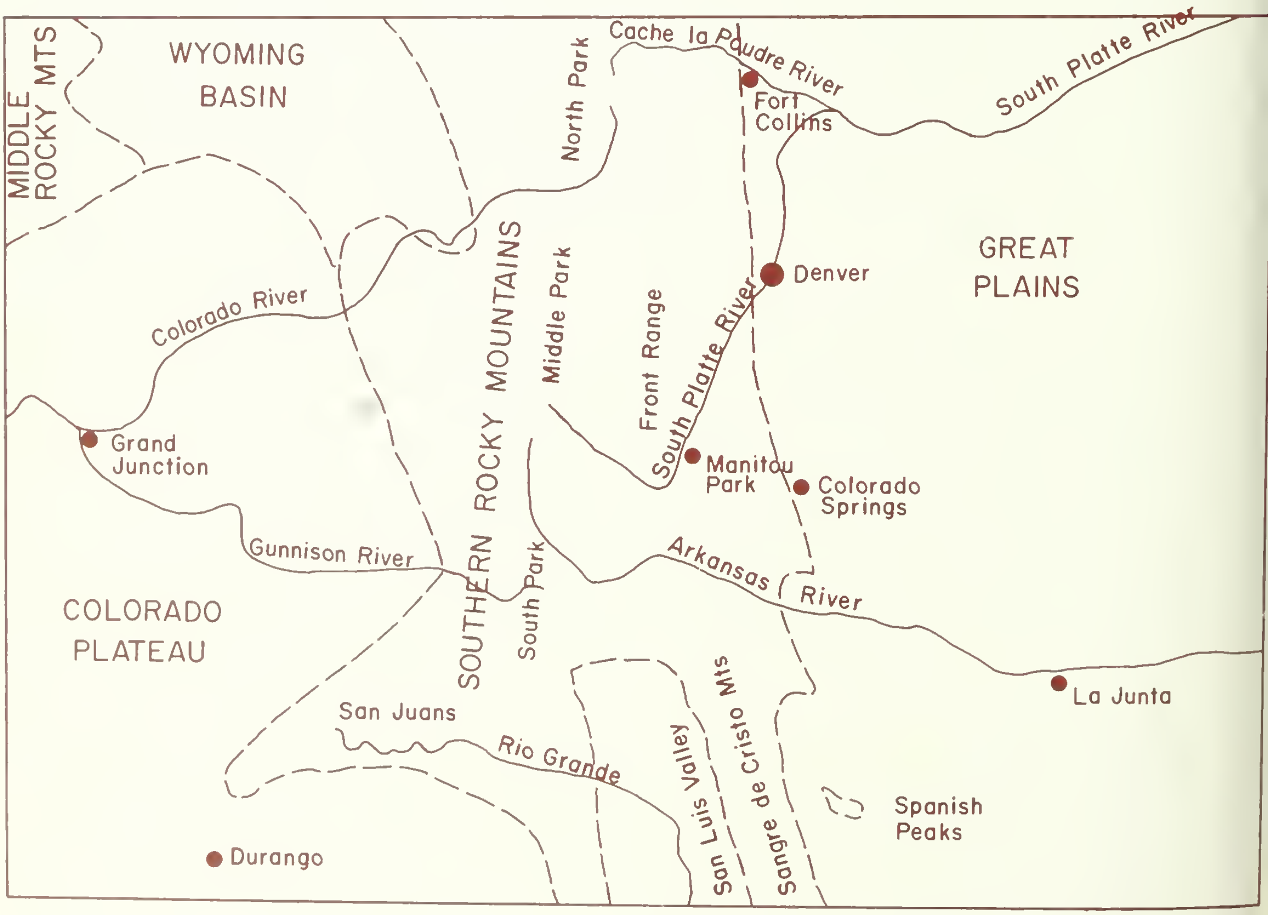


Abstract

Geologic features of four parts of the Montane Zone of central Colorado are described: (1) the Front Range, (2) the Sangre de Cristo Mountains, (3) the Spanish Peaks, and (4) the Wet Mountains. Detailed description and geologic map of the Manitou Experimental Forest are included, which provide some of the information useful in determining applicability of study results to other parts of the Zone.

Oxford: 551:788. **Keywords:** Geologic structures, Colorado Front Range, Montane Zone.



USDA Forest Service
Research Paper RM-113

October 1973

GEOLOGY OF THE MONTANE ZONE OF CENTRAL COLORADO—

With Emphasis on Manitou Park

by

Steven R. Marcus, Associate Geologist

Rocky Mountain Forest and Range Experiment Station [1]

[1] *Central headquarters maintained in cooperation with Colorado State University, at Fort Collins.*

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GEOLOGY OF THE MONTANE ZONE OF CENTRAL COLORADO–
With Emphasis on Manitou Park

Steven R. Marcus

Use of the Montane Zone of central Colorado for residential development and recreation is increasing rapidly. These activities, plus the need for a high level of management of all natural resources, place great demands on land managers and other decisionmakers. Complex decisions that involve people and their use of the resources must be made with knowledge of the effect of one activity on many others. A series of studies is underway to provide decisionmakers with facts and tools that will help them do a better job. This publication provides a summary of some of the information that is basic to these studies.

Most of the Montane Zone of central Colorado occurs on four geologic units: (1) the Front Range, (2) the Sangre de Cristo Mountains, (3) the Spanish Peaks, and (4) the Wet Mountains. Each is described in this Paper. Detailed studies of Montane Zone resources are being conducted at the Manitou Experimental Forest, west of Colorado Springs. Geologic features on and near the Experimental Forest, the Manitou Park area, are described in detail. Decisionmakers throughout the Montane Zone of Colorado can compare conditions at Manitou Park with those of their area of interest. This provides one means of determining how well results of studies may be extrapolated to their area.

Front Range

Igneous and Metamorphic Petrology

The Front Range extends from the Wyoming border to just south of Denver on the eastern slope of the Colorado Rockies, and trends from directly north-south to N. 20° W. It consists of a wide variety of metamorphic and granitic rocks. Since the granitic rocks intrude the metamorphic layers, the metamorphics are therefore older.

There are three major granitic plutons in the Front Range: Pikes Peak Granite in the south, and Boulder Creek and Silver Plume Granites in the northern two-thirds (fig. 1). According to radiometric data cited by Hedge et al. (1967), the Boulder Creek Granite is the oldest, Silver Plume Granite intermediate, and Pikes Peak Granite is the youngest. There are only minor differences in composition between the different granitic types (Lovering and Goddard 1950); one difference is that Pikes Peak Granite is slightly richer in silica than the others (table 1).

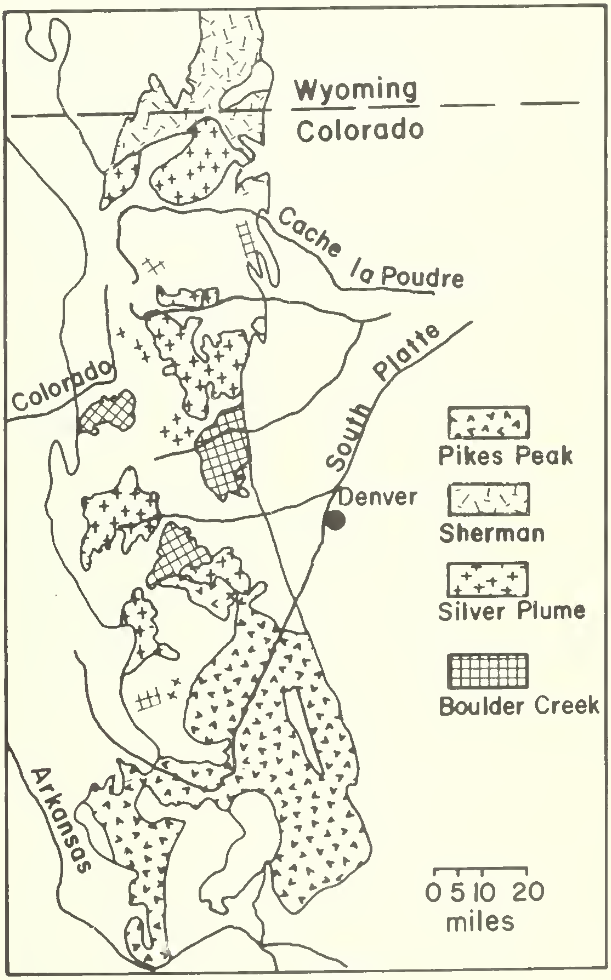


Figure 1.—Granites of the Front Range.

Table 1.--Chemical composition of the granites of the Front Range (after Lovering and Goddard 1950)

Specimen	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O-	H_2O	TiO_2
1. Boulder Creek granite from the fifth level of the Cold Spring mine close to the new shaft, about 3 miles northeast of Nederland	68.71	14.93	1.02	2.07	1.50	2.01	2.85	5.14	0.14	0.56	0.62
2. Local syenitic facies of the Pikes Peak granite, Ajax mine, level 6. Believed to be related to gneissic aplite.[1]	66.20	14.33	2.09	1.93	.89	1.39	2.58	7.31	.48	.83	.65
3. Gneissic aplite near the breast of the Lilly tunnel, Clyde mine, about 2 miles north-northeast of Nederland	66.31	15.07	1.35	2.71	1.03	2.06	2.48	5.96	0.06	0.90	0.66
4. Pikes Peak granite from Sentinel Point, Pikes Peak, Colo.[2]	77.03	12.00	.76	.86	.04	.80	3.21	4.92	.14	.30	.13
5. Pikes Peak granite from Platte Canyon, Jefferson County, Colo.[2]	77.02	11.63	.32	1.09	.14	1.24	2.85	5.21		.35	
6. Silver Plume granite, Silver Plume, Colo.[3]	67.38	15.22	1.49	2.58	1.12	2.12	2.73	5.41	.01	.39	.70
7. Fresh pre-Cambrian Silver Plume granite from the Climax district, Colo.[4]	70.83	14.41	.35	2.94	.56	.64	2.44	6.21	.04	1.34	.24
8. Longs Peak granite, Longs Peak, Colorado.[3]	71.14	16.00	.00	.80	.13	.94	5.13	3.74	.09	.50	.17
9. Longs peak granite from Sta. 191 South St. Vrain Highway [3]	70.85	15.14	.65	1.57	.64	.71	2.44	6.09	.06	.77	.31
10. Mount Olympus granite, Glen Comfort [3]	71.40	16.34	.15	1.71	.31	1.40	4.59	3.24	.11	.22	.36
Average of 4 and 5	77.02	11.81	.54	.97	.09	1.02	3.03	5.06	.07	.32	.06
Average of 6, 7, 8, 9, and 10	70.32	17.42	.53	1.92	.55	1.16	3.47	4.49	.06	.64	.36

Specimen	P_2O_5	SO_3	S (total)	ZrO_2	Cl	F	FeS_2	MnO	BaO	SrO	Li_2O
1. Boulder Creek granite from the fifth level of the Cold Spring mine close to the new shaft, about 3 miles northeast of Nederland	0.16		Tr?								
2. Local syenitic facies of the Pikes Peak granite, Ajax mine, level 6. Believed to be related to gneissic aplite.[1]	.25	0		0.02	Tr.	(?)	0.12	0.13	0.18	Tr.	Tr.
3. Gneissic aplite near the breast of the Lilly tunnel, Clyde mine, about 2 miles north-northeast of Nederland	0.32		0.04								
4. Pikes Peak granite from Sentinel Point, Pikes Peak, Colo.[2]	Tr.					0.36		Tr.	Tr.		Tr.
5. Pikes Peak granite from Platte Canyon, Jefferson County, Colo.[2]											
6. Silver Plume granite, Silver Plume, Colo.[3]	.32		.06					.04	.14		
7. Fresh pre-Cambrian Silver Plume granite from the Climax district, Colo.[4]	.15		.01		0.04				.02		
8. Longs Peak granite, Longs Peak, Colorado [3]	.19							.01			
9. Longs peak granite from Sta. 191 South St. Vrain Highway [3]	.30							.02	.06		
10. Mount Olympus granite, Glen Comfort [3]	.36							.02			
Average of 4 and 5	Tr.					.25		Tr.	Tr.		Tr.
Average of 6, 7, 8, 9, and 10	.26		.03		.01			.02	.04		

[1] Geology and gold deposits of the Cripple Creek district, Colo.: U. S. Geol. Survey Prof. Paper 54, p. 45, 1906.
[2] U. S. Geol. Survey, Geol. Atlas, Castle Rock folio (No. 198), p. 3, 1915.
[3] Geol. Soc. America Bull., vol. 45, p. 320, 1934.
[4] U. S. Geol. Survey Bull. 846-C, p. 225, 1933.

NOTE.—Analyses 1, 3, and 7, by J. G. Fairchild; 2 and 4, by W. F. Hillebr[...] by H. N. Stokes; 6, by R. B. Ellestad; 8 and 10, by D. F. Higgins; 9, by T. K[...]

Boulder Creek Granite

This granite is consistently light gray to dark gray, faintly banded to gneissic, and biotite rich. Strung-out aggregates of black biotite and embayed grains of K-feldspar distinguish the outcrops. The fresh rock is medium to coarse grained, massive, and tough. It disintegrates to gray or rusty gravel of biotite-flected quartz and feldspar crystals. Pegmatites of Boulder Creek genesis contain books of biotite.

Silver Plume Granite

This granite occurs in five small batholiths, numerous plutons, and many dikes and sills in the eastern flank of the Front Range. The granites that compose the Log Cabin, Longs Peak-St. Vrain, Kenosha, and Cripple Creek batholiths and Indian Creek plutons are variants of the typical granite of the Silver Plume batholith and have a common magmatic source. Typical, fresh Silver Plume-type granite is massive, hard, and tough. It is flesh colored to tan, fine to medium grained, and produces little gravel. Pegmatites genetically related to Silver Plume-type granites are fresh, flesh colored to gray, and consist mostly of abundant smoky quartz, flesh-colored potash feldspar, and silver-colored muscovite.

Pikes Peak Granite

The Pikes Peak batholith crops out over 80 percent, or about 1,250 square miles, of the southern third of the Front Range, while the Sherman batholith covers less than 150 square miles of the north end. These two granites are nearly identical in mineral content, texture, color, and response to weathering.

Metamorphic Rocks

The unit of biotite gneiss along the southeastern margin of the central Front Range is considered the lowest unit in the area. The Idaho Springs layer, a lenticular layer of microcline-quartz-plagioclase-biotite gneiss, overlies the biotite gneiss. This unit pinches out in depth and to the south, but appears to thicken toward the east. Another layer that differs from the lowest exposed biotite gneiss, mainly in containing less granite gneiss and pegmatite, overlies the Idaho Springs layer. Above this unit is the Central City layer of microcline-quartz-plagioclase-biotite gneiss, a unit that appears to be uniformly thick throughout the northeastern part of the central Front Range but pinches out southwest of Idaho Springs. Above the Central City layer is a thick succession of biotite gneiss, the most widespread unit at the surface in the area. It includes a lenticular layer of quartz diorite gneiss. The uppermost unit in the region is a thick body of microcline-plagioclase-biotite gneiss called the Lawson layer. All told, about 13,500 feet of metamorphic strata are exposed in the central Front Range area (Moench et al. 1962).

Structure

The Front Range is a complexly faulted, anticlinal, partly fault-bounded arch. The main body of the Range is composed of Precambrian crystalline rocks consisting of highly metamorphosed metasedimentary rocks that have been intruded by granitic masses of at least three generations. This Precambrian belt is 30 to 40 miles wide throughout the length of the Range. The uplift is bounded by several gently deformed structural basins containing sedimentary rocks ranging in age from Cambrian to Tertiary. The east flank is clearly marked by the Denver Basin, an asymmetric downwarp with the axis close to the Front Range. On the south the Range ends at the Canon City embayment, with the Wet Mountains considered as a separate unit. The west flank is less clearly defined by two elongated basins, South Park and North Park, and by a more complex intermediate basin, Middle Park. At the Wyoming border, the Front Range merges into the Laramie and Medicine Bow Ranges (Harms 1965).

Elevations of the Precambrian surface within the surrounding basins and on the prominent peaks of the Range indicate a maximum relief of about 21,000 feet. This maximum occurs near Denver where, in the Denver Basin, the crystalline basement lies at about 7,000 feet below sea level in contrast to the 14,260-foot summit of Mount Evans. Although the elevation contrasts are less along other segments of the margin, relief on the Precambrian surface of 10,000 feet or more is common (Harms 1965).

The margins of the Front Range are typically marked by major faults and/or steep monoclines. Most of these faults are reverse and dip toward the center of the Range. In areas where no major faults are known, monoclines with dips commonly more than 30° form the margin of the Range. Prominent hogbacks of resistant Paleozoic and Mesozoic strata form a narrow foothills belt in the zone of steep dips near the mountains, but dips decrease basinward to a few degrees within a few miles. This means that a large part of the structural relief between basins and peaks is concentrated within narrow belts by large reverse faults and steep monoclines (Harms 1964).

Geologic History and Development of the Area

Following complex deformation and intrusion during the Precambrian, erosion reduced the Front Range area to low relief. As noted by Crosby (1895) the Precambrian surface is very smooth.

In the early Paleozoic, the Front Range area was stable. Earliest Paleozoic deposition in Colorado was in Late Cambrian time when the Sawatch sandstone was deposited. Other marine sandstones and carbonates followed deposition of the Sawatch. They extend over broad areas and represent a period of stability. No lower Paleozoic sediments are present in the central and northern Front Range, and Pennsylvanian sediments rest directly on the Precambrian basement rocks. The southern Front Range area, with preserved lower Paleozoic sediments, has been called the Colorado Sag. It behaved differently than adjacent areas which are referred to as the Transcontinental Arch. Lower Paleozoic beds are exposed in a broken linear belt extending from Parry Park to Canon City, with a second belt extending along the east side of Manitou Park. No basins of deposition developed at this time, and the marine carbonates and sandstone show little facies change.

In Pennsylvanian time there was a pronounced uplift in the area that was called the Ancestral Rockies. This exposed the Precambrian core, and rapid stream erosion and subsequent deposition produced the arkosic and conglomeratic Fountain Formation. Widespread overlap unconformities were produced along the Front Range margins. The area of greatest uplift was slightly more northwest trending than the present Front Range, though occupying much the same position. To the north and south, Fountain sediments rest on successively older beds until the Fountain is in contact with the Precambrian at Parry Park and south of Canon City.

There is a general absence of major deformation in areas adjacent to the uplift. This indicates positive movements without broad lateral belts of deformation. In this respect, the Pennsylvanian uplift resembles the Laramide uplift, although igneous activity is absent. The coarse clastic wedges of the Pennsylvanian and Lower Permian require an uplift of only about 2,000 to 3,000 feet, and based upon this, the late Paleozoic uplift can be considered a tectonically mild feature bordered by narrow fault zones or monoclines. Tectonic stability returned to the area at the end of the Paleozoic when burial of the uplift began.

A mild epeirogenic uplift occurred in Mid-Triassic time, indicated by the truncation of Lower Triassic and Permian beds. Also, Mid- and Upper-Triassic beds are absent in an area centering upon the Wet Mountains. During the Late Cretaceous, this area became part of a major marine basin and approximately 10,000 feet of shale and siltstone, with some sandstone and limestone, was deposited. Structurally, the Front Range lost its identity at this time, and deposition was more or less continuous. The most significant orogenic movement in the post-Cambrian history of the Front Range, the Laramide orogeny, began at the end of the Cretaceous. Marine inundation ended with a regressive sequence of sandstones and coals called the Laramie Formation. Structural movement began at this time, and arkosic and tuffaceous sands and conglomerates flooded outward from the Front Range into the Denver Basin and South Park. Angular unconformities locally record the severity of the orogeny. An example of this severity is the fact that the Upper Cretaceous Laramie sandstone is overlain by Upper Cretaceous and Paleocene Dawson arkose with an angular discordance of 40° a few miles north of Colorado Springs. The nature of the Late Cretaceous and Eocene sediments also attest to the significance of the Laramide orogeny. These sediments are coarse, conglomeratic, contain volcanic fragments and tuffs, and are coarsest at the edges of the Front Range, becoming finer grained farther away. Post-Miocene deformation appears limited to regional warping, so it is apparent that major orogenic movement ended in Miocene time. The present day Front Range owes its height to orogenic uplift, but it was shaped by the erosional agents of wind, water, and ice.

The various sedimentary beds in the foothills and plains are not described here since they are not part of the Front Range proper.

The tectonic origin of the Front Range and its structural implications are a subject of debate. There are two major theories, one based on lateral compression, the other on vertical uplift. Harms (1964) supports the vertical uplift theory. Some reasons he gives are the mild deformation of adjacent basins, the fact that uplift is concentrated in relatively narrow belts along the margins of the Range, the high relief between mountains and basins of the Precambrian surface, the symmetry of the Range, and the large reverse faults and narrow monoclines along its margins.

The Laramide and late Paleozoic uplifts are of similar origin though not corresponding in outline. The zones of weakness that define Laramide structure rarely occupy positions that mark Paleozoic or Precambrian deformation. There is little evidence that early structures controlled later movements.

The Cenozoic geomorphic history of the Front Range, from Thornbury (1965), is as follows:

1. Development of the Front Range during the Laramide Revolution began with the formation of a broad anticlinal arch contemporaneously with the downwarping of the Denver Basin. Dikes, sills, and extrusive sheets are evidence for local volcanic activity at this time.
2. Truncation of the Front Range anticline during Eocene, Oligocene, and Miocene time during a period of intermittent uplift was accompanied by deposition in the Denver Basin and Great Plains. During one of the periods of less rapid uplift, the Flattop peneplain was produced. This peneplain is represented by ridges extending 1,500 to 2,000 feet above the Rocky Mountain erosion surface. Rising above the Flattop remnants are numerous peaks rising above 12,000 feet and forming a distinct axis from northern Colorado to south of Denver.
3. During a period of relative quiescence in Pliocene time, the widespread Rocky Mountain peneplain formed. This peneplain rises gradually from an elevation of about 8,000 feet at the edge of the Front Range to around 10,000 feet at the crest of the range. The sediments removed from the mountains to produce this erosion surface were deposited to the east and

may have overlapped onto the eastern edge of the Precambrian core.

4. Widespread regional uplift initiated erosion which removed most of the Tertiary sediments from the Colorado Piedmont area east of the Front Range and some of the Mesozoic sediments. This uplift also caused canyon cutting in the crystalline rock belt.

5. Alternating periods of valley cutting and pedimentation in the foothills during Pleistocene time formed a number of gravel-capped pediments and terraces. These erosional surfaces can be traced a short distance back into the mountains.

6. Periods of glaciation occurred in the high mountains, modifying valley profiles and producing glacial outwash that was carried down into the foothills and deposited as gravel caps on the Pleistocene terraces. Alternation of cutting and deposition in the foothills and on the plains was in response to the periods of glaciation in the mountains.

7. Recent erosion began at the end of the Pleistocene.

Physiography

Eleven different erosion cycles have been postulated in the Cenozoic development of the Front Range (Van Tuyl and Lovering 1934). The early cycles were terminated mainly by orogenic uplift, the intermediate cycles by combined local and regional uplift, and the later cycles by epeirogenic uplift, glacially caused climatic changes, or both. Evidence for these cycles includes the presence of benches or straths along streams, accordant summits, and imperfect peneplain surfaces.

In the eastern portion of the Range many broad "parks" of comparatively gentle relief, partly or entirely surrounded by more rugged areas, occur in that portion of the mountains varying in elevation from about 6,500 to 10,000 feet. In the case of Manitou Park, the less resistant areas represent outliers of sedimentary rocks which were either folded or faulted down into the crystalline rocks. The other parks, however, such as Estes Park, appear to have formed upon crystalline rocks. They might represent the western limits of broad valleys formed during earlier erosion cycles. Modification by rock decay, stream erosion, sheet erosion, and pedimentation also may have had some effect in the formation of these parks. There seems to be little relationship between the character of the underlying bedrock and the development and preservation of erosion surfaces in the area.

Sangre de Cristo Mountains

The Sangre de Cristo Range extends from north-central New Mexico to south-central Colorado as a long, narrow, rugged range; in Colorado it is bounded on the east by the Arkansas River Valley, Wet Mountain Valley, and Huerfano Park, while on the west it is bounded by the broad, flat San Luis Valley. To the north, the Range terminates at the Arkansas River near Salida.

Although the Sangre de Cristo Mountains are the frontal range at the southern end of the Rocky Mountains, they are classified with the western granite belt rather than the Front Range.

Geologically, the Sangre de Cristos consist of a core of Precambrian schists, gneisses, pegmatites, granites, and diorite, along with what is one of the most complexly folded belts of sedimentary rocks in the southern Rockies on its eastern side. The sedimentary rocks range from Ordovician to Cretaceous (Thornbury 1965). The belt of deformed sediments comprises most of the Range in the north, but in the south the sediments are confined mainly to the foothills belt. The Precambrian rocks, which make up the western part of the Range south of Blanca Peak, are partially covered with Tertiary lavas.

Structurally, the northern Sangre de Cristo Range is a fault block uplifted along a concealed, high-angle fault that separates the Range from the San Luis Valley to the west. The sedimentary layers strike north-northwest, nearly parallel to the trend of the Range, and dip east 30° or more, forming the east flank of the Laramide Sawatch arch. Numerous high-angle strike faults are present. Faulting is more prominent than folding. Structures other than Precambrian are Laramide or younger in age. The west slope of the Range is much steeper than the east slope, and forms a linear eroded scarp throughout its length bounding the San Luis Valley.

Butler (1949) says that sediments in the northern Sangre de Cristos range from Cambrian to Permian at a section near Bushnell Ridge. In this area, he states that tightly compressed folds and faults characterize the highland structure, with Precambrian metamorphics and granites being exposed at the crest of the Range.

Litsey (1958) says that sediments in the northern Sangre de Cristos are Ordovician through Permian. The section he describes (fig. 2) is similar to that of Butler. The pre-Pennsylvanian units are thin and consist mainly

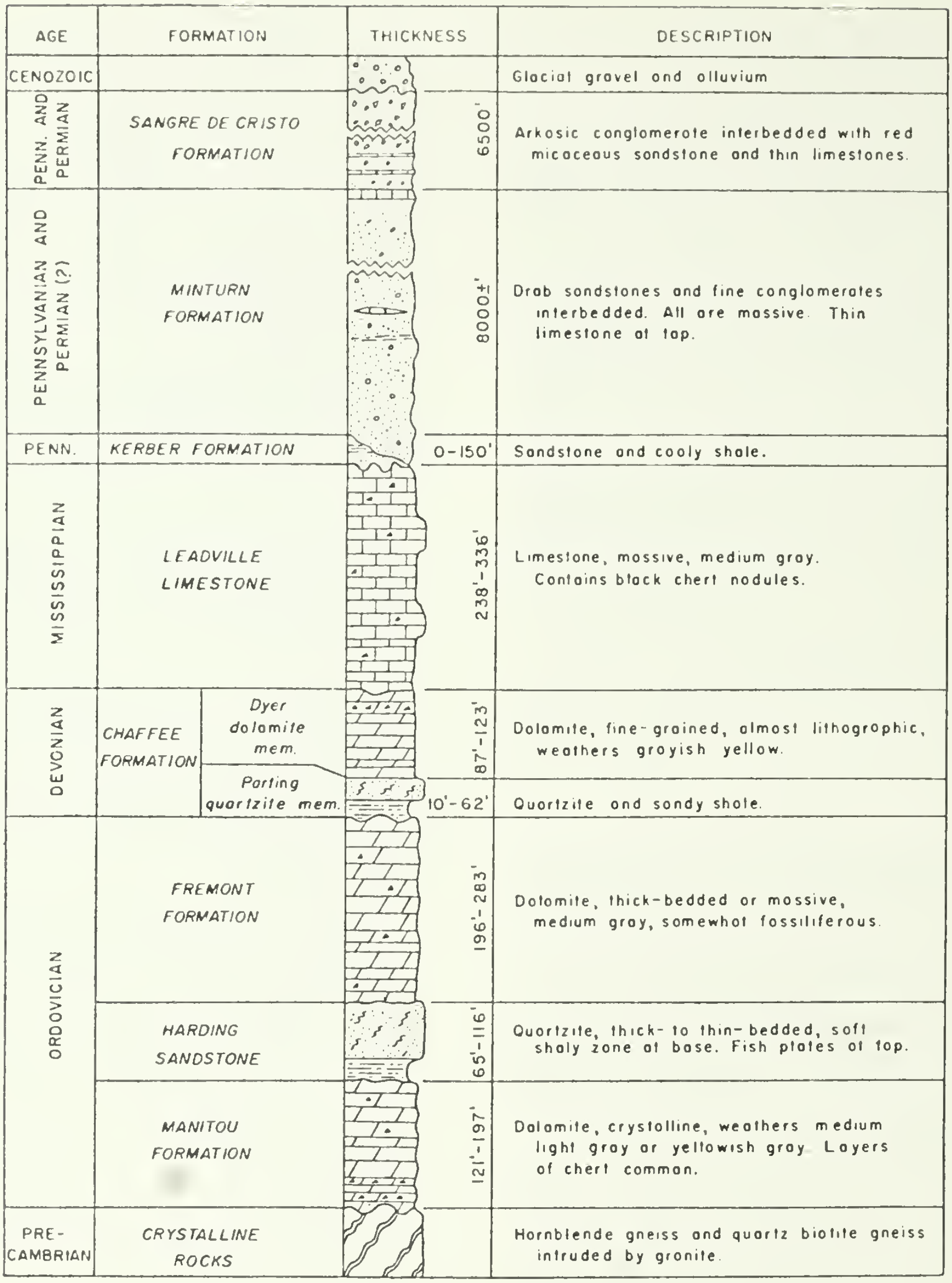


Figure 2.—Paleozoic section in northern Sangre de Cristo Mountains (after Litsey 1958).

of limestone and dolomite with some quartzite, sandstone, and shale. The lithology indicates stable shelf deposition. Pennsylvanian and Permian rocks were deposited as a thick series of clastic sediments in a geosyncline. The Ordovician Manitou Formation is found here. It is the only formation in the area that is distinctly correlated with one of the formations at Manitou Park. Here it rests on crystalline Precambrian rocks consisting of hornblende gneiss and quartz biotite gneiss intruded by granite, whereas at Manitou Park it rests on Sawatch quartzite. The Manitou Formation here is 121 to 197 feet thick, and consists of thin-bedded, siliceous dolomite. In some places the Formation is predominantly limestone or dolomitic limestone. Locally, there are sands or shales at the base. It is mostly fine to medium grained and generally medium bedded (2 inches to 2 feet). Fresh surfaces are medium gray weathered surfaces light to yellowish gray. The Pennsylvanian-Permian Sangre de Cristo Formation is basically an arkosic conglomerate and might be partially equivalent to the Fountain Formation.

The Precambrian crystalline rocks of the region represent an ancient complex of gneissic metasediments invaded by granite of at least two types and ages. West of the Pleasant Valley Fault the Precambrian rocks are metasedimentary, ranging from basic hornblende gneisses to acidic schists and quartzites. East of the Pleasant Valley Fault the Precambrian is composed almost entirely of Pikes Peak Granite with small inclusions of metasediments and Silver Plume Granite.

The Tertiary tectonic history of the northern Sangre de Cristo Range includes at least three distinct phases of deformation. The present range is the eastern flank of two earlier, larger uplifts.

The first phase of deformation began in Late Cretaceous as a broad domal uplift, which became elevated enough by Paleocene time to cause gravity sliding of Permian and Pennsylvanian sediments along bedding plant thrusts. Displacement is 10 to 15 miles on the northeastern and eastern flanks of the uplift. Block uplift of the San Luis Valley area caused a second stage of thrusting along boundary faults which extended eastward into the site of the present Range. This stage of thrusting folded the earlier thrusts and caused some deformation in the eastern foothills. A block which rose in the northeast interfered with thrusting and probably caused the high-angle faults found in the northern end of the Range. Collapse of the San Luis Valley uplift along steep portions of the second-stage thrusts began in Miocene and continues at present, as shown by Recent fault scarps in alluvium, along the western margin of the Range.

Spanish Peaks

The Spanish Peaks, located just east of the Sangre de Cristo Range, are famous for their unusual system of radial dikes. These dikes extend out from the peaks a distance of 25 miles or more (fig. 3). The peaks are bordered on the east by a sloping platform that extends up to an altitude of nearly 10,000 feet. Towering above this platform is the main bulk of the mountain. On the platform is a coarse, bouldery fanglomerate, consisting mainly of white porphyry. This platform has been dissected to a depth of 500 feet by valleys which extend to the foot of the mountain, but a short distance from the mountain they open out into broad, shallow, parklike valleys. Conclusive evidence of glaciation was found at only one locality on the Spanish Peaks, the north flank of West Peak. Sediments in the area range from Upper Cretaceous to Eocene.

The igneous geology of the Spanish Peaks consists of two stocks that cut through the Late Cretaceous and early Eocene strata, surrounded by an immense number of dikes and sills. The stocks have broken through an asymmetric syncline whose east limb is nearly horizontal and whose west limb is vertical or even has been overturned to the east so that locally it dips westward. Each stock is surrounded by a system of radial dikes.

The East Peak stock consists of: (1) white granite porphyry containing phenocrysts of quartz and feldspar, together with a little hornblende and biotite, in a phaneritic groundmass, and (2) granodiorite porphyry, containing accessory augite and biotite, which is intrusive into the granite porphyry and, therefore, younger. At the summit, the granodiorite is plutonic. Oligoclase is abundant, with lesser amounts of anorthoclase, augite, and biotite.

The West Peak stock, although much smaller than that of East Peak, consists of plutonic rock of several facies of syenodiorite. The summit is a pyroxene syenodiorite. The rock, comprising the bulk of the West Peak stock, contains oligoclase, augite, hypersthene, red biotite, anorthoclase, and minor amounts of interstitial quartz.

Between the two peaks is a blackish cordieritic hornfels, formed by the metamorphism of an arenaceous shale. The igneous intrusions occurred during one of the later phases of the Laramide Revolution (early Tertiary).

The area is heavily timbered, mostly second growth. The lower slopes support a dense growth of pinyon and juniper, while the higher slopes support pine forests with spruce, fir, or aspen as the elevation rises.

Wet Mountains

The Wet Mountains, located just south of the Front Range and the Canon City embayment, extend northwest-southeast about 50 miles and are about 20 miles in width. They form the central unit of an en echelon pattern with the Sangre de Cristo Range to the west and the Front Range to the north. There is a close genetic relationship with the Front Range.

The core of the southern Wet Mountains consists partially of Precambrian metasedimentary gneiss and schist concordantly foliated with granite gneiss. These rocks developed by meta-

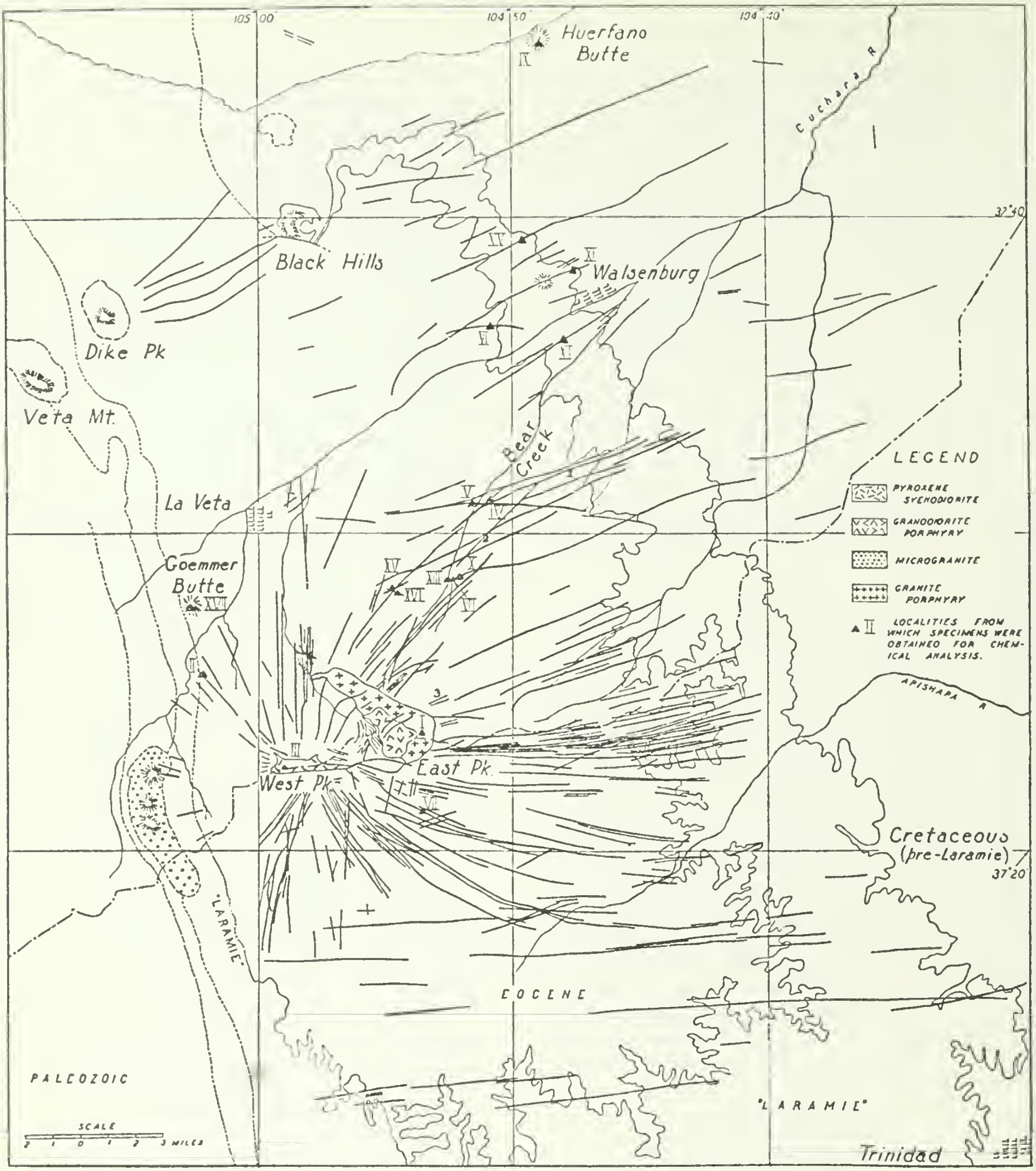


Figure 3.—Structural map of the Spanish Peaks area (after Knopf 1936).

morphic alternation during intrusion of the granitic San Isabel batholith and accessory smaller plutons. These plutons are probably offshoots of the San Isabel batholith, which is dated at about 1.5 billion years.

Structurally, the southern Wet Mountains form a southeast-plunging anticline. They were uplifted to their present elevation from middl Tertiary through Pleistocene. Uplift occurre in stages along major high-angle boundar faults and by slight displacement along th many joints in the area. The age of the sed ments ranges from Permo-Pennsylvanian t Recent (fig. 4).

AGE		FORMATION		LITHOLOGY	THICKNESS IN FEET	DESCRIPTION
QUATERNARY			ALLUVIUM		Varies	Unconsolidated gravel, sand, silt and clay along streams
			TERRACE GRAVEL		25 *	Poorly sorted gravel along foothills
	unconformity					
TERTIARY	PLIOCENE		CONGLOMERATE		25 *	Silica cemented conglomerate with Precambrian fragments
	unconformity					
	MIOCENE		VOLCANIC ROCKS		300 *	Porphyritic vesicular (in part) andesite lava underlain by lacustrine rhyolite tuff
	unconformity					
	EOCENE		FARIŠITA FORMATION		1 000 ?	Poorly consolidated heterogeneous yellow-brown conglomerate
			HUERFANO FORMATION		2.800	White to buff arkosic sandstone interbedded with reddish brown to green mudstone
			CUCHARA FORMATION		400	Conglomeratic arkose with partings of mudstone
	PALEOCENE		POISON CANYON FORMATION		1 300	Brown conglomeratic arkose and mudstone
	unconformity					
CRETACEOUS	UPPER		PIERRE SHALE		1.800	Calcareous concretionary gray shale
		NIOBRARA	SMOKY HILL MARL		700	White to yellow calcareous foraminiferal shale
			FORT HAYS LIMESTONE		50	White lithographic limestone with shale partings
		BENTON SHALE	CARLILE SHALE		200	Dark calcareous shale and siltstone with arkosic sandstone at top (Codell member)
			GREENHORN LIMESTONE		50	Bluish-gray lithographic limestone and calcareous shale
			GRANEROS SHALE		225 *	Dark carbonaceous shale with bentonite partings
			DAKOTA SANDSTONE		250	White-to-yellow quartz sandstone
	LOWER		PURGATOIRE FORMATION		50 *	Gray-white conglomeratic sandstone
JURASSIC	UPPER		MORRISON FORMATION		325 *	Mudstone with feldspathic lithic sandstone
			ENTRADA SANDSTONE		35 *	Massive calcareous quartz sandstone
	unconformity					
PENNSYLVANIAN-PERMIAN			SANGRE DE CRISTO FORMATION		7 000+	Reddish-brown mudstone above gray and brown conglomeratic arkosic sandstone, siltstone, and shale.
	unconformity					
PRECAMBRIAN			CRYSTALLINE ROCK		Unknown	Gneisses and schists intruded by granites

Figure 4.—Section of the Wet Mountains area (after Boyer 1962).

The metamorphosed sediments represent a sedimentary sequence which is probably interlayered with volcanic rocks. They have undergone moderate to high-grade regional metamorphism that produced amphibolite, hornblende, biotite gneiss, schist, and granite gneiss. The gneisses and schists are the oldest and are possibly related to the Idaho Springs Formation.

Another major part of the Precambrian area consists of band, stringers, and lenses of metamorphic rocks which are closely layered with granitic material.

The youngest Precambrian rocks are igneous bodies, mostly granitic, which cover half of the area. The most extensive igneous outcrop is the San Isabel batholith.

The gneissic granite is medium grained with abundant quartz and microcline, each of these minerals accounting for more than 30 percent of the rock. Sodium-rich oligoclase constitutes 10 to 15 percent of the rock. Mafics contribute a low percentage. The rock weathers into sharp, angular-jointed blocks, rather than into rounded or smooth-faced boulders as do the other granites found in the area. The gneissic granite is found in the southern end of the Range.

The San Isabel Granite, covering 20 percent of the southern Wet Mountains, consists of two distinct facies. The more common type is coarse porphyrytic granite cropping out in large bluffs and ridges; less common is a uniformly medium-grained phase. The composition of both types is similar, with quartz accounting for 25 percent of the rock, microcline about 25 to 30 percent, oligiclase 20 percent, and biotite 15 percent. Prominent accessory minerals are apatite and sphene. The San Isabel Granite extends throughout most of the length of the Wet Mountains.

Manitou Park

Setting

The Manitou Park Basin is a fault outlier about 30 miles long and 4 miles wide, bordered on the west by the Ute Pass Fault and on the east by the Devils Head Fault and Rampart Range (Boos and Boos 1957). Fowler (1952) called this eastern fault the Mt. Deception Fault. The southern part of the Manitou Park Basin contains an area of relatively soft sediments faulted down below the general summit level. The sedimentary structure is basically a westward dipping homocline or monocline. Relief in the area is approximately 1,600 feet, ranging from 9,200 feet in the Rampart Range to the east to about 7,600 feet in the Trout Creek Valley (Sweet 1952). Trout Creek is the only permanent stream in the area, though intermittent streams flow in most of the larger gulches. Drainage in the area is north-northwest toward the South Platte River which eventually empties into the Missouri River. In the southern part of the Basin, the Pikes Peak Granite is covered with Paleozoic sediments dipping west. Above these sediments is a gravelly soil derived mostly from granite. In the northern half of the Basin, Pikes Peak Granite is not covered by any Paleozoic sediments, though it is covered by a deep layer of Quaternary alluvium.

Stratigraphy

Sediments in the Manitou Park graben range from Upper Cambrian through Pennsylvanian (figs. 5, 6). The Sawatch sandstone of Upper Cambrian age rests unconformably on Precambrian Pikes Peak Granite. It forms east-facing cuestas throughout most of the mapped area.

In the Front Range the Sawatch sandstone is found only in Manitou Park, Parry Park, Manitou Springs, and in a limestone quarry west of Colorado Springs. The Ute Pass Fault marks its southern limit. It averages 68.4 feet thick in Manitou Park. The age of the Sawatch is indicated by the presence of two brachiopods, Lingulepis and Obolella. Addy (1949) recognized three different members in the Sawatch sandstone: lower sandstone, middle sandstone, and Peerless shale. The Sawatch is highly fractured, and slickensides are found on some surfaces. The sandstone surface is grooved and pitted, and weathers to a grayish color. The sandstone of the Sawatch is composed primarily of red, pink, brown, yellow, and white subrounded to quartz grains ranging from fine grained in the upper part to coarse grained in the lower part. The basal sandstone is pebbly or conglomeratic. The lower 25 feet is ferruginous and arkosic, and glauconite is common in the upper beds.

Maher (1950) referred to the calcareous and dolomitic upper 16 to 20 feet of the Sawatch sandstone as the Ute Pass Dolomite. He described it as a red, glauconitic, partly sandy, unfossiliferous, coarsely crystalline dolomite.

Berg and Ross (1959) referred to the Ute Pass Dolomite as the Peerless Formation. They described it as a unit of sandy, glauconitic dolomite. At Missouri and Illinois Gulches the Peerless Formation is represented by dark red, finely to coarsely granular, rhombic, sandy, and glauconitic dolomite about 16 feet thick. The upper few feet are conglomeratic with small discoid pebbles of siltstone. The rest of the formation consists of a few thin beds of very fine-grained sandstone, siltstone, and gray green shale. Berg and Ross state that, on the basis of lithology and stratigraphic position, the Ute Pass Dolomite described by Maher (1950) is the same as the Peerless Formation. In any case, the Peerless or Ute Pass Formation is gradational between the Sawatch sandstone and the overlying Manitou Limestone.

The Manitou Limestone is the only Ordovician deposit in Manitou Park. It is abou 80 to 90 feet thick in Manitou Park, less than half its thickness near Colorado Springs, and is a fossiliferous, well-bedded, pink to pale red limestone and dolomite. It is microcrystallin and weathers to an orange-red color. Som fossils described by Fowler (1952) at the fish hatchery exposure are Apheorthis, Nanorthis, Sinuites, a cystoid plate, Hystricurus, Finkelnburgia, a prorocycloceras cephalopod, Kainella, and Leiestegium manitouensis. This suite indicates a Lower Ordovician age.

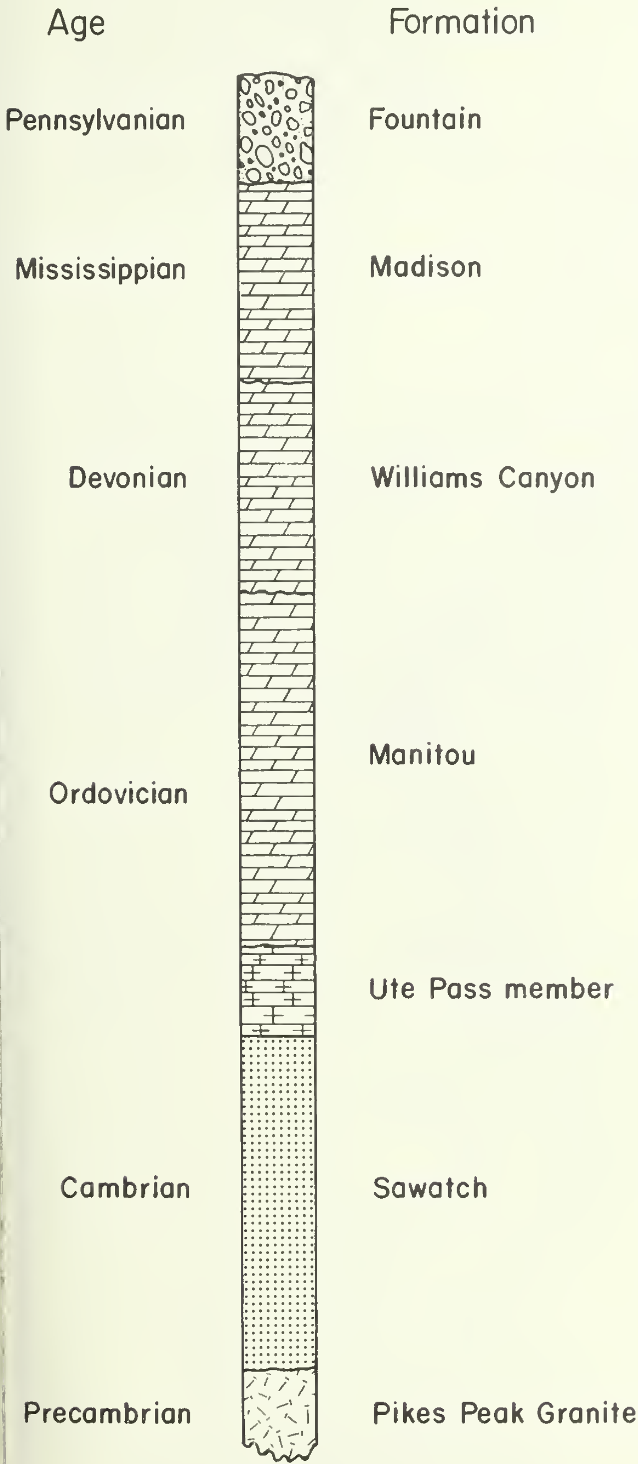


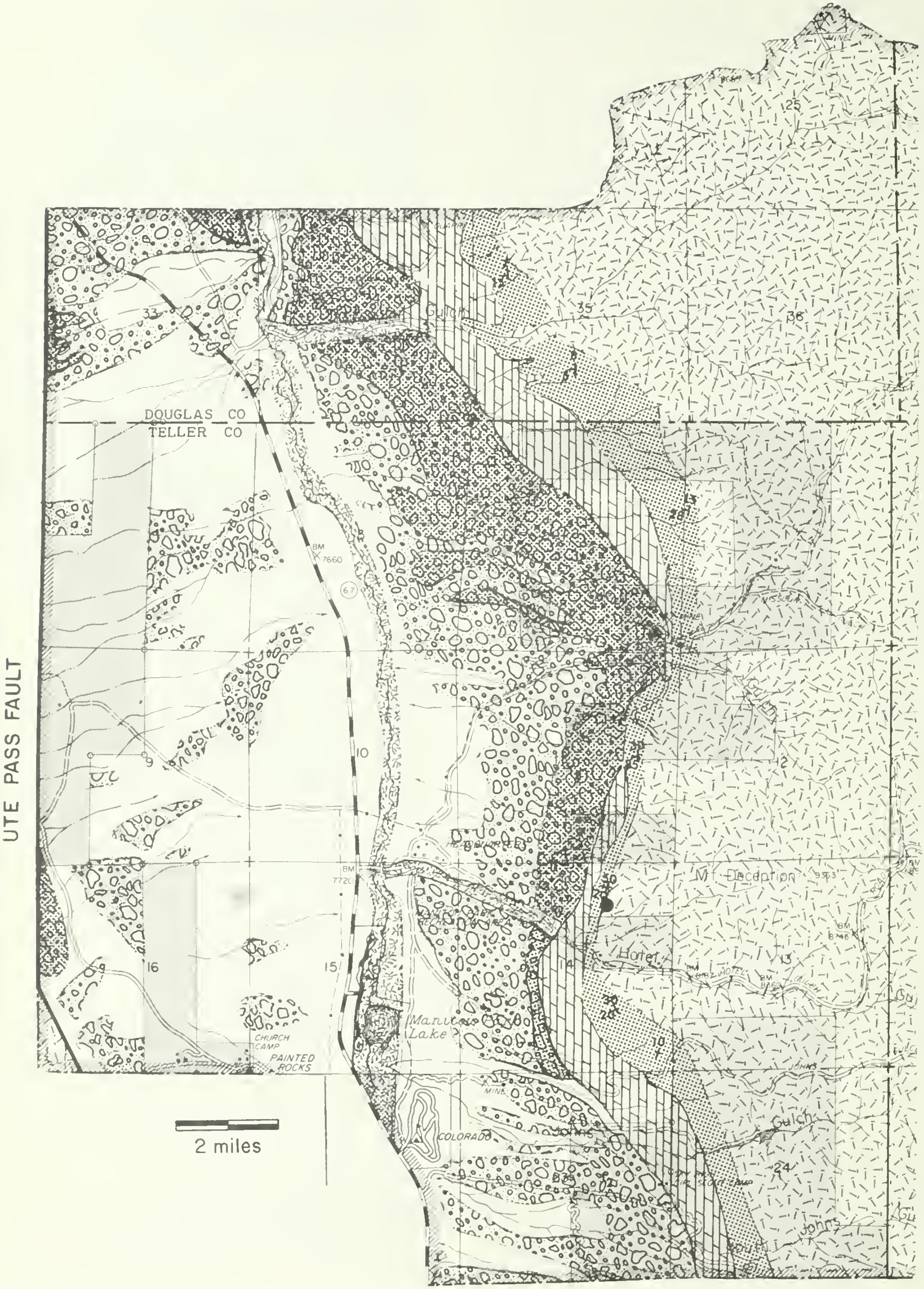
Figure 5.—Stratigraphic section of Manitou Park area.

Petrographic evidence indicates that the Manitou Formation originated in an environment of low to moderate energy. The particles show evidence of rounding and abrasion, but the energy level of the depositional environment was not sufficient to remove much of the microcrystalline material except during brief periods of high energy. Some of the minerals formed in place include dolomite, calcite, chert, limonite, hematite, and glauconite. The dolomite percentage in the samples studied by Swett (1964) ranged from 45 to 95. The dolomite can be recognized by its buff color in contrast to the grayish color of limestone. Chert is also present. Thin-section studies show evidence of five post-depositional alterations of the original limestone: (1) Grain growth caused by recrystallization of microcrystalline calcite to sparry calcite, (2) dolomitization, (3) silicification ranging from partial void filling to formation of chert layers, (4) the addition of calcite to the chert and dolomite layers, and (5) oxidation of iron-bearing minerals to limonite and hermatite.

The Devonian-Mississippian Williams Canyon Limestone is of uncertain thickness and separated by nonconformities from the Mississippian Madison Limestone above and the Ordovician Manitou Limestone below. The Williams Canyon, named for its type section exposed near the Cave of the Winds in Williams Canyon, consists of thin, pale, reddish purple to gray mottled limestone and dolomite, containing partings of gray calcareous shale. The upper 2 to 4 feet is a medium-grained sandstone (Maher 1950). Maher dates the Williams Canyon as Mississippian by lithologic correlation with subsurface units of eastern Colorado. Brainerd et al. (1933) considered it Devonian, and correlated it with the Chaffee Formation of central Colorado.

Blocks of the Williams Canyon Limestone are intermingled with the Madison Limestone due to folding and faulting. The Williams Canyon is more dolomitic than the Madison and also softer. Soils developed from the Williams Canyon are dark gray to nearly black. They are relatively high in clay and have a good ability to hold water. Nitrogen and potassium levels are adequate for growing most plants, but phosphorus is deficient. Lime content is high, and the pH is about 8.0, similar to that of Madison-derived soils.

The Mississippian-Madison Formation overlies the Williams Canyon Limestone unconformably. The upper surface of the Madison is irregular with a well-developed buried karst topography due to post-Madison and pre-Foun-


UTE PASS FAULT
DOUGLAS CO
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Gulch
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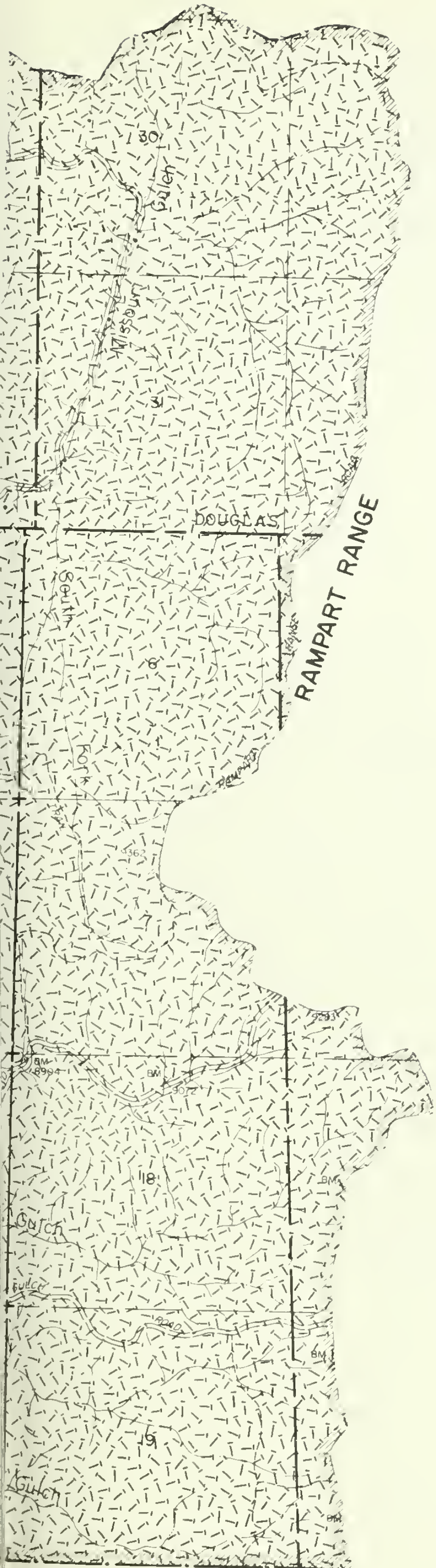

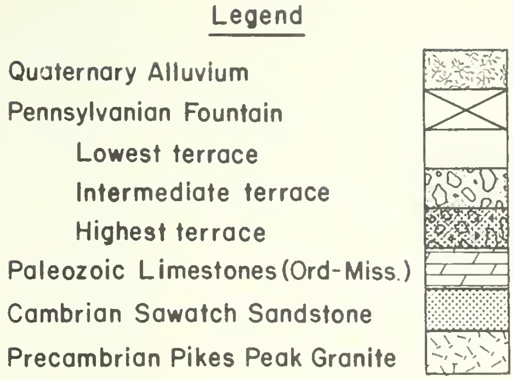

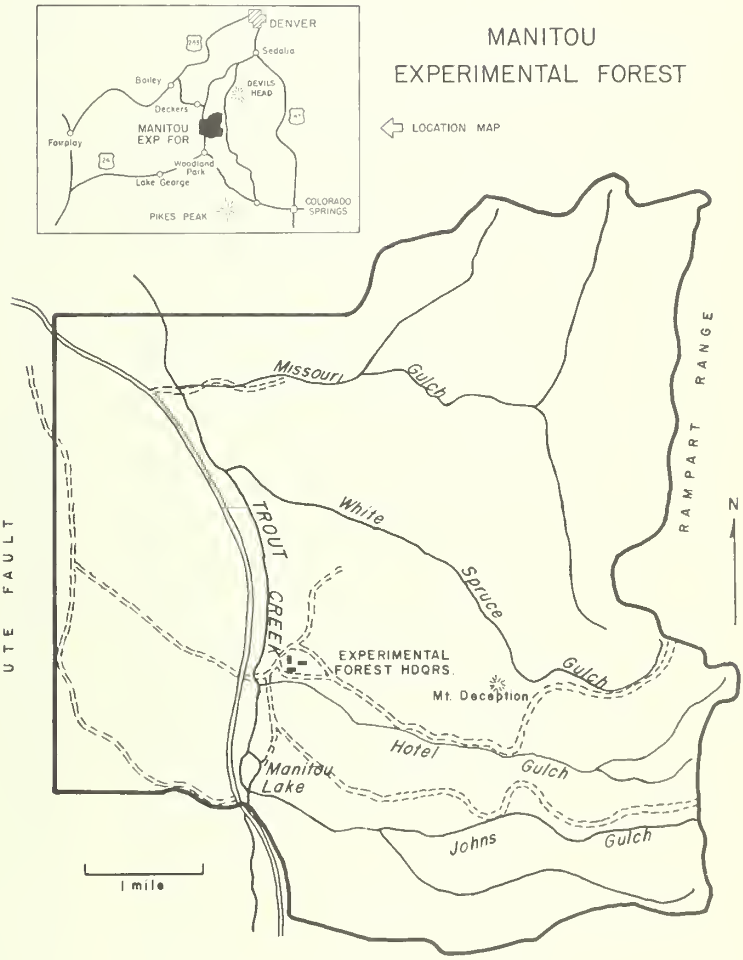

Figure 6.—Geologic map of Manitou Experimental Forest. Stippled (gray) areas indicate private land within the Forest area.

tain weathering. Thickness varies from 0 to 200 feet (Brainerd et al. 1933). The Formation consists of massive, brown to gray, finely crystalline limestone, with occasional chert stringers and a brecciated zone near the base. Red stains are found locally in the upper part of the Formation due to the overlying Fountain beds. Solution cavities and sinkholes are filled with Fountain shales and sandstones. Because few, if any, fossils are found in the Madison, age cannot be determined more precisely than Mississippian. Maher (1950) considers the Madison to be Middle-Mississippian, and calls the upper part the Beulah Limestone and the lower part the Hardscrabble Limestone. The Beulah beds are not present in Manitou Park, and the Hardscrabble is correlated on the basis of lithologic similarity and stratigraphic position with the St. Louis Limestone of eastern Colorado and western Kansas. Bedding is practically nonexistent in the Madison, and it forms steep escarpments. Brainerd et al. (1933) found an upper brecciated zone, and attributed it to pre-Pennsylvanian weathering. They also believe that the Madison was originally deposited over the whole Front Range, but was removed by pre-Pennsylvanian erosion. Brainerd et al. (1933) were the first to designate the Williams Canyon and Madison Formations as distinct entities. They had previously been included with the Ordovician Manitou Limestone.

Soils in limestone formations generally reflect the color of the parent rock, and in the Madison Limestone they are usually a rich brown. Scattered over the surface of Madison-derived soils are rounded flint or cherty boulders greater than 1 inch in diameter. This soil is high in clay and moisture-holding capacity, and also in nitrogen, potassium, phosphorus, and organic matter; the pH is 8.0 (tables 2, 3).

Table 2.--Physical characteristics of the top 6 inches of Manitou Park soils (Smith 1971)

Soil No.	Parent material and aspect	Soil texture class			Soil moisture characteristics		
		Sand	Silt	Clay	1/3 atm	15 atm	Available water
		Percent					
12	Madison Limestone						
	NW	36	32	32	27.4	15.2	12.2
	SW	31	41	28	26.7	14.0	12.7
4	Williams Canyon Limestone						
	NW	31	45	24	30.1	16.7	13.4
	SW	39	39	22	31.1	18.6	12.5
6	Fountain Arkose						
	NW	44	33	23	18.0	10.3	7.7
	SW	65	19	16	14.7	8.0	6.7
1	Pikes Peak Granite						
	NW	47	36	17	24.8	15.1	9.7
	SW	55	36	9	17.4	6.1	11.3

Table 3.--Chemical characteristics of the top 6 inches of Manitou Park soils (Smith 1971)

Soil No.	Parent material	pH	Conductivity	Organic matter	Total nitrogen (N)	Lime	Phosphorus (P_2O_5)	Potassium (K_2O)
			mmho/cm	*Percent*			*Pounds per acre*	
12	Madison Limestone							
	NW	7.8	0.7	5.4	0.20	3.6	72	958
	SW	8.1	0.7	6.1	0.24	11.9	78	766
4	Williams Canyon Limestone							
	NW	8.0	0.8	7.6	0.29	13.0	26	450
	SW	8.0	0.9	8.8	0.33	12.3	29	508
6	Fountain Arkose							
	NW	6.9	0.5	2.2	0.06	0.4	21	187
	SW	7.3	0.6	3.4	0.10	0.8	12	383
1	Pikes Peak Granite							
	NW	7.0	0.6	5.7	0.11	0.6	31	438
	SW	6.6	0.6	5.6	0.13	0.6	19	279

The Pennsylvanian Fountain Formation lies unconformably on older formations except for the Precambrian, with which it is in fault contact. It consists of a thick series of red, cross-bedded, coarse-grained, arkosic sandstones and conglomerates sparsely interbedded with thin shales. The grains show little abrasion. Maximum thickness of the Fountain is 4,500 feet in the Manitou embayment west of Colorado Springs. In Manitou Park, thickness ranges from a few feet at the northern end to about 1,000 feet at the southern end. Geographically, it extends from Iron Mountain, Wyoming, to Canon City, Colorado, about 215 miles. Geometrically, the Fountain is a north-south trending prism that wedges out into the Denver Basin 40 miles east of the Front Range.

Pettijohn (1957) gives a good description of arkosic rocks. He defines an arkose as being a sandstone, generally coarse and angular, moderatly well sorted, composed principally of quartz and feldspar, and derived from a rock of granitic composition. Quartz is the dominant mineral, although in some arkoses feldspar exceeds quartz. Color is generally pink or red though some are pale gray. Porosity may be high due to its degree of sorting and incomplete cementation. It occurs either as a thick blanketlike residuum at the base of a sedimentary section that overlies a granite area, or as a very thick wedge-shaped deposit interbedded with much conglomerate.

The ortho-quartzites, black shales, thin coals, deltaic arkoses, and minor marine limestones of the Glen Eyrie beds, which are the basal Fountain deposits and not found in Manitou Park, were deposited in the Early Pennsylvanian. Later in the Pennsylvanian, the uplift of the ancestral Front Range accentuated the relief so that streams flowed eastward, eroding fresh arkosic detritus and transporting it to the mountain front. These streams formed coalescing alluvial fans on a piedmont plain extending eastward from the ancestral Front Range during periods of near aridity. The ancestral Front Range underwent continuous but declining uplift during Fountain and post-Fountain time. During the time of Fountain deposition, the eastern margin of the ancestral Front Range was not far west of the present foothills belt. The bottom one-fifth of the Fountain contains coarser gravels than the rest of the Formation, and grain size decreases upwards. The ratio of channel arkose deposits: floodplain micaceous arkose: deltaic-lacustrine quartzose arkose in the Fountain varies from 71:29:0 in the lower beds to 85:7:8 in the upper beds.

In the area between Eldorado Springs and Colorado Springs, the Fountain, exclusive of the Glen Eyrie, averages about 80 percent stream channel conglomerates and sandstones, 17 percent floodplain clayey siltstones and shales, and 3 percent deltaic-lacustrine clayey sandstones and siltstones (Hubert 1960). The ratio of siliceous particles: feldspathic fragments: micaceous fragments in the channel arkoses is 44:53:3, in the floodplain arkoses 41:43:16, and in the deltaic-lacustrine arkoses 72:24:4. The channel arkoses are the coarsest of the three groups.

There is no sharp distinction between many of the sandstones and conglomerates of the Fountain; coarse-grained arkosic sandstones grade laterally into conglomeratic sandstones and conglomerates. A similar gradation occurs vertically. Well-bedded sandstones are found in the lower part of the Formation. Above these beds are found discontinuous channel fillings and irregularly cross-bedded zones. Fountain sandstones are red, arkosic, medium to coarse grained, and poorly sorted. A hand-lens study of Fountain sandstone showed that 90 percent of the rock was composed of poorly sorted subrounded to angular fragments of pink feldspar and quartz less than 2 mm in diameter. The rock is well indurated (McLaughlin 1947), and weathers to a buff color.

A thin-section study of a typical Fountain layer by McLaughlin (1947) showed that angular fragments of microcline perthite constitutes about 35 percent of the rock. Plagioclase feldspar is rare. Subrounded to angular quartz makes up most of the remainder of the specimen. There are also small, scattered fragments of partially altered biotite. The study revealed a low porosity as a result of the compaction of the poorly sorted, irregularly shaped fragments and the interstitial fillings of silty and clayey material and iron oxide.

Although the name Fountain is restricted to arkoses along the east flank of the Front Range, similar coarse red arkoses, such as the Maroon, Hermosa-Culter, and Sangre de Cristo Formations, were deposited in other areas adjacent to the ancestral Rocky Mountain highlands. The Maroon ranges up to 7,000 feet in thickness in central Colorado, and the Sangre de Cristo ranges up to 13,000 feet in southern Colorado and northern New Mexico, as compared to the 4,500-foot maximum thickness of the Fountain. These different arkose deposits exhibit extreme facies changes over very short distances, probably caused by torrential deposition at the margins of rapidly rising lands.

Mallory (1958) attributes the red color of these beds to two factors: (1) An abundance of orthoclase (primarily), and (2) a coating of ferric oxide on clastic particles making up the rock. McLaughlin (1947) attributes the red color to the presence of iron oxides, which may be only a stain on the grain surfaces or may occur as interstitial cementing material.

Soils developed from the Fountain are similar to those developed from the Pikes Peak Granite, from which it was largely derived. Both are infertile (table 3). The pedestals found in the area do not appear to have been important in the development of the soil.

Soils on northerly and easterly exposures have more pronounced zones than those on southerly and westerly exposures. Southerly exposures also generally have a ponderosa pine cover, while northern slopes contain mostly Douglas-fir, a few ponderosa pines, and an occasional aspen.[2]

In general, soil erosion in the Rocky Mountains is severe only where remnants of the pre-Wisconsin soils are extensive. The difference between the soils of pre-Wisconsin, Wisconsin, and Recent age in the Rockies are best shown by the difference in weathering of the moraines and other deposits of those ages. In Recent deposits, pebbles are fresh; in Wisconsin deposits they may have a weathered rind; and in pre-Wisconsin deposits they may be altered to clay (Hunt 1967).

Overlying the Fountain Formation and covering the major portion of the Manitou Park Basin is an accumulation of coarse, angular material which has either been washed downslope from the granitic and Paleozoic outcrops, or deposited by intermittent streams during heavy rains and spring runoff. These deposits are approximately 10 to 25 feet thick. In the Manitou Experimental Forest, these deposits form a large alluvial fan with an apex in the Paleozoic hogbacks of sec. 25, T. 11 S., R. 69 W. (Sweet 1952), just southeast of the Forest. On the west side of the Basin the gravels are composed of granitic detritus with fragments of ault breccia intermixed, while on the east side there is an admixture of lower Paleozoic material with the granitic debris. The deposits are Quaternary in age and cover the Ute Pass Fault line through most of its extent. The lateral movement of the fault activity must antedate the alluvial deposits.

[2] *Fox, C. J., J. Y. Nishimura, R. F. Bauer, C. R. Armstrong, and R. F. Willmot. 1962. Soil survey report of wildlife habitat study area, Manitou Experimental Forest, Colorado. 26 p. (Unpublished report on file at Region 2 office, USDA For. Serv., Denver, Colo.)*

Igneous Petrology

Pikes Peak Granite is the only Precambrian rock in the area. In Manitou Park it is part of a large batholith of coarse, even-grained to porphyritic pink rock consisting mostly of microcline and quartz.

Biotite occurs in clusters and large flakes and is the most important accessory mineral. Other accessory minerals are oligoclase, feldspar, zircon, apatite, allanite, magnetite, fluorite, and rutile. The red-pinkish color of the rock is due to a pigment of hydrous iron oxide which colors the feldspars. The feldspar and quartz grains are relatively large, and conspicuous feldspar phenocrysts are common, often attaining a diameter of several inches. Some areas of Pikes Peak Granite, however, contain feldspar grains little more than 0.25 inch long. Percentage of constituents, according to Mathews (1900), is quartz 33.4 percent, microcline feldspar 53.3 percent, biotite 10.7 percent, and oligoclase feldspar 2.6 percent.

Fine-grained granite dikes cut the Pikes Peak Granite in places. They are red to pink in color and very poor in mica. Feldspars dominate in these dikes (Peterson 1964).

Also cutting the Pikes Peak Granite are a number of pegmatite dikes. The pegmatites contain microcline, orthoclase, albite, oligoclase quartz, biotite, muscovite, and accessory minerals in very large individual grains, often segregated in different parts of the dikes. They are most abundant near the Platte River.

Age determinations based on Pb-U ratio give an age of about 1 billion years for the Pikes Peak Granite (Fowler 1952). This compare to Hutchinson's (1964) finding of 995 million years for the porphyritic aplitic facies of the Pikes Peak batholith.

Pikes Peak Granite has basically the same composition and grain size as the other major granites of the Front Range. However, Pikes Peak Granite is distinctively more susceptible to weathering and erosion than the Boulder Creek or Silver Plume Granites. It weathers typically into rounded masses, with great curving plates breaking away from the dome-like outcrops in the process of exfoliation. Weathering by disintegration forms an angular gravel that is widely distributed as a mantle on long, low divides. Weathering of the granite is so general that only about 10 percent of the area in Manitou Park underlain by granite contains outcrops.

Biotite is the most easily decomposed of the constituent minerals of the granite. As it weathers, iron is set free, staining the other minerals. The weathered rock shows every gradation from green through pink to deep red, the red being caused by iron oxide staining. The depth of the weathered layer averages 25 feet, due both to ease of weathering and the fact that some of the surfaces were subject to erosion during Cambrian times.

The terraces in Manitou Park are covered with gravels derived mostly from Pikes Peak Granite, though the bases of the terraces have some reworked Fountain material mixed in, since they are underlain by Fountain beds. The terrace deposits also weather very easily.

Soils developed from Pikes Peak Granite are pinkish or reddish in the lower parts of their profiles as an inheritance from the parent materials. The percentage of particles greater than 2 mm in size is greater than for any of the soils developed on sedimentary layers in the area (Smith 1971). The soil is a gravelly, sandy loam with a low clay content. Available water is slightly higher than for the Fountain-derived soil. Nitrogen, potassium, and phosphorus are deficient. The surface soil is neutral or slightly acidic, with acidity increasing with depth (tables 2, 3).

Structure

Manitou Park is a fault outlier: an outcrop of younger rocks isolated by faulting in an area of older rocks. The sedimentary structure consists of a westward-dipping homocline or monocline except for sharp drag along the fault at the west edge of the block.

The dominant structures in Manitou Park are faults. The area is bounded on the east by Mt. Deception Fault (Fowler 1952), and on the west by the Ute Pass Fault. In the Basin itself, there are no folds. The most significant structural feature in the area is the Ute Pass Fault zone, about 30 miles long and 800 to 1,700 feet wide. Fine-grained, calcium-rich breccia is found in the northern part of the fault zone, while larger uncemented breccia is found in the central and southern parts. In places, the zone can be traced by the presence of weathered or iron-stained belts in the granite. The fault plane is almost vertical with a possible eastward dip. Both horizontal and vertical movement has occurred along this fault plane. The west block has been upthrown with respect to the east block, with an estimated maximum vertical displacement of up to several thousand feet and minimum of several hundred feet. The horizontal displacement is not known. On the western side, the upthrown block of Pikes Peak Granite forms a prominent fault scarp.

There was a tremendous amount of shearing in the Ute Pass Fault zone. Movement began in the Precambrian and continued until Miocene-Pliocene time. Sweet (1952) states that the faulting is late Tertiary or early Pleistocene.

The Mt. Deception Fault zone on the east side of Manitou Park is closely related to the Ute Pass Fault zone. The trends of both fault zones are parallel for most of their extent. The sediments dip most steeply just to the west of the fault and then flatten out farther west. The west block is downthrown, probably a high-angle reverse fault dipping steeply to the east. Other minor faults in the area include the Trout Creek Fault, which extends for about 5 miles in a north-south direction halfway between the Ute Pass and Mt. Deception Faults, and the Fish Hatchery Fault, which connects the Ute Pass Fault with the Trout Creek Fault. Scott[3] referred to the Mt. Deception Fault as a branch of the Ute Pass Fault. Harms (1965) refers to the east side of the Manitou Park Basin as a monoclinal flexure rather than a fault.

Geologic History

The major events in the geologic history of the Manitou Park area, as determined by Sweet (1952), are:

1. Development of a peneplain on the surface of the Pikes Peak Granite before Late Cambrian time.
2. Advance of the Late Cambrian sea from the west around the margins of the Front Range highland, and deposition of the Sawatch Sandstone.
3. Change in depositional conditions without uplift, and deposition of the Early Ordovician Manitou Limestone.
4. Retreat of the sea at the end of Manitou deposition and erosion of the area during the remainder of the Ordovician, Silurian, and probably part of the Devonian.
5. Submergence in Devonian time, and deposition of the Williams Canyon Limestones and Sandstones.
6. Emergence and erosion during the Late Devonian and possibly the very Early Mississippian.
7. Submergence in the Early Mississippian, and deposition of the Madison Limestone.

[3] *Personal communication with Glenn R. Scott, U. S. Geological Survey, Denver Federal Center, Colorado, 1972.*

8. Uplift with mountain-building during the Early Pennsylvanian, and deposition of the Fountain Formation as a thick series of coarse clastic sediments around the margins of the mountain mass.

9. No record of the remainder of the Paleozoic and the entire Mesozoic.

10. A period of uplift and mountain-building at the close of the Cretaceous. The folding which occurred at this time probably formed the Manitou Park syncline.

11. Peneplanation on the surface of the Front Range mountains, and deposition of a thick series of stream gravels in Manitou Park by streams flowing eastward across the erosional surface.

12. Late Tertiary uplift.

13. Active stream erosion during the Quaternary, with development of narrow erosional surfaces along the major streams of Manitou Park during the Pleistocene.

Physiography

The topography of the area is mature, highly dissected, and well drained. The streams form a dendritic pattern in the east where homogeneous outcrops of granite are found. Here the relief is complex, with drainageways extending almost to the tops of the mountains, leaving only narrow summits. Limestone terrain is characterized by a trellis or blocky drainage system. Secondary drainages many times branch out perpendicular to the main drainage, forming blocks of gently sloping or rounded hills.

Broscoe (1959) divides the area in and near Manitou Park into four geomorphic districts: (1) The Pikes Peak Granite-pre-Pennsylvanian outcrop area of the Rampart Range, which he refers to as the Rampart Range granite area; (2) the widely spread outcrop area of Pikes Peak Granite west of the Ute Pass Fault, which he calls the Rule Creek granite area; (3) an area of widespread Oligocene gravels in the vicinity of the town of Divide; and (4) the lowland of the Manitou Park Basin which is underlain by the Fountain Formation.

Both the Rampart Range and Rule Creek granite areas are heavily forested. On weathering, Pikes Peak Granite forms large, rounded masses, which are surrounded by a very coarse gravel called grus. The soil developed on this material is very coarse and permeable. In several places, such as at the head of White Spruce Gulch, drainage ditches from the Rampart Range Road have been diverted into natural drainageways. Increased discharge at the head of the washes has caused active gullying. With the exception of man-disturbed areas, however, there is little erosion in the granite area. Any inequilibrium in the granite terrain is more in the direction of alluviation, rather than gullying. Broscoe (1959) considers the Rampart Range and Rule Creek areas to be unlikely sources for the sediment presently being deposited in Manitou Park Lake.

The area of gravel near Divide is similar to the granite areas, with its gravelly soil and lack of erosion, except for the man-disturbed areas. Therefore, Broscoe (1959) considers the most likely source of sediment in the area to be the Manitou Park Basin, with its extensive alluvial terrace and floodplain deposits.

Three terraces are found in the Manitou Park Basin (fig. 6), an oldest high terrace, an intermediate terrace, and a youngest low terrace (Broscoe 1959).[4] These terraces are developed on areas underlain by the Fountain Formation. The highest surface is preserved only in scattered ridges and benches. Remnants of this terrace stand approximately 80 to 100 feet above the intermediate terrace. All of the terraces are cut by numerous small channels. Many of the courses of the Trout Creek drainage system are underlain by Quaternary alluvium. Sweet (1952) called the highest terrace gravel the Woodland Park Formation and considered it to be of Tertiary age, though he thought the terrace developed in the Pleistocene.

Most of the second or intermediate terrace remnants west of highway 67 are near the west boundary of the Experimental Forest. The oldest stage of physiographic development on the lowest terrace, with a relatively flat slope, is found west of but near the highway. Here the ridges have been worn down to produce a gently rolling slope. West of the oldest stage, the low terrace consists of a mature, much dissected area with many ridges and gullies. Further west is a youthful area where ridges and gullies are just beginning to develop. The slopes on the different terraces vary from 4° to 8° with a trend of about N. 70° E. This trend accounts for the general northeast trend of the ridges and gullies. All three terraces were originally cut in Fountain arkose.

Pedestals, weirdly shaped remnants of the Fountain arkose, are scattered throughout west of highway 67 and around Manitou Park Lake. They represent remnants of the next higher terrace which has been eroded away in the surrounding area. Pedestals are not as common

[4] *Retzer, John L. 1949. Soils and physical conditions of Manitou Experimental Forest. 123 p. (Unpublished report on file at Rocky Mt. For. and Range Exp. Stn., USDA For. Serv., Fort Collins, Colo.)*

east of the highway, but outcrops of Fountain arkose are numerous, especially in northern portions of the area. Since the pedestals are being worn down, it is not possible to determine their original height and, therefore, the height of the next higher terrace in the adjacent area. Currently, the pedestals range from 20 to 50 feet in height, and strike approximately north-south and dip to the west. It is not known just why the pedestals remained while surrounding layers were eroded away, but one possibility could be that the pedestals have a slightly more durable cement than did the adjacent layers.

The pedestals, with their orange color standing in sharp contrast against the green background of the surrounding forest, add to the scenic beauty of the area. Near the Rainbow Falls Road, Trout Creek has cut through an outcrop of Fountain arkose and left orange cliffs about 100 feet high. Also, in Missouri Gulch the stream has cut a canyon about 150 feet deep, exposing the contact between the Sawatch Sandstone and the Pikes Peak Granite.

Setting of Manitou Park in the Front Range

Manitou Park is unique in that it is a structurally depressed block containing a Paleozoic sedimentary formation, while the other parklike areas in the Front Range were formed by erosional processes in crystalline rocks. The soils of Manitou Park are mostly of granitic origin, and, therefore, differ from other soils in the Front Range only because of their derivation from the distinctive Pikes Peak Granite. The erosive qualities of soils derived from Pikes Peak Granite make it imperative that extreme caution be exercised whenever any alteration of the surface profile is planned for road construction, housing developments, or other disturbance.

Reestablishment of shrubs and grasses is very slow on Pikes Peak and Fountain-derived soils. Once these plants are removed, the soil becomes greatly weakened. The soils are held together mostly by mats of needles dropped from the trees. Tramping on these soils is harmful and should be minimized to protect the area. Residential development would most likely cause a severe erosional problem. A good idea of the severe erosion potential in this area can be obtained by observing residential development just south of the town of Divide.

These restrictions apply not only to the Manitou Experimental Forest lands, but to any Front Range lands having soils derived from Pikes Peak Granite. The sedimentary formations in the area of the Experimental Forest are encountered nowhere else in the Front Range and are of minimal importance.

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Geologic features of four parts of the Montane Zone of central Colorado are described: (1) the Front Range, (2) the Sangre de Cristo Mountains, (3) the Spanish Peaks, and (4) the Wet Mountains. Detailed description and geologic map of the Manitou Experimental Forest are included, which provide some of the information useful in determining applicability of study results to other parts of the Zone.

Oxford: 551:788. **Keywords:** Geologic structures, Colorado Front Range, Montane Zone.

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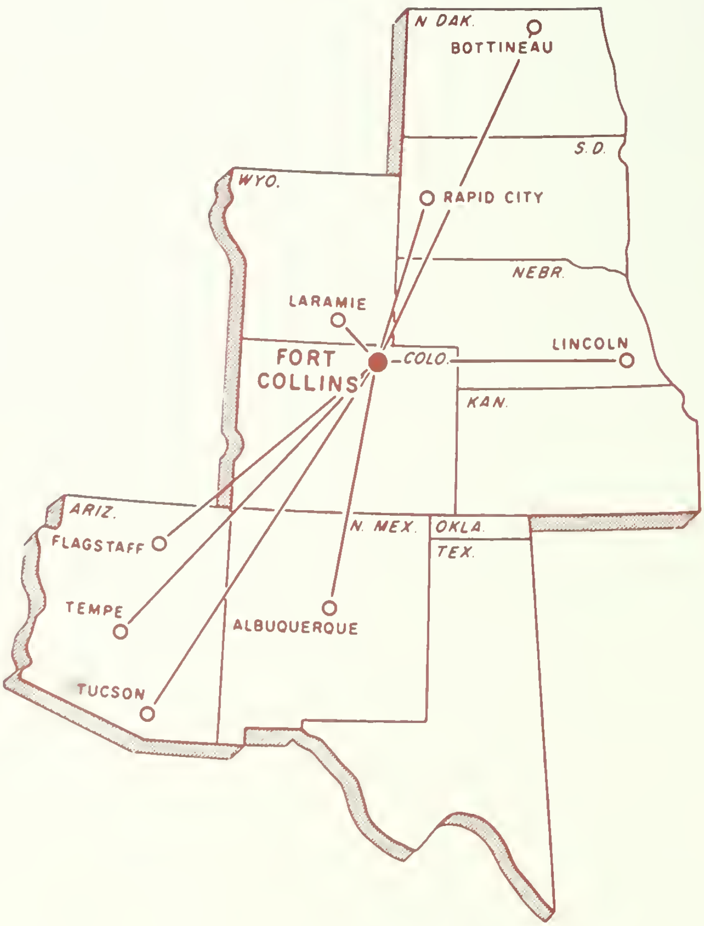
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ard A. Cunningham

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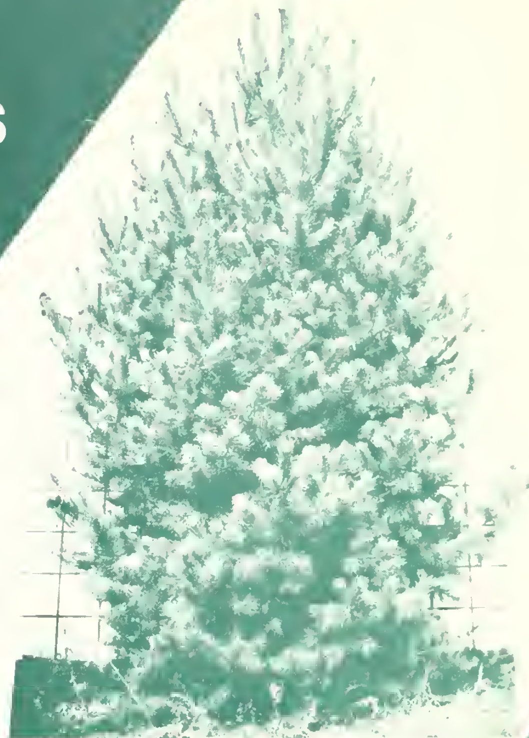


Forest Service

U.S. Department of Agriculture

Fort Collins. Colorado 80521

Abstract

A provenance test of 49 origins of Scotch pine (Pinus sylvestris L.) from eastern Europe, Russia, and Siberia was established at three locations in North Dakota and one in Nebraska. After 10 years (7 in Nebraska), trees from 50° to 55° latitude and 20° to 40° longitude survived best, were taller, and had greener winter foliage. Several provenances appear to be well suited for planting in shelterbelts and for Christmas tree culture.

Oxford: 232.12:165.52. **Keywords:** Geographic variation, provenance trials, *Pinus sylvestris*.

PREFACE

The cooperation of many individuals made this provenance study possible. Robert B. Hill, Institute of Forest Genetics at Rhinelander, Wisconsin, and Paul O. Rudolf, Lake States Forest Experiment Station, initiated the study. Some of the planting stock was provided by Mark Holst of the Petawawa Forest Experiment Station, Ontario, Canada, and by Jonathan W. Wright, Professor of Forestry, Michigan State University. David H. Dawson and Paul E. Slabaugh of the Shelterbelt Laboratory, Bottineau, were primarily responsible for the planting, maintenance, and measurements of the North Dakota plantings. Walter T. Bagley, Associate Professor of Horticulture and Forestry, University of Nebraska, made the Nebraska planting, and Ralph A. Read, Rocky Mountain Forest and Range Experiment Station, Lincoln, maintained and measured it.

Studies of this type are conducted by the USDA Forest Service through its Rocky Mountain Forest and Range Experiment Station Research Work Unit at Bottineau, North Dakota, to identify and develop, through selection and breeding, better adapted and more useful trees and shrubs for planting in the Great Plains.

USDA Forest Service
Research Paper RM-114

December 1973

Scotch Pine for the Northern Great Plains

by

Richard A. Cunningham, Associate Plant Geneticist

Rocky Mountain Forest and Range Experiment Station[1]

[1] *Central headquarters maintained at Fort Collins in cooperation with Colorado State University; research reported here was conducted at the Station's Shelterbelt Laboratory at Bottineau, in cooperation with North Dakota State University-Bottineau Branch and Institute of Forestry.*

Contents

Scotch Pine for the Northern Great Plains

Richard A. Cunningham

Introduction

A wider variety of pine species is needed for planting in shelterbelts and windbreaks in the northern Great Plains. Ponderosa pine (Pinus ponderosa Laws.), the only species of pine that has been widely planted in this region, has poor initial survival, slow initial growth, and is susceptible to winter injury.

Although Scotch pine (Pinus sylvestris L.) has not been planted very extensively, limited trials suggest it is well suited for shelterbelt plantings. These early trials indicated the importance of obtaining trees from the proper geographic region, however.

During the period 1956-61, seed and seedlings of known provenances from the U.S.S.R. became available to the Lake States (now North Central) Forest Experiment Station (fig. 1). Since these provenances represented northern latitudes and climatic conditions similar to those in the northern Great Plains, their availability provided an excellent opportunity to test a wide range of provenances for adaptability and growth in the northern Great Plains. This Paper summarizes 10 years of observations of growth survival, and winter foliage color of provenance trials in North Dakota and Nebraska.

Past Work

George (1953) reported the results of extensive trials, in the northern Great Plains, of many tree and shrub species. Of two Scotch pine origins, a provenance from Russia was more hardy than one of unknown origin obtained from a commercial dealer. At 10 years of age, 75 percent of the Russian origin had survived and averaged 12.5 feet in height. In 1950, 20 years after planting, survival was still 75 percent and the trees averaged 28.5 feet tall. Winter injury was rated none or minor.

Species trials at the Denbigh Experimental Forest indicated that, in north-central North Dakota, Scotch pine from Latvia and Finland survived best and grew moderately fast.[2]

[2] *Stoeckeler, J. H., and E. J. Dortignac. 1939. Report of work at Denbigh Station. Unpublished report on file at USDA Forest Service Shelterbelt Laboratory, Bottineau, N. D.*

Cram and Brack (1953) studied vigor and seed crops of trees representing six geographic races of Scotch pine growing in a prairie-plains environment. Survival and growth seemed to be two distinct characteristics of the geographic races studied. Some seeds from Russian sources apparently were frost-hardy during the reproductive process (anthesis stage of the flowers and the initial enlargement of the embryonic cones). The Russian provenance suffered no winter injury in 1951 when all but one other provenance did. A Scottish provenance showed greatest vigor, while the Finnish and Russian provenances survived best. The Russian provenance had the best combination (relative vigor x survival) of these two characteristics at the test site.

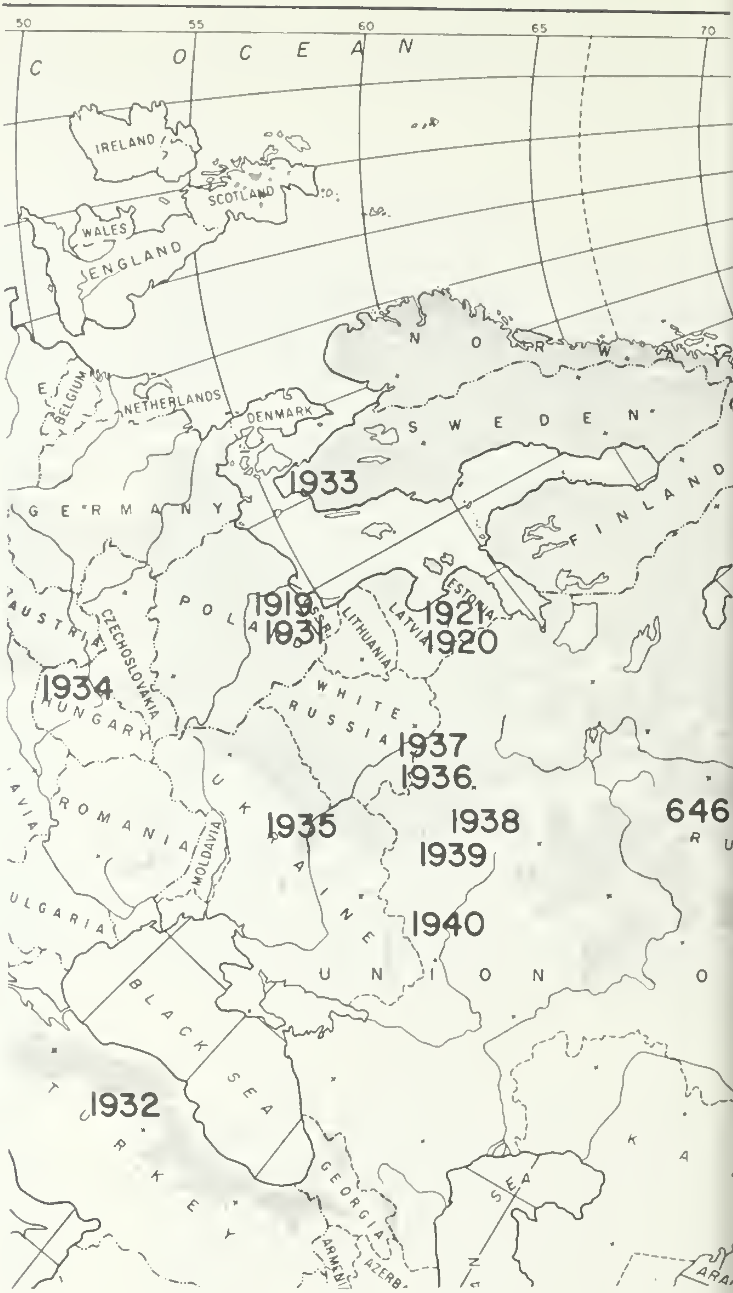
Stoeckeler and Rudolf (1949) reported on winter injury and recovery of conifers in the Lake States following unusual weather conditions in 1946 through 1948. In north-central North Dakota, Scotch pine of Finnish origin showed no browning of foliage while other pines suffered varying degrees of needle discoloration. Similar results were reported from plantations of Scotch pine on the Chippewa National Forest in Minnesota. Generally the trees representing the more northerly sources had less damage than those from farther south. Scotch pine of Manchurian and northern European origin suffered less foliage injury than local red pine (Pinus resinosa Arr.).

Winter injury following a severe winter was observed by Rudolf (1948) on Scotch pine planted in northern Minnesota. Trees grown from seed collected in the same climatic zone as Cass Lake (Minnesota) suffered very little foliage injury. Trees from seed originating in a milder climate suffered greater foliage loss.

Read (1971) reported on a field test of 36 provenances of Scotch pine in eastern Nebraska. Results after 8 years revealed that (1) southern origins bordering the Mediterranean grow slowly to moderately fast and remain dark green in winter, (2) central European origins grow very fast and turn yellowish green in winter, and (3) northern origins grow slowly and turn very yellow in winter. Southern origins were recommended for Christmas trees, fast growing central European origins were recommended for windbreaks, and the northern origins were recommended as special-purpose ornamentals.

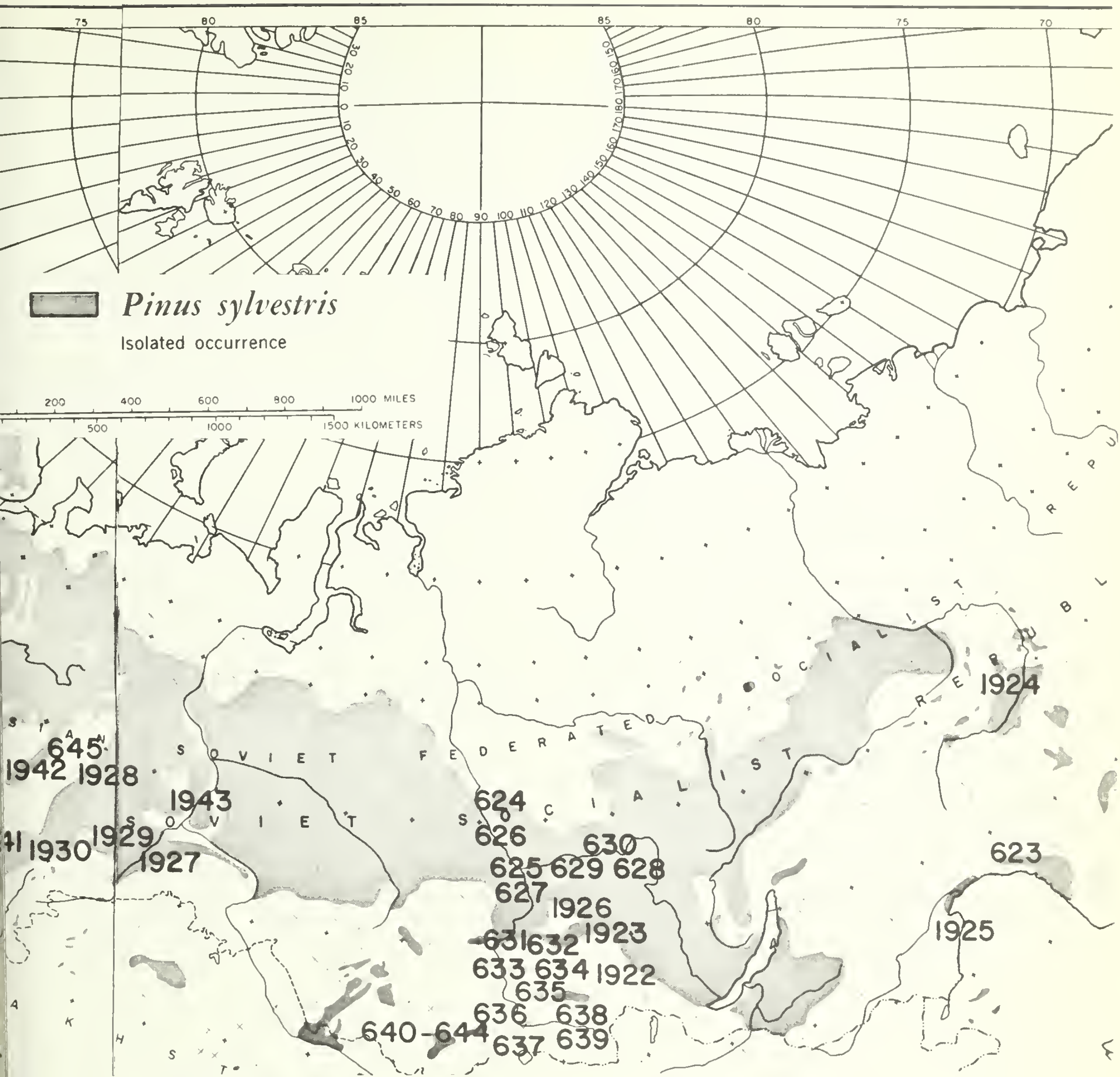
Figure 1.—Natural distribution of Scotch pine, and location of origins tested.

(see Map 32, Critchfield and Little 1966)



Origin number	Latitude °N	Longitude °E	Geographic variety
U.S.S.R--FAR EASTERN SIBERIA			
623	54.00	124.00	*mongolica*[1]
1924	60.75	131.67	*mongolica*
1925	52.33	117.67	*mongolica*
U.S.S.R.--NORTHERN SIBERIA[2]			
624	60.25	90.00	*lapponica*[1] *orientalis*[3]
626	60.25	90.00	*lapponica orientalis*
U.S.S.R.--CENTRAL SIBERIA, MIDDLE YENESEI RIVER			
625	58.50	92.00	*eniseensis*[3]
627	57.50	92.00	*eniseensis*
628	57.00	95.00	*eniseensis*
629	57.00	93.00	*eniseensis*
630	58.50	96.00	*eniseensis*
631	56.00	91.00	*eniseensis*
632	55.25	92.00	*eniseensis*
1923	56.00	95.00	*eniseensis*
1926	56.67	96.36	*eniseensis*
U.S.S.R.--SOUTH CENTRAL SIBERIA, SOUTHERN YENESEI RIVER			
1922	54.03	94.03	*eniseensis*
633	54.25	91.00	*eniseensis*
634	54.25	93.00	*eniseensis*
635	53.75	92.00	*eniseensis*
636	53.00	90.50	*eniseensis*
637	52.75	90.00	*eniseensis*
638	52.00	93.75	*eniseensis*
639	51.50	93.00	*eniseensis*
U.S.S.R.--SOUTHERN SIBERIA, ALTAI MOUNTAINS[2]			
640	52.00	84.00	*altaica*[1]
641	52.00	84.00	*altaica*
642	52.00	84.00	*altaica*
643	52.00	84.00	*altaica*
644	52.00	84.00	*altaica*
U.S.S.R.--EAST URAL MOUNTAINS			
1927	56.83	65.02	*uralensis*[1]
1928	58.83	60.83	*uralensis*
1929	56.92	63.25	*uralensis*
1930	56.85	61.38	*uralensis*
1943	58.00	68.00	*uralensis*
U.S.S.R.--WEST URAL MOUNTAINS			
645	59.50	57.50	*uralensis*
646	58.00	45.00	*uralensis*
1941	55.00	57.00	*uralensis*
1942	58.00	57.00	*uralensis*

Origin number	Latitude °N	Longitude °E	Geographic variety
U.S.S.R.--CENTRAL RUSSIA			
1935	50.00	30.00	*balcanica*[3]
1936	54.00	32.00	*balcanica*
1937	54.50	32.00	*balcanica*
1938	54.00	36.00	*balcanica*
1939	53.00	37.00	*balcanica*
1940	52.00	39.00	*balcanica*



rigin umber	Lati- tude °N	Longi- tude °E	Geographic variety
.S.S.R.--LATVIA			
920	57.50	25.83	*rigensis*[1]
921	57.67	26.33	*rigensis*
ORTHERN POLAND			
919	53.83	20.45	*polonica*[1]
931	53.72	20.45	*polonica*
OUTHERN SWEDEN			
933	55.87	14.08	*septentrionalis*[1]

Origin number	Lati- tude °N	Longi- tude °E	Geographic variety
WESTERN HUNGARY			
1934	47.68	16.58	*pannonica*[1]
TURKEY			
1932	40.50	32.67	*armena*[1]

[1]Wright et al. (1966).
[2]From different sites and age classes.
[3]Pravdin (1969).

Materials and Methods

Seed from 24 Russian and Siberian provenances was received by the Lake States Forest Experiment Station in 1956. Part of this seed was sown in the Hugo Sauer Nursery, Rhinelander, Wisconsin, in 1957. After 2 years in the seedbed, the stock was lifted and shipped to North Dakota where it was lined out in transplant beds at the Towner Nursery.

In addition to the 24 sources grown from seed, the Petawawa Forest Experiment Station, Chalk River, Ontario, supplied 9 different seed sources of Russian origin as 2-1 stock. These seedlings were lined out in transplant beds at the Towner Nursery in 1960. In the spring of 1961 both groups of seedlings were field planted.

A randomized complete block design was used in all field plantings. Single tree plots were arranged in 24 replications. Three outplantings were made in North Dakota and one in Nebraska (fig. 2, table 1). An additional outplanting at Indian Head, Saskatchewan, was a complete failure, primarily due to drought-induced mortality.

A block planting was made at Denbigh Experimental Forest in central North Dakota (Denbigh-1). The soil on this site is a loamy fine sand. Each test tree was separated by filler trees of ponderosa pine from a Black Hills seed source. Spacing was 7 feet by 7 feet.

Plantings in Richland and Ransom counties in southeastern North Dakota were in the form of a shelterbelt in which two center pine rows were flanked by a shrub (Caragana aborescens Lam.) row and a hardwood (Fraxinus pennsylvanica Marsh.) row. The Richland planting was oriented east-west; the Ransom planting, north-south. Tree rows were spaced 10 feet apart, and trees within the rows about 6.5 feet apart.

Figure 2.—Location of test sites in North Dakota and Nebraska.

At Ransom, the site is an alluvial bottomland with soils ranging from silty clay loam to fine sandy loam. Soil at the Richland site varies from loamy fine sand to loam.

All three locations were planted by hand. Site preparation consisted of plowing and disking a year prior to, as well as immediately before, planting.

Table 1.--Test site locations and climatic data[1]

Site location	County	Latitude	Longitude	Elevation	Average temperature Jan.	Average temperature July	Freeze-free days	Average precipitation April-Sept.	Average precipitation Annual	Period of record
		°N	°W	Feet	°F	°F	No.	Inches	Inches	
Denbigh, N.D.	McHenry	48°17'	100°39'	1486	4.8	69.7	114	13.30	15.92	1961-70
Ransom, N.D.	Ransom	46°31'	97°19'	1080	4.6	71.1	120	15.60	19.16	1961-70
Richland, N.D.	Richland	46°23'	97°14'	1080	4.6	71.1	120	15.60	19.16	1961-70
Horning, Nebr.	Cass	41°00'	95°54'	1100	22.2	77.2	163	24.54	31.92	1961-65

[1]Nearest U.S. Weather Bureau used: Denbigh--Granville, N.D.
Ransom and Richland--McLeod, N.D.
Horning--precipitation, Plattsmouth, Nebr.; temperature, Weeping Water, Nebr.

Plantation failures were replanted with extra line-out stock in the spring of 1962.

Weeds were controlled by rototilling at the Ransom and Richland sites annually for the first 7 years after planting, and at Denbigh for the first 5 years.

Low-lying portions of the Richland planting were inundated for an extended period in the spring of 1962, which resulted in higher than normal mortality.

The outplanting in Nebraska was on the University of Nebraska Horning State Farm near Plattsmouth. The soil is a silty clay loam derived from loess. A block planting design was used, with single tree plots and 24 replications per seed source. Eastern redcedar (Juniperus virginiana L.) filler trees were planted to give a final spacing of 7 feet by 7 feet. The soil was disked the fall of 1960, and the trees were machine planted in mid-April 1961. Plantation failures (except origins 624 and 626) were replanted with extra line-out stock in the springs of 1962 and 1963. Weeds were controlled by rototilling the first year after planting, and with chemicals thereafter (simazine, 4 lbs/acre).

In April 1968, a wildfire completely destroyed the plantation at Horning Farm.

In the spring of 1963 the original study was enlarged by the acquisition of 16 additional Scotch pine provenances from western Europe and eastern Asia. In 1961, Jonathan Wright, Michigan State University, sent 2-0 seedlings from 16 provenances to the Institute of Forest Genetics at Rhinelander, Wisconsin. The seedlings were lined out in transplant beds until April 1963 when they were lifted and sent to the Shelterbelt Laboratory, Bottineau, North Dakota.

A block planting of these additional provenances was made in the spring of 1963 on the Denbigh Experimental Forest (Denbigh-2). Ten replications of square four-tree plots were hand planted at a spacing of 7 feet by 7 feet. The soil is a loamy fine sand. Plantation failures were replanted with extra line-out stock in the spring of 1964. Weeds were rototilled the first 5 years after planting.

Survival, total height, and current leader growth were measured in the North Dakota plantings at the end of the first, second, fifth, and tenth years after planting. These variables were measured annually in the Nebraska planting until the spring of 1968 when the planting burned.

Winter foliage color was scored after 6 growing seasons in Nebraska and after 10 growing seasons in the North Dakota plantings.

Crown density was scored after 10 growing seasons in the four North Dakota plantings.

Results

Survival

Relative survivals summarized by variety are listed in table 2; detailed information on each origin at each test site is in table 3.

Table 2.--Relative performance of Scotch pine varieties in the northern and central Great Plains (percent of all-plantation mean)

Geographic area	Variety	Survival	Total height	Crown density	Winter foliage color
Far eastern Siberia	*mongolica*	91	84	95	67
Central Siberia	*lapponica*	36	58	78	68
	eniseensis	103	94	104	83
	altaica	107	116	94	97
Eastern Russia	*uralensis*	103	105	102	102
Central Russia	*balcanica*	108	122	103	151
Eastern Europe	*rigensis*	104	111	97	114
	polonica	102	119	97	112
	septentrionalis	102	109	100	119
	pannonica	80	92	89	118
Turkey	*armena*	93	64	94	140
		Percent	*Meters*	*Scale*[1]	*Scale*[2]
Average, all test sites		79	3.47	1.95	2.56

[1]Ranked on a scale of 1 = sparse, 3 = dense.
[2]Ranked on a scale of 1 = yellowest, 5 = darkest green.

Table 3.--Seed origin[1] locations and geographic varieties of Scotch pine *(Pinus sylvestris)* tested in the Great Plains, with measurements[2] of relative survival, total height, crown density, and winter foliage color at the test sites (in percent of plantation mean)

Seed origin number	Latitude °N	Longitude °E	Geographic variety	SURVIVAL Oenbigh 1	SURVIVAL Oenbigh 2	SURVIVAL Ransom	SURVIVAL Richland	SURVIVAL Horning	SURVIVAL Average	TOTAL HEIGHT Oenbigh 1	TOTAL HEIGHT Oenbigh 2	TOTAL HEIGHT Ransom	TOTAL HEIGHT Richland	TOTAL HEIGHT Horning	TOTAL HEIGHT Average	CROWN DENSITY Oenbigh 1	CROWN DENSITY Oenbigh 2	CROWN DENSITY Ransom	CROWN DENSITY Richland	CROWN DENSITY Average	WINTER FOLIAGE COLOR Oenbigh 1	WINTER FOLIAGE COLOR Oenbigh 2	WINTER FOLIAGE COLOR Horning	WINTER FOLIAGE COLOR Average
			U.S.S.R.-- FAR EASTERN SIBERIA																					
623	54.00	124.00	*mongolica*[3]	98		69	99	106	93	86		91	103	89	92	95		85	89	90	76		49	62
1924	60.75	131.67	*mongolica*		72				72		47				47		89			89		55		55
1925	52.33	117.67	*mongolica*		104				104		91				91		105			105		89		89
			Average	98	88	69	99	106	91	86	69	91	103	89	84	95	97	85	89	93	76	72	49	67
			U.S.S.R.-- NORTHERN SIBERIA[4]																					
624	60.25	90.00	*lapponica*[3] *orientalis*[5]	67		21	31	53	43	40		58	87	34	55	76		55	79	70	54		62	58
626	60.25	90.00	*lapponica orientalis*	67		14	15	18	28	70		59	65	48	60	86		90	79	85	77		77	77
			Average	67		18	23	36	36	55		58	76	41	58	81		72	79	78	66		70	68
			U.S.S.R.-- CENTRAL SIBERIA, MIDDLE YENESEI RIVER																					
625	58.50	92.00	*eniseensis*[5]	107		69	114	106	99	89		66	92	77	81	100		110	89	100	78		49	64
627	57.50	92.00	*eniseensis*	94		104	84	102	89	86		76	85	78	81	95		95	84	91	78		54	66
628	57.00	95.00	*eniseensis*	107		83	99	106	99	87		93	91	85	89	105		100	84	96	76		49	62
629	57.00	93.00	*eniseensis*	103		132	91	102	107	97		100	96	90	96	100		95	116	104	73		64	68
630	58.50	96.00	*eniseensis*	103		90	99	106	100	85		86	90	86	87	105		90	95	97	98		49	74
631	56.00	91.00	*eniseensis*	89		97	84	102	93	75		86	83	77	80	105		115	95	105	82		67	74
632	55.25	92.00	*eniseensis*	103		104	122	106	109	99		105	89	95	97	119		120	105	115	92		90	91
1923	56.00	95.00	*eniseensis*		104				104		109				109		105			105		94		94
1926	56.67	96.36	*eniseensis*		104				104		95				95		94			94		84		84
			U.S.S.R.-- SOUTH CENTRAL SIBERIA, SOUTHERN YENESEI RIVER																					
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633	54.25	91.00	*eniseensis*	107		118	99	102	106	105		91	91	95	96	119		125	105	116	92		78	85
634	54.25	93.00	*eniseensis*	98		111	130	106	111	101		99	108	95	101	110		120	100	110	96		75	86
635	53.75	92.00	*eniseensis*	98		104	99	102	101	94		102	104	101	100	114		110	105	110	94		86	90
636	53.00	90.50	*eniseensis*	103		118	114	106	110	105		105	105	102	104	114		105	100	106	98		85	86
637	52.75	90.00	*eniseensis*	98		118	107	106	107	104		111	105	102	106	114		95	105	105	118		119	118
638	52.00	93.75	*eniseensis*	103		118	99	106	106	88		102	106	93	97	100		105	105	103	86		90	88
639	51.50	93.00	*eniseensis*	107		125	91	97	105	98		102	95	97	98	114		105	111	110	92		80	86
			Average	101	104	106	102	104	103	94	101	95	96	91	94	108	101	107	100	105	90	91	74	83
			U.S.S.R.-- SOUTHERN SIBERIA, ALTAI MOUNTAINS[4]																					
640	52.00	84.00	*altaica*[3]	103		111	107	106	107	118		120	115	113	116	90		95	84	90	102		85	94
641	52.00	84.00	*altaica*	89		118	137	106	112	112		109	108	118	112	100		80	84	88	108		103	106
642	52.00	84.00	*altaica*	103		118	130	106	114	114		127	122	115	120	100		95	105	100	101		85	93
643	52.00	84.00	*altaica*	107		97	122	106	108	106		124	117	115	116	86		90	100	92	102		88	95

645	59.50	57.50	*uralensis*	98		69	91	102	90	96		96	103	91	96	100		95	100	98	94		80	87
646	58.00	45.00	*uralensis*	98		62	84	106	88	96		93	90	91	92	105		110	89	101	108		90	99
1941	55.00	57.00	*uralensis*	107		111	107	106	108	121		121	116	130	122	100		85	111	99	134		178	156
1942	58.00	57.00	*uralensis*	107		132	68	106	103	103		105	114	106	107	114		105	95	105	110		106	108
			Average	103	106	98	88	104	103	103	108	106	105	103	105	106	100	101	103	103	108	88	106	102
										U.S.S.R.--CENTRAL RUSSIA														
1935	50.00	30.00	*balcanica*[5]	103		90	84	106	96	120		129	124	139	128	100		105	100	102	130		214	172
1936	54.00	32.00	*balcanica*	94		104	107	102	102	115		125	117	125	120	100		110	95	102	144		180	162
1937	54.50	32.00	*balcanica*	107		138	114	102	115	101		101	107	102	103	100		110	111	107	104		128	116
1938	54.00	36.00	*balcanica*	103		118	137	106	116	115		124	115	122	119	86		115	105	102	130		149	140
1939	53.00	37.00	*balcanica*	103		125	114	97	110	130		130	125	133	130	90		105	111	102	130		188	159
1940	52.00	39.00	*balcanica*	107		118	107	102	108	129		125	130	136	130	90		105	111	102	126		188	157
			Average	103		116	110	102	108	118		122	120	126	122	94		108	106	103	127		174	151
											U.S.S.R.--LATVIA													
1920	57.50	25.83	*rigensis*[3]		104				104		113				113		94			94		112		112
1921	57.67	26.33	*rigensis*		104				104		109				109		100			100		117		117
			Average		104				104		111				111		97			97		114		114
											NORTHERN POLAND													
1919	53.83	20.45	*polonica*[3]		107				107		119				119		100			100		112		112
1931	53.72	20.45	*polonica*		96				96		119				119		94			94		113		113
					102				102		119				119		97			97		112		112
											SOUTHERN SWEDEN													
1933	55.87	14.08	*septentrionalis*[3]		102				102		109				109		100			100		119		119
											WESTERN HUNGARY													
1934	47.68	16.58	*pannonica*[3]		80				80		92				92		89			89		118		118
											TURKEY													
1932	40.50	32.67	*armena*[3]		93				93		64				64		94			94		140		140
				- - - - - *Percent* - - - - - -						- - - - - *Meters* - - - - -						- - - - - *Scale*[6] - - - -					- - *Scale*[7] - -			
Plantation mean				93	94	60	55	94	74	3.84	4.15	3.32	3.74	2.30	3.47	2.1	1.8	2.0	1.9	1.95	2.08	2.39	2.62	2.56

[1]Seed of 33 origins received in 1956, sown in 1957, field planted in 1961; 2-0 stock of 16 additional origins received in 1961, planted at Denbigh-2 in 1963.

[2]Measurements taken at age from seed: 11 years at Horning, 12 years at Oenbigh-2, 14 years at all other sites. Horning plantation was destroyed by wildfire in April 1968.

[3]Wright et al. (1966).

[4]From different sites and age classes.

[5]Pravdin (1969).

[6]Crown density ranked on a scale of 1 = sparse, 3 = dense.

[7]Winter foliage color ranked on a scale of 1 = yellowest, 5 = darkest green.

Trees from only two seed sources suffered serious mortality (greater than 50 percent). These were trees from northern Siberia of the lapponica variety (624, 626). Survival of the 49 origins averaged over all sites was 79 percent.

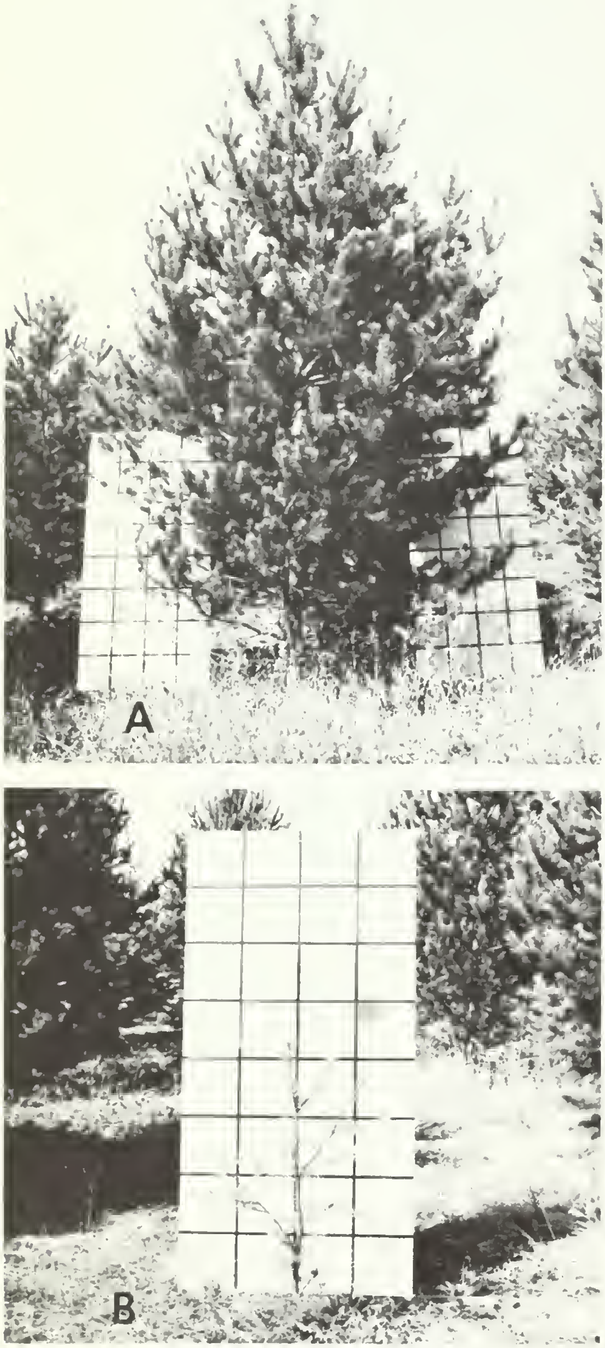

Figure 3.—Differences in height growth were striking. Origin 1936, balcanica (A), outgrew origin 624 lapponica (B), by a wide margin at all sites.

Trees of the balcanica variety from central Russia averaged the highest overall survival, followed closely by the altaica variety.

Height Growth

Generally trees from the more southwesterly origins grew tallest (fig. 3, tables 2 and 3). At Denbigh-1 and Horning, approximately 67 and 78 percent of the variation in total height could be attributed to the combined effect of latitude and longitude. At Denbigh-2 where a more restricted range of varieties were tested the combined effect of latitude and longitude accounted for 45 percent of the variation in total height.

Fastest growing varieties included polonica from eastern Europe, balcanica from central Russia, and altaica from south-central Siberia. The mongolica, and lapponica varieties from far-eastern and central Siberia grew slowest.

Significant intra-variety variation was evident in several of the geographic varieties. Origin 1941 of the uralensis variety out performed any other origin within that variety. Its more southerly location likely accounts for its superior performance.

More localized variation is expressed by the relative performances of origins 1936 and 1937. Separated by only one-half degree of latitude (about 34 miles), origin 1936 outgrew origin 1937 by a wide margin at each of the test sites.

Varietal performance at different locations was quite consistent. At least 9 of the overall top 10 origins could be predicted from individual test site performance (table 4). The maximum change in rank for any origin at any test site was four positions. This apparent lack of sizable genotype-environment interaction sug-

Table 4.--Relative ranking at each test site of the 10 provenances averaging tallest over 4 test sites

Origin number	All-site average	Ransom	Richland	Denbigh -1	Horning
1939	1	1	2	1	3
1940	2	4	1	2	2
1935	3	2	3	4	1
1941	4	8	7	3	4
1936	5	5	5	7	5
642	6	3	4	9	10
1938	7	7	10	8	6
644	8	11	8	6	7
640	9	9	9	5	11
643	10	6	6	11	9

gests that the results of this study may indicate performance of the origins over a wide range of sites in the northern and central Plains.

The accuracy with which performance after 10 years in the field could have been predicted from fifth-year data is indicated below:

Plantation	Correlation (r)	Success ratio
Denbigh-1	0.96	9/10
Denbigh-2	.98	9/10
Ransom	.96	9/10
Richland	.90	8/10

The success ratio is the number of origins correctly predicted from fifth-year data to be the best of 10 origins after 10 years. All r values are significant at the 1 percent level. These ratios show that, at 3 of the 4 locations, 9 of the top 10 origins could have been correctly predicted 5 years in advance. Early evaluation of performance should shorten the time interval between test initiation and practical application of results.

Crown Density

Considerable intra-origin variation was evident in crown density. One tree from a particular origin might exhibit a dense, compact crown while another tree from the same origin would be very open and sparsely branched (fig. 4). This intra-origin variation tended to obscure between-origin differences.

Generally the central Siberian origins from the southern Yenesei River exhibited the best crown density (tables 2 and 3). Next best were those origins of the balcanica variety. Poorest were the most northerly origins of the lapponica variety.

Crown density is a function of several variables. (Dawson and Read 1964). It appears that, in order of decreasing importance, branch angle would be the most important, followed by number of branches, live branch retention, kind and amount of foliage, and finally branch thickness. The degree to which each of these variables contributes to overall crown density requires further investigation. It should be possible, how-

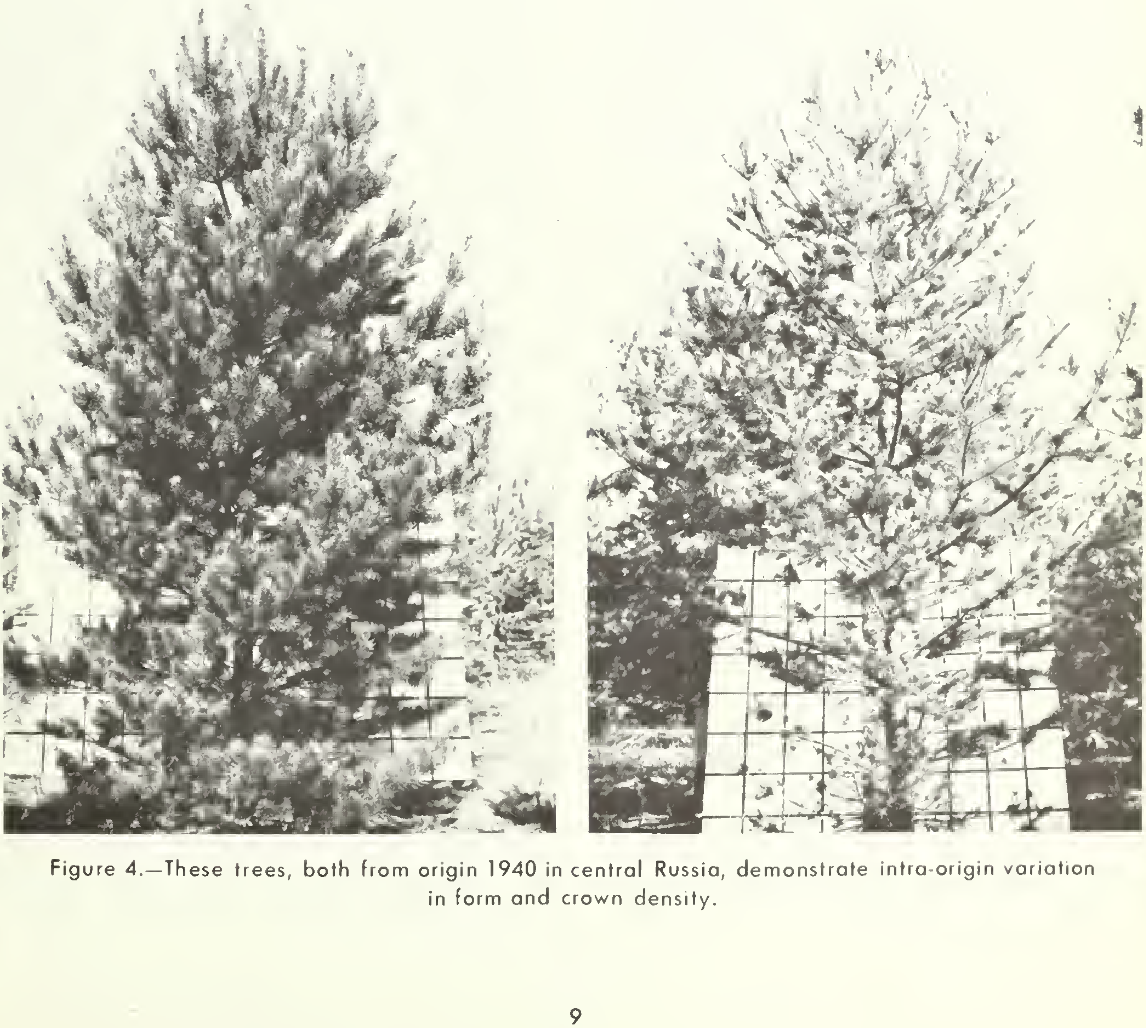

Figure 4.—These trees, both from origin 1940 in central Russia, demonstrate intra-origin variation in form and crown density.

ever, to find a rapidly growing tree that exhibits good crown density, a desirable characteristic for a shelterbelt tree. Origins that combine such desirable characteristics will be discussed later.

Winter Foliage Color

Generally, the more westerly origins produced trees with the darkest green foliage (tables 2 and 3). A weaker trend was for more southerly origins to be darker green. From 75 percent to 89 percent of the variation in winter foliage color was related to the combined effect of latitude and longitude.

The six darkest green origins at each test site where color was scored were from south of 56° north latitude and west of 57° east longitude. Varieties represented by these origins were armena, septentrionalis, pannonica, regensis, polonica, and balcanica.

Conclusions and Recommendations

All of the Scotch pine varieties but two survived adequately at all test sites. Origins 624 and 626 of the lapponica variety suffered extensive mortality at all test sites. The absence of a prolonged drought during the test period precludes the identification of origins particularly susceptible to, or tolerant of, extreme drought. Scotch pine is generally considered less tolerant of drought than is ponderosa pine.

In shelterbelt plantings, adequate survival, rapid growth rate, and moderately good crown density are important traits. Foliage color, particularly winter color, is important where esthetic values should be considered, particularly in farmstead plantings.

Although crown density was not highly variable among the origins tested, the central Siberian and Russian origins were generally most dense and the northern Siberian origins the least dense.

Both growth rate and winter foliage color varied considerably (table 5). Generally, trees from the more southwesterly origins grew fastest and had the darkest green winter foliage. Read (1971) reported a similar trend with trees from origins in France, Belgium, and Germany growing faster and having greener winter foliage than trees from origins in Siberia.

For windbreaks, where foliage color is not important, the best origins for planting in the northern Great Plains are from central Russia (1939, 1940) and the Ural Mountains (1927, 1930). Nearly as good are a number of origins from central Siberia (1922, 1923, 1926, 637). For windbreak plantings in the central Great Plains, Read (1971) recommended fast-growing central European origins from Belgium, Germany, and France. The adaptability of these origins to the colder climate of the northern Great Plains has not been adequately tested.

The fastest growing origins with good color are from Poland (1919, 1931) and Latvia (1920). Other origins combining fast growth rate with good color are those from southern Sweden (1933), central Russia (1935), Hungary (1934), and Latvia (1921). Poorest were origins from northern Siberia.

For Christmas tree culture, origin 1934 from Turkey would be a good choice for the northern Great Plains. Its blue-green foliage and moderately slow growth are traits favored by Christmas tree growers. Read (1971) also recommended this variety (armena) for Christmas tree culture in Nebraska.

The incidence of insect and disease attacks has been only minor, and it is not yet possible to rank the provenances in order of susceptibility to particular insect or disease problems.

Nurserymen or tree planters should make specific inquiries to seed dealers regarding the availability of seed from desired origins or varieties. Often seed dealers can procure seed of many varieties that are not normally listed in their catalogs. At least two of the varieties recommended in this Paper are presently listed by United States seed dealers. Others may be available upon request. The extra effort invested in obtaining the best variety for a specific use is nearly always repaid many times over in the increased value of the trees produced.

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Table 5.--Groupings of Scotch pine origins by growth rate and winter foliage color

Height growth	Blue-green foliage	Green foliage	Yellow-green foliage	Yellow foliage
VERY FAST (more than 46 cm per year)		1919 Poland 1931 Poland 1920 Latvia	1927 Ural Mountains 1940 Central Russia 1939 Central Russia 1930 Ural Mountains	
FAST (38 to 45 cm per year)		1921 Latvia 1933 Sweden 1935 Central Russia 1934 Hungary	1923 Central Siberia 1929 Ural Mountains 1928 Ural Mountains 1941 Ural Mountains 1936 Central Russia 1938 Central Russia 1922 Central Siberia 1926 Central Siberia 1925 East Siberia 637 Central Siberia	642 Altai Mountains 644 Altai Mountains 640 Altai Mountains 643 Altai Mountains 641 Altai Mountains 1942 Ural Mountains
MEDIUM FAST (30 to 37 cm per year)			1937 Central Russia	1943 Ural Mountains 636 Central Siberia 634 Central Siberia 635 Central Siberia 639 Central Siberia 638 Central Siberia 632 Central Siberia 629 Central Siberia 633 Central Siberia 628 Central Siberia 630 Central Siberia 645 Ural Mountains 646 Ural Mountains 623 East Siberia
MEDIUM SLOW (22 to 29 cm per year)	1932 Turkey			627 Central Siberia 625 Central Siberia 631 Central Siberia
SLOW (less than 21 cm per year)				626 North Siberia 1924 East Siberia 624 North Siberia

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife — if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Agriculture—CSU, Ft. Collins

Cunningham, Richard A.
1973. Scotch pine for the Northern Great Plains. USDA For. Serv. Res. Pap. RM-114, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

A provenance test of 49 origins of Scotch pine (Pinus sylvestris L.) from eastern Europe, Russia, and Siberia was established at three locations in North Dakota and one in Nebraska. After 10 years (7 in Nebraska), trees from 50° to 55° latitude and 20° to 40° longitude survived best, were taller, and had greener winter foliage. Several provenances appear to be well suited for planting in shelterbelts and for Christmas tree culture.

Oxford: 232.12:165.52. **Keywords:** Geographic variation, provenance trials, *Pinus sylvestris.*

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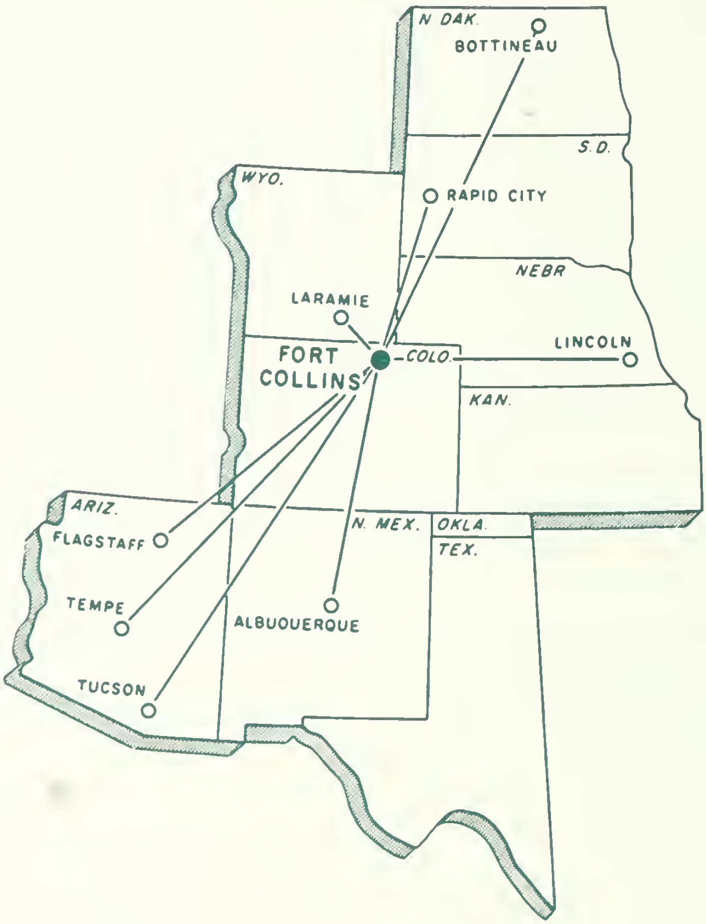
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USDA Forest Service
Research Paper RM-115

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Computerized Preparation of Timber Management Plans: TEVAP2

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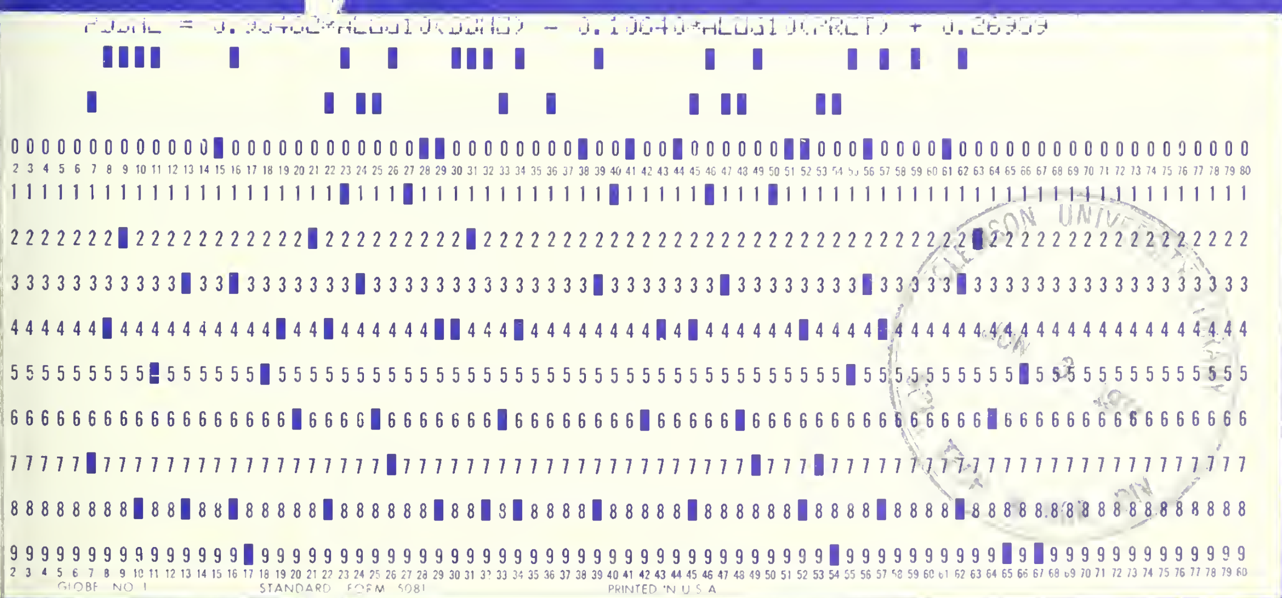
Clifford A. Myers



Rocky Mountain Forest and Range Experiment Station
U. S. Department of Agriculture
Forest Service

Abstract

Presents computer programs, written in FORTRAN IV, for analysis of inventory data, and computation of actual and optimum growing stocks and allowable cuts, and other values needed for forest management planning. Computed volumes and areas are summarized in a timber management plan. Effects of cultural operations and other changes are accounted for in computation of both actual and optimum conditions. Supersedes Research Paper RM-63.

Oxford: 624:U681.3. **Keywords:** Allowable cut, forest management, timber management, *Pinus ponderosa, Pinus contorta.*

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

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[1] *Central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

CONTENTS

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The original version of these procedures was tested for 2 years on the Black Hills National Forest. The test team, headed by Professor Warren E. Frayer, Colorado State University, and Gary E. Metcalf, Black Hills National Forest, provided valuable suggestions for improving the procedures and computer programs.

Computerized Preparation of Timber Management Plans: TEVAP2

Clifford A. Myers

Introduction

Procedures and a computer program (TEVAP) to process inventory records and to write timber management plans (Myers 1970) were tested for 2 years on the Black Hills National Forest. Following successful completion of the test (Edwards et al. 1973), the procedures and program TEVAP were revised. Modified procedures and computer program TEVAP2 are presented here to supersede the 1970 publication, USDA Forest Service Research Paper RM-63. Some changes resulted from experience gained during the field test. These include increasing the number of blocks and working groups that can be accommodated, and changing program organization to simplify application to additional species. Other modifications reflect improved modeling of changes caused by silvicultural treatments (Myers 1971) and addition of the effects of dwarf mistletoe to appropriate growth equations (Myers et al. 1971, Myers et al. 1972).

As listed in appendix 1, TEVAP2 may be used for: (1) ponderosa pine (Pinus ponderosa Laws.) in the Black Hills of South Dakota and Wyoming, (2) ponderosa pine in Arizona and New Mexico, and (3) lodgepole pine (Pinus contorta Dougl.) in Colorado and Wyoming. It is quite easy to modify the program for use with other species. The changes and additions needed are explained in detail.

TEVAP2 was written in standard FORTRAN IV and tested on a CDC 6400 computer. In addition, it was run on a Univac 1108. Several FORTRAN statements were modified to match the rounding operations of the 1108, where proper execution by a CDC 6400 would not be affected.

Purpose

A forest operated as a business enterprise produces more than wood, forage, and other products. It is a prolific source of treatment and inventory records, reports, plans, maps, and other information. As with other businesses, efficient information processing is needed so that all relevant information can be used for decisionmaking.

Procedures for analyzing inventory and other data and reducing them to summary values useful in planning have been available for many years. These procedures have long provided information needed for management, and their validity and usefulness usually have been widely accepted. There are, however, important deficiencies in the ways data have been handled and in the conventional methods of computation described in forest management texts. Specifically, the use of maps and overlays, timber atlas and similar records, and desk calculators involve such difficulties as the following:

1. There is usually more information available than can be stored, retrieved, and analyzed efficiently.
2. Maps, photographs, overlays, and tabulations of numerical data freeze the information at one or a few points in time. Changes in recorded information in response to changes in the forest are expensive and time consuming.
3. Higher offices may ask for information already assembled in whole or in part for a previous report, but for which the worksheets are no longer available. Such requests can lead to much repetition in the assembly and analysis of data.
4. Information gathered for a specific purpose may be placed in a dead file after immediate needs are met. It may, however, have future value in management and decisionmaking, if it could be stored and relocated efficiently.
5. Timber management appears to proceed by steps, from management plan to management plan. Standing timber can and should be accounted for continuously, however, as is done for products entering and leaving a warehouse. There is danger of forgetting that a productive forest is a continuous, dynamic system.

High-speed computers with reasonably large memory capacity provide a means of efficiently extracting large amounts of information from an accumulation of records. Data can be stored, retrieved, and updated with relative ease. Computations, if preplanned, can be done so cheaply that higher offices can obtain all the reports desired without disrupting the work schedule of local managers. There is no need to depend on plans that are expected to apply for several years despite fires, epidemics, and changes in economic conditions. A new plan, new maps, new cutting budget, and a new work schedule can be obtained as soon as recent changes in forest conditions have been recorded in the data file.

Program TEVAP2 (Timber EValuation And Planning), described herein and listed in appendix 1, provides a means of obtaining guidance quickly from a large volume of information. It is an example of the application of some information handling and analysis procedures to forest management. The program was developed around relationships that apply to timber production in even-aged stands because such relationships were available. It can be expanded, however, to include forage and other products and timber production in many-aged stands without change in the basic system.

With program TEVAP2, a manager can obtain a management plan whenever he wants one. A computer run, using updated records, can be made each winter during the planning period between field or growing seasons. Because large amounts of tedious computations and analyses are automated, management plans need not be prepared only at intervals of perhaps 10 years.

The term management plan, as used here, refers to the quantitative section of a conventional timber management plan. This material, in the form produced by TEVAP2 and in the way in which it is used, is perhaps better referred to as a management guide. Such information, regardless of how computed, serves as a guide or aid to management rather than as a plan, but the term "plan" has been used for many years. Following common modern practice, the transportation system and other general details can best be described in a report that covers the entire forest and provides information common to all resources. The output of TEVAP2 is, then, a specialized chapter to be added to this general report.

Programs such as TEVAP2 produce information that can be used for more purposes than control of current operations. They provide input data for programs that simulate operation of a forest under actual conditions. A manager can use the results of simulation to determine which one of several management alternatives will best meet his objectives (Chorafas 1965).

Data Handling and Management

Forest resource records are assembled from several sources. For timber, these sources are: (1) periodic forest inventory, (2) job reports prepared at the completion of each thinning, planting, sale, or other cultural operation, (3) area descriptions written after each fire or other catastrophe, and (4) stand and compartment analyses made as funds become available. Results of periodic inventories appear in management plans prepared after each inventory. Job reports and other data may be posted on the maps and tables of a timber atlas and summarized in annual reports. Although procedures vary among forest regions and classes of ownership, almost every item of information is used at some step in management and decision making. Several operational computer programs for the analysis of periodic inventories illustrate how well the development of computation procedures has progressed.

It is unusual, however, for every item of information to be used for all appropriate purposes. For example, an individual fire report becomes part of the annual report on losses and suppression costs. It may then go to the protection file rather than to be processed as an important item of inventory data.

There are valid reasons why the maximum amount of information may not be extracted from each item of data. Problems related to storage and retrieval are frequently of great importance. These include the size of record files, problems of assembling the data for use, and reassignment of people who know what has been recorded and where to find it.

A forest manager is faced with other information problems that are less easily solved. There is little value in pooling records unless they can be updated to put them on a common time base. Also, data sufficient for a particular purpose may not be complete enough for more general use. A report on a thinning job may not contain sufficient stand or site data to permit its use in growth projections.

Procedures used in TEVAP2 to bypass some of the problems mentioned above are based on availability of a file of inventory records that can be updated as needed. This file contains stand data from many sources such as land books, job reports, and inventories. Stand descriptions prepared soon after thinning, fire suppression, or other activities provide excellent up-to-date inventory data and are used as such. Conventional inventories sample parts of a forest not already described in other records.

Inventory records for TEVAP2 are summaries of work reports and of conventional inventory records. They contain the specific items needed for program execution plus other items useful in sorting and summarizing the records. Overstory and understory components of a stand are described separately, if both are present. Computations can thus be made for stands being regenerated by shelterwood or seed-tree systems. Growth can also be estimated for the many uneven-aged stands that may be described mathematically as two stands, overstory and understory.

Data used by TEVAP2 can be updated by computer once the basic relationships needed have been determined. How inventory records may be updated is explained in appendix 4.

Description of Program TEVAP2

Program TEVAP2 consists of: (1) a main program, (2) 16 subroutines that perform operations common to all species and working groups, and (3) a variable number of subroutines, each of which contains all the species-specific relationships required for one species. For brevity, the program listing in appendix 1 includes only three species-related subroutines. Any or all of the three may be replaced by following the instructions in the section headed Basic Information Used. Alternatively, any number of species-specific subroutines may be added. Three subroutines (MAPS, AREA1, and AREA2) provide alternative ways of computing areas, and only one of them is used during a single run. A single, complete program run thus uses the main program, 14 general subroutines, and at least one species-specific subroutine.

Content and purpose of each routine are described in the following sections. Variable names are defined in the program listing in appendix 1 and in the list of contents of the data deck. The list of data cards (in the section "Data Deck for TEVAP2") also reports the number of cards needed and the sequence in which they are read. An example of an application of TEVAP2 (appendix 2) further explains the program.

Numbers of blocks, working groups, site classes, and age classes that can be accommodated are limited by the dimensions assigned in COMMON and DIMENSION statements. As listed in appendix 1, each type of subdivision has a different number of units so the dimensions and loops that pertain to each subdivision can be identified. Restrictions to be observed, unless appropriate changes are made, are as follows:

1. The working circle may be subdivided into one to seven blocks. A block may be an isolated unit of the working circle or one or more basic administrative units, such as Ranger Districts. There must be at least one block in the working circle for program execution.

2. A maximum of five working groups may be defined without program modification. A working group consists of stands of the same forest type and managed under the same silvicultural system (Chapman 1950). It may sometimes be necessary to exclude a portion of the working circle from allowable cut computations. At the same time, all the other values may be needed to prepare impact statements and for other use. Examples of such special situations are stands on areas being examined for possible wilderness classification. In such cases, a working group named DEFERRED can be created. Statements are already in TEVAP2 to bypass DEFERRED working groups in computing allowable cut totals. If more than one species is involved, the excluded working groups may be named DEFERRED1, DEFERRED2, etc., and the area where they occur designated as a separate block.

3. Provision is made for 35 vegetative or use types. As used for the example in appendix 2, they are as follows:

Types 1- 5	- Five broad age classes within the first working group.
Types 6-10	- Five age classes within the second working group.
Types 11-15	- Five age classes within the third working group.
Types 16-20	- Five age classes within the fourth working group.
Types 21-25	- Five age classes within the fifth working group.
Type 26	- Deforested areas covered by brush.
Type 27	- Deforested areas covered by grass.
Type 28	- Recreation areas not included in computations of volume or allowable cut.
Type 29	- Rock outcrops and other areas where plant products cannot be produced.
Type 30	- Areas covered by brush that will not be converted to forest.
Type 31	- Areas with grasses and other herbaceous species that can be managed for forage production.
Type 32	- Areas of other ownership.
Type 33	- Areas included in cleared rights-of-way along roads, power lines, etc.
Types 34-35	- Available for assignment.

4. Stand ages may be grouped into 15 or fewer 10-year age classes. This classification is in addition to, but correlated with, the use of age in the forest type definitions.

5. Ten-foot site index classes from 10 to 140 are used to group various volume and area data by productivity classes.

6. Provision is made for up to 30 subcompartments per compartment. This specification

need be considered only if subroutine MAPS is the source of area data. Following long-established practice, a compartment is the smallest permanent unit and is useful for record keeping. A subcompartment is a temporary subdivision equivalent to a stand, and is an area reasonably uniform in such characteristics as site quality, stand structure, and treatment (Chapman 1950).

Main Program

The main program calls 13 subroutines to execute five sets of operations in the following order:

1. Read values of control variables and initialize variables applicable to the working circle.
2. Compute area totals and subtotals.
3. Compute optimum growing stocks and yields.
4. Compute present and future volumes, periodic yields, and other values useful in timber management.
5. Summarize computations and print a timber management plan.

TEVAP2 provides three alternatives for the second set of operations, computation of areas. One alternative (MAPS) requires complete forest subdivision plus compartment maps on punched cards or magnetic tape. Another (AREA2) requires only a knowledge of total area of the working circle and of each nontimber vegetative or use type. The third alternative (AREA1) represents one intermediate possibility, knowledge of type areas by compartments but with subcompartments not designated or mapped. A new routine may replace any of the three examples if still another level of information is of interest.

Ten subroutines called by the main program and one routine called by another subroutine write one or more pages each. Pages are identified by a type number such as "page type 3," as shown in appendix 2. Each type number, except type 5, designates a specific page layout. Pages are not numbered consecutively because page requirements will vary with size of the working circle, number of working groups, and area alternative used. The last three pages printed are designated types 1, 2, and 3 since many managers prefer that summary pages be the initial pages of a plan. Pages of Z-fold paper can be separated and placed in proper numerical order. Temporary storage on scratch tapes can be used to reorder pages for output onto film.

Subroutine BASIS

BASIS reads data card types one to eight (p. 12) to enter values of control variables that do not change during program execution. With many variables, a value is entered for each working group of the working circle. Some variables quantify management decisions and economic limitations. These include frequency and intensity of thinning, rotation lengths, regeneration system, and minimum volumes for commercial operations. Other variables describe regeneration goals in terms of the average stand diameter and number of trees per acre expected at time of the first thinning. Goals are described for each site class of each working group. Since the number of site classes may not be known before the inventory records are processed, it is necessary to include data cards of types 6 and 7 for every 10-foot site class from the lowest to be managed in the working group up to at least the highest expected. The last type 6 card for each working group is blank to stop further reading for that working group, unless class 140 is represented by data cards. A blank type 6 card is not followed by a type 7 card.

Values to be assigned to the control variables can be obtained from analysis of past records, measurements on temporary plots, and from computer simulations that permit examination of alternatives (Myers 1971, 1973).

Several of the values read by BASIS are printed on page type 4 to provide a partial record of the control variables.

Subroutine INIT

INIT is called by the main program to assign an initial value of zero to many subscripted and unsubscripted variables. These variables are later used to describe major subdivisions of the working circle and usually appear in several subroutines.

Subroutine SCAN

SCAN executes the first of two readings of the inventory records on type 9 data cards or card images. Totals are then compiled as follows: (1) number of records by block and type (broad age classes within a working group), (2) area of each cover type by block and type, (3) nonstocked areas by block and site class, (4) area in each working group by block and site class, and (5) area, by block and type, below minimum site class for management. TEVAP2 will handle inventory records with or without a known area in acres, or a mixture of the two. If the area field of a record reports an acreage, the data describe a stand of that size. If no area is given, the data apply to an inventory plot. SCAN sums reported areas by each combination of subdivisions listed above. Otherwise, numbers of plots of each classification are obtained. Numbers of plots are converted to equivalent areas by later subroutines.

SCAN determines the number of site index classes represented in the inventory records of each working group. Number of site classes controls the number of yield tables produced by YIELD. Subroutine YIELD, in turn, computes overwood volumes and their growth rates, if seed tree or shelterwood systems are used. These values are thus available when needed for processing of the inventory records by subroutine GOT.

Subroutine MAPS

Subroutine MAPS is one of three alternative routines used to compute areas. Items needed are (1) complete forest subdivision to the subcompartment, and (2) compartment maps that show types and subcompartments. The sequence of operations is explained by COMMENT statements in the program listing (appendix 1).

MAPS accepts map data in the form of arrays of map codes on punch cards or tape. These are labeled card types 12, 13, and 14 in the list of contents of the data deck. The form of input is specified by assignment of logical unit 3 to the card reader or to a tape drive. Array sizes, related DIMENSION statements, the system of map codes, and the area represented by one square of the map grid may be changed as desired.

Coding of types (KTYP) and subcompartments (KSUB) follows a procedure used for demographic and other studies. In the example of appendix 3, each section of 640 acres on a forest stand map was subdivided into 144 small squares. Each square of 4.444 acres (map 4 inches to 1 mile) was then assigned the code number of the predominant type. Portions of sections were combined to reproduce the entire compartment. Subcompartments were then designated and coded on the basis of type codes and field data. In the forest used as an example, all compartments fit into squares three sections on a side, and could be represented by arrays of 36 by 36 2-digit code numbers. One west-to-east row of coding occupied the first 72 columns of a punch card. As many cards as necessary, but not more than 36, were punched to complete a type or subcompartment map for a compartment. All cards were run through an editing program to locate errors. This included a check that each subcompartment contained only one type. Corrected maps and control variables were then recorded on magnetic tape, using WRITE statements equivalent to the READ statements for data card types 12, 13, and 14.

The mapping procedure used is intended to illustrate the types of information needed and what can be done with them. In actual applications, more efficient procedures for coding and data storage may be available. Hand coding, for example, can be replaced by use of equipment that reduces map areas to digitized form. Forest managers can obtain procedural guides from the many applications of computer graphics to studies of urban problems and land use (Shahar 1970).

MAPS contains the only machine-dependent operations in program TEVAP2. Map code numerals are converted to display code so blank areas of the maps will not be filled with minus zeros. Converted numbers are then printed with R format. Program statements must be modified if available equipment uses a different display code than the CDC 6400 used to test the program.

Two pages, types 5 and 6, are printed by MAPS. The form of page type 5 is optional and is specified by the value read initially for the variable MAP from data card type 11. Type and subcompartment maps and related area totals may be printed, if desired. Two pages are produced per compartment, one with the type map and one with the subcompartment map (appendix 3). Alternatively, only type and subcompartment areas may be printed (MAP = O). Page type 6 reports block and working circle totals, and has the same format as the equivalent page produced by AREA1 and AREA2 (appendix 2).

Type and subcompartment boundaries are continually subject to change according to the usual rules for forest subdivision (Chapman 1950). The map file must, therefore, be updated prior to each computer run with subroutine MAPS. Cultural operations, growth into the next age class, and fire or other catastrophe create need for recoding.

Subroutine AREA1

Subroutine AREA1 is another of the three alternative routines that compute areas. It is used if compartments have been established and if type areas within compartments are known. It is assumed that subcompartments have not been established, or that compartment maps are not available. AREA1 illustrates one possible situation in the range of degrees of administrative complexity between the limits served by MAPS and AREA2.

Type areas by compartment — inputs to the subroutine from data card types 15 and 16 — are summed to obtain total acres by working group, by block, and by various other classifications and combinations thereof. These sums are stored in unlabeled COMMON blocks for use by later routines. COMMENT statements in the program listing, appendix 1, explain the operations involved.

AREA1 prints type areas of each compartment on one form of type 5 pages (appendix 3) and prints a type 6 page to report block, working group, and working circle totals. The type 6 page is the same as that produced by MAPS and AREA2 (appendix 2).

Subroutine AREA2

Subroutine AREA2 is the third of the routines used to compute areas (appendix 1). It is used if compartments have not been established, or if type areas within compartments are not known. This is the situation assumed for the example in appendix 2. Areas of blocks and of nonforest types are read from data card types 17 and 18.

Type areas are computed from total production area, including nonstocked, and inventory information already compiled by subroutine SCAN. Areas of nonforest types and of unregulated stands in recreation areas are subtracted from working circle area to get the area available for timber management. Stands of known area were assigned to the appropriate block and type by SCAN and are now subtracted from equivalent total areas. Remainder of the production area is allocated to forest types, by block, in proportion to the number of inventory records without area from each type.

Type, working group, and block areas are recorded on pages type 5 and 6 (appendix 2).

Subroutine LAND

LAND completes the processing of the areas of blocks, working groups, and types. Area of the working circle not in subcompartments of known area is computed by: (1) working group and block, and (2) block and type. Total area of all timber types, excluding nonstocked, and the area of nonstocked land in each block are then computed.

Acreages not in subcompartments of known area and record counts made by SCAN are used to complete the computations. Nonstocked area is determined for each site class of each block. Areas of each site class in each block and working group are then computed.

LAND prints page type 7 as a record, by site class and block, of the nonstocked area and the area in each working group.

Finally, the deforested area is allocated to working groups by blocks and site classes. Each working group is assigned a percentage of the deforested area equal to the proportion of the area of the working group to total timbered area. These adjusted areas are later used to compute optimum growing stocks and allowable cuts.

Subroutine GOAL

Subroutine GOAL computes the optimum conditions that would exist if all stands were thinned on schedule to a specified level, with a balanced series of age classes already established. Values needed to make these computations come from other routines. Management decisions based on experience, results of simulations, and statements of policy are entered by BASIS. Acres in each site index class of each working group are computed by LAND from area data and the inventory file read by SCAN.

Most computations are executed once for each site index class of each working group. Major operations, in the order performed for a site class, are as follows:

1. Subroutine YIELD is called to compute and print a yield table.
2. Annual volumes per acre, computed by YIELD, are printed on page type 9. These volumes, in board feet and cubic feet, are later summed to obtain optimum growing stocks. Recording the volumes on page type 9 preserves them for other use after the management plan has been printed.
3. Mean annual increment at rotation age is computed for each site class of each working group. If appropriate, tree felling ages do not equal rotation ages but include the effects of delays in obtaining regeneration and the period seed trees or a shelterwood may be left over the new crop. Mean annual increments computed from yield table volumes are later used as "normal" increments in application of Heyer's formula:

$$E = WZ + \frac{WV - NV}{a}$$

where: WZ is mean annual increment, WV is actual growing stock, NV is normal growing stock, and a is the adjustment period (Burger 1920).

4. GOAL calculates for each 10-year age class the number of acres and the growing stock resulting from a balanced series of age classes. The results are printed on page type 10. Area regulation is assumed for these computations; annual cut for a site class of a working group is area divided by rotation length. Acres with stands of zero age are listed as such if delays in regeneration are expected with clearcutting. Volumes of seed trees or shelterwood are included in appropriate age class totals if these regeneration systems are used. Tables of pages type 10 in appendix 2 show examples of working groups managed by shelterwood and clearcut systems.

5. Annual cuts that might be obtained with a balanced series of age classes and optimum stand densities are computed for each working group. Volumes from intermediate, regeneration, and final cuts are not combined into working group totals until subroutine SUMRY is called. Volumes of final cuts result from the final removal of overwood with seed tree or shelterwood systems. All other cuts for purposes of stand regeneration, including clearcutting, are classed as regeneration cuts.

After processing of all site classes is completed, GOAL prints a record of optimum volumes by site classes on page type 11 and area equivalents in standard acres on page type 12. One page of each type is produced for each working group.

Subroutine YIELD

YIELD is called by GOAL to compute and print a yield table for each site index class of each working group. Prediction equations and other relationships needed are obtained by calls to subroutines CUTS and WORKGP. Information used is described in the section headed Basic Information Used.

A yield table for a site class of a working group incorporates management objectives relating to frequency and intensity of thinning and other matters. It serves as a "normal" or standard for stands of that classification. A yield table represents the goal toward which operations are directed. It is possible to produce many yield tables for a site class, which emphasizes that there cannot be a single table for managed stands of a species and site class. The term "managed" indicates that there are additional variables to be considered; one table cannot account for all the possibilities. Each table is useful only where goals and management decisions are as specified for its computation.

Details of field work and computations needed to produce yield tables have been published elsewhere (Myers 1971, Myers et al. 1971, Myers et al. 1972). Subroutine YIELD is most of what is used elsewhere as a separate program. The yield tables are printed as page type 8.

Volumes per acre at each year of stand age are obtained by interpolation between yield table values. These volumes, in board feet and cubic feet, are printed by subroutine GOAL.

Additional computations are performed by YIELD if seed tree or shelterwood systems are used for stand regeneration. Volumes of the residual overwood remaining after each regeneration cut, in board feet and cubic feet, are obtained from the yield tables. Growth rate of the residual overwood during the period it remains standing is also computed.

Subroutine CUTS

Subroutine CUTS estimates average stand diameter after a thinning from below that includes removal of occasional larger trees. Estimated diameter after thinning (DBHE) is computed from diameter before thinning and the percentage of trees to be retained. Some of the relationships used, described in the section headed Basic Information Used, are contained in the species-specific subroutines. Successive percentages of retention are tested until d.b.h. after thinning, number of trees retained, and residual basal area agree with the growing stock goal specified by THIN(I) or DLEV(I). Each call by YIELD or GOT is preceded by a statement that specifies the thinning level (REST) to be used.

Growing stock levels specify the basal area to be left after thinning in relation to average stand diameter (Myers 1971). Definition of several levels provides for alternative thinning intensities. Each level is named by the basal area to be left when average diameter is 10.0 inches or larger. Residual basal area increases with stand diameter until the diameter reaches 10.0 inches. Thereafter, basal area remains constant for any one stocking level. Subroutine CUTS therefore has two iterative loops so a full range of diameters, with both variable and constant basal area, may be accommodated. Limiting d.b.h. for selection of loops is 10.0 inches minus the smallest change expected from usual thinning practice.

Subroutine WORKGP

Subroutine WORKGP is included solely to serve as a switching center. Its presence permits TEVAP2 to be used with many species and working groups, and for all species-specific statements to be grouped into separate subroutines for convenient program modification. WORKGP is called by YIELD, CUTS, or GOT, as needed. The species number for the working group, SPNUM(I), is used by WORKGP to call the appropriate set of species-specific relationships. For example, if SPNUM(I) equals one, the call will be to subroutine BHPP, species-specific statements for Black Hills ponderosa pine, with the program organized as in appendix 1.

BASIS reads both an identifying number for each working group and a number for the species in the working group. This combination permits flexibility in silvicultural specifications for working groups without lengthening the program. For example, part of the area of a given species may be managed for wood fiber with two-cut shelterwood and a short rotation if high intensity recreation use is not a factor. Elsewhere, the species could be managed with three-cut shelterwood and a longer rotation to provide pleasing variety in the landscape. The identification procedure used in TEVAP2 keeps data from the two working groups separate at all times. By assigning the same species number to both working groups, however, only one species-specific subroutine is needed.

For brevity, the listing of WORKGP in appendix 2 calls only three species-specific subroutines, and has dummy statements for two more. Any or all of these five may be replaced by calls to subroutines that contain statements for other species. The GO TO statement may be expanded to provide for the addition of many more species-specific subroutines to TEVAP2. One copy of TEVAP2, stored in one computer, can thus serve all the working groups and species of an entire region.

Subroutine GOT

Subroutine GOT processes the set of inventory records (data card type 9) to obtain present and future volumes and other values. Controls described in the following paragraphs apply to all computations.

Inventory records have a number in the ACRE field if the tree and site index values are amounts per acre averaged over a specific stand. The ACRE field has a blank or zero if the record is for a sample plot that describes a portion of the "unknown" forest area. In terms of recent National Forest inventories, the working circle may be at stage one (sampling the working circle), at stage two (compartment analysis), or with parts of the working circle at each level.

Volume computations are bypassed for records from: (1) deforested areas, (2) areas below minimum site index for management, (3) trees too young or too small to have more than a few merchantable cubic feet per acre, and (4) stands below minimum age for inclusion in growing stock totals. With these exceptions. operations performed on individual inventory records produce the following values:

1. Present basal areas and volumes per acre.
2. Basal areas and volumes at the end of the planning period.
3. Growth expected during the next planning period, in cubic feet and board feet. Thinnings are computed as though done at the beginning and end of the period, and average growth is determined. It is assumed that about equal areas will be thinned each year of the period.
4. Potential yields during the next planning period if all areas are treated as specified by WORK on the inventory records. Half the potential growth of stands to be cut during the period is added to potential yields. Volumes are not included in total yields if they are less than the minimum commercial cuts specified by values of variables COMBF(I) and COMCU(I).

Two variables define time periods. TIME is the number of years in a planning period. It is the period considered in assigning the WORK index that identifies stands in need of treatment in the near future. Values of WORK that relate to computations in GOT are defined at the beginning of appendix 1. RINT(I) is the number of years for which the equations predict future d.b.h., height, and stand density. RINT(I) may vary among working groups. TIME must be equal to or a multiple of RINT(I).

Two sets of volume totals are maintained for block, age, and other subdivisions until all inventory records are processed. One set reports volumes of stands of known area. Volumes per acre are multiplied by area to obtain stand volumes for addition to the totals. The second set reports volumes from records with no entry for area in the ACRE field. Volumes per acre are summed for each subdivision specified in the program. Final volumes are totaled by subroutine SUMS.

Inventory records used by SCAN and GOT can be listed according to the work to be performed (WORK) and the fiscal year (FISC) in which it is scheduled. This listing would provide information on where stands to be treated during the next management period are located. Such a list is not made by TEVAP2, but could be produced by a separate run of the inventory records. Locations, WORK index, and fiscal year appear on the inventory records of data card type 9.

Subroutine SUMS

Sums completes the processing of volumes and prints a record of the computations. For records without a value in the ACRE field, SUMS will: (1) compute separately for each block the proportion of the total area of a type represented by one sample plot, (2) use this area to convert the sum of acre volumes to actual volumes of that portion of the working circle without ACRE records, and (3) add volume totals, with and without ACRE records, to obtain actual totals for various subdivisions of the working circle.

Summaries of present volumes are printed on pages type 13 and 14. Working circle totals are subdivided by blocks and timber types. Many computed values are not reported at this point in the program, but are printed by the subroutines described below.

Subroutine SUMRY

SUMRY performs several operations:

1. Computes differences between actual and optimum growing stocks for each age class of each working group.
2. Prints page type 3 as a record of actual and optimum growing stocks and of the differences between them. One page is printed for each working group.
3. Summarizes the number of acres coded for treatment and the volumes obtainable from thinning, regeneration cutting, and other operations during the next management period.
4. Summarizes the annual cuts obtainable with balanced distribution of age classes (equal area in each age class) and optimum growing stock. Totals are obtained for each working group and for the working circle. Totals for the working circle do not include volumes possible from working groups named DEFERRED.
5. Computes the annual cuts obtainable during the next management period if all operations called for by the WORK index are performed.
6. Computes annual cut by Heyer's formula. Total annual cut for the working circle will not include any amount contributed by any working group named "DEFERRED." It is thus possible to have all the area and volume information of a "deferred" working group but to omit the working group from computations of allowable cut.

Subroutine GIDE1

Subroutine GIDE1 prints page type 1 as a summary of computations made by the entire program. Major items of page type 1 are the statements of the allowable cuts computed by SUMRY. As listed in appendix 1, page type 1 contains only a few of the items that could be assembled on summary pages.

TEVAP2 computes and reports four annual cuts, as examples of what can be done by this or similar programs. The types of cut are:

1. Idealized cut based on area regulation and a balanced series of age classes. Components of this cut are computed by GOAL and summarized by SUMRY.
2. Potential cut if all operations called for by the WORK index are performed, without regard to other restrictions. Periodic cuts are computed by GOT and SUMS and converted to annual volumes by SUMRY.
3. Annual cut computed with the modification of Heyer's formula and an adjustment period of ADJ(I) years. Growing stock volumes computed from mean annual increment, as called for by the formula (Burger 1920), are not used. Instead, actual and optimum growing stocks computed by GOAL and SUMS are used by SUMRY to compute the desired values. Initial term of the formula is mean annual increment obtained from the idealized yield tables produced by YIELD.
4. Current annual cut with area regulation.

Convenient comparisons of annual cuts provided by page type 1 suggest another use of programs such as TEVAP2. They can be used as tools for research on the principles of allowable cut determination. For example, various modifications of the Heyer formula would yield quite dissimilar results. Periodic annual increments, PAIBD(I) and PAICU(1), are computed by SUMS for use in such comparisons.

Subroutine GIDE2

GIDE2 prints page type 2, a summary of the potential work load and yield for the next management period. Separate values are printed for each combination of block, cover type, and operation to be performed. Bases for the values are the WORK codes in the inventory records and the computations performed by GOT and SUMS. If all entries for a particular operation would be zero, no record of that type of operation is printed. For example, no inventory record used to produce appendix 2 has a WORK code of 3. No statement of volumes to be salvaged, therefore, appears on page type 2 of any working group. Subroutine GIDE2 does, however, contain the necessary FORTRAN statements to print a salvage record, when needed.

Species-Specific Subroutines

The listing of TEVAP2 in appendix 1 contains three species-specific subroutines: (1) BHPP for ponderosa pine in the Black Hills of South Dakota and Wyoming, (2) LDGP for lodgepole pine in Colorado and Wyoming, and (3) SWPP for ponderosa pine in Arizona and New Mexico. As explained in a previous section, as many more species as desired can be accommodated. The computed GO TO in subroutine WORKGP must be expanded as far as necessary by the addition of more species numbers. Each call to a subroutine is labeled with the appropriate species number, SPNUM(I), to be entered on data card type 4. Then, a new subroutine is added to TEVAP2 for each new species, corresponding to the calls added to subroutine WORKGP. There will be no need for changes in subroutines YIELD, CUTS, or GOT if the arrangement of one of the listed routines is followed. Relationships needed are described in the section headed Basic Information Used.

Operations performed by the 12 sections of a species-specific subroutine are listed in order, below. Any section needed during program execution is specified by assigning a value to the switching variable IJ just before calling subroutine WORKGP. A computed GO TO at the beginning of each species-specific subroutine then selects the appropriate section. Some sections compute values of only one variable; others compute values of several variables from a series of species-specific statements.

The numbered sections compute:

1. Total cubic feet per acre in the overstory and understory, as used by subroutine GOT.
2. Factors to convert total cubic feet to other units. Factors for cubic feet to a 4-inch top and for board feet Scribner Rule are computed by the subroutines in appendix 2. This section is called by YIELD and GOT.
3. An inventory record to obtain volume and other stand measures at the end of the projection period, for use by subroutine GOT.
4. Future volume and other measures of an unthinned understory, from all appropriate inventory records, if the overstory is removed at the beginning of the projection period. This section is called from GOT.
5. Average stand d.b.h. after thinning to any specified residual percentage of trees. Thinnings are simulated by subroutine CUTS, which is called by YIELD and GOT.
6. Merchantable cubic feet obtainable from tops and small trees as a byproduct of a sawlog cut, for subroutine GOT.
7. Stand volume after thinning at the beginning of the management period and after thinning at the end of the period. These values are used by subroutine GOT.
8. Volume per acre and other measurements at the end of the management period, of a stand thinned at the start of the period. The section is called from GOT.
9. Average height of dominant and codominant trees and of volume in cubic feet, before thinning, for YIELD.
10. Average height of dominants and codominants and of volume in cubic feet, after thinning. This computation differs from section 9 in that height is not based on age and site index, but is height before thinning plus an adjustment to show the effect of thinning. The call is from YIELD.
11. Average stand d.b.h. at the end of the projection period, for YIELD.
12. Mortality during the projection period as a percentage of the number of live trees at the beginning of the period. This section is called by YIELD.

It will often be possible to use single equations for diameter and height growth, with no distinction between "good" stand density and a wide range of densities. Single equations were not used for the species represented in appendix 1; the computations in TEVAP2 parallel those in other available management tools (Myers 1971, Myers 1973).

Data Deck for TEVAP2

Eighteen types of punch cards or card images, listed below, are used to enter initial values of variables into computer memory. In this section, the word "card" may refer either to a standard 80-column punch card or to a card image on magnetic tape. Records that can best be handled by tape are identified in the descriptions of the subroutines.

In the following list, type numbers with asterisks designate alternatives (types 11 to 18, inclusive). Only two to four of these types need appear in the data deck for a single run of the program. Basis for choice is the area subroutine (MAPS, AREA1, AREA2) selected for call by the main program. All cards with type numbers not followed by asterisks must be included in the data deck so READ statements will be executed properly. Data cards are read in order of type numbers with three exceptions: (1) card type 9 is read twice, (2) as many sets of card types 4, 5, 6, and 7 are read as there are working groups in the working circle, and (3) unneeded cards of optional types 11 to 18 are omitted.

Card types 1 to 8, inclusive are read by BASIS. Types 1, 3, and 8 consist of one card each; type 2 consists of 5 cards. One card each of types 4 and 5 must be provided for each working group. Up to 14 cards each of types 6 and 7 must be added to the data deck for each working group. There must be one set of types 6 and 7 for each 10-foot site index class of each working group, from POOR(I) to at least the highest site class expected. The last card of these 6-7 sets must be a blank type 6 card if not all site classes through 140 are represented by data cards.

With two working groups, the sequence of cards read by BASIS would be:

1. One card type 1.
2. Five cards type 2.
3. One card type 3.
4. One card type 4 for working group 1.
5. One card type 5 for working group 1.
6. One card type 6 for site class POOR(1) of working group 1.
7. One card type 7 for site class POOR(1) of working group 1.
8. Alternate single cards of types 6 and 7 for additional site classes of working group 1. Last card is a blank type 6 if not all site classes through 140 are represented.
9. One card type 4 for working group 2.
10. One card type 5 for working group 2.
11. One card type 6 for site class POOR(2) of working group 2.
12. One card type 7 for site class POOR(2) of working group 2.
13. Alternate single cards of types 6 and 7 for additional site classes of working group 2. Last card is a blank type 6 if not all site classes through 140 are represented.
14. One card type 8.

Subroutine SCAN reads card types 9 and 10 after BASIS has read card type 8. Types 9 and 10 will be read again later in the program. A REWIND command is in SCAN for use if the inventory records are on magnetic tape.

Subroutine MAPS, if used, reads card types 11 to 14, inclusive. One card of type 11 is needed to enter values that apply to all compartments. A set of cards for one compartment consists of type 12 (one card), type 13 (up to 36 cards), and type 14 (up to 36 cards). These sets are read in the sequence 12, 13, 14, 12, 13, 14, etc. until the number of sets or compartments (NCMP) on card type 3 has been processed.

AREA1, if used, reads card types 15 and 16. A set of cards for one compartment consists of one card of type 15 and the four cards that make up type 16. Sets are read in the sequence 15, 16, 15, 16, etc. until the number of sets or compartments (NCMP) on card type 3 has been processed.

Subroutine AREA2, if used, reads card types 17 and 18. First, one card of type 17 with one to seven block areas is read. Areas are in the order: block 1, block 2, etc., to block 7. One card of type 18 is then read for each entry on card type 17. Cards of type 18 must be arranged in the order block 1, block 2, and so forth, up to the highest block number needed, to match the order in which block areas will be read from card type 17.

GOT reads card types 9 and 10, the inventory records already read once by subroutine SCAN. The number of cards or card images of type 9 is determined by the number of inventory plots measured and/or by the number of subcompartments for which inventory data are known. To avoid counting of inventory records prior to program execution, a record (type 10) with 99 punched for block number follows the type 9 records. This terminates processing of the inventory and moves control to another subroutine. Fields for KOMP, ISUB, and ACRE on an inventory record will be blank when the forest is not completely subdivided or subdivisions are not used for the record.

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
1	BASIS	1	OPTION	1-5	A5	Name of area subroutine (MAPS, AREA1, AREA2) to be used.
			ICT9	6	I1	Number of logical unit for input of inventory records.
			FORET(I)	7-80	18A4,A2	Name of the forest or working circle.
2	BASIS	5	TYPNM(I,J)	1-80	8(5A2)	Brief name for each vegetative or use type, ten characters each.
3	BASIS	1	NBK	1-4	I4	Number of blocks in working circle. Must be at least one.
			NCMP	5-8	I4	Number of compartments in working circle. Zero with AREA2.
			NWGP	9-12	I4	Number of working groups in the working circle.
			MIN	13-16	I4	Minimum age for inclusion of stand volume in growing stock.
			BFMRCH	17-20	F4.2	Minimum M bd. ft. per acre for inclusion in growing stock.
			TIME	21-24	F4.2	Number of years in planning period.
4	BASIS	1 per working group	WGPNM(I,J)	1-12	3A4	Name of working group I, preferably from a standard list of working groups.
			WGNUM(I)	13-17	F5.0	Standardized number of the working group named above.
			THIN(I)	18-21	F4.1	Growing stock level for initial thinning in working group I.
			DLEV(I)	22-25	F4.1	Growing stock level for cuts after initial thinning, working group I.
			POOR(I)	26-29	F4.1	Minimum site index to be managed for timber, working group I.
			COMBF(I)	30-33	F4.1	Minimum commercial cut in M bd. ft. per acre, working group I.

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
			COMCU(I)	34-38	F5.2	Minimum commercial cut in hundreds of cu. ft. per acre, working group I.
			ADJ(I)	39-42	F4.1	Length of period of adjustment in allowable cut formula, working group I.
			DELAY(I)	43-46	F4.1	Years between clearcutting, if used, and regeneration; working group I.
			RINT(I)	47-50	F4.1	Number of years for which the equations predict growth, working group I.
			CUCY(I)	51-54	F4.1	Years between intermediate cuts, working group I.
			SPNUM(I)	55-58	F4.0	Number assigned to a species of working group I so appropriate set of species-specific relationships can be called. One of the numbers in computed GO TO of SUBROUTINE WORKGP.
5	BASIS	1 per working group	WGPDES(I,J)	1-80	20A4	Statement of regeneration system, etc. used for working group I.
6	BASIS	up to 14 per working group	REGN(I,1,J)	1-4	F4.0	Stand age at which first regeneration cut will occur in working group I, site class J. Never zero or blank, as this is rotation length for clearcutting.
			VLLV(I,1,J)	5-10	F6.3	Percentage of previous growing stock level to be left at first regeneration cut in working group I, site class J. Enter zero for clearcutting.
			INVL(I,1,J)	11-13	I3	New interval between cuts in effect after first regeneration cut in working group I, site class J. Enter zero for clearcutting.

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
			REGN(I,2,J)	14-17	F4.0	Stand age at which second regeneration cut, if any, will occur. Removal of seed trees or second cut of shelterwood. Working group I, site class J.
			VLLV(I,2,J)	18-23	F6.3	Percentage of previous growing stock level to be left at second regeneration cut, working group I, site class J. Previous level includes effect of VLLV(I,1,J). Enter zero if no third cut.
			INVL(I,2,J)	24-26	I3	New interval between cuts in effect after second regeneration cut in working group I, site class J. Enter zero if no third cut.
			REGN(I,3,J)	27-30	F4.0	Stand age at which third regeneration cut, if any will occur, working grou I, site class J. Final cut of 3-cut shelterwood
7	BASIS	up to 14 per working group	AGETH(I,J)	1-5	F5.1	Initial age in yield table for working group I, site class J. Age at which first thinning wil be done.
			DENTH(I,J)	6-10	F5.1	Number of trees per acre expected just before thinning at age AGETH (I,J). Working group I, site class J.
			DBHTH(I,J)	11-15	F5.1	Average stand d.b.h. expected at age AGETH(I,J) with density DENTH(I,J). Working group I, site class J.
8	BASIS	1	DATE(I)	1-24	6A4	Date of most recent changes in data files.
9	SCAN GOT	1 per plot or subcomp.	IBK	1-2	I2	Block number. Must be at least one block in working circle.
			KOMP	3-6	I4	Compartment number. Enter only if applicable
			ISUB	7-9	I3	Subcompartment number. Enter only if applicable

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
			QTR1	10-12	A3	Location in ¼ ¼ of public land survey. Replace columns 10-26 with other location data, where appropriate.
			QTR2	13-15	A3	Location in ¼ section of public land survey. See description of QTR1.
			SECT	16-18	A3	Section in which inventory plot or largest part of compartment is located. See description of QTR1.
			TOWN	19-22	A4	Township location of the section. See description of QTR1.
			RANG	23-26	A4	Range location of the section. See description of QTR1.
			SITE	27-29	F3.0	Average site index of the plot or subcompartment.
			STRY	30	F1.0	Indicates whether type is based on overstory (blank) or on understory (1).
			NTYP	31-32	I2	Vegetative or use type of the plot or subcompartment. Number from list on page type 5 of output in Appendix 2.
			WORK	33	F1.0	Code number of treatment needed during planning period, as shown in definitions of variables in Appendix 1.
			FISC	34-37	F4.0	Year in which treatment coded in WORK field is to be accomplished. For use in listing work loads with other computer programs.
			DBH(1)	38-40	F3.1	Average d.b.h. of the overstory trees.
			HT(1)	41-43	F3.0	Average height of dominant and codominant overstory trees.
			DEN(1)	44-48	F5.0	Number of overstory trees per acre.

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
			AGE(1)	49-51	F3.0	Average age of overstory trees.
			DMR(1)	52-53	F2.1	Dwarf mistletoe rating of overstory trees.
			DBH(2)	54-56	F3.1	Average d.b.h. of the understory trees.
			HT(2)	57-59	F3.0	Average height of potential dominants and codominants in the understory.
			DEN(2)	60-64	F5.0	Number of understory trees per acre.
			AGE(2)	65-67	F3.0	Average age of understory trees.
			DMR(2)	68-69	F2.1	Dwarf mistletoe rating of the understory trees.
			ACRE	70-74	F5.1	Area of the subcompartment described. Leave blank if data refer to plot, not stand, measurements.
			WHEN	75-78	F4.0	Year of first growing season after inventory record was made. For use in updating with PROGRAM GROW.
10	SCAN GOT	1	(Punch 99 in first two columns to stop reading of type 9 records.)			
11*	MAPS	1	MAP	1-4	I4	Index to print (1) or to omit (0) compartment maps.
			SCALE	5-10	F6.4	Acres represented by one code number on a compartment map.
12*	MAPS	1 per comp.	KBK	1-4	I4	Number of block in which the compartment is located.
			KOMP	5-8	I4	Number of the compartment being processed.
			NROW	9-12	I4	Number of rows of map symbols in the compartment map.
13*	MAPS	NROW per comp.	KTYP(I,J)	1-72	36I2	Type numbers in compartment type map.

Card type	Read by	No. of cards	Variable name	Columns	Format	Description of variable
14*	MAPS	NROW per comp.	KSUB(I,J)	1-72	36I2	Subcompartment numbers in compartment map of the subcompartments.
15*	AREA1	1 per comp.	KBK	1-4	I4	Number of block in which the compartment is located.
			KOMP	5-8	I4	Number of the compartment being processed.
16*	AREA1	4 per comp.	ARETY(I)	1-80	10F8.1	Acres of type I in the compartment being processed
17*	AREA2	1	ARBK(I)	1-56	7F8.1	Acres in block I.
18*	AREA2	1 per block	SARETY(I,J)	1-64	8F8.1	Acres of nontimber type J in block I.

Basic Information Used

Tabulations and explanations that follow describe the relationships to be determined locally to adapt TEVAP2 to other species or conditions. The first relationships appear as FORTRAN statements in subroutines CUTS and GOT; the remainder are part of the species-specific subroutines. Descriptions of the relationships include explanations of the program variables and related FORTRAN statements involved. Tabulations include only enough entries to explain the nature of the information needed; they do not indicate sample sizes or desirable ranges of data. Methods used to determine the relationships are found in standard mensuration texts and elsewhere (Myers 1971).

1. Stand density after partial cutting. — Some relationships are based on the basal area to be left after cutting for various average stand diameters. These relationships control amount of the reserve stand left after intermediate or partial regeneration cutting, once THIN(I) and DLEV(I) have been specified by the program user. Data needed take the following form:

Average stand d.b.h. after cutting (inches)	Basal area per acre	Average stand d.b.h. after cutting (inches)	Basal area per acre
	Sq. Ft.		Sq. Ft.
2.0	12.1	6.4	60.3
2.4	16.7	6.8	63.8
2.8	21.3	7.2	67.0
3.2	26.0	7.6	69.9
3.6	30.6	8.0	72.5
4.0	35.2	8.4	74.8
4.4	39.9	8.8	76.7
4.8	44.5	9.2	78.2
5.2	48.8	9.6	79.3
5.6	52.8	10.0+	80.0
6.0	56.6		

Values in this tabulation represent a few points on one of a family of curves (Myers 1971). Reserve basal area increases with average stand d.b.h. until 10.0 inches is reached. Thereafter, reserve basal area remains constant for any one growing stock level. In the tabulation, constant basal area is 80.0 square feet per acre, and the values represent growing stock level 80. Other levels are named similarly. Thus, if THIN(I) or DLEV(I) is 100, basal area at any d.b.h. below 10.0 inches is the basal area for level 80 multiplied by 100/80. If d.b.h. is greater than 10.0 inches, retained basal area is DLEV(I).

Several statements in subroutine CUTS are derived from basal area values for level 80. Basal areas computed by them are multiplied by terms including THIN(I) or DLEV(I), redefined as REST, to provide for a range of possible growing stock levels. Variables defined by the statements and their use, are:

a. DBHP—to find a d.b.h. less than 10.0 inches when basal area is known. Three equations for DBHP are used to simplify representation of the nonlinear relationship between d.b.h. and basal area.

b. BREAK and BUST—to compute values of basal area that are the upper limits of applicability of the first two equations for DBHP.

c. SQFT—to find basal area when d.b.h. is known. Two equations represent the nonlinear relationship for d.b.h. less than 10.0 inches.

Two equations used to compute LEVL in subroutine GOT include the equations for SQFT. They give the equivalent growing stock level when average d.b.h. and basal area are known.

2. Total cubic feet per acre.—Stand volumes in total cubic feet are computed with stand volume equations. As listed in appendix 1, cubic volume is determined from: (1) basal area per acre, (2) average height of dominant and codominant trees, (3) average stand d.b.h., and (4) number of trees per acre.

Plot tallies of tree diameters and heights are converted to volumes per acre in total cubic feet and to basal areas and other values used as independent variables. Stand volume equations are then obtained by regression analysis. Total cubic volume per acre from ground line to tip of all trees more than 4.5 feet tall is the only volume computed directly by TEVAP2. Volumes in other units are obtained by use of conversion factors.

Values of six variables in each species-specific subroutine are obtained from the same regression coefficients: (1) TOT(IK) in section 1, (2) FVL(I) in section 3 and FVL(1) in section 8, (3) VLUS in section 4, (4) TVL(IK) in section 7, (5) TOTO in section 9, and (6) TOTT in section 10. Two statements are used for each variable because the relationship is not linear over the ranges of D^2 H that may appear in computations of inventory data.

3. Conversion of total cubic feet to other units.—Volumes are first computed in total cubic feet per acre, as described above. They are then converted to other units with factors computed by section 2 of each species-specific subroutine. The second column, below, shows some of the ratios used to obtain equations for FCTR(I) in subroutine BHPP. The third column shows ratios used to compute PROD(I) for BHPP.

Average stand d.b.h. (Inches)	Merchantable cubic feet ÷ total cubic feet	Board feet ÷ total cubic feet
5.1	0.355	- -
6.0	.552	- -
6.9	.725	- -
8.3	.860	0.99
9.1	.901	1.55
10.3	.931	2.38
19.0	.962	5.33
23.4	.969	5.88

Utilization standards are given in COMMENT statements of section 2 of each species-specific subroutine. Other conversions could be added, such as those based on tree contents in square feet of veneer or in pounds of wood (Myers 1960).

Volume or weight per acre of numerous plots are determined in units of interest and in total cubic feet. Selection of appropriate units includes choice of minimum merchantable top diameter. The quantity of each unit per total cubic foot is determined separately for each plot. Regression analysis is used to obtain coefficients for computing the factors when average stand diameter and basal area are known. Minimum average diameters are specified for each factor in TEVAP2. Variability is so great with small diameters that the results serve no useful purpose.

Each call to section 2 of a species-specific subroutine is preceded by specification of the number of values of each factor needed and by the average diameter to be used. It is thus possible to keep separate such paired requirements as present and future stand and overstory and understory.

4. Future average stand d.b.h. with wide range of stand density.—Regression analysis is performed on stand data obtained on temporary and/or permanent plots that cover a wide range of stand densities, site indexes, etc. Average stand d.b.h. in 10 years is expressed as a function of several readily measured stand variables. For the species named in appendix 1, the following were significant independent variables: present average d.b.h., average height of dominants and codominants, basal area, and site index.

The relationship appears in two places in each species-specific subroutine: (1) FDM(I) in section 3, and (2) DMUS in section 4. Elsewhere, future average d.b.h. is estimated with an equation developed from data from stands at or near densities that could be objectives of management.

5. **Noncatastrophic mortality.** — Normal mortality may be important in unthinned stands, but minor and erratic in thinned stands. Such was the case with the species represented by subroutines in appendix 1. No pattern of mortality could be found in stands with an average d.b.h. of 10.0 inches or larger.

Data for the mortality equation come from two sources:

a. Permanent plots that have been measured at least as frequently as the prediction period to be used.

b. Temporary plots that have not been partially cut for a number of years equal to the prediction period. Trees dead at time of treatment must have been felled or marked at that time.

For species used as examples, percentage reduction in number of trees was expressed as a function of average d.b.h. and basal area, both at the beginning of the period.

Future stand density is computed as FDN(I) in section 3, as FDN(1) in section 8, as DENO in section 12, and as DNUS in section 4 of each species-specific subroutine. Definitions and values of the variables change during record processing. The first computation, the equation that varies by species, produces percentage mortality in 10 years, expressed as a decimal. The 10-year period equals the projection period of related equations that estimate future diameter and height. Later FDN(I), DNUS, or DENO is redefined as future number of trees and is computed from the original value of FDN(I), DNUS, or DENO.

6. **Tree heights with wide range of stand density.** — Future average heights of dominant and codominant trees, without restrictions on stand density, are computed as FHT(I) in section 3, as FHT(1) in section 8, and as HTUS by section 4 of each species-specific subroutine. Heights in 10 years are estimated from present average height, stand age, site index, and basal area. Data needed for regression analysis may be obtained from remeasurements of permanent plots or from borings and ring counts on temporary plots.

7. **Increase in average d.b.h. from cutting.** — Effect of partial regeneration cutting or thinning from below on average stand d.b.h. is simulated by subroutine CUTS. Thinning from below includes the removal of occasional larger trees, as occurs in actual practice. Statements for DBHE and PDBHE, which may vary by species, appear in section 5 of each species-specific subroutine. DBHE represents the estimated d.b.h. after thinning and is computed directly if at least 50 percent of the trees are to be retained. The relationship is highly nonlinear if fewer trees are retained, so PDBHE is then computed and its antilogarithm becomes DBHE.

Change in average diameter can be estimated from data obtained during repeated trial marking of plots that cover a range of tree sizes and densities. By multiple regression analysis, equations are obtained that estimate diameter after cutting from diameter before cutting and the percentage of trees retained.

A computer program that simulates partial cutting, computes the values needed for regression analysis, and punches the data cards is described elsewhere (Myers 1971).

8. **Cubic feet from saw-log cut.** — An equation for ADD in section 6 of each species-specific subroutine estimates the merchantable cubic feet obtainable as a byproduct of saw-log cuts. To obtain the basic data, plots representing a wide range of stand conditions are measured. Cubic- and board-foot volumes of all trees above minimum size for saw logs are summed to obtain equivalent volumes per acre for each plot. The dependent variable for regression analysis is merchantable cubic feet per thousand board feet. Independent variables are average d.b.h. and thousands of board feet per acre. Whenever a cut is computed by subroutine GOT, the statement for ADD is used to compute the cubic volume contained in saw logs. ADD is then redefined to equal the difference between the total cubic volume of the cut and the cubic volume of saw logs. The new value for ADD is treated as a commercial yield if it is equal to or larger than the minimum commercial volume entered as COMCU(I).

9. **Tree heights with density near management goals.** — Average height of dominant and codominant trees, where height growth is not reduced by high stand density, is computed from data of the form:

Main stand age (Years)	Site index class			
	40	50	60	70
20	8	10	13	16
40	17	22	28	34
60 . . .	26	33	41	49
150	50	62	73	85

The relationships are expressed by statements for HTSO in the ninth section of each species-specific subroutine. If data from site index curves are used, the crown classes described must be the same as those used to develop the site curves. The crown classes must be the same as those used in the equations for total cubic feet, described in item 2, above.

10. Increase in average height from thinning. — Increases in average height of dominant and codominant trees due to partial cutting are estimated the same way as increases in average d.b.h. Results of repeated trial markings on plots covering a range of average diameters and densities provide the data needed for regression analysis. The increase, in feet, is correlated with the percentage of trees retained.

The relationship appears as the statement for ADDHT in section 10 of each species-specific subroutine, and as part of the statements for HT(KI) in section 7 and for HT(1) in section 8. At each cutting, the amount of the increase is added to height before thinning to obtain height after thinning. In section 10, it is also added to a cumulative sum of changes, HTCUM, so computed heights before thinning will show the effects of past treatment as well as of age and site quality.

As with change in diameter, it is possible to simulate thinnings on a computer to increase the number of combinations of variables available for regression (Myers 1971).

11. Future average stand d.b.h. with density near management goals. — Diameter in 10 years is estimated from present average d.b.h., site index, and present basal area. Future diameters are computed as FDM(1) in section 8 and as DBHO in section 11 of each species-specific subroutine. Data needed to obtain the prediction equations by regression analysis are gathered on temporary and/or permanent plots with stands within the desired range of densities (Myers 1971). This prediction equation is used in TEVAP2 wherever diameter growth in recently thinned stands is to be computed.

12. Effects of dwarf mistletoe. — Subroutine LDGP and SWPP give examples of how the effects of a damaging agent may be included in growth computations. In these cases, growth reduction is caused by dwarf mistletoe, Arceuthobium americanum Nutt. ex Engelm. or A. vaginatum subsp. cryptopodum (Engelm.) Hawks. and Wiens. Three statements in each subroutine contain species-specific relationships involving the amount of dwarf mistletoe present and its effect on growth. They are: (1) the last half of the statement for TEM, (2) the statements for DIE, and (3) the statement for PCT. Each of the three statements appears in sections 3, 4, and 8 of subroutines LDGP and SWPP. In each case, the measure of dwarf mistletoe present is the dwarf mistletoe rating, DMR (Hawksworth 1961).

The last half of the statement for TEM gives the percentages of the 10-year increase in average d.b.h. of healthy stands that will occur with varying amounts of dwarf mistletoe. The statements for DIE give the percentage of live trees at start of the period that will die during the period. This percentage will be used instead of the percentage from FDN(I), if larger. FDN(I) is based on noncatastrophic mortality in healthy stands and will be less than DIE unless the dwarf mistletoe rating is so low that FDN(I) and DIE are equal. PCT is the percentage of the periodic height growth of healthy stands that will occur in stands with various degrees of infestation. Additional information on these relationships is available elsewhere (Myers et al. 1971, Myers et al. 1972, Hawksworth and Myers 1973).

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APPENDIX 1

Listing of Program TEVAP2

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      PROGRAM TEVAP2
     1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE4=TAPE5,TAPE3=TAPE5)
C
C DEFINITIONS OF VARIABLES.
C
C     ABFAG(I,J) = ACTUAL GROWING STOCK IN M BD. FT. FOR WORKING GROUP I
C          AND AGE CLASS J.
C     ACBAR(I) = DEFORESTED ACRES IN BLOCK I.
C     ACFNL(I,J,K) = ACRES TO RECEIVE FINAL CUT DURING NEXT PERIOD -
C          WORKING GROUP I, BLOCK J, AGE CLASS K.
C     ACINT(I) = ACRES RECEIVING INTERMEDIATE CUT ANNUALLY IN BALANCED
C          FOREST, WORKING GROUP I.
C     ACRE = AREA OF THE STAND DESCRIBED BY THE INVENTORY RECORD, IE
C          KNOWN. BLANK INDICATES RECORD APPLIES TO SAMPLE PLOT.
C     ACRGN(I,J,K) = ACRES TO RECEIVE REGENERATION CUT DURING NEXT
C          PERIOD - WORKING GROUP I, BLOCK J, AGE CLASS K.
C     ACSI(I,J,K) = ACRES OF WORKING GROUP I, BLOCK J, SITE CLASS K.
C     ACSP(I,J) = ACRES OF WORKING GROUP I IN BLOCK J.
C     ADD = CUBIC FEET PRODUCED AS BYPRODUCT OF SAWLOG CUTS.
C     ADDHT = INCREASE IN AVERAGE HEIGHT FROM THINNING FROM BELOW.
C     ADJ(I) = YEARS IN ADJUSTMENT PERIOD, WORKING GROUP I.
C     AGE(I) = AVERAGE AGE OF OVERSTORY(I=1) OR UNDERSTORY(I=2).
C     AGED = STAND AGE AT EACH STEP OF YIELD TABLE.
C     AGETH(I,J) = AGE AT INITIAL THINNING, WORKING GROUP I,
C          SITE CLASS J.
C     ALLCF(I,J) = GROWING STOCK GOAL FOR WORKING GROUP I, SITE CLASS J.
C          CUBIC FEET OF ENTIRE STANDS TO ROTATION AGE.
C     ALOWC(I) = ALLOWABLE ANNUAL CUT IN HUNDREDS OF CU. FT., BASED ON
C          ACTUAL AND DESIRED GROWING STOCKS OF WORKING GROUP I.
C     ALWBF(I) = ALLOWABLE ANNUAL CUT IN M BD. FT., BASED ON ACTUAL AND
C          DESIRED GROWING STOCKS OF WORKING GROUP I.
C     AMCAG(I,J) = ACTUAL GROWING STOCK IN HUNDREDS OF CU. FT. FOR
C          WORKING GROUP I AND AGE CLASS J.
C     ANBDF(I) = M BD. FT. PER ACRE AT END OF EACH YEAR.
C     ANCUT(I,J) = AREA / ROTATION FOR WORKING GROUP I, SITE CLASS J.
C     ANCUV(I) = CU. FT. STANDING PER ACRE AT END OF EACH YEAR.
C     ANNAC = TOTAL ACRES TO BE TREATED ANNUALLY DURING NEXT PERIOD.
C     ANNBD = EXPECTED TOTAL ANNUAL YIELD DURING NEXT PERIOD IN
C          M BD. FT.
C     ANNCU = EXPECTED TOTAL ANNUAL YIELD DURING NEXT PERIOD IN CU. FT.
C     ARBK(I) = AREA OF BLOCK I.
C     AREA(I,J) = AREA OF SITE CLASS J OCCUPIED BY WORKING GROUP I.
C          INCLUDES SHARE OF DEFORESTED AREA.
C     ARECP = TOTAL AREA OF COMPARTMENT.
C     ARESC(I) = ACRES IN SUBCOMPARTMENT I.
C     ARETY(I) = ACRES OF TYPE I IN ONE COMPARTMENT.
C     BARE = DEFORESTED ACRES IN A COMPARTMENT.
C     BARSI(I,J) = DEFORESTED ACRES OF SITE J IN BLOCK I.
C     BAS(I) = BASAL AREA OF OVERSTORY(I=1) OR UNDERSTORY(I=2).
C     BASD = BASAL AREA PER ACRE BEFORE THINNING.
C     BAST = BASAL AREA PER ACRE AFTER THINNING.
C     BAUS = BASAL AREA OF UNDERSTORY.
C     BDAI = M.A.I. IN M BD. FT. FROM YIELD TABLE.
C     BDFC(I) = M BD. FT. REMOVED PER ACRE.
C     BDFO(I) = M BD. FT. PER ACRE BEEORE THINNING.
C     BDFT = M BD. FT. PER ACRE AFTER THINNING.
C     BDMAI(I) = M.A.I. IN M BD. FT. FROM YIELD TABLE AND ACRES IN SITE
C          CLASS, WORKING GROUP I.
C     BDUS = M BD. FT. IN UNDERSTORY.
C     BFAGE(I,J) = GROWING STOCK GOAL IN M BD. FT. FOR WORKING GROUP I
C          AND AGE CLASS J.
C     BFBLK(I) = M BD. ET. IN BLOCK I.
C     BFINT(I) = M BD. FT. FROM INTERMEDIATE CUTS ANNUALLY IN BALANCED
C          FOREST, WORKING GROUP I.
C     BFM(I) = M BD. FT. IN OVERSTORY(I=1) OR IN UNDERSTORY(I=2).
C     BFMRCH = MINIMUM VOLUME TO BE INCLUDED IN BD. FT. GROWING STOCK.
C     BFS(I) = GROWING STOCK GOAL BY AGE CLASS I FOR ONE SITE CLASS OF
C          WORKING CIRCLE, M BD. FT.
C     BFSP(I,J) = M BD. FT. OF WORKING GROUP I IN BLOCK J.
C     BFTB(I,J) = M BD. FT. IN TYPE J OF BLOCK I.
C     BFTH(I,J) = CURRENT POTENTIAL PERIODIC YIELD FROM THINNINGS IN
C          BLOCK I AND TYPE J, M BD. FT.
C     BFVOL = M BD. FT. PER ACRE MINUS VOLUME LEFT AS SEED SOURCE.
C     CFAGE(I,J) = GROWING STOCK GOAL IN MERCHANTABLE CUBIC EEET FOR
C          WORKING GROUP I AND AGE CLASS J.
C     CFAI = M.A.I. IN HUNDREDS OF CU. FT. FROM YIELD TABLE.
C     CEBF(I,J) = GROWING STOCK GOAL FOR WORKING GROUP I, SITE CLASS J.
C          CUBIC FEET IN SAWLOG TREES.
C     CFMC(I) = MERCHANTABLE CU. FT. REMOVED PER ACRE.
C     CFMER(I) = MERCH. CU. FT. IN BLOCK I, IN HUNDREDS.
C     CFMO(I) = MERCHANTABLE CU. FT. PER ACRE BEFORE THINNING.
C     CFMT = MERCHANTABLE CU. FT. PER ACRE AFTER THINNING.
C     CFTB(I,J) = TOTAL CU. FT. IN TYPE J OF BLOCK I, IN HUNDREDS.
C     CFVOL = CU. ET. PER ACRE MINUS VOLUME LEFT AS SEED SOURCE.
C     CM(I) = HUNDREDS OF MERCH. CU. FT. IN OVERSTORY(I=1) OR IN
C          UNDERSTORY(I=2).
C     CMS(I) = GROWING STOCK GOAL BY AGE CLASS I FOR ONE SITE CLASS OF
C          WORKING CIRCLE, HUNDREDS OF CU. FT.
C     CMSP(I,J) = MERCH. CU. FT. OF WORKING GROUP I IN BLOCK J.
C     CMTB(I,J) = HUNDREDS OF MERCH. CU. FT. IN TYPE J OF BLOCK I.
C     CMTH(I,J) = CURRENT POTENTIAL PERIODIC YIELD FROM THINNINGS IN
C          BLOCK I AND TYPE J, HUNDREDS OF CUBIC FEET.
C     COMBF(I) = MINIMUM COMMERCIAL CUT OF WORKING GROUP I IN M BD. FT.
C     COMCU(I) = MINIMUM COMMERCIAL CUT OF WORKING GROUP I IN HUNDREDS
C          OF CUBIC FEET PER ACRE.
C     CUCY(I) = INTERVAL BETWEEN INTERMEDIATE CUTS FOR WORKING GROUP I.
C     CUINT(I) = CU. FT. FROM INTERMEDIATE CUTS ANNUALLY IN BALANCED
C          FOREST, WORKING GROUP I.
C     CUMAI(I) = M.A.I. IN HUNDREDS OE CU. FT. FROM YIELD TABLE AND
C          ACRES IN SITE CLASS, WORKING GROUP I.
C     CUTA(I,J) = POTENTIAL BD. ET. VOLUME, LESS SHELTERWOOD, AVAILABLE
C          FROM REGENERATION CUTS - BLOCK I, TIMBER TYPE J.
C     CUTB(I,J) = POTENTIAL BD. FT. VOLUME AVAILABLE FROM REMOVAL OF
C          OVERWOOD - BLOCK I, TIMBER TYPE J.
C     CVR(I) = NUMBER OF MAP SQUARES IN TYPE I.
C     CYCL = INTERVAL BETWEEN INTERMEDIATE CUTS.
C     DATE = DATE OF MOST RECENT CHANGES IN INVENTORY OR OTHER DATA.
C     DBH(I) = AVERAGE D.B.H. OF OVERSTORY(I=1) OR UNDERSTORY(I=2).
C     DBHE = ESTIMATE OF AVERAGE D.B.H. AFTER THINNING.
C     DBHO = AVERAGE STAND D.B.H. BEFORE THINNING.
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C     DBHT = AVERAGE STAND D.B.H. AFTER THINNING.                         C
C     DBHTH(I,JI = AVERAGE STAND D.B.H. AT AGE AGETH(I,JI, WORKING         C
C          GROUP I, SITE CLASS J.                                          C
C     DELAY(I) = YEARS DELAY BETWEEN CLEARCUTTING AND ESTABLISHMENT OF     C
C          NEW STAND, WORKING GROUP I.                                     C
C     DEN(I) = TREES PER ACRE IN OVERSTORY(I=1) OR UNDERSTORY(I=2I.        C
C     DENO = TREES PER ACRE BEFORE THINNING.                               C
C     DENT = TREES PER ACRE AFTER THINNING.                                C
C     DENTH(I,JI = NUMBER OF TREES PER ACRE JUST BEFORE INITIAL            C
C          THINNING, WORKING GROUP I, SITE CLASS J.                        C
C     DFBF(I,JI = DIFFERENCE BETWEEN ACTUAL STOCK AND GOAL IN M BD. FT.    C
C          FOR WORKING GROUP I AND AGE CLASS J.                            C
C     DFMC(I,J) = DIFFERENCE BETWEEN ACTUAL STOCK AND GOAL IN HUNDREDS     C
C          OF CU. FT. FOR WORKING GROUP I AND AGE CLASS J.                 C
C     DLEV(II = GROWING STOCK LEVEL FOR THINNINGS AFTER INITIAL CUT,       C
C          WORKING GROUP I.                                                C
C     DMR(I) = DWARF MISTLETOE RATING OF PLOT OR SUBCOMPARTMENT, BY        C
C          OVERSTORY(I=II AND UNDERSTORY(I=2).                             C
C     DMUS = AVERAGE D.B.H. OF UNDERSTORY.                                 C
C     DNUS = NUMBER OF TREES IN UNDERSTORY.                                C
C     EQIV(I) = ACRES PER STANDARD ACRE, SITE CLASS I, FROM BOARD FEET.    C
C     EQVCF(I) = ACRES PER STANDARD ACRE, SITE CLASS I, FROM CUBIC FEET.   C
C     FAC(I) = RATIO OF YIELD OF SITE CLASS I TO STANDARD YIELD, BOTH      C
C          IN BOARD FEET.                                                  C
C     FACCF(I) = RATIO OF YIELD OF SITE CLASS I TO STANDARD YIELD, BOTH    C
C          IN CUBIC FEET.                                                  C
C     FBA(II = FUTURE BASAL AREA OF OVERSTORY(I=I) OR UNDERSTORY(I=2I.     C
C     FBD(II = FUTURE M BD. FT. IN OVERSTORY(I=I) OR UNDERSTORY(I=2I.      C
C     FCTR(II = MERCHANTABLE CU. FT. PER TOTAL CU. FT. - FACTOR.           C
C     FDM(I) = FUTURE AVERAGE D.B.H. OF OVERSTORY(I) OR UNDERSTORY(2).     C
C     FDN(II = FUTURE TREES PER ACRE IN OVERSTORY(I) OR UNDERSTORY(2).     C
C     FHT(II = FUTURE AVE. HEIGHT OF OVERSTORY(I=I) OR UNDERSTORY(I=2).    C
C     FINB(I) = EXPECTED ANNUAL YIELD IN M BD. FT. FROM FINAL CUTS         C
C          DURING NEXT PERIOD, WORKING GROUP I.                            C
C     FINC(II = EXPECTED ANNUAL YIELD IN CU. FT. FROM FINAL CUTS DURING    C
C          NEXT PERIOD, WORKING GROUP I.                                   C
C     FMC(I) = FUTURE MERCH. CU. FT. IN OVERSTORY(I) OR UNDERSTORY(2I.     C
C     FNAC(I) = EXPECTED ACRES TO RECEIVE FINAL CUTS ANNUALLY DURING       C
C          NEXT PERIOD, WORKING GROUP I.                                   C
C     FNBD(I) = ANNUAL YIELD FROM FINAL CUTS WITH BALANCED SERIES OF AGE   C
C          CLASSES, M BD. FT. OF WORKING GROUP I.                          C
C     FNCU(I) = ANNUAL YIELD FROM FINAL CUTS WITH BALANCED SERIES OF AGE   C
C          CLASSES, CU. FT. OF WORKING GROUP I.                            C
C     FORET(II = NAME OF FOREST OR WORKING CIRCLE.                         C
C     FVL(II = FUTURE TOTAL VOLUME OF OVERSTORY(I=I) OR UNDERSTORY(I=2I.   C
C     GRBD(I,J,KI = PERIODIC GROWTH OF WORKING GROUP I, BLOCK J, AND AGE   C
C          CLASS K IN M BD. FT.                                            C
C     GRMC(I,J,K) = PERIODIC GROWTH OF WORKING GROUP I, BLOCK J, AND AGE   C
C          CLASS K IN HUNDREDS OF MERCH. CU. FT.                           C
C     GROWB(I,J,KI = GROWTH RATE OF BD. FT. IN SHELTERWOOD.  WORKING       C
C          GROUP I, REMOVAL CUT J, SITE INDEX CLASS K.                     C
C     GROWC(I,J,K) = GROWTH RATE OF CU. FT. IN SHELTERWOOD.  WORKING       C
C          GROUP I, REMOVAL CUT J, SITE INDEX CLASS K.                     C
C     GRUP(I) = AREA OF WORKING GROUP I IN A COMPARTMENT.                  C
C     GVLBF(II = TOTAL GROWING STOCK GOAL FOR WORKING GROUP I, M BD. FT.   C
C     GVLCU(I) = TOTAL GROWING STOCK GOAL FOR WORKING GROUP I, CU. FT.     C
C          SUM OF APPROPRIATE SUBCF(I,J) FOR SUB-SAWLOG TREES.             C
C     HELP(I,J) = POTENTIAL NONCOMMERCIAL THINNING IN NEXT PERIOD, ACRES   C
C          OF TYPE J IN BLOCK I.                                           C
C     HT(I) = AVERAGE HEIGHT OF OVERSTORY(I=1) OR UNDERSTORY(I=2).         C
C     HTCUM = CUMULATIVE CHANGE IN AVERAGE HEIGHT FROM THINNING.           C
C     HTSO = TREE HEIGHT BEFORE THINNING.                                  C
C     HTST = TREE HEIGHT AFTER THINNING.                                   C
C     HTUS = AVERAGE HEIGHT OF UNDERSTORY TREES.                           C
C     IBK = BLOCK SOURCE OF INVENTORY RECORD.                              C
C     ICT9 = NUMBER OF LOGICAL UNIT FOR CARD TYPE 9 INPUT.                 C
C          ICT9 = 4, READ INVENTORY FROM TAPE FILE.                        C
C          ICT9 = 5, READ INVENTORY FROM CARD FILF.                        C
C     INVL(I,J,K) = INTERVAL BETWEEN CUTS AFTER AGE REGN(I,J,K). WORKING   C
C          GROUP I, REMOVAL CUT J, SITE CLASS K. J=1 OR 2.                 C
C     ISUB = SUBCOMPARTMENT SOURCE OF INVENTORY RECORD.                    C
C     KAK = SUBSCRIPT FOR WORKING GROUP IN VARIOUS ARRAYS.                 C
C     KAN = SUBSCRIPT FOR SITE CLASS IN VARIOUS ARRAYS.                    C
C     KBK = BLOCK NUMBER.                                                  C
C     KOMP = COMPARTMENT NUMBER.                                           C
C     KSUB(I,JI = SUBCOMPARTMENT NUMBERS OF MAP SQUARES.                   C
C     KTYP(I,J) = TYPE CLASSIFICATION OF MAP SQUARES.                      C
C     MAP = INDEX TO PRINT (I) OR OMIT (OI MAPS.                           C
C     MIN = MINIMUM AGE FOR STAND TO BE INCLUDED IN GROWING STOCK.         C
C     MNK = TEMPORARY VARIABLE, ASSIGNED MEANINGS AS NEEDED.               C
C     NBK = NUMBER OF BLOCKS IN WORKING CIRCLE. MUST BE AT LEAST ONE.      C
C     NCMP = NUMBER OF COMPARTMENTS IN WORKING CIRCLE.                     C
C     NROW = NUMBER OF ROWS IN COMPARTMENT MAP.                            C
C     NSBK(II = NUMBER OF SUBCOMPARTMENTS IN BLOCK I.                      C
C     NSI(I) = NUMBER OF SITE CLASSES IN WORKING GROUP I.                  C
C     NSUB = NUMBER OF SUBCOMPARTMENTS IN WORKING CIRCLE.                  C
C     NTYP = COVER OR USE TYPE OF INVENTORY PLOT OR SUBCOMPARTMENT.        C
C     NWGP = NUMBER OF WORKING GROUPS IN WORKING CIRCLE.                   C
C     OPBD(II = ALLOWABLE ANNUAL CUT IN M BD. FT. FOR WORKING GROUP I      C
C          WITH BALANCED AGE CLASSES, REGENERATION CUTS.                   C
C     OPCU(II = ALLOWABLE ANNUAL CUT IN CU. FT. FOR WORKING GROUP I WITH   C
C          BALANCED AGE CLASSES, REGENERATION CUTS.                        C
C     OPEN(I,JI = POTENTIAL COMMERCIAL THINNING IN NEXT PERIOD, ACRES OF   C
C          TYPE J IN BLOCK I.                                              C
C     OPTION = OPTION DESIRED TO MAKE AREA CALCULATIONS. MAY BE AREAI,     C
C          AREA2, OR MAPS.                                                 C
C     OURS = ACRES IN WORKING CIRCLE, EXCLUDING OTHER OWNERSHIP.           C
C     PABR(I) = DEFORESTED ACRES IN BLOCK I, EXCLUDING UNITS WITH KNOWN    C
C          AREA ON INVENTORY RECORD.                                       C
C     PAFN(I,J,KI = ACRES TO RECEIVE FINAL CUT - WORKING GROUP I, BLOCK    C
C          J, AGE CLASS K - EXCLUDES AREAS ON INVENTORY RECORD.            C
C     PAIBD(II = P.A.I. IN M BD. FT., WORKING GROUP I.                     C
C     PAICU(II = P.A.I. IN HUNDREDS OF CUBIC FEET, WORKING GROUP I.        C
C     PARG(I,J,K) = ACRES TO RECEIVE REGENERATION CUT - WORKING GROUP I,   C
C          BLOCK J, AGE CLASS K - EXCLUDES KNOWN AREAS.                    C
C     PARTY(I,J) = AREA OF TYPE J IN BLOCK I, EXCLUDING UNITS WITH KNOWN   C
C          AREA ON INVENTORY RECORD.                                       C
C     PASI(I,J,KI = ACRES OF WORKING GROUP I, BLOCK J, AND SITE CLASS K,   C
C          EXCLUDING KNOWN AREAS.
C     PASP(I,J) = AREA OF WORKING GROUP I IN BLOCK J, EXCLUDING UNITS
C          WITH KNOWN AREA ON INVENTORY RECORD.
C     PBFT(I,J) = POTENTIAL YIELD IN M BD. FT. FROM THINNINGS - BLOCK I,
C          TYPE J - EXCLUDING UNITS OF KNOWN AREA.
C     PBRSI(I,JI = DEFORESTED ACRES OF SITE J IN BLOCK I, EXCLUDING
C          UNITS WITH KNOWN AREA ON INVENTORY RECORD.
C     PCMT(I,J) = POTENTIAL YIELD IN MERCH. CU. FT. FROM THINNINGS -
C          BLOCK I, TYPE J - EXCLUDING UNITS OF KNOWN AREA.
C     PCTA(I,JI = POTENTIAL BD. FT. CUT FROM REGENERATION CUTS- BLOCK I,
C          TYPE J - EXCLUDING UNITS OF KNOWN AREA.
C     PCTB(I,J) = POTENTIAL BD. FT. CUT FROM FINAL CUTS - BLOCK I, TYPE
C          J - EXCLUDING UNITS OF KNOWN AREA.
C     PDCFN(I,JI = EXPECTED YIELD IN CU. FT. FROM EINAL CUTS DURING NEXT
C          PERIOD, BLOCK I, TYPE J.
C     PDCFR(I,J) = EXPECTED YIELD IN CU. FT. FROM REGENERATION CUTS NEXT
C          PERIOD, BLOCK I, TYPE J.
C     PDCUT(II = ACRES IN AGE CLASS WITH BALANCED SERIES OF AGE CLASSES.
C     PGBD(I,J,K) = PERIODIC GROWTH IN M BD. FT. WORKING GROUP I, BLOCK
C          J, AGE CLASS K, EXCLUDING UNITS OF KNOWN AREA.
C     PGMC(I,J,KI = PERIODIC GROWTH IN MERCH. CU. FT. WORKING GROUP I,
C          BLOCK J, AGE CLASS K, EXCLUDING UNITS OF KNOWN AREA.
C     PHLP(I,J) = POTENTIAL NONCOMMERCIAL THINNING IN NEXT PERIOD, ACRES
C          OF TYPE J IN BLOCK I. RECORDS WITH AREA = 0.0, ONLY.
C     POOR(I) = MINIMUM SITE INDEX FOR MANAGEMENT, WORKING GROUP I.
C     POPN(I,J) = POTENTIAL COMMERCIAL THINNING IN NEXT PERIOD, ACRES OF
C          TYPE J IN BLOCK I. RECORDS WITH AREA = 0.0, ONLY.
C     PPBF(I,J,K) = TOTAL VOLUME IN M BD. FT. FOR WORKING GROUP I, BLOCK
C          J, AGE CLASS K. EXCLUDES UNITS OF KNOWN AREA.
C     PPCR(I,J) = EXPECTED YIELD IN CU. FT. FROM REGENERATION CUTS -
C          BLOCK I, TYPE J - EXCLUDING UNITS OF KNOWN AREA.
C     PPFN(I,JI = EXPECTED YIELD IN CU. FT. FROM FINAL CUTS - BLOCK I,
C          TYPE J - EXCLUDING UNITS OF KNOWN AREA.
C     PPMC(I,J,K) = TOTAL VOLUME IN MERCH. CU. FT. FOR WORKING GROUP I,
C          BLOCK J, AND AGE CLASS K. EXCLUDES KNOWN AREAS.
C     PPTC(I,J,K) = SUM OF TOTAL CU. FT. FOR WORKING GROUP I, BLOCK J,
C          AGE CLASS K. EXCLUDES UNITS OF KNOWN AREA.
C     PRET = PERCENTAGE OF TREES RETAINED AFTER INITIAL THINNING.
C     PROD(II = BOARD EEET PER TOTAL CUBIC FOOT - CONVERSION FACTOR.
C     PS(I,J,K) = NUMBER OF INVENTORY PLOTS OF WORKING GROUP I, BLOCK J,
C          AND SITE CLASS K.
C     PSLV(I,JI = BD. FT. VOLUME TO BE SALVAGED - BLOCK I, TYPE J -
C          EXCLUDING UNITS OF KNOWN AREA.
C     PSPLT(I,J) = NUMBER OF INVENTORY PLOTS OF BLOCK I AND TYPE J. NOT
C          INCLUDING UNITS OF KNOWN AREA.
C     PTBF(I,J,K) = TOTAL VOLUME IN M BD. FT. FOR WORKING GROUP I, BLOCK
C          J, AND AGE CLASS K.
C     PTCU(I,J,K) = SUM OF TOTAL CU. FT. FOR WORKING GROUP I, BLOCK J,
C          AND AGE CLASS K. IN HUNDREDS OF CU. FT.
C     PTMC(I,J,K) = TOTAL VOLUME IN MERCH. CU. FT. FOR WORKING GROUP I,
C          BLOCK J, AND AGE CLASS K. IN HUNDREDS OF CU. FT.
C     PUNC(I,JI = AREA OF BLOCK I, TYPE J BELOW MINIMUM SITE QUALITY
C          FOR REGULATION, EXCLUDING UNITS OF KNOWN AREA.
C     QUAL(II = SITE CLASSES PRESENT IN WORKING GROUP I.
C     REGN(I,J,K) = AGE AT WHICH REGENERATION CUT MADE. WORKING GROUP I,
C          CUT J, SITE CLASS K. J=I,2, OR 3.
C     RGAC(I) = EXPECTED ACRES GIVEN REGENERATION CUTS ANNUALLY DURING
C          NEXT PERIOD, WORKING GROUP I.
C     RGBD(I) = EXPECTED ANNUAL YIELD IN M BD. FT. FROM REGENERATION
C          CUTS DURING NEXT PERIOD, WORKING GROUP I.
C     RGCU(I) = EXPECTED ANNUAL YIELD IN CU. FT. FROM REGENERATION CUTS
C          DURING NEXT PERIOD, WORKING GROUP I.
C     RINT(I) = NUMBER OF YEARS FOR WHICH EQUATIONS PREDICT GROWTH WITH
C          A SINGLE PROJECTION, WORKING GROUP I.
C     ROTA = OLDEST STAND AGE IN A YIELD TABLE.
C     SACCF = AREA OF WORKING CIRCLE IN STANDARD ACRES, FROM CU. FT.
C     SAHP(II = POTENTIAL NONCOMMERCIAL THINNING IN NEXT PERIOD, ACRES
C          IN WORKING GROUP I.
C     SANCUT(II = ALLOWABLE ANNUAL CUT IN ACRES, WORKING GROUP I.
C     SARETY(I,J) = AREA OF TYPE J IN BLOCK I.
C     SARSC = TOTAL AREA OF SUBCOMPARTMENTS OF A COMPARTMENT.
C     SARSP(I) = TOTAL AREA OF WORKING GROUP I, INCLUDING SHARE OF
C          DEFORESTED AREA.
C     SATH(II = POTENTIAL COMMERCIAL THINNING IN NEXT PERIOD, ACRES IN
C          WORKING GROUP I.
C     SBARB = TOTAL BRUSHY DEFORESTED ACRES IN WORKING CIRCLE.
C     SBARE = TOTAL DEFORESTED ACRES IN WORKING CIRCLE.
C     SBARG = TOTAL GRASSY DEFORESTED ACRES IN WORKING CIRCLE.
C     SBDF = M BD. FT. IN WORKING CIRCLE.
C     SBF(II = TOTAL M BD. FT. IN WORKING GROUP I.
C     SBFR(II = BD. FT. FROM THINNINGS NEXT PERIOD, WORKING GROUP I.
C     SBH(I) = BD. FT. FROM REGENERATION CUTS DURING NEXT PERIOD,
C          WORKING GROUP I.
C     SBM(I,JI = BD. FT. FROM THINNING DURING NEXT PERIOD, WORKING GROUP
C          I, BLOCK J.
C     SBSV(I) = BD. FT. FROM SALVAGE NEXT PERIOD, WORKING GROUP I.
C     SCA(I,JI = BD. FT. FROM REGENERATION CUTS DURING NEXT PERIOD,
C          WORKING GROUP I, BLOCK J.
C     SCALE = ACRES IN ONE MAP SQUARE.
C     SCB(I,J) = BD. FT. FROM FINAL CUTS NEXT PERIOD, WORKING GROUP I,
C          BLOCK J.
C     SCFM = HUNDREDS OF MERCH. CU. FT. IN WORKING CIRCLE.
C     SCN(I) = EXPECTED YIELD IN CU. FT. FROM FINAL CUTS DURING NEXT
C          PERIOD, WORKING GROUP I.
C     SCNB(I,J) = EXPECTED YIELD IN CU. FT. FROM FINAL CUTS DURING NEXT
C          PERIOD, WORKING GROUP I, BLOCK J.
C     SCNT(I) = EXPECTED YIELD IN CU. FT. FROM FINAL CUTS DURING NEXT
C          PERIOD, TYPE I.
C     SCR(II = EXPECTED YIELD IN CU. FT. FROM REGENERATION CUTS DURING
C          NEXT PERIOD, WORKING GROUP I.
C     SCRB(I,J) = EXPECTED YIELD IN CU. FT. FROM REGENERATION CUTS
C          DURING NEXT PERIOD, WORKING GROUP I, BLOCK J.
C     SCRT(II = EXPECTED YIELD IN CU. FT. FROM REGENERATION CUTS DURING
C          NEXT PERIOD, TYPE I.
C     SCU(I,JI = CU. FT. FROM THINNING NEXT PERIOD, WORKING GROUP I,
C          BLOCK J.
C     SCUR(I) = CU. FT. FROM THINNING NEXT PERIOD, WORKING GROUP I.
C     SDBF(I) = TOTAL DIFFERENCE BETWEEN ACTUAL AND GOAL GROWING STOCKS
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      IN M BD. FT. FOR WORKING GROUP I.
 SOMC(I) = TOTAL DIFFERENCE BETWEEN ACTUAL AND GOAL GROWING STOCK
      IN HUNDREDS OF CU. FT. FOR WORKING GROUP I.
 SFNL(I) = ACRES FOR FINAL CUT ANNUALLY WITH OVERWOOD AND BALANCED
      DISTRIBUTION OF AGE CLASSES, WORKING GROUP I.
 SFR(I) = BD. FT. FROM FINAL CUTS, NEXT PERIOD, WORKING GROUP I.
 SHELT(I,J,K) = M BD. FT. PER ACRE LEFT AS SHELTERWOOD.  WORKING
      GROUP I, REMOVAL CUT J, SITE CLASS K.
 SHL(I,J) = POTENTIAL NONCOMMERCIAL THINNING IN NEXT PERIOD,
      WORKING GROUP I IN BLOCK J.
 SHWO(I,J,K) = CU. FT. PER ACRE LEFT AS SHELTERWOOD.  WORKING
      GROUP I, REMOVAL CUT J, SITE CLASS K.
 SIDLA = TOTAL ALLOWABLE CUT IN ACRES FOR ONE YEAR IN A BALANCED
      WORKING CIRCLE.
 SIDLB = TOTAL ALLOWABLE CUT IN M BD. FT. FOR ONE YEAR IN A
      BALANCED WORKING CIRCLE.
 SIDLC = TOTAL ALLOWABLE CUT IN CU. FT. FOR ONE YEAR IN A BALANCED
      WORKING CIRCLE.
 SITE = SITE INDEX.
 SLAND = TOTAL ACRES IN WORKING CIRCLE.
 SLVG(I,J) = BD. FT. VOLUME TO BE SALVAGED, BLOCK I, TYPE J.
 SMC(I) = HUNDREDS OF CUBIC FEET OF WORKING GROUP I IN WORKING
      CIRCLE.
 SMPL = ACRES OF TYPE J OF BLOCK I REPRESENTED BY ONE INVENTORY
      PLOT.
 SMSP(I) = AREA OF WORKING GROUP I IN WORKING CIRCLE.
 SOP(I,J) = POTENTIAL COMMERCIAL THINNING IN NEXT PERIOD, WORKING
      GROUP I IN BLOCK J.
 SOPTA(I) = TOTAL ALLOWABLE CUT IN ACRES FOR ONE YEAR IN BALANCED
      WORKING GROUP I.
 SOPTB(I) = TOTAL M BD. FT. CUT IN ONE YEAR WITH A BALANCED SERIES
      OF AGE CLASSES, WORKING GROUP I.
 SOPTC(I) = TOTAL CU. FT. CUT IN ONE YEAR WITH A BALANCED SERIES OF
      AGE CLASSES, WORKING GROUP I.
 SPLT(I,J) = NUMBER OF PLOT AND SUBCOMPARTMENT RECORDS, TIMBER TYPE
      J OF BLOCK I.
 SPNUM(I) = INDEX NUMBER TO IDENTIFY SET OF SPECIES-SPECIFIC
      STATEMENTS TO BE CALLED BY SUBROUTINE WORKGP.
 SSL(I,J) = BD. FT. FROM SALVAGE NEXT PERIOD, WORKING GROUP I,
      BLOCK J.
 SSPT = TOTAL OF INVENTORY PLOTS IN WORKING CIRCLE.
 SSTAC = AREA OF WORKING CIRCLE IN STANDARD ACRES FROM BOARD FEET.
 STACF(I) = AREA OF SITE CLASS I IN STANDARD ACRES - FROM CU. FEET.
 STBS(I) = BD. FT. FROM THINNINGS DURING NEXT PERIOD, TYPE I.
 STC(I) = TOTAL CU. FT. OF WORKING GROUP I IN WORKING CIRCLE.
 STCF = TOTAL CU. FT. IN WORKING CIRCLE, IN HUNDREDS.
 STDAC(I) = AREA OF SITE CLASS I IN STANDARD ACRES - FROM BD. FEET.
 STFO(I) = BD. FT. FROM FINAL CUTS DURING NEXT PERIOD, TYPE I.
 STHBF = CURRENT POTENTIAL PERIODIC YIELD FROM THINNINGS, TOTAL FOR
      WORKING CIRCLE IN M BD. FT.
 STHCM = CURRENT POTENTIAL PERIODIC YIELD FROM THINNINGS, TOTAL FOR
      WORKING CIRCLE IN HUNDREDS OF CUBIC FEET.
 STHP(I) = POTENTIAL NONCOMMERCIAL THINNING IN NEXT PERIOD, ACRES
      OF TYPE I.
 STHR(I) = BD. FT. FROM REGENERATION CUTS DURING NEXT PERIOD,
      TYPE I.
 STLV(I) = BD. FT. FROM SALVAGE DURING NEXT PERIOD, TYPE I.
 STNC(I) = CU. FT. FROM THINNING DURING NEXT PERIOD, TYPE I.
 STON(I) = POTENTIAL COMMERCIAL THINNING IN NEXT PERIOD, ACRES OF
      TYPE I.
 STRY = STAND COMPONENT USED TO TYPE THE STAND. ENTER 1 IF THE
      UNDERSTORY WAS USED. OTHERWISE LEAVE BLANK.
 STYP(I) = ACRES OF TYPE I IN WORKING CIRCLE.
 SUBBF(I,J) = GROWING STOCK GOAL FOR WORKING GROUP I, SITE CLASS J.
      M BD. FT. IN SAWLOG TREES.
 SUBCF(I,J) = GROWING STOCK GOAL FOR WORKING GROUP I, SITE CLASS J.
      CUBIC FEET IN TREES BELOW SAWLOG SIZE.
 SUBTY(I) = TYPE OF SUBCOMPARTMENT I.
 SUMCF(I) = TOTAL GROWING STOCK GOAL FOR WORKING GROUP I IN MERCH.
      CU. FT. SUM OF APPROPRIATE ALLCF(I,J) FOR ENTIRE STANDS.
 SUNC = TOTAL LOW SITE ACRES IN WORKING CIRCLE.
 SYST(I) = FLAG SET IF WORKING GROUP I TO BE REGENERATED BY SEED
      TREES OR SHELTERWOOD.
 TBA(I) = BASAL AREA AFTER THINNING TO SPECIFIED LEVEL NOW (I=1) OR
      IN TIME YEARS (I=2).
 TBD(I) = M BD. FT. AFTER THINNING TO SPECIFIED LEVEL NOW (I=1) OR
      IN TIME YEARS (I=2).
 TCF(I) = TOTAL CUBIC FEET IN BLOCK I.
 TCM(I) = HUNDREDS OF CU. FT. AFTER THINNING TO SPECIFIED LEVEL NOW
      (I=1) OR IN TIME YEARS (I=2).
 TCSP(I,J) = TOTAL CU. FT. OF WORKING GROUP I IN BLOCK J.
 TDM(I) = AVERAGE D.B.H. AFTER THINNING TO SPECIFIED LEVEL NOW
      (I=1) OR IN TIME YEARS (I=2).
 TEM = TEMPORARY VARIABLE, ASSIGNED MEANINGS AS NEEDED.
 THAC(I) = POSSIBLE ACRES TO THIN ANNUALLY DURING NEXT PERIOD,
      WORKING GROUP I.
 THB = AVERAGE POTENTIAL VOLUME FROM THINNING, M BD. FT.
 THBD(I) = EXPECTED ANNUAL YIELD IN M BD. FT. FROM THINNINGS DURING
      NEXT PERIOD, WORKING GROUP I.
 THC = AVERAGE POTENTIAL VOLUME FROM THINNING, HUNDREDS OF CU. FT.
 THCU(I) = EXPECTED ANNUAL YIELD IN CU. FT. FROM THINNINGS DURING
      NEXT PERIOD, WORKING GROUP I.
 THIN(I) = GROWING STOCK LEVEL, INITIAL THINNING, WORKING GROUP I.
 TIME = NUMBER OF YEARS IN PLANNING PERIOD. BASIS FOR WORK INDEX.
 TMBR = TOTAL TIMBERED AREA IN WORKING CIRCLE.
 TMPD = TOTAL AREA OF FOREST TYPES IN WORKING CIRCLE, INCLUDING
      NONSTOCKED TYPES.
 TOT(I) = TOTAL CUBIC FEET IN OVERSTORY(I=1) OR UNDERSTORY(I=2).
 TOTAC(I) = TOTAL ACRES EXPECTED TO BE TREATED IN ONE YEAR DURING
      NEXT PERIOD, WORKING GROUP I.
 TOTBD(I) = EXPECTED TOTAL ANNUAL YIELD IN M BD. FT. DURING NEXT
      PERIOD, WORKING GROUP I.
 TOTC = TOTAL CUBIC FEET REMOVED PER ACRE.
 TOTCU(I) = EXPECTED TOTAL ANNUAL YIELD IN CU. FT. DURING NEXT
      PERIOD, WORKING GROUP I.
 TOTO = TOTAL CUBIC FEET PER ACRE BEFORE THINNING.
 TOTT = TOTAL CUBIC FEET PER ACRE AFTER THINNING.
 TPB(I,J) = NUMBER OF INVENTORY PLOTS, WORKING GROUP I, BLOCK J.
C     TVL(I) = TOTAL CU. FT. AFTER THINNING TO SPECIFIED LEVEL NOW (I=1)
C          OR IN TIME YEARS (I=2).
C     TYPNM(I,J) = DESCRIPTION OF VEGETATIVE TYPE OR USE TYPE NUMBER I.
C     UNCML(I,J) = AREA OF BLOCK I AND TIMBER TYPE J BELOW MINIMUM
C          SITE QUALITY FOR TIMBER MANAGEMENT AND REGULATION.
C     UNIT(I) = NUMBER OF MAP SQUARES IN SUBCOMPARTMENT I.
C     VLBF(I) = VOLUME IN M BD. FT. CUT FROM SITE I.
C     VLCU(I) = VOLUME IN CU. FT. CUT FROM SITE I.
C     VLLV(I,J,K) = PERCENTAGE OF PREVIOUS DLEV(I) LEFT AT AGE
C          REGN(I,J,K). WORKING GROUP I, CUT J, SITE CLASS K. J=1 OR 2.
C          ENTERED AS A DECIMAL.
C     WGNUM(I) = NUMBER ASSIGNED TO WORKING GROUP I.
C     WGPDES(I,J) = DESCRIPTION OF SILVICULTURAL PRESCRIPTION FOR
C          WORKING GROUP I.
C     WGPNM(I,J) = NAME OF WORKING GROUP I.
C     WHEN = YEAR OF FIRST GROWING SEASON AFTER INVENTORY WAS MADE.
C     WORK = CODE FOR TREATMENT IN NEXT PERIOD, AS -
C          0 = DO NOTHING THIS PERIOD
C          1 = PLANT OR SEED
C          2 = THIN
C          3 = SALVAGE
C          4 = REGENERATION CUT
C          5 = REMOVE SEED TREES OR SHELTERWOOD
C          6 = REMOVE OVERWOOD AND THIN RESIDUAL
C
      COMMON ADO,AGE(2),AGEO,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWO(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /OPT/ OPTION,ICT9
C
      COMMON /BLKA/ ANBDF(151),ANCUV(151),BDFC(150),BDFO(150),CFMC(150),
     1CFMO(150),CYCL,IROT,KAN,POI,PD2,QUAL(14),ROTA,VLBF(14),VLCU(14)
C
      COMMON /BLKB/ PAFN(5,7,15),PARG(5,7,15),
     1PBFT(7,27),PCMT(7,27),PCTA(7,27),PCTB(7,27),PGBD(5,7,15),PGMC(5,7,
     215),PHLP(7,27),POPN(7,27),PPBF(5,7,15),PPCR(7,27),PPFN(7,27),
     3PPMC(5,7,15),PPTC(5,7,15),PSLV(7,27),PTBF(5,7,15),PTCU(5,7,15),
     4PTMC(5,7,15)
C
      COMMON /BLKC/ ANNAC,ANNBD,ANNCU,FINB(5),FINC(5),FNAC(5),RGAC(5),
     1RGBD(5),RGCU(5),SAHP(5),SANCUT(5),SATH(5),SBFR(5),SBH(5),SBSV(5),
     2SCA(5,7),SCB(5,7),SCN(5),SCNB(5,7),SCNT(25),SCR(5),SCRB(5,7),
     3SCRT(25),SCU(5,7),SCUR(5),SFNL(5),SFR(5),SHL(5,7),SIDLA,SIDLB,
     4SIDLC,SOP(5,7),SOPTA(5),SOPTB(5),SOPTC(5),SSL(5,7),STBS(25),STFO
     5(25),STHP(25),STHR(25),STLV(25),STNC(25),STON(25),THAC(5),THBD(5),
     6THCU(5),TOTAC(5),TOTBD(5),TOTCU(5),SBM(5,7)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      COMMON /BLKE/ RABDF(5),RABDI(5),RABDR(5),RABT(5),RACFN(5),RACIT(5)
     1,RACRG(5),RATC(5),SRABD,SRACF
C
C READ VARIABLES THAT APPLY TO THE WORKING CIRCLE.
C
      CALL BASIS
C
C INITIALIZE VARIABLES APPLICABLE TO THE WORKING CIRCLE.
C
      CALL INIT
C MAKE INITIAL READING OF INVENTORY RECORDS.
C
      CALL SCAN
C
C CALL APPROPRIATE ROUTINE TO COMPUTE AREAS.
C
      IF (OPTION .EQ. 4HMAPS ) CALL MAPS
      IF (OPTION .EQ. 4HREA1) CALL AREA1
      IF (OPTION .EQ. 4HREA2) CALL AREA2
C
C COMPUTE AREAS OF VARIOUS SUBDIVISIONS OF WORKING CIRCLE.
C
      CALL LAND
C
C COMPUTE GROWING STOCK GOALS AND AREA CONTROL.
C
      CALL GOAL
C
C COMPUTE PRESENT VOLUMES, FUTURE GROWTH, ETC., FROM INVENTORY DATA.
C
      CALL GOT
      CALL SUMS
C
C DETERMINE DIFFERENCES BETWEEN PRESENT FOREST AND GOALS. PRINT A
C GUIDE TO MANAGEMENT.
C
      CALL SUMRY
      CALL GIDE1
      CALL GIDE2
      CALL EXIT
      END
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Subroutine BASIS

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      SUBROUTINE BASIS
C
C TO READ VARIABLES THAT APPLY TO THE WORKING CIRCLE.
C
      COMMON AOD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),OLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBO(5),OPCU(5),PAIBO(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWO(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /OPT/ OPTION,ICT9
C
      DO 1 I=1,5
      DO 1 J=1,3
      DO 1 K=1,14
      INVL(I,J,K) = 0
      REGN(I,J,K) = 0.0
      VLLV(I,J,K) = 0.0
    1 CONTINUE
      DO 5 I=1,5
      DO 5 J=1,14
      AGETH(I,J) = 0.0
      DBHTH(I,J) = 0.0
    5 DENTH(I,J) = 0.0
C
C INITIALIZE AREA OPTION FIELD TO BLANK.
C
      OPTION = 5H
C
C READ CARD TYPE 1.
C
      READ (5,10) OPTION,ICT9,(FORET(I),I=1,19)
   10 FORMAT (1X,A4,I1,18A4,A2)
      IF(ICT9 .EQ. 0) ICT9 = 5
C
C READ CARD TYPE 2.
C
      READ (5,15) ((TYPNM(I,J),J=1,5),I=1,35)
   15 FORMAT (8(5A2))
C
C READ CARD TYPE 3.
C
      READ (5,20) NBK,NCMP,NWGP,MIN,BFMRCH,TIME
   20 FORMAT (4I4,2F4.2)
C
C DO LOOP TO READ A CARD GROUP FOR EACH WORKING GROUP.
C
      DO 45 I=1,NWGP
C
C INITIALIZE VARIABLES TO BE READ IN.
C
      ADJ(I) = 0.0
      COMBF(I) = 0.0
      COMCU(I) = 0.0
      CUCY(I) = 0.0
      DELAY(I) = 0.0
      OLEV(I) = 0.0
      POOR(I) = 0.0
      RINT(I) = 0.0
      SPNUM(I) = 0.0
      THIN(I) = 0.0
C
C READ CARD TYPE 4.
C
      READ (5,25) (WGPNM(I,J),J=1,3),WGNUM(I),THIN(I),OLEV(I),POOR(I),CO
     1MBF(I),COMCU(I),ADJ(I),DELAY(I),RINT(I),CUCY(I),SPNUM(I)
   25 FORMAT (3A4,F5.0,4F4.1,F5.2,4F4.1,F4.0)
C
C READ CARD TYPE 5.
C
      READ (5,30) (WGPDES(I,K),K=1,20)
   30 FORMAT (20A4)
C
C READ CONTROLS FOR REGENERATION CUTS.  (INCLUDE UP TO 14 CARDS FOR EACH
C WORKING GROUP TO COVER ALL 10-FOOT SITE INDEX CLASSES FROM POOR(I)
C TO AT LEAST HIGHEST CLASS POSSIBLE.  END WITH A BLANK TYPE 6 CARD IF
C CLASSES DO NOT GO TO 140.
C
      MPR = POOR(I) * 0.1 + 0.45
      DO 40 J=MPR,14
C
C READ CARD TYPE 6.
C
      READ (5,35) REGN(I,1,J),VLLV(I,1,J),INVL(I,1,J),REGN(I,2,J),VLLV(I
     1,2,J),INVL(I,2,J),REGN(I,3,J)
   35 FORMAT (F4.0,F6.3,I3,F4.0,F6.3,I3,F4.0)
      IF(REGN(I,1,J) .EQ. 0.0) GO TO 45
C
C READ CARD TYPE 7.
C
      READ (5,38) AGETH(I,J),DENTH(I,J),DBHTH(I,J)
   38 FORMAT (3F5.1)
   40 CONTINUE
   45 CONTINUE
C
C READ CARD TYPE 8.
C
      READ (5,50) (DATE(I),I=1,6)
   50 FORMAT (6A4)
C
C PRINT PAGE TYPE 4 - RECORD OF VALUES READ BY THIS ROUTINE.
C
      WRITE (6,60)
   60 FORMAT (1H1,///,61X,11HPAGE TYPE 4)
      WRITE (6,65)
   65 FORMAT (1H0,39X,53HRECORD OF MANAGEMENT DECISIONS AND CURRENT COND
     1ITIONS)
      WRITE (6,70) (FORET(I),I=1,19)
   70 FORMAT (1H ,29X,18A4,A2,//)
      WRITE (6,75) NBK,NCMP
   75 FORMAT (1H ,10X,18HNUMBER OF BLOCKS -,I3,32X,24HNUMBER OF COMPARTM
     1ENTS -,I4)
      WRITE (6,80) MIN,NWGP
   80 FORMAT (1H0,10X,31HMINIMUM AGE FOR GROWING STOCK -,I3,19X,26HNUMBE
     1R OF WORKING GROUPS -,I4)
      WRITE (6,85) BFMRCH,TIME
   85 FORMAT (1H0,10X,37HMINIMUM M BD. FT. FOR GROWING STOCK -,F5.1,11X,
     134HLENGTH OF PLANNING PERIOD, YEARS -,F4.0,/)
      WRITE (6,90)
   90 FORMAT (1H0,55X,72H*- - - - - - - - - - - - W O R K I N G    G R O U P
     1 - - - - - - - - - - - - -*)
      WRITE (6,95) ((WGPNM(I,J),J=1,3),I=1,NWGP)
   95 FORMAT (1H ,55X,5(3A4,3X))
      WRITE (6,100) (POOR(I),I=1,NWGP)
  100 FORMAT (1H0,10X,31HLOWEST SITE CLASS TO BE MANAGED,14X,F7.1,4(8X,F
     17.1))
      WRITE (6,105) (CUCY(I),I=1,NWGP)
  105 FORMAT (1H0,10X,30HLENGTH OF CUTTING CYCLE, YEARS,15X,F7.1,4(8X,F7
     1.1))
      WRITE (6,110) (ADJ(I),I=1,NWGP)
  110 FORMAT (1H0,10X,34HLENGTH OF ADJUSTMENT PERIOD, YEARS,11X,F7.1,4(8
     1X,F7.1))
      WRITE (6,115) (DELAY(I),I=1,NWGP)
  115 FORMAT (1H0,10X,37HEXPECTED DELAY IN REGENERATION, YEARS,8X,F7.1,4
     1(8X,F7.1))
      WRITE (6,120) (THIN(I),I=1,NWGP)
  120 FORMAT (1H0,10X,35HSTOCKING LEVEL FOR INITIAL THINNING,10X,F7.1,4(
     18X,F7.1))
      WRITE(6,125) (OLEV(I),I=1,NWGP)
  125 FORMAT (1H0,10X,36HSTOCKING LEVEL, SUBSEQUENT THINNINGS,9X,F7.1,4(
     18X,F7.1))
      WRITE (6,130) (COMBF(I),I=1,NWGP)
  130 FORMAT (1H0,10X,33HMINIMUM COMMERCIAL CUT, M BD. FT.,12X,F7.1,4(8X
     1,F7.1))
      WRITE (6,135) (COMCU(I),I=1,NWGP)
  135 FORMAT (1H0,10X,31HMINIMUM COMMERCIAL CUT, CU. FT.,14X,F7.1,4(8X,F
     17.1))
      WRITE (6,140) (RINT(I),I=1,NWGP)
  140 FORMAT (1H0,10X,34HLENGTH OF PREDICTION PERIOD, YEARS,11X,F7.1,4(8
     1X,F7.1))
      WRITE (6,150)
  150 FORMAT (1H0,//,11X,23HCUBIC FEET IN HUNDREDS.)
      RETURN
      END
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Subroutine INIT

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      SUBROUTINE INIT
C
C TO INITIALIZE VARIABLES THAT APPLY TO WORKING CIRCLE.
C
      COMMON AOD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),OLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBO(5),OPCU(5),PAIBO(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWO(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBO(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      IJ = 0
      IK = 0
      KI = 0
      MNK = 0
      NSUB = 0
      SBARB = 0.0
      SBARE = 0.0
      SBARG = 0.0
      SLAND = 0.0
      TEM = 0.0
      TMBR = 0.0
      TMPO = 0.0
      TVOL = 0.0
      VOL = 0.0
```

```
      DO 5 I=1,NBK
      ACBAR(I) = 0.0
      ARBK(I) = 0.0
      NSBK(I) = 0
      PABR(I) = 0.0
      TMTY(I) = 0.0
      DO 5 J=1,35
      PARTY(I,J) = 0.0
    5 SARETY(I,J) = 0.0
      DO 10 I=1,35
   10 STYP(I) = 0.0
      DO 15 I=1,NWGP
      ACINT(I) = 0.0
      ALOWC(I) = 0.0
      ALWBF(I) = 0.0
      BDMAI(I) = 0.0
      BFINT(I) = 0.0
      CUINT(I) = 0.0
      CUMAI(I) = 0.0
      FNBO(I) = 0.0
      FNCU(I) = 0.0
      OPBD(I) = 0.0
      OPCU(I) = 0.0
      PAIBO(I) = 0.0
      PAICU(I) = 0.0
      SYST(I) = 0.0
      DO 15 J=1,NBK
      ACSP(I,J) = 0.0
      PASP(I,J) = 0.0
      TPB(I,J) = 0.0
      DO 15 K=1,14
      ACSI(I,J,K) = 0.0
      PASI(I,J,K) = 0.0
      PS(I,J,K) = 0.0
   15 CONTINUE
      DO 20 I=1,NWGP
      DO 20 J=1,NBK
      DO 20 K=1,15
      ACFNL(I,J,K) = 0.0
      ACRGN(I,J,K) = 0.0
      GRBO(I,J,K) = 0.0
   20 GRMC(I,J,K) = 0.0
      DO 25 I=1,NBK
      DO 25 J=1,14
      BARSI(I,J) = 0.0
      PBRSI(I,J) = 0.0
   25 CONTINUE
      DO 30 I=1,NWGP
      GVLBF(I) = 0.0
      GVLCU(I) = 0.0
      NSI(I) = 0
      SARSP(I) = 0.0
      SBF(I) = 0.0
      SMC(I) = 0.0
      SMSP(I) = 0.0
      SUMCF(I) = 0.0
      DO 30 J=1,14
      ALLCF(I,J) = 0.0
      ANCUT(I,J) = 0.0
      AREA(I,J) = 0.0
      CFBF(I,J) = 0.0
      SUBBF(I,J) = 0.0
      SUBCF(I,J) = 0.0
   30 CONTINUE
      DO 35 I=1,NWGP
      DO 35 J=1,15
      ABFAG(I,J) = 0.0
      AMCAG(I,J) = 0.0
      BFAGE(I,J) = 0.0
   35 CFAGE(I,J) = 0.0
      DO 40 I=1,NBK
      DO 40 J=1,27
      BFTH(I,J) = 0.0
      CMTH(I,J) = 0.0
      CUTA(I,J) = 0.0
      CUTB(I,J) = 0.0
      HELP(I,J) = 0.0
      OPEN(I,J) = 0.0
      POCFN(I,J) = 0.0
      POCFR(I,J) = 0.0
      PSPLT(I,J) = 0.0
      PUNC(I,J) = 0.0
      SLVG(I,J) = 0.0
      SPLT(I,J) = 0.0
      UNCML(I,J) = 0.0
   40 CONTINUE
      DO 45 I=1,2
      BA(I) = 0.0
      FCTR(I) = 0.0
      PROD(I) = 0.0
      VOM(I) = 0.0
   45 CONTINUE
      DO 50 I=1,NBK
      DO 50 J=1,2
      DO 50 K=1,14
      GROWB(I,J,K) = 0.0
      GROWC(I,J,K) = 0.0
      SHELT(I,J,K) = 0.0
      SHWO(I,J,K) = 0.0
   50 CONTINUE
      RETURN
      END
```

Subroutine SCAN

```
      SUBROUTINE SCAN
C
C TO MAKE PRELIMINARY EXAMINATION OF INVENTORY RECORDS.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),OLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWO(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBO(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /OPT/ OPTION,ICT9
C
C READ INVENTORY RECORDS FROM CARD TYPE 9 TO COUNT THEM BY BLOCK, TYPE,
C ETC. LAST RECORD IS CARD TYPE 10 WITH IBK = 99 TO STOP PROCESSING.
C
   10 READ (ICT9,15) IBK,KOMP,ISUB,QTR1,QTR2,SECT,TOWN,RANG,SITE,STRY,
     1NTYP,WORK,FISC,DBH(1),HT(1),DEN(1),AGE(1),DMR(1),DBH(2),HT(2),DEN(
     22),AGE(2),DMR(2),ACRE,WHEN
   15 FORMAT (I2,I4,I3,3A3,2A4,F3.0,F1.0,I2,F1.0,F4.0,F3.1,F3.0,F5.0,F3.
     10,F2.1,F3.1,F3.0,F5.0,F3.0,F2.1,F5.1,F4.0)
      IF(IBK .EQ. 99) GO TO 50
      SPLT(IBK,NTYP) = SPLT(IBK,NTYP) + 1.0
      IF(ACRE .GT. 0.0) GO TO 20
      PSPLT(IBK,NTYP) = PSPLT(IBK,NTYP) + 1.0
      GO TO 22
   20 SARETY(IBK,NTYP) = SARETY(IBK,NTYP) + ACRE
      PARTY(IBK,NTYP) = PARTY(IBK,NTYP) + ACRE
      TMTY(IBK) = TMTY(IBK) + ACRE
   22 ISI = (SITE + 4.5) * 0.1
      IF(ISI .LT. 1) GO TO 10
      IF(NTYP .LE. 25) GO TO 30
      IF(ACRE .EQ. 0.0) GO TO 25
      BARSI(IBK,ISI) = BARSI(IBK,ISI) + ACRE
      GO TO 10
   25 PBRSI(IBK,ISI) = PBRSI(IBK,ISI) + 1.0
      GO TO 10
   30 IF(NTYP .GT. 0 .AND. NTYP .LT. 6) KAK = 1
      IF(NTYP .GT. 5 .AND. NTYP .LT. 11) KAK = 2
      IF(NTYP .GT. 10 .AND. NTYP .LT. 16) KAK = 3
      IF(NTYP .GT. 15 .AND. NTYP .LT. 21) KAK = 4
      IF(NTYP .GT. 20 .AND. NTYP .LT. 26) KAK = 5
      IF(ACRE .EQ. 0.0) GO TO 35
      ACSI(KAK,IBK,ISI) = ACSI(KAK,IBK,ISI) + ACRE
      PASP(KAK,IBK) = PASP(KAK,IBK) + ACRE
      GO TO 40
   35 PS(KAK,IBK,ISI) = PS(KAK,IBK,ISI) + 1.0
   40 IF(SITE .GE. POOR(KAK)) GO TO 10
      IF(ACRE .EQ. 0.0) GO TO 45
      UNCML(IBK,NTYP) = UNCML(IBK,NTYP) + ACRE
      GO TO 10
   45 PUNC(IBK,NTYP) = PUNC(IBK,NTYP) + 1.0
      GO TO 10
   50 IF(ICT9 .NE. 5) REWIND ICT9
C
C COUNT NUMBER OF SITE CLASSES FOR EACH WORKING GROUP.
C
      DO 95 I=1,NWGP
      CD = POOR(I) * 0.1
      DO 90 K=1,14
      M = 15 - K
      AB = M + 1
      IF(AB .LE. CD) GO TO 95
      DO 85 J=1,NBK
      IF(ACSI(I,J,M) .GT. 0.0) GO TO 80
      IF(PS(I,J,M) .GT. 0.0) GO TO 80
      GO TO 85
   80 NSI(I) = AB - CD
      GO TO 95
   85 CONTINUE
   90 CONTINUE
   95 CONTINUE
      DO 130 I=1,NWGP
      DO 120 K=1,14
      IF(REGN(I,2,K) .GT. 0.0) GO TO 125
  120 CONTINUE
      GO TO 130
  125 SYST(I) = 1.0
  130 CONTINUE
      RETURN
      END
```

Subroutine MAPS

```
      SUBROUTINE MAPS
C
C TO COMPUTE AREAS FROM TYPE AND SUBCOMPARTMENT MAPS.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
```

```
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),ENBD(5),
     4ENCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      DIMENSION KSUB(36,36),KTYP(36,36),ARESC(30),ARETY(35),CVR(35),SUBT
     1Y(30),UNIT(30),GRUP(5)
C
      DO 5 I=1,NBK
      DO 5 J=1,35
    5 SARETY(I,J) = 0.0
C
C READ CARD TYPE 11.
C
      READ (5,10) MAP,SCALE
   10 FORMAT (I4,F6.4)
C
C REPEAT LOOP FOR EACH COMPARTMENT.
C
      DO 500 KOL=1,NCMP
C
C INITIALIZE VARIABLES APPLICABLE TO A COMPARTMENT.
C
      DO 15 I=1,30
      ARESC(I) = 0.0
      SUBTY(I) = 0.0
   15 UNIT(I) = 0.0
      DO 20 I=1,NWGP
   20 GRUP(I) = 0.0
      DO 25 I=1,36
      DO 25 J=1,36
      KSUB(I,J) = 0
   25 KTYP(I,J) = 0
      DO 30 I=1,35
      ARETY(I) = 0.0
      CVR(I) = 0.0
   30 CONTINUE
      ARECP = 0.0
      BARE = 0.0
      SARSC = 0.0
C
C READ COMPARTMENT DATA FROM CARD TYPES 12, 13, AND 14.
C LOGICAL UNIT 3 HOLDS THE TAPE WITH MAPS IF TAPE IS USED.
C
      READ (3,35) KBK,KOMP,NROW
   35 FORMAT (3I4)
      READ (3,40) ((KTYP(I,J),J=1,36),I=1,NROW)
   40 FORMAT (36I2)
      READ (3,40) ((KSUB(I,J),J=1,36),I=1,NROW)
C
C COMPUTE TYPE AREAS AND TOTAL AREA.
C
      DO 50 I=1,NROW
      DO 45 J=1,36
      IF(KTYP(I,J) .LE. 0) GO TO 45
      MNK = KTYP(I,J)
      CVR(MNK) = CVR(MNK) + 1.0
   45 CONTINUE
   50 CONTINUE
      DO 55 I=1,35
      ARETY(I) = CVR(I) * SCALE
      SARETY(KBK,I) = SARETY(KBK,I) + ARETY(I)
      ARECP = ARECP + ARETY(I)
   55 CONTINUE
C
C COMPUTE AREA OF EACH WORKING GROUP AND DEFORESTED AREA.
C
      M = 1
      N = 5
      DO 65 I=1,NWGP
      DO 60 J=M,N
      GRUP(I) = GRUP(I) + ARETY(J)
   60 CONTINUE
      M = M + 5
      N = N + 5
   65 CONTINUE
      BARE = ARETY(26) + ARETY(27)
      ACBAR(KBK) = ACBAR(KBK) + BARE
      DO 70 I=1,NWGP
      ACSP(I,KBK) = ACSP(I,KBK) + GRUP(I)
   70 CONTINUE
      ARBK(KBK) = ARBK(KBK) + ARECP
C
C COMPUTE SUBCOMPARTMENT AREAS AND TYPES.
C
      DO 75 I=1,NWGP
      IF(GRUP(I) .GT. 0.0) GO TO 80
   75 CONTINUE
      IF(BARE .GT. 0.0) GO TO 80
      MNK = 0
      GO TO 150
   80 DO 90 I=1,NROW
      DO 85 J=1,36
      IF(KSUB(I,J) .LE. 0) GO TO 85
      NOS = KSUB(I,J)
      UNIT(NOS) = UNIT(NOS) + 1.0
      IF(SUBTY(NOS) .NE. 0.0) GO TO 85
      SUBTY(NOS) = KTYP(I,J)
   85 CONTINUE
   90 CONTINUE
      DO 95 I=1,30
      ARESC(I) = UNIT(I) * SCALE
      SARSC = SARSC + ARESC(I)
   95 CONTINUE
C
C COUNT NUMBER OF SUBCOMPARTMENTS IN A BLOCK.
C COMPUTE INDEX FOR PRINTING SUBCOMPARTMENT AREAS.
C
      DO 100 I=1,30
      MNK = I
      IF(ARESC(I) .EQ. 0.0) GO TO 105
  100 CONTINUE
  105 NSBK(KBK) = NSBK(KBK) + MNK - 1
      IF(ARESC(30) .GT. 0.0) NSBK(KBK) = NSBK(KBK) + 1.0
      TEM = MNK
      MNK = TEM * 0.9
C
C PRINT TYPE AND SUBCOMPARTMENT MAPS, IF DESIRED.
C
  150 IF(MAP .EQ. 0) GO TO 450
C
C CONVERT MAP CODES TO DISPLAY CODE AND RIGHT JUSTIFY. OCTAL CODE WILL
C VARY WITH MODEL OF COMPUTER.
C
      DO 175 I=1,36
      DO 175 J=1,36
      IF(KTYP(I,J) .LT. 1) GO TO 160
      IF(KTYP(I,J) .LE. 9) GO TO 165
      N = 0
  155 N = N + 1
      KTYP(I,J) = KTYP(I,J) - 10
      IF(KTYP(I,J) .GT. 9) GO TO 155
      GO TO 170
  160 KTYP(I,J) = 5555B
      GO TO 175
  165 KTYP(I,J) = KTYP(I,J) + 2907
      GO TO 175
  170 KTYP(I,J) = KTYP(I,J) + 27
      KTYP(I,J) = KTYP(I,J) + (N * 64 + 1728)
  175 CONTINUE
      DO 200 I=1,36
      DO 200 J=1,36
      IF(KSUB(I,J) .LT. 1) GO TO 185
      IF(KSUB(I,J) .LE. 9) GO TO 190
      N = 0
  180 N = N + 1
      KSUB(I,J) = KSUB(I,J) - 10
      IF(KSUB(I,J) .GT. 9) GO TO 180
      GO TO 195
  185 KSUB(I,J) = 5555B
      GO TO 200
  190 KSUB(I,J) = KSUB(I,J) + 2907
      GO TO 200
  195 KSUB(I,J) = KSUB(I,J) + 27
      KSUB(I,J) = KSUB(I,J) + (N * 64 + 1728)
  200 CONTINUE
C
C PRINT PAGE TYPE 5 - TYPE AND SUBCOMPARTMENT MAPS AND AREAS.
C
C PRINT TYPE MAP AND TYPE AREAS.
C
      WRITE (6,250)
  250 FORMAT (1H1,/,62X,11HPAGE TYPE 5)
      WRITE (6,255) (FORET(I),I=1,19)
  255 FORMAT (1H ,30X,18A4,A2)
      WRITE (6,260) KOMP,KBK
  260 FORMAT (1H ,49X,27HTYPE MAP OF COMPARTMENT NO.,I4,25X,9HBLOCK NO.,
     1I2,/)
      DO 270 I=1,NROW
      WRITE (6,265) (KTYP(I,J),J=1,36)
  265 FORMAT (1H ,28X,36R2)
  270 CONTINUE
      WRITE (6,275)
  275 FORMAT (1H0,17X,10HCOVER TYPE,13X,5HACRES,4X,1H*,6X,10HCOVER TYPE,
     113X,5HACRES,4X,1H*,6X,10HCOVER TYPE,13X,5HACRES,/)
      DO 285 I=1,10
      J = I + 15
      N = I + 25
      WRITE (6,280) I,(TYPNM(I,K),K=1,5),ARETY(I),J,(TYPNM(J,K),K=1,5),
     1ARETY(J),N,(TYPNM(N,K),K=1,5),ARETY(N)
  280 FORMAT (1H ,15X,I2,2X,5A2,4X,F12.1,4X,1H*,4X,I2,2X,5A2,4X,F12.1,
     14X,1H*,4X,I2,2X,5A2,4X,F12.1)
  285 CONTINUE
      DO 295 I=11,15
      WRITE (6,290) I,(TYPNM(I,K),K=1,5),ARETY(I)
  290 FORMAT (1H ,15X,I2,2X,5A2,4X,F12.1,4X,1H*)
  295 CONTINUE
      WRITE (6,300) ARECP
  300 FORMAT (1H0,39X,10HTOTAL AREA,2X,F12.1)
      WRITE (6,305)
  305 FORMAT (1H0,39X,57H**************** ACRES BY WORKING GROUPS *****
     1***********)
      WRITE (6,310) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  310 FORMAT (1H0,34X,5(3A4,3X))
      WRITE (6,315) (GRUP(I),I=1,NWGP)
  315 FORMAT (1H ,31X,5(F12.1,3X))
      WRITE (6,320) BARE
  320 FORMAT (1H0,5X,19HDEFORESTED ACRES -,F12.1)
C
C PRINT SUBCOMPARTMENT MAPS AND RELATED DATA.
C
      IF(MNK .EQ. 0) GO TO 500
      WRITE (6,250)
      WRITE (6,350) (FORET(I),I=1,19)
  350 FORMAT (1H ,16X,18A4,A2)
      WRITE (6,355) KOMP,KBK
  355 FORMAT (1H ,45X,37HSUBCOMPARTMENT MAP OF COMPARTMENT NO.,I4,20X,9H
     1BLOCK NO.,I2,/)
```

```
      DO 360 I=1,NROW
      WRITE (6,265) (KSUB(I,J),J=1,36)
  360 CONTINUE
      WRITE (6,365)
  365 FORMAT (1H0,16X,8HSUBCOMP.,6X,10HCOVER TYPE,10X,5HACRES,4X,1H*,4X,
     18HSUBCOMP.,6X,10HCOVER TYPE,10X,5HACRES,/)
      DO 385 I=1,MNK
      J = I + MNK
      MOL = SUBTY(I)
      JAM = SUBTY(J)
      IF(MOL .EQ. 0) GO TO 390
      IF(JAM .EQ. 0) GO TO 375
      WRITE (6,370) I,SUBTY(I),(TYPNM(MOL,K),K=1,5),ARESC(I),J,SUBTY(J),
     1(TYPNM(JAM,K),K=1,5),ARESC(J)
  370 FORMAT (1H ,19X,I2,6X,F3.0,2X,5A2,4X,F9.1,4X,1H*,7X,I2,6X,F3.0,2X,
     15A2,4X,F9.1)
      GO TO 385
  375 WRITE (6,380) I,SUBTY(I),(TYPNM(MOL,K),K=1,5),ARESC(I)
  380 FORMAT (1H ,19X,I2,6X,F3.0,2X,5A2,4X,F9.1,4X,1H*)
  385 CONTINUE
  390 WRITE (6,395) SARSC
  395 FORMAT (1H0,82X,10HTOTAL AREA,2X,F9.1)
      WRITE (6,305)
      WRITE (6,405) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  405 FORMAT (1H0,34X,5(3A4,3X))
      WRITE (6,410) (GRUP(I),I=1,NWGP)
  410 FORMAT (1H ,31X,5(F12.1,3X))
      WRITE (6,415) BARE
  415 FORMAT (1H0,5X,18HDEFORESTED ACRES -,F12.1)
      GO TO 500
C
C PRINT PAGE TYPE 5 - AREAS ONLY IF MAPS NOT DESIRED.
C
  450 WRITE (6,250)
      WRITE (6,255) (FORET(I),I=1,19)
      WRITE (6,460) KOMP,KBK
  460 FORMAT (1H ,48X,29HTYPE AREAS OF COMPARTMENT NO.,I4,24X,9HBLOCK NO
     1.,I2)
      WRITE (6,275)
      DO 465 I=1,10
      J = I + 15
      N = I + 25
      WRITE (6,280) I,(TYPNM(I,K),K=1,5),ARETY(I),J,(TYPNM(J,K),K=1,5),
     1ARETY(J),N,(TYPNM(N,K),K=1,5),ARETY(N)
  465 CONTINUE
      DO 468 I=11,15
      WRITE (6,290) I,(TYPNM(I,K),K=1,5),ARETY(I)
  468 CONTINUE
      WRITE (6,300) ARECP
      IF(MNK .EQ. 0) GO TO 500
      WRITE (6,470) (FORET(I),I=1,19)
  470 FORMAT (1H0,//,16X,18A4,A2)
      WRITE (6,475) KOMP,KBK
  475 FORMAT (1H ,27X,34HSUBCOMPARTMENTS OF COMPARTMENT NO.,I4,21X,9HBLO
     1CK NO.,I2)
      WRITE (6,365)
      DO 485 I=1,MNK
      J = I + MNK
      MOL = SUBTY(I)
      JAM = SUBTY(J)
      IF(MOL .EQ. 0) GO TO 490
      IF(JAM .EQ. 0) GO TO 480
      WRITE (6,370) I,SUBTY(I),(TYPNM(MOL,K),K=1,5),ARESC(I),J,SUBTY(J),
     1(TYPNM(JAM,K),K=1,5),ARESC(J)
      GO TO 485
  480 WRITE (6,380) I,SJBTY(I),(TYPNM(MOL,K),K=1,5),ARESC(I)
  485 CONTINUE
  490 WRITE (6,395) SARSC
      WRITE (6,305)
      WRITE (6,310) ((WGPNM(I,J),J=1,3),I=1,NWGP)
      WRITE (6,315) (GRUP(I),I=1,NWGP)
      WRITE (6,320) BARE
C
C WHEN STAND AREAS ARE KNOWN AND INVENTORY DATA REFER TO THE STAND,
C VALUES OF ARESC(I), KBK, AND KOMP MAY BE EXTRACTED AT THIS POINT FOR
C MACHINE ADDITION OF ARESC(I) TO APPROPRIATE INVENTORY RECORDS.
C
  500 CONTINUE
C
C GET WORKING CIRCLE TOTALS FROM BLOCK TOTALS.
C
      DO 550 I=1,NBK
      DO 550 J=1,35
  550 STYP(J) = STYP(J) + SARETY(I,J)
      DO 555 I=1,NBK
      SBARB = SBARB + SARETY(I,26)
      SBARG = SBARG + SARETY(I,27)
      SLAND = SLAND + ARBK(I)
      NSUB = NSUB + NSBK(I)
      DO 555 J=1,NWGP
  555 SMSP(J) = SMSP(J) + ACSP(J,I)
      SBARE = SBARB + SBARG
      DO 558 I=1,NBK
      TEM = 0.0
      DO 556 J=28,35
  556 TEM = TEM + SARETY(I,J)
  558 TMPO = TMPO + ARBK(I) - TEM
C
C PRINT PAGE TYPE 6 - SUMMARY OF BLOCK AND WORKING CIRCLE AREAS.
C
      WRITE (6,560)
  560 FORMAT (1H1,////,59X,11HPAGE TYPE 6)
      WRITE (6,565)
  565 FORMAT (1H0,44X,40HTOTAL AREAS OF BLOCKS AND WORKING CIRCLE)
      WRITE (6,255) (FORET(I),I=1,19)
      WRITE (6,570)
  570 FORMAT (1H0,//,2X,5HBLOCK,5X,5HTOTAL,5X,6HNUMBER,6X,31H* PLANTABLE
     1 ACRES FOREST SOIL *,7X,60H******** FOREST AND REGENERATING BY WOR
     2KING GROUPS ********)
      WRITE (6,575) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  575 FORMAT (1H ,2X,3HNO.,6X,5HACRES,4X,8HSUBCOMPT,6X,6HBRUSHY,6X,
     16HGRASSY,7X,5HTOTAL,5X,5(3A4,1X))
      WRITE (6,580)
  580 FORMAT (1H0)
      DO 590 I=1,NBK
      WRITE (6,585) I,ARBK(I),NSBK(I),SARETY(I,26),SARETY(I,27),
     1ACBAR(I),(ACSP(K,I),K=1,NWGP)
  585 FORMAT (1H0,2X,I2,3X,F10.1,4X,I5,4X,F10.1,2X,F10.1,2X,F10.1,2X,
     15(3X,F10.1))
  590 CONTINUE
      WRITE (6,595) SLAND,NSUB,SBARB,SBARG,SBARE,(SMSP(I),I=1,NWGP)
  595 FORMAT (1H0,//,3X,5HTOTAL,F10.1,4X,I5,4X,F10.1,2X,F10.1,2X,
     1F10.1,5X,5(F10.1,3X))
      RETURN
      END
```

Subroutine AREA1

```
      SUBROUTINE AREA1
C
C TO COMPUTE AREAS FOR WORKING CIRCLE FROM TOTAL AREA OF EACH TYPE IN
C EACH COMPARTMENT.
C
      COMMON AOD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BEMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,POBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMA1(5),BFAGE(5,15)
     2,BFINT(5),CEAGE(5,15),CEBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBO(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RIN1(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPOES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLTI
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACS1(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      DIMENSION ARETY(35),GRUP(5)
C
      DO 5 I=1,NBK
      DO 5 J=1,35
    5 SARETY(I,J) = 0.0
      KOUNT = 0
      DO 155 KOL=1,NCMP
C
C INITIALIZE VARIABLES APPLICABLE TO A COMPARTMENT.
C
      ARECP = 0.0
      BARE = 0.0
      DO 10 I=1,NWGP
   10 GRUP(I) = 0.0
C
C READ AREA OF EACH TYPE, ONE COMPARTMENT AT A TIME.
C DATA CARD TYPES 15 AND 16.
C
      READ (5,15) KBK,KOMP
   15 FORMAT (2I4)
      READ (5,20) (ARETY(I),I=1,35)
   20 FORMAT (10F8.1)
C
C SUM AREAS OF TYPES TO GET COMPARTMENT AND BLOCK TOTALS.
C
      DO 25 I=1,35
      SARETY(KBK,I) = SARETY(KBK,I) + ARETY(I)
      ARECP = ARECP + ARETY(I)
   25 CONTINUE
      M=1
      N=5
      DO 35 I=1,NWGP
      DO 30 J=M,N
      GRUP(I) = GRUP(I) + ARETY(J)
   30 CONTINUE
      M = M + 5
      N = N + 5
   35 CONTINUE
      BARE = ARETY(26) + ARETY(27)
      ACBAR(KBK) = ACBAR(KBK) + BARE
      DO 40 I=1,NWGP
   40 ACSP(I,KPK) = ACSP(I,KPK) + GRUP(I)
      ARBK(KBK) = ARBK(KBK) + ARECP
C
C PRINT PAGE TYPF 5 - AREAS OF TYPES AND WORKING GROUPS BY COMPARTMENT.
C KOUNT CONTROLS PRINTER TO GET 2 COMPARTMENTS PER PAGE.
C
      KOUNT = KOUNT + 1
      IF(KOUNT .GT. 1) GO TO 85
      WRITE (6,70)
   70 FORMAT (1H1,  62X,11HPAGE TYPE 5)
      WRITE (6,75) (FORET(I),I=1,19)
   75 FORMAT (1H0,30X,18A4,A2)
      WRITE (6,80) KOMP,KBK
   80 FORMAT (1H0,48X,29HTYPE AREAS OF COMPARTMENT NO.,I4,24X,9HBLOCK NO
     1.,I2)
      GO TO 100
   85 WRITE (6,75) (FORET(I),I=1,19)
      WRITE (6,95) KOMP,KBK
   95 FORMAT (1H0,/,49X,29HTYPE AREAS OF COMPARTMENT NO.,I4,24X, 9HBLOCK
     1 NO.,I2)
  100 WRITE (6,105)
```

```
  105 FORMAT (1HO,17X,10HCOVER TYPE,13X,5HACRES,4X,1H*,6X,10HCOVER TYPE
     1,13X,5HACRES,4X,1H*,6X,10HCOVER TYPE,13X,5HACRES,/)
      DO 115 I=1,10
      J = I + 15
      N = I + 25
      WRITE (6,110) I,(TYPNM(I,K),K=1,5),ARETY(I),J,(TYPNM(J,K),K=1,5),A
     1RETY(J),N,(TYPNM(N,K),K=1,5),ARETY(N)
  110 FORMAT (1H ,15X,I2,2X,5A2,4X,F12.1,4X,1H*,4X,I2,2X,5A2,4X,F12.1,
     14X,1H*,4X,I2,2X,5A2,4X,F12.1)
  115 CONTINUE
      DO 125 I=11,15
      WRITE (6,120) I,(TYPNM(I,K),K=1,5),ARETY(I)
  120 FORMAT (1H ,15X,I2,2X,5A2,4X,F12.1,4X,1H*)
  125 CONTINUE
      WRITE (6,130) ARECP
  130 FORMAT (1H ,102X,10HTOTAL AREA,2X,F9.1)
      WRITE (6,135)
  135 FORMAT (1HO,39X,57H***************  ACRES BY WORKING GROUPS  *****
     1**********)
      WRITE (6,140) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  140 FORMAT (1HO,34X,5(3A4,3X))
      WRITE (6,145) (GRUP(I),I=1,NWGP)
  145 FORMAT (1H ,31X,5(F12.1,3X))
      WRITE (6,150) BARE
  150 FORMAT (1HO,5X,18HOEFOPESTED ACRES -,F12.1)
      IF(KOUNT .EQ. 2) KOUNT = 0
  155 CONTINUE
C
C GET WORKING CIRCLE TOTALS FROM BLOCK TOTALS.
C
      DO 200 I=1,NBK
      DO 200 J=1,35
  200 STYP(J) = STYP(J) + SARETY(I,J)
      DO 205 I=1,NBK
      SBARB = SBARB + SARETY(I,26)
      SBARG = SBARG + SARETY(I,27)
      SLAND = SLAND + ARBK(I)
      DO 205 J=1,NWGP
      SMSP(J) = SMSP(JI + ACSP(J,I)
  205 CONTINUE
      SBARE = SBARB + SBARG
      DO 215 I=1,NBK
      TEM = 0.0
      DO 210 J=28,35
  210 TEM = TEM + SARETY(I,J)
  215 TMPO = TMPO + ARBK(I) - TEM
C
C PRINT PAGE TYPE 6 - SUMMARY OF AREAS BY BLOCK AND WORKING CIRCLE.
C
      WRITE (6,240)
  240 FORMAT (1H1,////,59X,11HPAGE TYPE 6)
      WRITE (6,245)
  245 FORMAT (1HO,44X,40HTOTAL AREAS OF BLOCKS AND WORKING CIRCLE)
      WRITE (6,250) (FORET(I),I=1,19)
  250 FORMAT (1HO,29X,18A4,A2)
      WRITE (6,255)
  255 FORMAT (1HO,//,2X,5HBLOCK,8X,5HTOTAL,11X,31H* PLANTABLE ACRES FORE
     1ST SOIL *,10X,60H********* FOREST AND REGENERATING BY WORKING GROUP
     2S *********)
      WRITE (6,260) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  260 FORMAT (1H ,2X,3HNO.,9X,5HACRES,12X,6HBRUSHY,6X,6HGRASSY,7X,
     15HTOTAL,8X,5(3A4,1X))
      DO 275 I=1,NBK
      WRITE (6,265)
  265 FORMAT (1HO)
      WRITE (6,270) I,ARBK(I),SARETY(I,26),SARETY(I,27),ACBAR(I),(ACSP(K
     1,I),K=1,NWGP)
  270 FORMAT (1HO,2X,I2,6X,F10.1,7X,F10.1,2X,F10.1,2X,F10.1,5X,5(3X,F10.
     11))
  275 CONTINUE
      WRITE (6,280) SLAND,SBARB,SBARG,SBARE,(SMSP(I),I=1,NWGP)
  280 FORMAT (1HO,//,3X,5HTOTAL,3X,F10.1,7X,F10.1,2X,F10.1,2X,F10.1,
     18X,5(F10.1,3X))
      RETURN
      END
```

Subroutine AREA2

```
      SUBROUTINE AREA2
C
C TO COMPUTE TYPE AREAS WHEN COMPARTMENT AREAS ARE NOT KNOWN.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASD,BAST,BAJS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHF,DBHO,DPHT,DEN(2),DEND,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOT1,TOTT,TVL(2),VDM(2),VLJS,DMP(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),ENBD(5),
     4ENCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SAPSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPOES(5,20),WGPNM(5,3),SPNUM(5),TPR(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFP(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      DIMENSION SPL(7)
C
C INITIALIZE VARIABLES DEFINED BY THIS SUBROUTINE.
C
      DO 5 I=1,NBK
      SPL(I) = 0.0
    5 CONTINUE
      TMPO = 0.0
C
C READ AREAS OF BLOCKS AND OF NON-TIMBER TYPES.
C DATA CARD TYPES 17 AND 18.
C
      READ (5,10) (ARBK(I),I=1,NBK)
   10 FORMAT (7F8.1)
      DO 20 I=1,NBK
      READ (5,15) (SARETY(I,J),J=28,35)
   15 FORMAT (8F8.1)
   20 CONTINUE
C
C COMPUTE TOTAL AREAS OCCUPIED BY TIMBER TYPES.
C
      DO 30 I=1,NBK
      TEM = 0.0
      DO 25 J=28,35
   25 TEM = TEM + SARETY(I,J)
      TMTY(I) = ARBK(I) - TEM - TMTY(I)
   30 TMPO = TMPO + ARBK(I) - TEM
C
C TOTAL PLOTS BY BLOCK.
C
      DO 35 I=1,NBK
      DO 35 J=1,27
   35 SPL(I) = SPL(I) + PSPLT(I,J)
C
C COMPUTE TYPE AREAS WITHIN EACH BLOCK.
C
      DO 45 I=1,NBK
      IF(SPL(I) .EQ. 0.0) GO TO 45
      TEM = TMTY(I) / SPL(I)
      DO 40 J=1,27
      SARETY(I,J) = SARETY(I,J) + (PSPLT(I,J) * TEM)
   40 CONTINUE
   45 CONTINUE
C
C SUM TYPE AREAS TO GET BLOCK AND WORKING CIRCLE TOTALS.
C
      DO 50 I=1,NBK
      DO 50 J=1,35
      STYP(J) = STYP(J) + SARETY(I,J)
   50 CONTINUE
      DO 55 I=1,NBK
      SBARB = SBARB + SARETY(I,26)
      SBARG = SBARG + SARETY(I,27)
      ACBAR(I) = ACBAR(I) + SARETY(I,26) + SARETY(I,27)
   55 CONTINUE
      DO 65 I=1,NBK
      M = 1
      N = 5
      DO 65 J=1,NWGP
      DO 60 K=M,N
   60 ACSP(J,I) = ACSP(J,I) + SARETY(I,K)
      M = M + 5
      N = N + 5
   65 CONTINUE
      SBARE = SBARB + SBARG
      DO 70 I=1,NBK
      SLAND = SLAND + ARBK(I)
      DO 70 J=1,NWGP
      SMSP(J) = SMSP(JI + ACSP(J,I)
   70 CONTINUE
C
C WRITE PAGE TYPE 5 - AREAS OF TYPES AND WORKING GROUPS.
C
      WRITE (6,75)
   75 FORMAT (1H1,////,59X,11HPAGE TYPE 5I
      WRITE (6,80) (FORET(I),I=1,19)
   80 FORMAT (1HO,48X,32HAREAS OF TYPES IN WORKING CIRCLE/1H ,27X,18A4,A
     12,/1HO,17X,10HCOVER TYPE,11X,5HACRES,6X,1H*,6X,10HCOVER TYPE,11X,5
     2HACRES,6X,1H*,6X,10HCOVER TYPE,11X,5HACRES,/)
      DO 90 I=1,10
      J = I + 15
      N = I + 25
      WRITE (6,85) I,(TYPNM(I,K),K=1,5),STYP(I),J,(TYPNM(J,K),K=1,5),
     1STYP(J),N,(TYPNM(N,K),K=1,5),STYP(N)
   85 FORMAT (1HO,15X,I2,2X,5A2,4X,F12.1,4X,1H*,4X,I2,2X,5A2,4X,F12.1,
     14X,1H*,4X,I2,2X,5A2,4X,F12.1)
   90 CONTINUE
      DO 100 I=11,15
      WRITE (6,95) I,(TYPNM(I,K),K=1,5),STYP(I)
   95 FORMAT (1HO,15X,I2,2X,5A2,4X,F12.1,4X,1H*)
  100 CONTINUE
      WRITE (6,110I SLAND
  110 FORMAT (1HO,99X,10HTOTAL AREA,2X,F12.1)
      WRITE (6,120)
  120 FORMAT (1HO,//,39X,57H***************  ACRES BY WORKING GROUPS  **
     1*************)
      WRITE (6,130I ((WGPNM(I,J),J=1,3),I=1,NWGP)
  130 FORMAT (1HO,34X,5(3A4,3X))
      WRITE (6,140) (SMSP(II,I=1,NWGP)
  140 FORMAT (1H ,31X,5(F12.1,3X))
      WRITE (6,150) SBARE
  150 FORMAT (1HO,/,/,/,5X,18HDEFORESTED ACRES -,F12.1)
C
C PRINT PAGE TYPE 6 - SUMMARY OF AREAS BY BLOCK AND WORKING CIRCLE.
C
      WRITE (6,200)
  200 FORMAT (1H1,////,59X,11HPAGE TYPE 6)
      WRITE (6,205)
  205 FORMAT (1HO,44X,40HTOTAL AREAS OF BLOCKS AND WORKING CIRCLEI
      WRITE (6,210) (FOPET(I),I=1,19)
  210 FORMAT (1H ,27X,18A4,A2)
      WRITE (6,215)
```

```
215 FORMAT (1H0,//,2X,5HBLOCK,8X,5HTOTAL,11X,31H* PLANTABLE ACRES FOR E
   1ST SOIL *,10X,60H******** FOREST AND REGENERATING BY WORKING GROUP
   2S ********)
    WRITE (6,220) ((WGPNM(I,J),J=1,3),I=1,NWGP)
220 FORMAT (1H ,2X,3HNO.,9X,5HACRES,11X,6HBRUSHY,6X,6HGRASSY,7X,5HTOTA
   1L,9X,5(3A4,1X))
    DO 235 I=1,NBK
    WRITE (6,225)
225 FORMAT (1H0)
    WRITE (6,230) I,ARBK(I),SARETY(I,26),SARETY(I,27),ACBAR(I),IACSP(K
   1,I),K=1,NWGP)
230 FORMAT (1H0,2X,I2,6X,F10.1,7X,F10.1,2X,F10.1,2X,F10.1,8X,F10.1,3X,
   1F10.1,3X,F10.1,3X,F10.1,3X,F10.1)
235 CONTINUE
    WRITE (6,240) SLANO,SBARB,SBARG,SBARE,(SMSP(I),I=1,NWGP)
240 FORMAT (1H0,//,3X,5HTOTAL,3X,F10.1,7X,F10.1,2X,F10.1,2X,F10.1,
   18X,5(F10.1,3X))
    RETURN
    END
```

Subroutine LAND

```
      SUBROUTINE LAND
C
C  TO COMPUTE AREAS OF VARIOUS SUBDIVISIONS OF THE WORKING CIRCLE.
C
      COMMON AOD,AGE(2),AGEO,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DEND,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KND,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLANO,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTD,TOTT,TVL(2),VOM(2),VLUS,OMR(2)
      COMMON ABFAG(5,15),ACINT(5),AOJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5,14),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5,14),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
C  COMPUTE AREAS NOT IN SUBCOMPARTMENTS OF KNOWN AREA.
C
      DO 5 I=1,NWGP
      DO 5 J=1,NBK
    5 PASP(I,J) = ACSP(I,J) - PASP(I,J)
      DO 10 I=1,NBK
      DO 10 J=1,35
   10 PARTY(I,J) = SARETY(I,J) - PARTY(I,J)
      DO 15 I=1,NBK
      DO 15 J=1,25
   15 TMBR = SARETY(I,J) + TMBR
      DO 20 I=1,NBK
   20 PABR(I) = PARTY(I,26) + PARTY(I,27)
C
C  SUM ACRES BY WORKING GROUP, BLOCK, AND SITE CLASS.
C
      DO 30 I=1,NBK
      TEM = PSPLT(I,26) + PSPLT(I,27)
      IF(TEM .EQ. 0.0) GO TO 30
      DO 25 J=1,14
      PBRSI(I,J) = PBRSI(I,J) * (PABR(I) / TEM)
   25 CONTINUE
   30 CONTINUE
      DO 35 I=1,NBK
      DO 35 J=1,14
   35 BARSI(I,J) = BARSI(I,J) + PBRSI(I,J)
      M = 1
      N = 5
      DO 45 I=1,NWGP
      DO 40 J=1,NBK
      DO 40 K=M,N
   40 TPB(I,J) = TPB(I,J) + PSPLT(J,K)
      M = M + 5
      N = N + 5
   45 CONTINUE
C
C  COMPUTE AREAS BY WORKING GROUP, BLOCK, AND SITE CLASS.
C
      IF(TMBR .EQ. 0.0) GO TO 90
      DO 50 K=1,NWGP
      DO 50 I=1,NBK
      DO 50 J=1,14
      IF(TPB(K,I) .EQ. 0.0) GO TO 50
      PASI(K,I,J) = PASP(K,I) * PS(K,I,J) / TPB(K,I)
   50 CONTINUE
      DO 55 I=1,NWGP
      DO 55 J=1,NBK
      DO 55 K=1,14
   55 ACSI(I,J,K) = ACSI(I,J,K) + PASI(I,J,K)
C
C  PRINT PAGE TYPE 7 - AREAS BY SITE INDEX CLASS.
C
   90 WRITE (6,100)
  100 FORMAT (1H1,////,60X,11HPAGE TYPE 7)
      WRITE (6,105)
  105 FORMAT (1H0,/,46X,40HDISTRIBUTION OF AREA BY SITE INDEX CLASS)
      WRITE (6,110) (FORET(I), I=1,19)
  110 FORMAT (1H ,28X,18A4,A2)
      WRITE (6,115) ((WGPNM(I,J),J=1,3),I=1,NWGP)
  115 FORMAT (1H0,//,5X,5HBLOCK,10X,10HSITE INDEX,6X,16HDEFORESTED ACRES
     1,2X,5(3X,3A4))
      WRITE (6,120)
  120 FORMAT (1H0)
      KOUNT = 1
      DO 155 I=1,NBK
      IF(ARBK(I) .EQ. 0.0) GO TO 155
      KOUNT = KOUNT + 1
      IF(KOUNT .EQ. 4) GO TO 125
      GO TO 135
  125 WRITE (6,130)
  130 FORMAT (1H1,//,56X,18HPAGE TYPE 7, CONT.,//)
      WRITE (6,115) ((WGPNM(K,J),J=1,3),K=1,NWGP)
      WRITE (6,120)
  135 DO 150 J=1,14
      MNK = J * 10
      WRITE (6,140) I,MNK,BARSI(I,J),(ACSI(K,I,J),K=1,NWGP)
  140 FORMAT (1H ,6X,I2,16X,I3,10X,F10.1,2X,5(5X,F10.1))
      IF(MNK .LT. 140) GO TO 150
      WRITE (6,120)
  150 CONTINUE
  155 CONTINUE
      WRITE (6,160) SBARE,(SMSP(I),I=1,NWGP)
  160 FORMAT (1H0,//,10X,5HTOTAL,21X,F12.1,2X,5(3X,F12.1))
C
C  ASSIGN PART OF DEFORESTED AREA TO EACH WORKING GROUP.
C
      DO 215 I=1,NBK
      TEM = 0.0
      DO 200 J=1,NWGP
  200 TEM = ACSP(J,I) + TEM
      IF(TEM .EQ. 0.0) GO TO 215
      DO 210 K=1,NWGP
      FF = ACSP(K,I) / TEM
      DO 205 J=1,14
      ACSI(K,I,J) = ACSI(K,I,J) + BARSI(I,J) * FF
  205 CONTINUE
  210 CONTINUE
  215 CONTINUE
      DO 220 I=1,NWGP
      DO 220 J=1,NBK
      DO 220 K=1,14
  220 SARSP(I) = SARSP(I) + ACSI(I,J,K)
      DO 225 KAK=1,NWGP
      DO 225 I=1,NBK
      DO 225 J=1,14
  225 AREA(KAK,J) = AREA(KAK,J) + ACSI(KAK,I,J)
      RETURN
      END
```

Subroutine GOAL

```
      SUBROUTINE GOAL
C
C  TO COMPUTE GROWING STOCK NEEDED TO MEET MANAGEMENT OBJECTIVES.
C
      COMMON AOD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DEND,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KND,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLANO,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTD,TOTT,TVL(2),VOM(2),VLUS,OMR(2)
      COMMON ABFAG(5,15),ACINT(5),AOJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5,14),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5,14),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKA/ ANBOF(151),ANCUV(151),BDFC(150),BOFO(150),CFMC(150),
     1CFMO(150),CYCL,IROT,KAN,PO1,PO2,QUAL(14),ROTA,VLBF(14),VLCU(14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      DIMENSION BFS(15),CMS(15),EQIV(14),EQVCF(14),FACCF(14),FAC(14),
     1POCUT(16),STACF(14),STOAC(14)
C
      DO 600 KAK=1,NWGP
C
C  ZERO VARIABLES COMMON TO ALL SITES.
C
      CYCL = 0.0
      SACCF = 0.0
      SSTAC = 0.0
      DO 40 I=1,14
      EQIV(I) = 0.0
      EQVCF(I) = 0.0
      FACCF(I) = 0.0
      FAC(I) = 0.0
      QUAL(I) = 0.0
      STACF(I) = 0.0
      STOAC(I) = 0.0
      VLBF(I) = 0.0
   40 VLCU(I) = 0.0
      STOR = DLEV(KAK)
C
C  COMPUTE LOOP INDEXES FOR NUMBER OF SITE CLASSES INCLUDED IN GOALS.
C
      SITE = POOR(KAK)
      KSI = POOR(KAK) * 0.1
      KND = KSI + NSI(KAK) - 1
      IF(KND .GT. 14) KND = 14
C
```

```
C ENTER FOLLOWING LOOP ONCE FOR EACH SITE CLASS OF A WORKING GROUP.
C
      DO 400 KAN=KSI,KND
      PO1 = INVL(KAK,1,KAN)
      PO2 = INVL(KAK,2,KAN)
      QUAL(KAN) = SITE
      AGEO = AGETH(KAK,KAN)
      DBHO = DBHTH(KAK,KAN)
      DENO = DENTH(KAK,KAN)
C
C DETERMINE OLDEST AGE TO BE REPRESENTED IN YIELD TABLE.
C
      DO 45 NA=1,3
      L = 4 - NA
      IF(REGN(KAK,L,KAN) .EQ. 0.0) GO TO 45
      ROTA = REGN(KAK,L,KAN)
      GO TO 50
   45 CONTINUE
   50 IF(AGEO .EQ. 0.0 .OR. AGEO .GT. ROTA) GO TO 405
      IF(AREA(KAK,KAN) .EQ. 0.0) GO TO 390
C
C INITIALIZE VARIABLES RECOMPUTED FOR EACH SITE CLASS.
C
      ACTEM = 0.0
      BDAI = 0.0
      BFTEM = 0.0
      CFAI = 0.0
      CFTEM = 0.0
      DO 55 I=1,15
      BFS(I) = 0.0
   55 CMS(I) = 0.0
      DO 60 I=1,16
   60 POCUT(I) = 0.0
      CYCL = CUCY(KAK)
C
C COMPUTE YIELD TABLE FOR EACH SITE CLASS OF EACH WORKING GROUP.
C
      CALL YIELD
C
C PRINT PAGE TYPE 9 - ANNUAL VOLUMES PER ACRE.
C
C WRITE TABLE HEADINGS.
C
      QLEV(KAK) = STDR
      WRITE (6,100)
  100 FORMAT (1H1,//,61X,11HPAGE TYPE 9)
      WRITE (6,105) QUAL(KAN),CUCY(KAK),THIN(KAK),QLEV(KAK)
  105 FORMAT (1H0,41X,53HGROWING STOCK OF MANAGED, REGULATED, EVEN-AGED
     1STANDS/1H ,47X,10HSITE INDEX,F5.0,1H,,F5.0,19H-YEAR CUTTING CYCLE/
     21H ,53X,14HDENSITY LEVEL-,F5.0,1X,3HAND,F5.0)
      WRITE (6,110) (WGPNM(KAK,J),J=1,3)
  110 FORMAT (1H0,53X,16HWORKING GROUP - ,3A4,/)
      WRITE (6,115)
  115 FORMAT (1H0,43X,44HVOLUMES PRESENT PER ACRE AT END OF EACH YEAR,/)
      WRITE (6,120)
  120 FORMAT (1H0,54X,23HMERCHANTABLE CUBIC FEET/1H0,64X,4HYEAR/1H ,14X,
     16HDECADE,9X,1H0,9X,1H1,9X,1H2,9X,1H3,9X,1H4,9X,1H5,9X,1H6,9X,1H7,9
     2X,1H8,9X,1H9,//)
C
C WRITE CUBIC FEET PER ACRE FOR EACH YEAR.
C
      K = 0
      WRITE (6,125) K,(ANCUV(NN),NN=1,10)
  125 FORMAT (1H ,I20,F13.1,9F10.1)
      MNK = ROTA * 0.1 - 1.0 + 0.5
      DO 130 J=1,MNK
      NN = 10 * J + 1
      WRITE (6,125) J,ANCUV(NN),ANCUV(NN+1),ANCUV(NN+2),ANCUV(NN+3),
     1ANCUV(NN+4),ANCUV(NN+5),ANCUV(NN+6),ANCUV(NN+7),ANCUV(NN+8),
     2ANCUV(NN+9)
  130 CONTINUE
      J = ROTA * 0.1 + 0.5
      ANCUV(IROT+1) = CFMO(IROT)
      WRITE (6,125) J,ANCUV(IROT+1)
C
C WRITE BOARD FEET PER ACRE FOR EACH YEAR.
C
      WRITE (6,135)
  135 FORMAT (1H0,///,55X,23HTHOUSANDS OF BOARD FEET,//)
      WRITE (6,140) K,(ANBDF(NN),NN=1,10)
  140 FORMAT (1H ,I20,F13.3,9F10.3)
      DO 145 J=1,MNK
      NN = 10 * J + 1
      WRITE (6,140) J,ANBDF(NN),ANBDF(NN+1),ANBDF(NN+2),ANBDF(NN+3),
     1ANBDF(NN+4),ANBDF(NN+5),ANBDF(NN+6),ANBDF(NN+7),ANBDF(NN+8),
     2ANBDF(NN+9)
  145 CONTINUE
      J = ROTA * 0.1 + 0.5
      ANBDF(IROT+1) = BDFO(IROT)
      WRITE (6,140) J,ANBDF(IROT+1)
C
C COMPUTE M.A.I. FOR EACH WORKING GROUP AND SITE CLASS.
C
      TEM = 0.0
      REM = 0.0
      IF(REGN(KAK,2,KAN) .EQ. 0.0) GO TO 160
      MNK = REGN(KAK,1,KAN)
      GO TO 165
  160 MNK = REGN(KAK,1,KAN) - DELAY(KAK)
  165 DO 170 I=1,MNK
      TEM = TEM + BDFC(I)
  170 REM = REM + CFMC(I)
      REM = REM * 0.01
      MNK = MNK + 1
      BDAI = ANBDF(MNK) + (SHELT(KAK,1,KAN) * GROWB(KAK,1,KAN) * PO1) +
     1(SHELT(KAK,2,KAN) * GROWB(KAK,2,KAN) * PO2) + TEM
      BDAI = BDAI / REGN(KAK,1,KAN)
      CFAI = ANCUV(MNK) * 0.01 + (SHWD(KAK,1,KAN) * 0.01 * GROWC(KAK,1,K
     1AN) * PO1) + (SHWD(KAK,2,KAN) * 0.01 * GROWC(KAK,2,KAN) * PO2) +
     2EM
      CFAI = CFAI / REGN(KAK,1,KAN)
      BDMAI(KAK) = BDMAI(KAK) + BDAI * AREA(KAK,KAN)
      CUMAI(KAK) = CUMAI(KAK) + CFAI * AREA(KAK,KAN)
C
C COMPUTE ACRES IN EACH AGE CLASS WITH IDEAL CONDITIONS.
C
      ANCUT(KAK,KAN) = AREA(KAK,KAN) / REGN(KAK,1,KAN)
C
C CHANGE VALUE OF CLASS IF AGE CLASSES ARE NOT 10 YEARS.
C
      CLASS = 10.0
      TEM = ANCUT(KAK,KAN) * CLASS
      IF(DELAY(KAK) .EQ. 0.0) GO TO 180
      IF(REGN(KAK,2,KAN) .GT. 0.0) GO TO 180
      POCUT(1) = ANCUT(KAK,KAN) * DELAY(KAK)
      MNK = (REGN(KAK,1,KAN) - DELAY(KAK) + 9.5) * 0.1
      KK = MNK + 1
      DO 175 I=2,MNK
  175 POCUT(I) = TEM
      TEM = MNK - 1
      TEM = REGN(KAK,1,KAN) - DELAY(KAK) - (CLASS * TEM)
      POCUT(KK) = ANCUT(KAK,KAN) * TEM
      GO TO 190
  180 MNK = ((REGN(KAK,1,KAN) + 9.5) * 0.1) + 1.0
      DO 185 I=2,MNK
  185 POCUT(I) = TEM
C
C COMPUTE GROWING STOCK IN EACH AGE CLASS WITH IDEAL CONDITIONS.
C
  190 MAX = REGN(KAK,1,KAN) - DELAY(KAK) + 1.0
      DO 200 I=1,MAX
      IF(ANBDF(I) .LT. BFMRCH) GO TO 200
      MID = I
      GO TO 205
  200 CONTINUE
  205 MES = MID - 1
      MUO = MIN + 1
      DO 210 J=MUO,MES
  210 SUBCF(KAK,KAN) = SUBCF(KAK,KAN) + ANCUV(J) * 0.01
      SUBCF(KAK,KAN) = SUBCF(KAK,KAN) * ANCUT(KAK,KAN)
      DO 215 K=MID,MAX
  215 CFBF(KAK,KAN) = CFBF(KAK,KAN) + ANCUV(K) * 0.01
      CFBF(KAK,KAN) = CFBF(KAK,KAN) * ANCUT(KAK,KAN)
      IF(REGN(KAK,2,KAN) .EQ. 0.0) GO TO 220
      MAX = REGN(KAK,2,KAN) + 1.0
      IF(REGN(KAK,3,KAN) .GT. 0.0) MAX = REGN(KAK,3,KAN) + 1.0
  220 DO 240 I=1,15
      DO 230 J=2,11
      K = J + 10 * I - 10
      IF(K .GT. MAX) GO TO 250
      IF(K .LT. MUO) GO TO 230
      CMS(I) = CMS(I) + ANCUV(K) * 0.01
      IF(K .LT. MID) GO TO 230
      BFS(I) = BFS(I) + ANBDF(K)
  230 CONTINUE
  240 CONTINUE
  250 DO 255 L=1,15
      BFS(L) = BFS(L) * ANCUT(KAK,KAN)
      CMS(L) = CMS(L) * ANCUT(KAK,KAN)
  255 CONTINUE
      DO 260 I=1,15
      ALLCF(KAK,KAN) = ALLCF(KAK,KAN) + CMS(I)
  260 SUBBF(KAK,KAN) = SUBBF(KAK,KAN) + BFS(I)
      GVLBF(KAK) = GVLBF(KAK) + SUBBF(KAK,KAN)
      GVLCU(KAK) = GVLCU(KAK) + SUBCF(KAK,KAN)
C
C COMPUTE POTENTIAL ANNUAL CUTS WITH BALANCED DISTRIBUTION OF AGE
C CLASSES AND OPTIMUM GROWING STOCK FOR OBJECTIVES.
C INTERMEDIATE, REGENERATION, AND FINAL CUTS KEPT SEPARATE HERE.
C
      IF(REGN(KAK,2,KAN) .EQ. 0.0) GO TO 285
      DO 280 J=1,2
      IF(J .EQ. 1) GO TO 270
      IF(REGN(KAK,3,KAN) .EQ. 0.0) GO TO 280
  270 MNK = REGN(KAK,J,KAN)
      TEM = CFMC(MNK) * 0.01
      TMPY = BDFC(MNK)
      IF(TMPY .LT. COMBF(KAK)) GO TO 275
      OPBD(KAK) = OPBD(KAK) + TMPY * ANCUT(KAK,KAN)
      GO TO 280
  275 IF(TEM .LT. COMCU(KAK)) GO TO 280
      OPCU(KAK) = OPCU(KAK) + TEM * ANCUT(KAK,KAN)
  280 CONTINUE
      GO TO 300
  285 MNK = REGN(KAK,1,KAN) - DELAY(KAK) + 1.0
      IF(ANBDF(MNK) .LT. COMBF(KAK)) GO TO 290
      OPBD(KAK) = OPBD(KAK) + ANBDF(MNK) * ANCUT(KAK,KAN)
      GO TO 300
  290 TEM = ANCUV(MNK) * 0.01
      IF(TEM .LT. COMCU(KAK)) GO TO 300
      OPCU(KAK) = OPCU(KAK) + TEM * ANCUT(KAK,KAN)
  300 IF(REGN(KAK,2,KAN) .EQ. 0.0) GO TO 315
      DO 310 J=2,3
      IF(J .EQ. 3) GO TO 302
      IF(REGN(KAK,3,KAN) .GT. 0.0) GO TO 310
      GO TO 303
  302 IF(REGN(KAK,3,KAN) .EQ. 0.0) GO TO 310
  303 MNK = REGN(KAK,J,KAN) + 1.0
      TEM = ANBDF(MNK)
      IF(TEM .LT. COMBF(KAK)) GO TO 305
      FNBD(KAK) = FNBD(KAK) + TEM * ANCUT(KAK,KAN)
      GO TO 310
  305 TEM = ANCUV(MNK) * 0.01
      IF(TEM .LT. COMCU(KAK)) GO TO 310
      FNCU(KAK) = FNCU(KAK) + TEM * ANCUT(KAK,KAN)
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```
  310 CONTINUE
  315 MNK = REGN(KAK,I,KAN) - 3.0
      NR = CUCY(KAK)
      N1 = AGETH(KAK,KAN)
      DO 325 I=N1,MNK,NR
      ACTEM = ACTEM + 1.0
      IF(BDFC(I) .LT. COMBF(KAK)) GO TO 320
      BFTEM = BFTEM + BDFC(I)
      GO TO 325
  320 TEM = CFMC(I) * 0.01
      IF(TEM .LT. COMCU(KAK)) GO TO 325
      CFTEM = CFTEM + TEM
  325 CONTINUE
      ACINT(KAK) = ACINT(KAK) + ACTEM * ANCUT(KAK,KAN)
      BFINT(KAK) = BFINT(KAK) + BFTEM * ANCUT(KAK,KAN)
      CUINT(KAK) = CUINT(KAK) + CFTEM * ANCUT(KAK,KAN)
C
C PRINT PAGE TYPE 10 - GROWING STOCK GOALS BY WORKING GROUP AND SITE.
C
      WRITE (6,350)
  350 FORMAT (1H1,//,58X,12HPAGE TYPE 10,/)
      WRITE (6,352) QUAL(KAN),REGN(KAK,1,KAN),AREA(KAK,KAN)
  352 FORMAT (1H0,41X,44HDISTRIBUTION OF AREA AND GROWING STOCK GOALS/1H
     10,16X,21HFOR SITE INDEX CLASS-,F5.0,11H, ROTATION-,F5.0,5H, AND,F1
     20.1,35H ACRES OF THIS SITE CLASS AND GROUP)
      WRITE (6,110) (WGPNM(KAK,J),J=1,3)
      WRITE (6,354)
  354 FORMAT (1H0,44X,8HACRES IN,13X,11HHUNDREDS OF/1H ,23X,9HAGE CLASS,
     114X,5HCLASS,16X,7HCU. FT.,17X,9HM BD. FT.,/)
      IF(REGN(KAK,2,KAN) .GT. 0.0) GO TO 360
      IF(DELAY(KAK) .EQ. 0.0) GO TO 360
      WRITE (6,356) POCUT(1)
  356 FORMAT (1H0,27X,1H0,14X,F10.1)
  360 DO 364 I=2,16
      J = I - 1
      MNK = 1 + 10 * I - 20
      MO = MNK + 9
      WRITE (6,362) MNK,MO,POCUT(I),CMS(J),BFS(J)
  362 FORMAT (1H0,24X,I3,1H-,I3,11X,F10.1,10X,F15.1,10X,F15.1)
  364 CONTINUE
      WRITE (6,366) AREA(KAK,KAN),ALLCF(KAK,KAN),SUBBF(KAK,KAN)
  366 FORMAT (1H0,//,26X,6HTOTALS,11X,F10.1,10X,F15.1,10X,F15.1)
      IF(REGN(KAK,2,KAN) .GT. 0.0) GO TO 370
      IF(DELAY(KAK) .EQ. 0.0) GO TO 370
      WRITE (6,368) DELAY(KAK)
  368 FORMAT (1H0,//,17X,80HAGE CLASS ZERO REPRESENTS CLEARCUT ACRES NOT
     1 YET REFORESTED BECAUSE OF DELAY OF ,F4.0,6H YEARS/1H ,46HEXPECTED
     2 AFTER SCHEDULED REGENERATION CUTTING.)
  370 DO 375 I=1,15
      BFAGE(KAK,I) = BFAGE(KAK,I) + BFS(I)
  375 CFAGE(KAK,I) = CFAGE(KAK,I) + CMS(I)
  390 SITE = SITE + 10.0
  400 CONTINUE
  405 DO 410 I=KSI,KND
  410 SUMCF(KAK) = SUMCF(KAK) + ALLCF(KAK,I)
C
C COMPUTE STANDARD ACRES FOR SITE CLASSES.
C
      TEM = NSI(KAK)
      MNK = TEM * 0.5 + 0.5
      MNK = MNK + KSI - 1
      DO 420 I=KSI,KND
      IF(VLBF(MNK) .EQ. 0.0) GO TO 415
      FAC(I) = VLBF(I) / VLBF(MNK)
      STDAC(I) = AREA(KAK,I) * FAC(I)
      SSTAC = SSTAC + STDAC(I)
      IF(FAC(I) .EQ. 0.0) GO TO 415
      EQIV(I) = 1.0 / FAC(I)
  415 IF(VLCU(MNK) .EQ. 0.0) GO TO 420
      FACCF(I) = VLCU(I) / VLCU(MNK)
      STACF(I) = AREA(KAK,I) * FACCF(I)
      SACCF = SACCF + STACF(I)
      IF(FACCF(I) .EQ. 0.0) GO TO 420
      EQVCF(I) = 1.0 / FACCF(I)
  420 CONTINUE
C
C PRINT PAGE TYPE 11 - GROWING STOCK GOALS BY WORKING GROUP AND SITE.
C
      WRITE (6,500)
  500 FORMAT (1H1,///,61X,12HPAGE TYPE 11)
      WRITE (6,502)
  502 FORMAT (1H0,//,47X,38HGROWING STOCK GOALS FOR WORKING CIRCLE)
      WRITE (6,110) (WGPNM(KAK,J),J=1,3)
      WRITE (6,504) (FORET(I), I=1,19)
  504 FORMAT (1H ,30X,18A4,A2,////)
      WRITE (6,506)
  506 FORMAT (1H0,45X,8HROTATION,11X,10HCU. FT. TO,13X,10HCU. FT. TO,10X
     1,15HM BD. FT. ABOVE)
      WRITE (6,508)
  508 FORMAT (1H ,10X,10HSITE CLASS,10X,5HACRES,12X,3HAGE,13X,13HBD. FT.
     1 LIMIT,10X,12HROTATION AGE,10X,13HBD. FT. LIMIT,///)
      DO 512 I=KSI,KND
      WRITE (6,510) QUAL(I),AREA(KAK,I),REGN(KAK,1,I),SUBCF(KAK,I),ALLCF
     1(KAK,I),SUBBF(KAK,I)
  510 FORMAT (1H0,11X,F5.0,12X,F9.1,10X,F4.0,12X,F12.0,10X,F12.0,8X,F14.
     10)
  512 CONTINUE
      WRITE (6,514) SARSP(KAK),GVLCU(KAK),SUMCF(KAK),GVLBF(KAK)
  514 FORMAT (1H0,12X,6HTOTALS,9X,F10.1,25X,F13.0,9X,F13.0,7X,F15.0)
      WRITE (6,516)
  516 FORMAT (1H0,//,13X,101HCUBIC FEET IN HUNDREDS. TOTAL AREA INCLUDES
     1 ANY LOW SITE ACRES INCORRECTLY CLASSED AS OPERABLE TYPES.)
C
C PRINT PAGE TYPE 12 - STANDARD ACRES AND EQUIVALENT AREAS.
C
      WRITE (6,550)
  550 FORMAT (1H1,//,60X,12HPAGE TYPE 12)
      WRITE (6,552)
  552 FORMAT (1H0,/,47X,37HCONVERSION OF AREAS TO STANDARD ACRES)
      WRITE (6,110) (WGPNM(KAK,J),J=1,3)
      WRITE (6,504) (FORET(I), I=1,19)
      WRITE (6,554)
  554 FORMAT (1H0,9X,4HSITE,13X,11HTOTAL YIELD,13X,5HACRES,34X,7HAREA IN
     1,13X,13HEQUIVALENT OF)
      WRITE (6,556)
  556 FORMAT (1H ,9X,5HINDEX,13X,8HPER ACRE,14X,7HIN SITE,12X,9HREDUCTIO
     1N,12X,8HSTANDARD,12X,13HSTANDARD ACRE)
      WRITE (6,558)
  558 FORMAT (1H ,9X,5HCLASS,13X,9HM BD. FT.,14X,5HCLASS,14X,6HFACTOR,15
     1X,5HACRES,14X,13HIN SITE ACRES,//)
      DO 562 I=KSI,KND
      WRITE (6,560) QUAL(I),VLBF(I),AREA(KAK,I),FAC(I),STDAC(I),EQIV(I)
  560 FORMAT(1H0,8X,F5.0,12X,F9.1,12X,F10.1,11X,F9.5,11X,F10.1,13X,F9.5)
  562 CONTINUE
      WRITE (6,564)
  564 FORMAT (1H0,////)
      WRITE (6,554)
      WRITE (6,556)
      WRITE (6,566)
  566 FORMAT (1H ,9X,5HCLASS,14X,7HCU. FT.,15X,5HCLASS,14X,6HFACTOR,15X,
     15HACRES,14X,13HIN SITE ACRES,//)
      DO 568 I=KSI,KND
      WRITE (6,560) QUAL(I),VLCU(I),AREA(KAK,I),FACCF(I),STACF(I),
     1EQVCF(I)
  568 CONTINUE
  600 CONTINUE
      RETURN
      END
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Subroutine YIELD

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      SUBROUTINE YIELD
C
C TO COMPUTE A YIELD TABLE FOR EACH SITE CLASS OF EACH WORKING GROUP.
C
      COMMON ADD,AGE(2),AGED,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KND,MIN,MNK,NBK,NCMP,NSJB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKA/ ANBDF(151),ANCUV(151),BDFC(150),BDFD(150),CFMC(150),
     1CFMD(150),CYCL,IROT,KAN,PD1,PD2,QUAL(14),ROTA,VLBF(14),VLCU(14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
C INITIALIZE VARIABLES RECOMPUTED FOR EACH SITE CLASS.
C
      ADDHT = 0.0
      BDFT = 0.0
      CFMT = 0.0
      HTCUM = 0.0
      JBDFC = 0
      JBDFD = 0
      JBDFT = 0
      JCFMC = 0
      JCFMD = 0
      JCFMT = 0
      JSBD = 0
      JSMC = 0
      JSTF = 0
      DO 10 I=1,150
      BDFC(I) = 0.0
      BDFD(I) = 0.0
      CFMC(I) = 0.0
   10 CFMD(I) = 0.0
      DO 15 I=1,151
      ANBDF(I) = 0.0
   15 ANCUV(I) = 0.0
      N1 = AGED
      N = AGED
C
C OBTAIN HTSO AND TOTAL CU. FT. PER ACRE.
C
      BASD = DENO * 0.0054542 * DBHO * DBHO
      IJ = 9
      CALL WORKGP
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(DBHO .LE. 4.99) GO TO 25
      KND = 1
      BA(1) = BASD
      VOM(1) = DBHO
      IJ = 2
      CALL WORKGP
      BDFD(N) = TOTO * PROD(1)
      CFMD(N) = TOTO * FCTR(1)
   25 REST = THIN(KAK)
C
C ENTER LOOP FOR ALL REMAINING COMPUTATIONS AND PRINTOUT.
C
      DO 200 I=1,100
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C
C  CHANGE STANDARDS IF A REGENERATION CUT IS DUE.
C
   30 IF(AGED .GE. ROTA) GO TO 60
      IF(AGED .LT. REGN(KAK,1,KAN)) GO TO 50
      IF(AGED .NE. REGN(KAK,1,KAN)) GO TO 35
      OLEV(KAK) = OLEV(KAK) * VLLV(KAK,1,KAN)
      REST = OLEV(KAK)
      CYCL = INVL(KAK,1,KAN)
      GO TO 50
   35 IF(AGED .NE. REGN(KAK,2,KAN)) GO TO 40
      OLEV(KAK)= OLEV(KAK) * VLLV(KAK,2,KAN)
      REST = OLEV(KAK)
      CYCL = INVL(KAK,2,KAN)
      GO TO 50
   40 IF(AGED .NE. REGN(KAK,3,KAN)) GO TO 50
      OLEV(KAK) = OLEV(KAK) * VLLV(KAK,3,KAN)
      REST = OLEV(KAK)
      CYCL = INVL(KAK,3,KAN)
C
C INCREASE D.B.H. BY THINNING AND COMPUTE POST-THINNING VALUES.
C
   50 CALL CUTS
      JDENT = (BAST / (0.0054542 * DBHT * DBHT)) + 0.5
      DENT = JDENT
      BAST = 0.0054542 * DBHT * DBHT * DENT
      IF(BAST .LT. BASO) GO TO 55
      BAST = BASO
      HTST = HTSO
      DENT = DENO
      JDENT = DENO + 0.5
      DBHT = DBHO
      TOTT = TOTO
      BDFT = BDFO(N)
      CFMT = CFMO(N)
      GO TO 60
   55 IJ = 10
      CALL WORKGP
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(DBHT .LE. 4.99) GO TO 60
      KND = 1
      BA(1) = BAST
      VOM(1) = DBHT
      IJ = 2
      CALL WORKGP
      BDFT = TOTT * PROD(1)
      CFMT = TOTT * FCTR(1)
C
C CHANGE MODE AND ROUND OFF FOR PRINTING.
C
   60 JDENO = DENO + 0.5
      JHTSO = HTSO + 0.5
      JTOTO = TOTO + 0.5
      JBASO = BASO + 0.5
      JCFMO = CFMO(N) + 0.5
      JBDFO = BDFO(N) * 0.1 + 0.5
      JBDFO = JBDFO * 10
      JDENT = DENT + 0.5
      JHTST = HTST + 0.5
      JTOTT = TOTT + 0.5
      JDENC = JDENO - JDENT
      JCFMT = CFMT + 0.5
      CFMT = JCFMT
      IF(JCFMT .GT. JCFMO) JCFMO = JCFMT
      CFMO(N) = JCFMO
      JBDFT = BDFT * 0.1 + 0.5
      JBDFT = JBDFT * 10
      BDFT = JBDFT
      BDFT = BDFT * 0.001
      IF(JBDFT .GT. JBDFO) JBDFO = JBDFT
      BDFO(N) = JBDFO
      BDFO(N) = BDFO(N) * 0.001
      JBAST = BAST + 0.5
      JBASC = JBASO - JBAST
      JTOTC = JTOTO - JTOTT
      JCFMC = JCFMO - JCFMT
      IF(JCFMC .LE. 0) JCFMC = 0
      CFMC(N) = JCFMC
      JBDFC = JBDFO - JBDFT
      IF(JBDFC .LE. 0) JBDFC = 0
      BDFC(N) = JBDFC
      BDFC(N) = BDFC(N) * 0.001
C
C  SUM PERIODIC CUTS FOR LAST LINE OF YIELD TABLE.
C
      IF(AGED .GE. ROTA) GO TO 70
      JSTF = JSTF + JTOTC
      CCFMC = CFMC(N) * 0.01
      IF(CCFMC .LT. COMCU(KAK)) GO TO 65
      JSMC = JSMC + JCFMC
   65 IF(BDFC(N) .LT. COMBF(KAK)) GO TO 70
      JSBD = JSBD + JBDFC
C
C PRINT PAGE TYPE B - YIELD TABLE FOR EACH WORKING GROUP AND SITE.
C
   70 IF(I .GE. 2) GO TO 135
C
C WRITE HEADINGS FOR YIELD TABLE.
C
      WRITE (6,100)
  100 FORMAT (1H1,//,62X,11HPAGE TYPE B)
      WRITE (6,105) QUAL(KAN),CUCY(KAK),THIN(KAK),OLEV(KAK)
  105 FORMAT (1H0, /,28X,81HYIELDS PER ACRE OF MANAGED, EVEN-AGED STANDS
     1 BASED ON PREDETERMINED STANDARDS FOR/1H ,47X,10HSITE INDEX,F5.0,1
     2H,,F5.0,19H-YEAR CUTTING CYCLE/1H ,41X,26HTHINNING LEVELS= INITIAL
     3 -,F6.0,14H, SUBSEQUENT -,F6.0)
      WRITE (6,110) (WGPNM(KAK,J),J=1,3)
  110 FORMAT (1H0,53X,16HWORKING GROUP - ,3A4,/)
      WRITE (6,115)
  115 FORMAT (1H0,25X,38HENTIRE STAND BEFORE AND AFTER THINNING,28X,26HP
     1ERIODIC CUT AND MORTALITY)
      WRITE (6,120)
  120 FORMAT (1H0,9X,5HSTAND,10X,5HBASAL,3X,7HAVERAGE,2X,7HAVERAGE,3X,5H
     1TOTAL,3X,9HMERCHANT-,3X,9HSAWTIMBER,9X,5HBASAL,4X,5HTOTAL,3X,9HMER
     2CHANT-,3X,9HSAWTIMBER)
      WRITE (6,125)
  125 FORMAT (1H ,10X,3HAGE,4X,5HTREES,3X,4HAREA,4X,6HD.B.H.,3X,6HHEIGHT
     1,2X,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME,3X,5HTREES,3X,4HAREA,3X
     2,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME)
      WRITE (6,130)
  130 FORMAT (1H ,8X,7H(YEARS),3X,3HNO.,2X,7HSQ. FT.,4X,3HIN.,6X,3HFT.,4
     1X,7HCU. FT.,3X,7HCU. FT.,4X,9HM BD. FT.,3X,3HNO.,2X,7HSQ. FT.,2X,7
     2HCU. FT.,3X,7HCU. FT.,4X,9HM BD. FT.)
  135 WRITE (6,140) AGEO,JDENO,JBASO,DBHO,JHTSO,JTOTO,CFMO(N),BDFO(N)
  140 FORMAT (1H0,9X,F4.0,4X,I5,2X,I4,5X,F5.1,5X,I3,4X,I5,5X,F6.0,6X,F6.
     13)
      IF(AGED .GE. ROTA) GO TO 220
      WRITE (6,145) AGEO,JDENT,JBAST,DBHT,JHTST,JTOTT,CFMT,BDFT,JDENC,JB
     1ASC,JTOTC,CFMC(N),BDFC(N)
  145 FORMAT (1H ,9X,F4.0,4X,I5,2X,I4,5X,F5.1,5X,I3,4X,I5,5X,F6.0,6X,F6.
     13,4X,I5,3X,I3,5X,I4,5X,F5.0,7X,F6.3)
C
C COMPUTE VALUES FOR EACH PERIOD. THIN AS SPECIFIED.
C
      KK = CYCL / RINT(KAK)
      DO 190 L=1,KK
      AGEO = AGEO + RINT(KAK)
      N = AGEO
      IF(AGEO .GT. ROTA) GO TO 220
      IJ = 11
      CALL WORKGP
      MNK = DBHO * 10.0 + 0.5
      DBHO = MNK
      DBHO = DBHO * 0.1
C
C REDUCE FUTURE DENSITY BY AMOUNT OF PREDICTED MORTALITY.
C
      IF(DBHT .GE. 10.0) GO TO 170
      IJ = 12
      CALL WORKGP
      IF(DENO .LT. 0.0) DENO = 0.0
      MNK = DENT * (1.0 - DENO) + 0.5
      DENO = MNK
      GO TO 175
  170 DENO = DENT
  175 BASO = DENO * 0.0054542 * DBHO * DBHO
C
C COMPUTE HTSO FROM AGE AND SITE INDEX.
C
      IJ = 9
      CALL WORKGP
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(DBHO .LE. 4.99) GO TO 185
      KND = 1
      BA(1) = BASO
      VOM(1) = DBHO
      IJ = 2
      CALL WORKGP
      BDFO(N) = TOTO * PROD(1)
      CFMO(N) = TOTO * FCTR(1)
C
C  TEST IF REGENERATION CUT IS DUE.
C
      DO 180 KU=1,3
      IF(AGEO .EQ. REGN(KAK,KU,KAN)) GO TO 30
  180 CONTINUE
  185 IF(L .EQ. KK) GO TO 195
C
C WRITE VALUES FOR END OF PERIOD IF THINNING NOT DUE.
C
      JDENO = DENO + 0.5
      JHTSO = HTSO + 0.5
      JBASO = BASO + 0.5
      JTOTO = TOTO + 0.5
      JCFMO = CFMO(N) + 0.5
      CFMO(N) = JCFMO
      JBDFO = BDFO(N) * 0.1 + 0.5
      JBDFO = JBDFO * 10
      BDFO(N) = JBDFO
      BDFO(N) = BDFO(N) * 0.001
      WRITE (6,140) AGEO,JDENO,JBASO,DBHO,JHTSO,JTOTO,CFMO(N),BDFO(N)
      DBHT = DBHO
      BAST = BASO
      DENT = DENO
  190 CONTINUE
  195 REST = OLEV(KAK)
  200 CONTINUE
C
C  ADD FINAL CUTS TO TOTAL YIELDS AND WRITE TOTAL YIELDS.
C
  220 JSTF = JSTF + JTOTO
      CCFMO = JCFMO
      IF(CCFMO .LT. COMCU(KAK)) GO TO 225
      SSMC = JSMC + JCFMO
  225 BBDFO = JBDFO
      IF(BBDFO .LT. COMBF(KAK)) GO TO 230
      SBD = JSBD + JBDFO
      SBD = SBD * 0.001
  230 VLBF(KAN) = SBD
      VLCU(KAN) = SSMC
      WRITE (6,235) JSTF,SSMC,SBD
  235 FORMAT (1HG,67X,12HTOTAL YIELDS,1PX,I5,4X,F6.0,7X,F6.3)
      TEM = COMCU(KAK) * 100.0
      TMPY = COMBF(KAK) * 1000.0
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      WRITE (6,240) TEM,TMPY
  240 FORMAT (1H0,/,1X,44HMINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--
     1,F6.0,15H CUBIC FEET AND,F7.0,11H BOARD FEET)
      IROT = ROTA
      MNK = RINT(KAK)
      NVOL = ((IROT - N1)/MNK) + 1
      K = NVOL - 1
C
C INTERPOLATE BETWEEN VALUES FROM YIELD TABLE.
C
      DO 260 L=1,K
      DO 260 J=1,MNK
      NN = J + N1 + (L - 1) * MNK
      TEM = J - 1
      N = N1 + (L - 1) * MNK
      ANCUV(NN) = CFMO(N) - CFMC(N) + (TEM / RINT(KAK)) * (CFMO(N+MNK) -
     1 CFMO(N) + CFMC(N))
      ANBDF(NN) = BOFO(N) - BOFC(N) + (TEM / RINT(KAK)) * (BOFO(N+MNK) -
     1 BOFO(N) + BOFC(N))
  260 CONTINUE
C
C STORE VOLUMES AND GROWTH RATE OF SHELTERWOOD, IF ANY.
C
      IF(REGN(KAK,2,KAN) .EQ. 0.0) GO TO 335
      KX = REGN(KAK,1,KAN)
      MX = REGN(KAK,2,KAN)
      LX = REGN(KAK,3,KAN)
      SHWD(KAK,1,KAN) = CFMO(KX) - CFMC(KX)
      IF(SHWD(KAK,1,KAN) .LE. 0.0) GO TO 300
      GROWC(KAK,1,KAN) = CFMO(MX) / SHWD(KAK,1,KAN)
      GROWC(KAK,1,KAN) = (GROWC(KAK,1,KAN) - 1.0) / P01
      GO TO 305
  300 SHWD(KAK,1,KAN) = 0.0
      GROWC(KAK,1,KAN) = 0.0
  305 SHELT(KAK,1,KAN) = BOFO(KX) - BOFC(KX)
      IF(SHELT(KAK,1,KAN) .LE. 0.0) GO TO 310
      GROWB(KAK,1,KAN) = BOFO(MX) / SHELT(KAK,1,KAN)
      GROWB(KAK,1,KAN) = (GROWB(KAK,1,KAN) - 1.0) / P01
      GO TO 315
  310 SHELT(KAK,1,KAN) = 0.0
      GROWB(KAK,1,KAN) = 0.0
  315 IF(REGN(KAK,3,KAN) .EQ. 0.0) GO TO 335
      SHWD(KAK,2,KAN) = CFMO(MX) - CFMC(MX)
      IF(SHWD(KAK,2,KAN) .LE. 0.0) GO TO 320
      GROWC(KAK,2,KAN) = CFMO(LX) / SHWD(KAK,2,KAN)
      GROWC(KAK,2,KAN) = (GROWC(KAK,2,KAN) - 1.0) / P02
      GO TO 325
  320 SHWD(KAK,2,KAN) = 0.0
      GROWC(KAK,2,KAN) = 0.0
  325 SHELT(KAK,2,KAN) = BOFO(MX) - BOFC(MX)
      IF(SHELT(KAK,2,KAN) .LE. 0.0) GO TO 330
      GROWB(KAK,2,KAN) = BOFO(LX) / SHELT(KAK,2,KAN)
      GROWB(KAK,2,KAN) = (GROWB(KAK,2,KAN) - 1.0) / P02
      GO TO 335
  330 SHELT(KAK,2,KAN) = 0.0
      GROWB(KAK,2,KAN) = 0.0
  335 RETURN
      END
```

Subroutine CUTS

```
      SUBROUTINE CUTS
C
C TO ESTIMATE INCREASE IN AVERAGE D.B.H. DUE TO THINNING.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBO(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBO(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKA/ ANBOF(151),ANCUV(151),BOFC(150),BOFO(150),CFMC(150),
     1CFMO(150),CYCL,IROT,KAN,P01,P02,QUAL(14),ROTA,VLBF(14),VLCU(14)
C
      COMMON /BLKO/ IJ,IK,KI,VOL,TVOL
C
      IF(DBHO .LT. 9.4) GO TO 20
C
C COMPUTE D.B.H. IF DBHO IS LARGE ENOUGH FOR BASAL AREA TO REMAIN
C CONSTANT.
C
      PRET = 100.0
      DO 15 KJ=1,100
      IJ = 5
      CALL WORKGP
      IDBHE = DBHE * 10.0 + 0.5
      DBHE = IDBHE
      DBHE = DBHE * 0.1
      DENE = DENO * PRET * 0.01
      NDENE = DENE + 0.5
      DENE = NDENE
      BASE = 0.0054542 * DBHE * DBHE * DENE
      NBASE = BASE * 10.0 + 0.5
      BASE = NBASE
      BASE = BASE * 0.1
      TMPY = 0.0054542 * DBHE * DBHE
      TEM = BASE - REST
      IF(TEM .LE. TMPY) GO TO 60
      IF(TEM .LT. 4.0) GO TO 10
      PRET = PRET - 1.0
      GO TO 15
   10 PRET = PRET - 0.3
   15 CONTINUE
      GO TO 60
C
C COMPUTE D.B.H. IF BASAL AREA INCREASES WITH D.B.H.
C
   20 PRET = 40.0
      IF(DBHO .GT. 7.0) PRET = 70.0
      DO 55 J=1,100
      IJ = 5
      CALL WORKGP
      IDBHE = DBHE * 10.0 + 0.5
      DBHE = IDBHE
      DBHE = DBHE * 0.1
      DENE = DENO * (PRET * 0.01)
      NDENE = DENE + 0.5
      DENE = NDENE
      BASE = 0.0054542 * DBHE * DBHE * DENE
      NBASE = BASE * 10.0 + 0.5
      BASE = NBASE
      BASE = BASE * 0.1
      BREAK = 49.9 * REST / 80.0
      IF(BASE .GT. BREAK) GO TO 30
      DBHP = (80.0 / REST) * (0.08682 * BASE) + 0.94636
      GO TO 40
   30 BUST = 66.2 * (REST / 80.0)
      IF(BASE .GT. BUST) GO TO 35
      DBHP = (80.0 / REST) * (0.10938 * BASE) - 0.17858
      GO TO 40
   35 TMPY = BASE * (80.0 / REST)
      TEM = TMPY * TMPY
      DBHP = 19.04740 * TMPY - 0.26673 * TEM + 0.0012539 * TEM * TMPY
     1 - 448.76833
      IF(TMPY .GT. 80.0) DBHP = DBHO + 0.8
   40 IDBHP = DBHP * 10.0 + 0.5
      DBHP = IDBHP
      DBHP = DBHP * 0.1
      IF(DBHP - DBHE) 45,60,50
   45 PRET = PRET * 1.02
      GO TO 55
   50 PRET = PRET * 0.98
   55 CONTINUE
   60 DBHT = DBHE
C
C COMPUTE POST-THINNING BASAL AREA.
C
      IF(DBHT .GT. 5.0) GO TO 65
      SQFT = 11.58495 * DBHT - 11.09724
      GO TO 70
   65 IF(DBHT .GE. 10.0) GO TO 75
      TEM = DBHT * DBHT
      SQFT = 7.76226 * DBHT +0.85289 * TEM -0.07952 * TEM * DBHT-3.45624
   70 BAST = (REST / 80.0) * SQFT
      GO TO 80
   75 BAST = REST
   80 RETURN
      END
```

Subroutine WORKGP

```
      SUBROUTINE WORKGP
C
C TO CALL SUBROUTINES CONTAINING SPECIES - SPECIFIC STATEMENTS.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BOMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),DPBO(5),OPCU(5),PAIBO(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBO(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKO/ IJ,IK,KI,VOL,TVOL
C
C EXPAND FOLLOWING GO TO AS NEEDED FOR ADDITIONAL SPECIES.
C
      NKAK = SPNUM(KAK)
      GO TO (1,2,3,4,5), NKAK
    1 CALL BHPP
      RETURN
    2 CALL LOGP
      RETURN
    3 CALL SWPP
      RETURN
C
C CONTINUE CALLS TO SUBROUTINES TO MATCH LENGTH OF GO TO.
C
    4 CONTINUE
      RETURN
    5 CONTINUE
      RETURN
      END
```

Subroutine GOT

```
      SUBROUTINE GOT
C
C TO COMPUTE PRESENT VOLUMES, DISTRIBUTIONS OF AREA AND VOLUME, AND
C POTENTIAL GROWTH FROM INVENTORY DATA.
C
      COMMON ADD,AGE(2),AGED,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DEND,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTD,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /OPT/ OPTION,ICT9
C
      COMMON /BLKA/ ANBDF(151),ANCUV(151),BDFC(150),BDFD(150),CFMC(150),
     1CFMD(150),CYCL,IROT,KAN,PD1,PD2,QUAL(14),ROTA,VLBF(14),VLCU(14)
C
      COMMON /BLKB/ PAFN(5,7,15),PARG(5,7,15),
     1PBFT(7,27),PCMT(7,27),PCTA(7,27),PCTB(7,27),PGBD(5,7,15),PGMC(5,7,
     215),PHLP(7,27),POPN(7,27),PPBF(5,7,15),PPCR(7,27),PPFN(7,27),
     3PPMC(5,7,15),PPTC(5,7,15),PSLV(7,27),PTBF(5,7,15),PTCU(5,7,15),
     4PTMC(5,7,15)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      DIMENSION FBD(2),FMC(2),BFM(2),CM(2),TBD(2),TCM(2)
C
C INITIALIZE VARIABLES FIRST DEFINED IN THIS SUBROUTINE.
C
      DO 2 I=1,NWGP
      DO 2 J=1,NBK
      DO 2 K=1,15
      PAFN(I,J,K) = 0.0
      PARG(I,J,K) = 0.0
      PGBD(I,J,K) = 0.0
      PGMC(I,J,K) = 0.0
      PPBF(I,J,K) = 0.0
      PPMC(I,J,K) = 0.0
      PPTC(I,J,K) = 0.0
      PTBF(I,J,K) = 0.0
      PTCU(I,J,K) = 0.0
      PTMC(I,J,K) = 0.0
    2 CONTINUE
      DO 4 I=1,NBK
      DO 4 J=1,27
      PBFT(I,J) = 0.0
      PCMT(I,J) = 0.0
      PCTA(I,J) = 0.0
      PCTB(I,J) = 0.0
      PHLP(I,J) = 0.0
      POPN(I,J) = 0.0
      PPCR(I,J) = 0.0
      PPFN(I,J) = 0.0
      PSLV(I,J) = 0.0
    4 CONTINUE
C
C INITIALIZE VARIABLES RECOMPUTED FOR EACH INVENTORY RECORD.
C
   10 DO 15 I=1,2
      BAS(I) = 0.0
      BFM(I) = 0.0
      CM(I) = 0.0
      FBA(I) = 0.0
      FBD(I) = 0.0
      FDM(I) = 0.0
      FDN(I) = 0.0
      FHT(I) = 0.0
      FMC(I) = 0.0
      FVL(I) = 0.0
      TBA(I) = 0.0
      TBD(I) = 0.0
      TCM(I) = 0.0
      TDM(I) = 0.0
      TVL(I) = 0.0
   15 TOT(I) = 0.0
      BAUS = 0.0
      BDUS = 0.0
      BFVOL = 0.0
      CFVOL = 0.0
      CMUS = 0.0
      DMUS = 0.0
      DNUS = 0.0
      FTBD = 0.0
      FTCM = 0.0
      HTUS = 0.0
      STOR1 = 0.0
      STOR2 = 0.0
      TEM = MIN
      TMBD = 0.0
      TMCF = 0.0
      VLUS = 0.0
C
C READ INVENTORY DATA, ONE RECORD AT A TIME FROM CARD TYPE 9. LAST
C RECORD IS CARD TYPE 10 WITH IBK = 99 TO STOP PROCESSING.
C
      READ (ICT9,20) IBK,KOMP,ISUB,DTR1,DTR2,SECT,TOWN,RANG,SITE,STRY,
     1NTYP,WORK,FISC,DBH(1),HT(1),DEN(1),AGE(1),DMR(1),DBH(2),HT(2),DEN(
     22),AGE(2),DMR(2),ACRE,WHEN
   20 FORMAT (I2,I4,I3,3A3,2A4,F3.0,F1.0,I2,F1.0,F4.0,F3.1,F3.0,F5.0,F3.
     10,F2.1,F3.1,F3.0,F5.0,F3.0,F2.1,F5.1,F4.0)
C
C STOP VOLUME COMPUTATIONS IF ALL INVENTORY RECORDS READ.
C
      IF (IBK .EQ. 99) GO TO 400
C
C CONTINUE COMPUTATIONS IF ALL RECORDS NOT READ.
C
      IF (NTYP .GT. 25) GO TO 10
      KAN = (SITE + 4.5) * 0.1
      STOR1 = HT(1)
      STOR2 = HT(2)
      JS = (AGE(1) + 9.5) * 0.1
      IF(STRY .GT. 0.0) JS = (AGE(2) + 9.5) * 0.1
      IF(JS .GT. 15) JS = 15
      IF(NTYP .GT. 0 .AND. NTYP .LT. 6) KAK = 1
      IF(NTYP .GT. 5 .AND. NTYP .LT. 11) KAK = 2
      IF (NTYP .GT. 10 .AND. NTYP .LT. 16) KAK = 3
      IF (NTYP .GT. 15 .AND. NTYP .LT. 21) KAK = 4
      IF (NTYP .GT. 20 .AND. NTYP .LT. 26) KAK = 5
      IF(SITE .LT. POOR(KAK)) GO TO 10
      IF(DBH(1) .GT. 0.0) GO TO 35
C
C TEST FOR NONCOMMERCIAL THINNING IN VERY YOUNG STANDS.
C
      IF(WORK .NE. 2.0) GO TO 10
      IF(ACRE .EQ. 0.0) GO TO 30
      HELP(IBK,NTYP) = HELP(IBK,NTYP) + ACRE
      GO TO 10
   30 PHLP(IBK,NTYP) = PHLP(IBK,NTYP) + 1.0
      GO TO 10
C
C COMPUTE BASAL AREAS AND VOLUMES PER ACRE.
C
   35 DO 40 I=1,2
      BAS(I) = 0.0054542 * DBH(I) * DBH(I) * DEN(I)
      IF(DBH(I) .LT. 3.0) GO TO 40
      IF(AGE(I) .LT. TEM) GO TO 40
      IJ = 1
      IK = I
      CALL WORKGP
   40 CONTINUE
C
C IF WORK CODED FOR THINNING, VERIFY THAT IT CAN BE DONE.
C
      IF(WORK .EQ. 2.0) GO TO 50
      IF(WORK .EQ. 6.0) GO TO 55
      GO TO 90
   50 K = 1
      GO TO 60
   55 K = 2
   60 IF(DBH(K) .LT. 2.0) GO TO 90
      IF(DBH(K) .GT. 5.0) GO TO 65
      LEVL = 80.0 * BAS(K) / (11.58495 * DBH(K) - 11.09724)
      TMPY = THIN(KAK)
      GO TO 80
   65 IF(DBH(K) .GE. 10.0) GO TO 70
      TEM = DBH(K) * DBH(K)
      LEVL = 80.0 * BAS(K) / (7.76226 * DBH(K) + 0.85289 * TEM - 0.07952
     1* TEM * DBH(K) - 3.45624)
      GO TO 75
   70 LEVL = BAS(K)
   75 TMPY = DLEV(KAK)
   80 IF(WORK .EQ. 6.0) GO TO 85
      IF(LEVL .LE. TMPY) WORK = 0.0
      GO TO 90
   85 IF(LEVL .LE. TMPY) WORK = 5.0
   90 IF(TOT(1) .EQ. 0.0) GO TO 120
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(DBH(1) .LE. 4.99) GO TO 105
      KNO = 2
      BA(1) = BAS(1)
      BA(2) = BAS(2)
      VDM(1) = DBH(1)
      VDM(2) = DBH(2)
      IJ = 2
      CALL WORKGP
      DO 100 I=1,2
      BFM(I) = TOT(I) * PROD(I) * 0.001
  100 CM(I) = TOT(I) * FCTR(I) * 0.01
  105 DO 110 I=1,2
  110 TOT(I) = TOT(I) * 0.01
C
C ADD VOLUMES TO APPROPRIATE TOTALS.
C
      TMCF = CM(1) + CM(2)
      TMBD = BFM(1) + BFM(2)
      IF(ACRE .EQ. 0.0) GO TO 115
      PTCU(KAK,IBK,JS) = PTCU(KAK,IBK,JS) + (TOT(1) + TOT(2)) * ACRE
      PTMC(KAK,IBK,JS) = PTMC(KAK,IBK,JS) + (TMCF * ACRE)
      IF(TMBD .LT. BFMRCH) GO TO 120
      PTBF(KAK,IBK,JS) = PTBF(KAK,IBK,JS) + (TMBD * ACRE)
      GO TO 120
  115 PPTC(KAK,IBK,JS) = PPTC(KAK,IBK,JS) + TOT(1) + TOT(2)
      PPMC(KAK,IBK,JS) = PPMC(KAK,IBK,JS) + TMCF
      IF(TMBD .LT. BFMRCH) GO TO 120
      PPBF(KAK,IBK,JS) = PPBF(KAK,IBK,JS) + TMBD
C
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```
C COMPUTE GROWTH FOR NEXT PERIOD BY WORKING GROUP, BLOCK, AND AGE CLASS.
C
  120 IF(WORK .NE. 3.0) GO TO 130
      IF(BFM(1) .LT. COMBF(KAK)) GO TO 10
      IF(ACRE .EQ. 0.0) GO TO 125
      SLVG(IBK,NTYP) = SLVG(IBK,NTYP) + (BFM(1) * ACRE)
      GO TO 10
  125 PSLV(IBK,NTYP) = PSLV(IBK,NTYP) + BFM(1)
      GO TO 10
  130 TMOY = AGE(1) + TIME
      TEM = MIN
      IF(TMOY .LT. TEM) GO TO 150
      SBAS = BAS(1) + BAS(2)
      IF(SBAS .EQ. 0.0) GO TO 150
      J = TIME / RINT(KAK)
      DO 140 K=1,J
      IJ = 3
      CALL WORKGP
      IF(J .EQ. 1) GO TO 140
      DO 135 I=1,2
      AGE(I) = AGE(1) + RINT(KAK)
      DBH(I) = FDM(I)
      DEN(1) = FDN(I)
      HT(I) = FHT(1)
  135 CONTINUE
      SBAS = FBA(1) + FBA(2)
  140 CONTINUE
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(FDM(1) .LE. 4.99) GO TO 150
      KND = 2
      BA(1) = FBA(1)
      BA(2) = FBA(2)
      VDM(1) = FDM(1)
      VDM(2) = FDM(2)
      IJ = 2
      CALL WORKGP
      DO 145 I=1,2
      FBD(I) = FVL(1) * PROD(I) * 0.001
      FMC(I) = FVL(1) * FCTR(I) * 0.01
  145 CONTINUE
C
C ADD PERIODIC GROWTH IF NO WORK IS PLANNED DURING NEXT PERIOD.
C
  150 IF(WORK .GT. 1.0) GO TO 170
      IF(ACRE .EQ. 0.0) GO TO 155
      GRBD(KAK,IBK,JS) = GRBD(KAK,IBK,JS) + (FBD(1)+FBD(2)-TMBD) * ACRE
      GRMC(KAK,IBK,JS) = GRMC(KAK,IBK,JS) + (FMC(1)+FMC(2)-TMCF) * ACRE
      GO TO 10
  155 PGBD(KAK,IBK,JS) = PGBD(KAK,IBK,JS) + FBD(1) + FBD(2) - TMBD
      PGMC(KAK,IBK,JS) = PGMC(KAK,IBK,JS) + FMC(1) + FMC(2) - TMCF
      GO TO 10
C
C COMPUTE FUTURE UNTHINNED UNDERSTORY IF OVERSTORY IS REDUCED NOW.
C
  170 IF(WORK .LT. 4.0) GO TO 175
      IF(WORK .GT. 5.0) GO TO 175
      IF(DBH(2) .EQ. 0.0) GO TO 175
      IJ = 4
      CALL WORKGP
      IF(DMUS .LT. 5.0) GO TO 175
      KND = 1
      BA(1) = BAUS
      VDM(1) = DMUS
      IJ = 2
      CALL WORKGP
      BDUS = VLUS * PROD(1) * 0.001
      CMUS = VLUS * FCTR(1) * 0.01
C
C DETERMINE POTENTIAL WORK LOAD FOR NEXT PERIOD. CREDIT FUTURE CUTS
C WITH HALF PERIODIC GROWTH OBTAINED IF NOT CUT.
C INCLUDE STANDS NEAR ROTATION AGE IN POTENTIAL REGENERATION CUTS
C REGARDLESS OF WORK INDEX.
C
  175 IF(WORK .EQ. 2.0) GO TO 285
      IF(WORK .GT. 4.0) GO TO 245
C
C COMPUTE GROWTH AND YIELD OF STANDS TO BE REGENERATED IN NEXT PERIOD.
C
      IF(AGE(1) .GE. REGN(KAK,2,KAN)) GO TO 180
      TEM = GROWB(KAK,1,KAN) * TIME
      DMY = SHELT(KAK,1,KAN)
      GO TO 185
  180 TEM = GROWB(KAK,2,KAN) * TIME
      DMY = SHELT(KAK,2,KAN)
  185 TMPY = (FBD(1) + BFM(1)) * 0.5
      IF(TMPY .LT. DMY) DMY = TMPY
      IF(ACRE .EQ. 0.0) GO TO 190
      GRBD(KAK,IBK,JS) = GRBD(KAK,IBK,JS) + (FBD(2) + BDUS - BFM(2) - BF
     1M(2) + FBD(1) - BFM(1) + DMY * TEM) * 0.5 * ACRE
      ACRGN(KAK,IBK,JS) = ACRGN(KAK,IBK,JS) + ACRE
      GO TO 195
  190 PGBD(KAK,IBK,JS) = PGBD(KAK,IBK,JS) + (FBD(2) + BDUS - BFM(2) - BF
     1M(2) + FBD(1) - BFM(1) + DMY * TEM) * 0.5
      PARG(KAK,IBK,JS) = PARG(KAK,IBK,JS) + 1.0
  195 IF(AGE(1) .GE. REGN(KAK,2,KAN)) GO TO 200
      TEM = GROWC(KAK,1,KAN) * TIME
      DMY = SHWD(KAK,1,KAN) * 0.01
      GO TO 205
  200 TEM = GROWC(KAK,2,KAN) * TIME
      DMY = SHWD(KAK,2,KAN) * 0.01
  205 TMPY = (FMC(1) + CM(1)) * 0.5
      IF(TMPY .LT. DMY) DMY = TMPY
      IF(ACRE .EQ. 0.0) GO TO 210
      GRMC(KAK,IBK,JS) = GRMC(KAK,IBK,JS) + (FMC(2) + CMUS - CM(2) - CM(
     12) + FMC(1) - CM(1) + DMY * TEM) * 0.5 * ACRE
      GO TO 215
  210 PGMC(KAK,IBK,JS) = PGMC(KAK,IBK,JS) + (FMC(2) + CMUS - CM(2) - CM(
     12) + FMC(1) - CM(1) + DMY * TEM) * 0.5
  215 IF(AGE(1) .GE. REGN(KAK,2,KAN)) GO TO 220
      BFVOL = (BFM(1) + FBD(1)) * 0.5 - SHELT(KAK,1,KAN)
      CFVOL = (CM(1) + FMC(1)) * 0.5 - SHWD(KAK,1,KAN) * 0.01
      GO TO 225
  220 BFVOL = (BFM(1) + FBD(1)) * 0.5 - SHELT(KAK,2,KAN)
      CFVOL = (CM(1) + FMC(1)) * 0.5 - SHWD(KAK,2,KAN) * 0.01
  225 IF(BFVOL .LT. COMBF(KAK)) GO TO 235
      IJ = 6
      KI = 1
      VOL = BFVOL
      TVOL = CFVOL
      CALL WORKGP
      IF(ACRE .EQ. 0.0) GO TO 230
      CUTA(IBK,NTYP) = CUTA(IBK,NTYP) + (BFVOL * ACRE)
      PDCFR(IBK,NTYP) = PDCFR(IBK,NTYP) + (ADD * ACRE)
      GO TO 10
  230 PCTA(IBK,NTYP) = PCTA(IBK,NTYP) + BFVOL
      PPCR(IBK,NTYP) = PPCR(IBK,NTYP) + ADD
      GO TO 10
  235 IF(CFVOL .LT. COMCU(KAK)) GO TO 10
      IF(ACRE .EQ. 0.0) GO TO 240
      PDCFR(IBK,NTYP) = PDCFR(IBK,NTYP) + (CFVOL * ACRE)
      GO TO 10
  240 PPCR(IBK,NTYP) = PPCR(IBK,NTYP) + CFVOL
      GO TO 10
C
C COMPUTE GROWTH AND YIELD OF STANDS TO LOSE OVERSTORY IN NEXT PERIOD.
C
  245 IF(ACRE .EQ. 0.0) GO TO 250
      GRBD(KAK,IBK,JS) = GRBD(KAK,IBK,JS)+((FBD(1) - BFM(1)) * 0.5)*ACRE
      GRMC(KAK,IBK,JS) = GRMC(KAK,IBK,JS)+((FMC(1) - CM(1)) * 0.5)*ACRE
      ACFNL(KAK,IBK,JS) = ACFNL(KAK,IBK,JS) + ACRE
      GO TO 255
  250 PGBD(KAK,IBK,JS) = PGBD(KAK,IBK,JS) + (FBD(1) - BFM(1)) * 0.5
      PGMC(KAK,IBK,JS) = PGMC(KAK,IBK,JS) + (FMC(1) - CM(1)) * 0.5
      PAFN(KAK,IBK,JS) = PAFN(KAK,IBK,JS) + 1.0
  255 BFVOL = (BFM(1) + FBD(1)) * 0.5
      CFVOL = (CM(1) + FMC(1)) * 0.5
      IF(BFVOL .LT. COMBF(KAK)) GO TO 265
      IJ = 6
      KI = 1
      VOL = BFVOL
      TVOL = CFVOL
      CALL WORKGP
      IF(ACRE .EQ. 0.0) GO TO 260
      CUTB(IBK,NTYP) = CUTB(IBK,NTYP) + BFVOL * ACRE
      PDCFN(IBK,NTYP) = PDCFN(IBK,NTYP) + (ADD * ACRE)
      GO TO 275
  260 PCTB(IBK,NTYP) = PCTB(IBK,NTYP) + BFVOL
      PPFN(IBK,NTYP) = PPFN(IBK,NTYP) + ADD
      GO TO 275
  265 IF(CFVOL .LT. COMCU(KAK)) GO TO 275
      IF(ACRE .EQ. 0.0) GO TO 270
      PDCFN(IBK,NTYP) = PDCFN(IBK,NTYP) + CFVOL * ACRE
      GO TO 275
  270 PPFN(IBK,NTYP) = PPFN(IBK,NTYP) + CFVOL
  275 IF(WORK .GT. 5.0) GO TO 285
      IF(ACRE .EQ. 0.0) GO TO 280
      GRBD(KAK,IBK,JS) = GRBD(KAK,IBK,JS) + (FBD(2) - BFM(2) + BDUS - BF
     1M(2)) * 0.5 * ACRE
      GRMC(KAK,IBK,JS) = GRMC(KAK,IBK,JS) + (FMC(2) - CM(2) + CMUS - CM(
     12)) * 0.5 * ACRE
      GO TO 10
  280 PGBD(KAK,IBK,JS) = PGBD(KAK,IBK,JS) + (FBD(2) - BFM(2) + BDUS - BF
     1M(2)) * 0.5
      PGMC(KAK,IBK,JS) = PGMC(KAK,IBK,JS) + (FMC(2) - CM(2) + CMUS - CM(
     12)) * 0.5
      GO TO 10
  285 HT(1) = STOR1
      HT(2) = STOR2
C
C GET VOLUME IF THINNED NOW AND IF THINNED IN TIME YEARS.
C
      K = 1
      IF(WORK .EQ. 6.0) K = 2
      DO 310 I=1,2
      REST = DLEV(KAK)
      IF(I .EQ. 2) GO TO 300
      IF(DBH(K) .EQ. 0.0) GO TO 310
      IF(DBH(K) .LT. 6.0) REST = THIN(KAK)
      DBHO = DBH(K)
      DENO = DEN(K)
      GO TO 305
  300 IF(FDM(K) .EQ. 0.0) GO TO 310
      IF(FDM(K) .LT. 6.0) REST = THIN(KAK)
      DBHO = FDM(K)
      DENO = FDN(K)
  305 CALL CUTS
      TBA(I) = BAST
      TDM(I) = DBHT
      IF(I .EQ. 1) SAVE = PRET
      IF(I .EQ. 2) HT(K) = FHT(K)
      IJ = 7
      IK = 1
      KI = K
      CALL WORKGP
  310 CONTINUE
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      IF(TDM(2) .LE. 4.99) GO TO 320
      KND = 2
      BA(1) = TBA(1)
      BA(2) = TBA(2)
      VDM(1) = TDM(1)
      VDM(2) = TDM(2)
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      IJ = 2
      CALL WORKGP
      DO 315 I=1,2
      IF(TVL(I) .EQ. 0.0) GO TO 315
      TBDI(I) = TVL(I) * PROD(I) * 0.001
      TCM(I) = TVL(I) * FCTR(I) * 0.01
  315 CONTINUE
C
C GET STATUS AT END OF PERIOD OF A PLOT THINNED AT START OF PERIOD.
C
  320 HT(1) = STOR1
      IF(K .EQ. 2) HT(1) = STOR2
      IJ = 8
      KI = K
      CALL WORKGP
      IF(FDM(1) .LE. 4.99) GO TO 330
C
C CONVERT TOTAL CU. FT. TO OTHER UNITS.
C
      KND = 1
      BA(1) = FBA(1)
      VDM(1) = FDM(1)
      IJ = 2
      CALL WORKGP
      FTBD = FVL(1) * PROD(1) * 0.001
      FTCM = FVL(1) * FCTR(1) * 0.01
      IF(ACRE .EQ. 0.0) GO TO 325
      GRBD(KAK,IBK,JS) = GRBD(KAK,IBK,JS) + (FBD(K) - BFM(K) + FTBD - TB
     1D(1)) * 0.5 * ACRE
      GRMC(KAK,IBK,JS) = GRMC(KAK,IBK,JS) + (FMC(K) - CM(K) + FTCM - TCM
     1(1)) * 0.5 * ACRE
      GO TO 335
  325 PGBD(KAK,IBK,JS) = PGBD(KAK,IBK,JS) + (FBD(K) - BFM(K) + FTBD - TB
     1D(1)) * 0.5
      PGMC(KAK,IBK,JS) = PGMC(KAK,IBK,JS) + (FMC(K) - CM(K) + FTCM - TCM
     1(1)) * 0.5
C
C ASSIGN THINNINGS TO BD. FT. OR CU. FT. TOTALS, IF COMMERCIAL.
C
  330 THB = (FBD(K) - TBD(2) + BFM(K) - TBD(1)) * 0.5
      THC = (FMC(K) - TCM(2) + CM(K) - TCM(1)) * 0.5
      IF(THB .LT. COMBF(KAK)) GO TO 340
      IJ = 6
      KI = K
      VOL = THB
      TVOL = THC
      CALL WORKGP
      IF(ACRE .EQ. 0.0) GO TO 335
      BFTH(IBK,NTYP) = BFTH(IBK,NTYP) + (THB * ACRE)
      CMTH(IBK,NTYP) = CMTH(IBK,NTYP) + (ADD * ACRE)
      OPEN(IBK,NTYP) = OPEN(IBK,NTYP) + ACRE
      GO TO 10
  335 PBFT(IBK,NTYP) = PBFT(IBK,NTYP) + THB
      PCMT(IBK,NTYP) = PCMT(IBK,NTYP) + ADD
      POPN(IBK,NTYP) = POPN(IBK,NTYP) + 1.0
      GO TO 10
  340 IF(THC .LT. COMCU(KAK)) GO TO 350
      IF(ACRE .EQ. 0.0) GO TO 345
      CMTH(IBK,NTYP) = CMTH(IBK,NTYP) + (THC * ACRE)
      OPEN(IBK,NTYP) = OPEN(IBK,NTYP) + ACRE
      GO TO 10
  345 PCMT(IBK,NTYP) = PCMT(IBK,NTYP) + THC
      POPN(IBK,NTYP) = POPN(IBK,NTYP) + 1.0
      GO TO 10
C
C MAKE RECORD OF NONCOMMERCIAL THINNINGS.
C
  350 IF(ACRE .EQ. 0.0) GO TO 355
      HELP(IBK,NTYP) = HELP(IBK,NTYP) + ACRE
      GO TO 10
  355 PHLP(IBK,NTYP) = PHLP(IBK,NTYP) + 1.0
      GO TO 10
  400 RETURN
      END
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Subroutine SUMS

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      SUBROUTINE SUMS
C
C TO COMPUTE VOLUME AND AREA TOTALS BY WORKING GROUP, AGE CLASS, ETC.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAJS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DPHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARF,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUE,DMR(2)
      COMMON ARFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALDWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMA(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMA(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),ENHD(5),
     4ENCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHFLT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPOES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARS(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PHPS(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT
     37,27),TMTY(7),UNCML(7,27),PARR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACS(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PAS(5,7,14)

      COMMON /BLKP/ PAFN(5,7,15),PARG(5,7,15),
     1PBFT(7,27),PCMT(7,27),PCTA(7,27),PCTB(7,27),PGBD(5,7,15),PGMC(5,7,
     215),PHLP(7,27),POPN(7,27),PPBF(5,7,15),PPCR(7,27),PPFN(7,27),
     3PPMC(5,7,15),PPTC(5,7,15),PSLV(7,27),PTBF(5,7,15),PTCU(5,7,15),
     4PTMC(5,7,15)
      DIMENSION BFBLK(7),BFSP(5,7),BFTB(7,27),CFMER(7),CFTB(7,27),
     1CMSP(5,7),CMTB(7,27),TCF(7),TCSP(5,7),STC(5)
C
C INITIALIZE VARIABLES FIRST DEFINED IN THIS SUBROUTINE.
C
      SBDF = 0.0
      SCFM = 0.
      SSPT = 0.0
      STCF = 0.0
      SUNC = 0.0
      DO 1 I=1,NWGP
      STC(I) = 0.0
      DO 1 J=1,NBK
      BFSP(I,J) = 0.0
      CMSP(I,J) = 0.0
      TCSP(I,J) = 0.0
    1 CONTINUE
      DO 4 I=1,NBK
      BFBLK(I) = 0.0
      CFMER(I) = 0.0
      TCF(I) = 0.0
      DO 4 J=1,27
      BFTB(I,J) = 0.0
      CFTB(I,J) = 0.0
      CMTB(I,J) = 0.0
    4 CONTINUE
C
C COMPUTE TOTAL VOLUMES BY WORKING GROUP, BLOCK, AND AGE CLASS.
C
      DO 50 I=1,NWGP
      DO 50 J=1,NBK
      K = 1 + (I - 1) * 5
      IF(PSPLT(J,K) .EQ. 0.0) GO TO 15
      TEM = PARTY(J,K) / PSPLT(J,K)
      DO 10 MNK=1,3
      PGBD(I,J,MNK) = PGBD(I,J,MNK) * TEM
      PGMC(I,J,MNK) = PGMC(I,J,MNK) * TEM
      PPBF(I,J,MNK) = PPBF(I,J,MNK) * TEM
      PPTC(I,J,MNK) = PPTC(I,J,MNK) * TEM
      PPMC(I,J,MNK) = PPMC(I,J,MNK) * TEM
   10 CONTINUE
   15 K = K + 1
      IF(PSPLT(J,K) .EQ. 0.0) GO TO 25
      TEM = PARTY(J,K) / PSPLT(J,K)
      DO 20 MNK=4,5
      PGBD(I,J,MNK) = PGBD(I,J,MNK) * TEM
      PGMC(I,J,MNK) = PGMC(I,J,MNK) * TEM
      PPBF(I,J,MNK) = PPBF(I,J,MNK) * TEM
      PPTC(I,J,MNK) = PPTC(I,J,MNK) * TEM
      PPMC(I,J,MNK) = PPMC(I,J,MNK) * TEM
   20 CONTINUE
   25 K = K + 1
      IF(PSPLT(J,K) .EQ. 0.0) GO TO 35
      TEM = PARTY(J,K) / PSPLT(J,K)
      DO 30 MNK=6,10
      PGBD(I,J,MNK) = PGBD(I,J,MNK) * TEM
      PGMC(I,J,MNK) = PGMC(I,J,MNK) * TEM
      PPBF(I,J,MNK) = PPBF(I,J,MNK) * TEM
      PPTC(I,J,MNK) = PPTC(I,J,MNK) * TEM
      PPMC(I,J,MNK) = PPMC(I,J,MNK) * TEM
   30 CONTINUE
   35 K = K + 1
      IF(PSPLT(J,K) .EQ. 0.0) GO TO 45
      TEM = PARTY(J,K) / PSPLT(J,K)
      DO 40 MNK=11,14
      PGBD(I,J,MNK) = PGBD(I,J,MNK) * TEM
      PGMC(I,J,MNK) = PGMC(I,J,MNK) * TEM
      PPBF(I,J,MNK) = PPBF(I,J,MNK) * TEM
      PPTC(I,J,MNK) = PPTC(I,J,MNK) * TEM
      PPMC(I,J,MNK) = PPMC(I,J,MNK) * TEM
   40 CONTINUE
   45 K = K + 1
      IF(PSPLT(J,K) .EQ. 0.0) GO TO 50
      TEM = PARTY(J,K) / PSPLT(J,K)
      PGBD(I,J,15) = PGBD(I,J,15) * TEM
      PGMC(I,J,15) = PGMC(I,J,15) * TEM
      PPBF(I,J,15) = PPBF(I,J,15) * TEM
      PPTC(I,J,15) = PPTC(I,J,15) * TEM
      PPMC(I,J,15) = PPMC(I,J,15) * TEM
   50 CONTINUE
      DO 55 I=1,NWGP
      DO 55 J=1,NBK
      DO 55 K=1,15
      GRBD(I,J,K) = GRBD(I,J,K) + PGBD(I,J,K)
      GRMC(I,J,K) = GRMC(I,J,K) + PGMC(I,J,K)
      PTBF(I,J,K) = PTBF(I,J,K) + PPBF(I,J,K)
      PTCU(I,J,K) = PTCU(I,J,K) + PPTC(I,J,K)
      PTMC(I,J,K) = PTMC(I,J,K) + PPMC(I,J,K)
   55 CONTINUE
C
C COMPUTE TOTAL VOLUMES BY BLOCK AND TYPE.
C
      DO 90 I=1,NWGP
      DO 90 J=1,NBK
      K = 1 + (I - 1) * 5
      DO 70 MNK=1,3
      BFTB(J,K) = BFTB(J,K) + PTBF(I,J,MNK)
      CFTB(J,K) = CFTB(J,K) + PTCU(I,J,MNK)
   70 CMTB(J,K) = CMTB(J,K) + PTMC(I,J,MNK)
      K = K + 1
      DO 75 MNK=4,5
      BFTB(J,K) = BFTB(J,K) + PTBF(I,J,MNK)
      CFTB(J,K) = CFTB(J,K) + PTCU(I,J,MNK)
   75 CMTB(J,K) = CMTB(J,K) + PTMC(I,J,MNK)
      K = K + 1
      DO 80 MNK=6,10
      BFTB(J,K) = BFTB(J,K) + PTBF(I,J,MNK)
      CFTB(J,K) = CFTB(J,K) + PTCU(I,J,MNK)
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   80 CMTB(J,K) = CMTB(J,K) + PTMC(I,J,MNK)
      K = K + 1
      DO 85 MNK=11,14
      BFTB(J,K) = BFTB(J,K) + PTBF(I,J,MNK)
      CFTB(J,K) = CFTB(J,K) + PTCU(I,J,MNK)
   85 CMTB(J,K) = CMTB(J,K) + PTMC(I,J,MNK)
      K = K + 1
      BFTB(J,K) = BFTB(J,K) + PTBF(I,J,15)
      CFTB(J,K) = CFTB(J,K) + PTCU(I,J,15)
      CMTB(J,K) = CMTB(J,K) + PTMC(I,J,15)
   90 CONTINUE
C
C COMPUTE TOTAL VOLUMES BY WORKING GROUP AND AGE CLASS.
C
      DO 95 I=1,NWGP
      DO 95 J=1,NBK
      DO 95 K=1,15
      ABFAG(I,K) = ABFAG(I,K) + PTBF(I,J,K)
   95 AMCAG(I,K) = AMCAG(I,K) + PTMC(I,J,K)
C
C CONVERT WORK TOTALS TO AREAS AND VOLUMES BY BLOCK AND TYPE.
C
      DO 100 I=1,NBK
      DO 100 J=1,27
      IF(PSPLT(I,J) .EQ. 0.0) GO TO 100
      TEM = PARTY(I,J) / PSPLT(I,J)
      PBFT(I,J) = PBFT(I,J) * TEM
      PCMT(I,J) = PCMT(I,J) * TEM
      PCTA(I,J) = PCTA(I,J) * TEM
      PCTB(I,J) = PCTB(I,J) * TEM
      PHLP(I,J) = PHLP(I,J) * TEM
      POPN(I,J) = POPN(I,J) * TEM
      PPFN(I,J) = PPFN(I,J) * TEM
      PPCR(I,J) = PPCR(I,J) * TEM
      PSLV(I,J) = PSLV(I,J) * TEM
      PUNC(I,J) = PUNC(I,J) * TEM
  100 CONTINUE
C
C COMPUTE TOTAL VOLUMES OF BLOCKS AND WORKING CIRCLE.
C
      DO 105 I=1,NBK
      DO 105 J=1,27
      BFTH(I,J) = BFTH(I,J) + PBFT(I,J)
      CMTH(I,J) = CMTH(I,J) + PCMT(I,J)
      CUTA(I,J) = CUTA(I,J) + PCTA(I,J)
      CUTB(I,J) = CUTB(I,J) + PCTB(I,J)
      HELP(I,J) = HELP(I,J) + PHLP(I,J)
      OPEN(I,J) = OPEN(I,J) + POPN(I,J)
      PDCFN(I,J) = PDCFN(I,J) + PPFN(I,J)
      PDCFR(I,J) = PDCFR(I,J) + PPCR(I,J)
      SLVG(I,J) = SLVG(I,J) + PSLV(I,J)
      UNCML(I,J) = UNCML(I,J) + PUNC(I,J)
  105 CONTINUE
      DO 110 I=1,NBK
      DO 110 J=1,27
      BFBLK(I) = BFBLK(I) + BFTO(I,J)
      CFMER(I) = CFMER(I) + CMTB(I,J)
      SSPT = SSPT + SPLT(I,J)
      SUNC = SUNC + UNCML(I,J)
  110 TCF(I) = TCF(I) + CFTB(I,J)
      DO 120 I=1,NBK
      SBOF = SBOF + BFBLK(I)
      SCFM = SCFM + CFMER(I)
  120 STCF = STCF + TCF(I)
C
C COMPUTE BLOCK VOLUMES BY WORKING GROUP.
C
      M = 1
      N = 5
      DO 130 I=1,NWGP
      DO 125 J=1,NBK
      DO 125 K=M,N
      BFSP(I,J) = BFSP(I,J) + BFTB(J,K)
      CMSP(I,J) = CMSP(I,J) + CMTB(J,K)
  125 TCSP(I,J) = TCSP(I,J) + CFTB(J,K)
      M = M + 5
      N = N + 5
  130 CONTINUE
C
C COMPUTE VOLUMES BY WORKING GROUP.
C
      DO 135 I=1,NWGP
      DO 135 J=1,NBK
      SBF(I) = SBF(I) + BFSP(I,J)
      SMC(I) = SMC(I) + CMSP(I,J)
  135 STC(I) = STC(I) + TCSP(I,J)
      IF(TMBR .EQ. 0.0) GO TO 210
C
C COMPUTE AREAS BY COMBINATIONS OF WORKING GROUP, BLOCK, AND AGE.
C
      DO 185 I=1,NWGP
      DO 180 J=1,NBK
      DO 180 K=1,15
      IF(TPB(I,J) .EQ. 0.0) GO TO 180
      PAFN(I,J,K) = PASP(I,J) * PAFN(I,J,K) / TPB(I,J)
      PARG(I,J,K) = PASP(I,J) * PARG(I,J,K) / TPB(I,J)
  180 CONTINUE
  185 CONTINUE
      DO 190 I=1,NWGP
      DO 190 J=1,NBK
      DO 190 K=1,15
      ACFNL(I,J,K) = ACFNL(I,J,K) + PAFN(I,J,K)
  190 ACRGN(I,J,K) = ACRGN(I,J,K) + PARG(I,J,K)
C
C COMPUTE PERIODIC ANNUAL INCREMENT.
C
      DO 200 I=1,NWGP
      DO 200 J=1,NBK
      DO 200 K=1,15
      PAIBD(I) = GRBD(I,J,K) + PAIBD(I)
      PAICU(I) = GRMC(I,J,K) + PAICU(I)
  200 CONTINUE
      DO 205 I=1,NWGP
      IF(TIME .EQ. 0.0) GO TO 205
      PAIBD(I) = PAIBD(I) / TIME
      PAICU(I) = PAICU(I) / TIME
  205 CONTINUE
C
C PRINT PAGE TYPE 13 - WORKING GROUP AND BLOCK VOLUMES.
C
  210 WRITE (6,250)
  250 FORMAT (1H1,//,60X,12HPAGE TYPE 13)
      WRITE (6,255)
  255 FORMAT (1H0,//,47X,36HVOLUMES OF BLOCKS AND WORKING CIRCLE)
      WRITE (6,260) (FORET(I), I=1,19)
  260 FORMAT (1H ,29X,18A4,A2)
      WRITE (6,265)
  265 FORMAT (1H0,//,23X,6HTOTALS,4X,11HBLOCK NO. 1,4X,11HBLOCK NO. 2,
     14X,11HBLOCK NO. 3,4X,11HBLOCK NO. 4,4X,11HBLOCK NO. 5,4X,
     211HBLOCK NO. 6,4X,11HBLOCK NO. 7)
      DO 300 I=1,NWGP
      WRITE (6,270) (WGPNM(I,J),J=1,3)
  270 FORMAT (1H0,/ ,1X,3A4)
      WRITE (6,275) STC(I),(TCSP(I,J),J=1,NBK)
  275 FORMAT (1H0,13HTOTAL CU. FT.,8(4X,F11.1))
      WRITE (6,280) SMC(I),(CMSP(I,J),J=1,NBK)
  280 FORMAT (1H0,14HMERCH. CU. FT.,8(3X,F11.1,1X))
      WRITE (6,285) SBF(I),(BFSP(I,J),J=1,NBK)
  285 FORMAT (1H0,9HM BD. FT.,4X,8(4X,F11.1))
      IF(I .EQ. 4) GO TO 290
      GO TO 300
  290 WRITE (6,295)
  295 FORMAT (1H1,//,56X,19HPAGE TYPE 13, CONT.//)
  300 CONTINUE
      WRITE (6,305)
  305 FORMAT (1H ,//,2X,12HTOTAL VOLUME,/,3X,8HOF BLOCK)
      WRITE (6,310) STCF,(TCF(I),I=1,NBK)
  310 FORMAT (1H0,13HTOTAL CU. FT.,8(4X,F11.1))
      WRITE (6,315) SCFM,(CFMER(I),I=1,NBK)
  315 FORMAT (1H0,14HMERCH. CU. FT.,8(3X,F11.1,1X))
      WRITE (6,320) SBOF,(BFBLK(I),I=1,NBK)
  320 FORMAT (1H0,9HM BD. FT.,4X,8(4X,F11.1))
      WRITE (6,325)
  325 FORMAT(1H0,10X,47HCUBIC FEET IN HUNDREDS, BOARD FEET IN THOUSANDS)
C
C PRINT PAGE TYPE 14 - TYPE AREAS AND VOLUMES.
C
      WRITE (6,350)
  350 FORMAT (1H1,//,60X,12HPAGE TYPE 14)
      WRITE (6,355)
  355 FORMAT (1H0,/,39X,52HTOTAL AREAS AND VOLUMES OF BLOCKS AND WORKING
     1 CIRCLE)
      WRITE (6,260) (FORET(I), I=1,19)
      KOUNT = 1
      DO 395 I=1,NBK
      IF(ARBK(I) .EQ. 0.0) GO TO 395
      IF(KOUNT .EQ. 1) GO TO 365
      WRITE (6,360)
  360 FORMAT (1H1,//,56X,19HPAGE TYPE 14, CONT.//)
  365 WRITE (6,370)
  370 FORMAT (1H0,5HBLOCK,7X,4HTYPE,12X,5HTOTAL,12X,5HTOTAL,12X,6HMERCH.
     1,13X,1HM,13X,5HACRES,11X,6HNUMBER)
      WRITE (6,375)
  375 FORMAT (1H ,1X,3HNO.,9X,3HNO.,12X,5HACRES,11X,7HCU. FT.,11X,7HCU.
     1FT.,9X,7HBD. FT.,9X,8HLOW SITE,7X,10HOF RECORDS,//)
      KOUNT = 0
      DO 390 J=1,27
      WRITE (6,380) I,J,SAFETY(I,J),CFTB(I,J),CMTB(I,J),BFTB(I,J),UNCML(
     1I,J),SPLT(I,J)
  380 FORMAT (1H ,1X,I2,10X,I2,9X,5(F11.1,6X),F6.0)
      IF(J .LT. 27) GO TO 390
      WRITE (6,385)
  385 FORMAT (1H0)
  390 CONTINUE
  395 CONTINUE
      WRITE (6,400) TMPO,STCF,SCFM,SBOF,SUNC,SSPT
  400 FORMAT (1H0,6HTOTALS,18X,5(F11.1,6X),F6.0)
      WRITE (6,325)
      RETURN
      END
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Subroutine SUMRY

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      SUBROUTINE SUMRY
C
C TO COMPUTE DIFFERENCES BETWEEN PRESENT VOLUMES AND STOCKING GOALS.
C
      COMMON ADD,AGE(2),AGED,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHF,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVC,SBARB,SBARE,SBARC,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMPR
     5,TMPU,TOT(2),TOTU,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON APFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMA((5),BFAGE(5,15(
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMA((5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNPD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POCR(5),REGN(5,3,14),
     6RINT(5),SABSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPRES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACHAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSPK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TOTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACS((5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PAS((5,7,14)
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C
      COMMON /BLKC/ ANNAC,ANNBD,ANNCU,FINB(5),FINC(5),FNAC(5),RGAC(5),
     1RGBD(5),RGCU(5),SAHP(5),SANCUT(5),SATH(5),SBFR(5),SBH(5),SBSV(5),
     2SCA(5,7),SCB(5,7),SCN(5),SCNB(5,7),SCNT(25),SCR(5),SCRB(5,7),
     3SCRT(25),SCU(5,7),SCUR(5),SFNL(5),SFR(5),SHL(5,7),SIDLA,SIDLB,
     4SIDLC,SOP(5,7),SOPTA(5),SOPTB(5),SOPTC(5),SSL(5,7),STBS(25),STFO
     5(25),STHP(25),STHR(25),STLV(25),STNC(25),STON(25),THAC(5),THBD(5),
     6THCU(5),TOTAC(5),TOTBD(5),TOTCU(5),SBM(5,7)
C
      COMMON /BLKE/ RABDF(5),RABDI(5),RABDR(5),RABT(5),RACFN(5),RACIT(5)
     1,RACRG(5),RATC(5),SRABD,SRACF
C
      DIMENSION DFBF(5,15),DFMC(5,15),SDBF(5),SDMC(5)
C
C INITIALIZE VARIABLES COMPUTED BY THIS ROUTINE.
C
      DO 1 I=1,NWGP
      FINB(I)  = 0.0
      FINC(I)  = 0.0
      FNAC(I) = 0.0
      RABDF(I) = 0.0
      RABDI(I) = 0.0
      RABDR(I) = 0.0
      RABT(I) = 0.0
      RACFN(I) = 0.0
      RACIT(I) = 0.0
      RACRG(I) = 0.0
      RATC(I) = 0.0
      RGAC(I) = 0.0
      RGBD(I)  = 0.0
      RGCU(I)  = 0.0
      SAHP(I) = 0.0
      SANCUT(I) = 0.0
      SATH(I) = 0.0
      SBFR(I) = 0.0
      SBH(I) = 0.0
      SBSV(I) = 0.0
      SCN(I) = 0.0
      SCR(I) = 0.0
      SCUR(I) = 0.0
      SDBF(I) = 0.0
      SDMC(I) = 0.0
      SFNL(I) = 0.0
      SFR(I) = 0.0
      SOPTA(I) = 0.0
      SOPTB(I) = 0.0
      SOPTC(I) = 0.0
      THAC(I)  = 0.0
      THBD(I)  = 0.0
      THCU(I)  = 0.0
      TOTAC(I) = 0.0
      TOTBD(I) = 0.0
      TOTCU(I) = 0.0
      DO 1 J=1,NBK
      SBM(I,J) = 0.0
      SCA(I,J) = 0.0
      SCB(I,J) = 0.0
      SCNB(I,J) = 0.0
      SCRB(I,J) = 0.0
      SCU(I,J) = 0.0
      SHL(I,J) = 0.0
      SOP(I,J) = 0.0
      SSL(I,J) = 0.0
    1 CONTINUE
      DO 3 I=1,2
    3 TOT(I) = 0.0
      DO 5 I=1,NWGP
      DO 5 J=1,15
      DFBF(I,J) = 0.0
    5 DFMC(I,J) = 0.0
      DO 10 I=1,25
      SCNT(I) = 0.0
      SCRT(I) = 0.0
      STBS(I) = 0.0
      STFO(I) = 0.0
      STHP(I) = 0.0
      STHR(I) = 0.0
      STLV(I) = 0.0
      STNC(I) = 0.0
   10 STON(I) = 0.0
      ANNAC = 0.0
      ANNBD = 0.0
      ANNCU = 0.0
      SIDLA = 0.0
      SIDLB = 0.0
      SIDLC = 0.0
      SRABD = 0.0
      SRACF = 0.0
      STHBF = 0.0
      STHCM = 0.0
C
C COMPUTE DIFFERENCES BETWEEN ACTUAL AND DESIRED GROWING STOCKS.
C
      DO 15 I=1,NWGP
      DO 15 J=1,15
      DFBF(I,J) = ABFAG(I,J) - BFAGE(I,J)
   15 DFMC(I,J) = AMCAG(I,J) - CFAGE(I,J)
C
C COMPUTE TOTAL DIFFERENCES BETWEEN ACTUAL AND DESIRED STOCKS.
C
      DO 20 I=1,NWGP
      DO 20 J=1,15
      SDBF(I) = SDBF(I) + DFBF(I,J)
   20 SDMC(I) = SDMC(I) + DFMC(I,J)
C
C PRINT PAGE TYPE 3 - ACTUAL AND DESIRED GROWING STOCKS AND DIFFERENCES.
C
      DO 100 KA=1,NWGP
      WRITE (6,30)
   30 FORMAT (1H1,/,60X,11HPAGE TYPE 3)
      WRITE (6,32)
   32 FORMAT (1H0,34X,58HCOMPARISON OF ACTUAL GROWING STOCK WITH GROWING
     1 STOCK GOAL)
      WRITE (6,34) (FORET(I),I=1,19)
   34 FORMAT (1H ,29X,18A4,A2)
      WRITE (6,36) (WGPNM(KA,J),J=1,3)
   36 FORMAT (1H0,53X,16HWORKING GROUP - ,3A4,/)
      WRITE (6,38)
   38 FORMAT (1H ,33X,52HTHOUSANDS OF BOARD FEET IN TREES OF COMMERCIAL
     1SIZE.)
      WRITE (6,40)
   40 FORMAT (1H0,12X,3HAGE,11X,14HACTUAL GROWING,10X,13HGROWING STOCK,1
     15X,6HVOLUME,15X,9HSTATUS OF)
      WRITE (6,42)
   42 FORMAT (1H ,11X,5HCLASS,14X,5HSTOCK,19X,4HGOAL,18X,10HDIFFERENCE,1
     11X,13HACTUAL VOLUME,/)
      DO 70 I=1,15
      J = I * 10
      IF(DFBF(KA,I) .LT. 0.0) GO TO 50
      IF(DFBF(KA,I) .EQ. 0.0) GO TO 60
      WRITE (6,45) J,ABFAG(KA,I),BFAGE(KA,I),DFBF(KA,I)
   45 FORMAT (1H ,12X,I3,11X,F14.1,9X,F14.1,9X,F14.1,14X,7HSURPLUS)
      GO TO 70
   50 WRITE (6,55) J,ABFAG(KA,I),BFAGE(KA,I),DFBF(KA,I)
   55 FORMAT (1H ,12X,I3,11X,F14.1,9X,F14.1,9X,F14.1,14X,7HDEFICIT)
      GO TO 70
   60 WRITE (6,65) J,ABFAG(KA,I),BFAGE(KA,I),DFBF(KA,I)
   65 FORMAT (1H ,12X,I3,11X,F14.1,9X,F14.1,9X,F14.1,14X,7HCORRECT)
   70 CONTINUE
      WRITE (6,75) SBF(KA),GVLBF(KA),SDBF(KA)
   75 FORMAT (1H0,11X,5HTOTAL,10X,F14.1,9X,F14.1,9X,F14.1,/)
      WRITE (6,80)
   80 FORMAT (1H0,31X,67HHUNDREDS OF MERCH. CUBIC FEET IN TREES 6.0 INCH
     1ES D.B.H. AND LARGER,/)
      WRITE (6,40)
      WRITE (6,42)
      DO 95 I=1,15
      J = I * 10
      IF(DFMC(KA,I) .LT. 0.0) GO TO 85
      IF(DFMC(KA,I) .EQ. 0.0) GO TO 90
      WRITE (6,45) J,AMCAG(KA,I),CFAGE(KA,I),DFMC(KA,I)
      GO TO 95
   85 WRITE (6,55) J,AMCAG(KA,I),CFAGE(KA,I),DFMC(KA,I)
      GO TO 95
   90 WRITE (6,65) J,AMCAG(KA,I),CFAGE(KA,I),DFMC(KA,I)
   95 CONTINUE
      WRITE (6,75) SMC(KA),SUMCF(KA),SDMC(KA)
  100 CONTINUE
C
C SUMMARIZE VOLUMES EXPECTED DURING NEXT PERIOD BY BLOCK AND TYPE.
C
      M = 1
      N = 5
      DO 115 K=1,NWGP
      DO 110 I=1,NBK
      DO 110 J=M,N
      SBM(K,I) = SBM(K,I) + BFTH(I,J)
      SCA(K,I) = SCA(K,I) + CUTA(I,J)
      SCB(K,I) = SCB(K,I) + CUTB(I,J)
      SCNB(K,I) = SCNB(K,I) + POCFN(I,J)
      SCRB(K,I) = SCRB(K,I) + POCFR(I,J)
      SCU(K,I) = SCU(K,I) + CMTH(I,J)
      SHL(K,I) = SHL(K,I) + HELP(I,J)
      SOP(K,I) = SOP(K,I) + OPEN(I,J)
      SSL(K,I) = SSL(K,I) + SLVG(I,J)
  110 CONTINUE
      M = M + 5
      N = N + 5
  115 CONTINUE
      DO 120 I=1,NBK
      DO 120 J=1,25
      SCNT(J) = SCNT(J) + POCFN(I,J)
      SCRT(J) = SCRT(J) + POCFR(I,J)
      STBS(J) = STBS(J) + BFTH(I,J)
      STFO(J) = STFO(J) + CUTB(I,J)
      STHP(J) = STHP(J) + HELP(I,J)
      STHR(J) = STHR(J) + CUTA(I,J)
      STLV(J) = STLV(J) + SLVG(I,J)
      STNC(J) = STNC(J) + CMTH(I,J)
      STON(J) = STON(J) + OPEN(I,J)
  120 CONTINUE
      DO 125 I=1,NWGP
      DO 125 J=1,NBK
      SAHP(I) = SAHP(I) + SHL(I,J)
      SATH(I) = SATH(I) + SOP(I,J)
      SBFR(I) = SBFR(I) + SBM(I,J)
      SBH(I) = SBH(I) + SCA(I,J)
      SBSV(I) = SBSV(I) + SSL(I,J)
      SCN(I) = SCN(I) + SCNB(I,J)
      SCR(I) = SCR(I) + SCRB(I,J)
      SCUR(I) = SCUR(I) + SCU(I,J)
      SFR(I) = SFR(I) + SCB(I,J)
  125 CONTINUE
C
C SUM THE ANNUAL CUTS BASED ON OPTIMUM AREA REGULATION BY WORKING GROUP
C AND WORKING CIRCLE.
C
      DO 130 I=1,NWGP
      DO 130 J=1,14
  130 SANCUT(I) = SANCUT(I) + ANCUT(I,J)
      DO 135 I=1,NWGP
      SFNL(I) = SANCUT(I)
      IF(SYST(I) .EQ. 0.0) SFNL(I) = 0.0
      K = PGOR(I) * 0.1 + 0.5
      IF(REGN(I,3,K) .GT. 0.0) SANCUT(I) = SANCUT(I) * 2.0
  135 CONTINUE
      DO 140 I=1,NWGP
      SOPTA(I) = SANCUT(I) + SFNL(I) + ACINT(I)
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      SOPTB(I) = OPBD(I) + FNBD(I) + BFINT(I)
      SOPTC(I) = OPCU(I) + FNCU(I) + CUINT(I)
      IF(WGPNM(I,1) .EQ. 4HDEFE) GO TO 140
      SIDLA = SIDLA + SOPTA(I)
      SIDLB = SIDLB + SOPTB(I)
      SIDLC = SIDLC + SOPTC(I)
  140 CONTINUE
C
C COMPUTE POSSIBLE ANNUAL CUTS DURING NEXT PERIOD - BASIS WORK INDEX.
C
      DO 150 I=1,NWGP
      DO 150 J=1,NBK
      DO 150 K=1,15
      RGAC(I) = RGAC(I) + ACRGN(I,J,K)
  150 FNAC(I) = FNAC(I) + ACFNL(I,J,K)
      TEM = 1.0 / TIME
      DO 155 I=1,NWGP
      FINB(I) = SFR(I) * TEM
      FINC(I) = SCN(I) * TEM
      FNAC(I) = FNAC(I) * TEM
      RGAC(I) = RGAC(I) * TEM
      RGBD(I) = SBH(I) * TEM
      RGCU(I) = SCR(I) * TEM
      THAC(I) = (SATH(I) + SAHP(I)) * TEM
      THBD(I) = SBFR(I) * TEM
      THCU(I) = SCUR(I) * TEM
  155 CONTINUE
      DO 160 I=1,NWGP
      TOTAC(I) = RGAC(I) + FNAC(I) + THAC(I)
      TOTCU(I) = RGCU(I) + FINC(I) + THCU(I)
      TOTBD(I) = RGBD(I) + FINB(I) + THBD(I)
      ANNAC = ANNAC + TOTAC(I)
      ANNCU = ANNCU + TOTCU(I)
  160 ANNBD = ANNBD + TOTBD(I)
C
C COMPUTE ANNUAL CUT BY HEYER FORMULA USING M.A.I. FROM YIELD TABLES.
C
      DO 210 I=1,NWGP
      IF(ADJ(I) .EQ. 0.0) GO TO 190
      ALWBF(I) = BDMAI(I) + (SDBF(I) / ADJ(I))
      ALOWC(I) = CUMAI(I) + (SDMC(I) / ADJ(I))
      GO TO 200
  190 ALWBF(I) = BDMAI(I) + SDBF(I)
      ALOWC(I) = CUMAI(I) + SDMC(I)
  200 IF(ALWBF(I) .LT. 0.0) ALWBF(I) = 0.0
      IF(ALOWC(I) .LT. 0.0) ALOWC(I) = 0.0
  210 CONTINUE
      DO 220 I=1,NWGP
      IF(WGPNM(I,1) .EQ. 4HDEFE) GO TO 220
      TOT(1) = ALWBF(I) + TOT(1)
  220 TOT(2) = ALOWC(I) + TOT(2)
C
C COMPUTE AREA REGULATION VOLUMES FOR THIRD TABLE, PAGE TYPE 1.
C CHANGE MULTIPLIER OF RACIT AND RABOI IF GOAL OF ONE PRECOMMERCIAL
C THINNING IS NOT APPLICABLE.
C
      DO 230 I=1,NWGP
      IF(RGAC(I) .LE. 0.0) GO TO 226
      RACRG(I) = (RGCU(I) / RGAC(I)) * SANCUT(I)
      RABDR(I) = (RGBD(I) / RGAC(I)) * SANCUT(I)
  226 IF(FNAC(I) .LE. 0.0) GO TO 228
      RACFN(I) = (FINC(I) / FNAC(I)) * SFNL(I)
      RABDF(I) = (FINB(I) / FNAC(I)) * SFNL(I)
  228 IF(SATH(I) .LE. 0.0) GO TO 230
      K = POOR(I) * 0.1 + 0.5
      IF(REGN(I,3,K) .GT. 0.0) SANCUT(I) = SFNL(I)
      RACIT(I) = (THCU(I) / (SATH(I) * TEM)) * (ACINT(I) - SANCUT(I))
      RABDI(I) = (THBD(I) / (SATH(I) * TEM)) * (ACINT(I) - SANCUT(I))
  230 CONTINUE
      DO 240 I=1,NWGP
      RATC(I) = RACRG(I) + RACFN(I) + RACIT(I)
      RABT(I) = RABDR(I) + RABDF(I) + RABDI(I)
  240 CONTINUE
      DO 250 I=1,NWGP
      SRACF = SRACF + RATC(I)
      SRABD = SRABD + RABT(I)
  250 CONTINUE
      RETURN
      END
```

Subroutine GIDE1

```
      SUBROUTINE GIDE1
C
C PRINT PAGE TYPE 1 - SUMMARY OF RESULTS AND GUIDE TO MANAGEMENT.
C
       COMMON ADD,AGE(2),AGEC,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNC,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARC,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMPR
     5,TMPC,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
       COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHFLT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
       COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PCCFA(7,27
     2),PCCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
       COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
       COMMON /BLKC/ ANNAC,ANNBD,ANNCU,FINB(5),FINC(5),FNAC(5),RGAC(5),
     1RGBD(5),RGCU(5),SAHP(5),SANCUT(5),SATH(5),SBFR(5),SBH(5),SBSV(5),
     2SCA(5,7),SCB(5,7),SCN(5),SCNB(5,7),SCNT(25),SCR(5),SCRB(5,7),
     3SCRT(25),SCU(5,7),SCUR(5),SFNL(5),SFR(5),SHL(5,7),SIDLA,SIDLB,
     4SIDLC,SCP(5,7),SOPTA(5),SOPTB(5),SOPTC(5),SSL(5,7),STBS(25),STFO
     5(25),STHP(25),STHR(25),STLV(25),STNC(25),STON(25),THAC(5),THBD(5),
     6THCU(5),TOTAC(5),TOTBD(5),TOTCU(5),SBM(5,7)

       COMMON /BLKE/ RABDF(5),RABDI(5),RABDR(5),RABT(5),RACFN(5),RACIT(5
     1),RACRG(5),RATC(5),SRABD,SRACF

       DIMENSION A(3)

       DATA A/3*1H /

       CURS = SLAND - STYP(32)
       WRITE (6,505)
  505  FORMAT (1H1,59X,11HPAGE TYPE 1)
       WRITE (6,510) (FORET(I), I=1,19)
  510  FORMAT (1H0,/,10X,21HGUIDE FOR MANAGEMENT ,18A4,A2)
       WRITE (6,515) (DATE(I),I=1,6)
  515  FORMAT (1H0,5X,25HBASED ON DATA CURRENT TO ,6A4)
       WRITE (6,520) SLAND,CURS,STYP(32),TMBR,SBARE,STYP(31),STYP(28)
  520  FORMAT (1H0,31HTHE WORKING CIRCLE CONSISTS OF ,F10.1,18H ACRES. OF
     1 THESE, ,F10.1,29H ACRES ARE OWNED BY U.S. AND ,F10.1,19H ACRES AR
     2E INTERIOR/1H ,45HTRACTS OF OTHER OWNERSHIP. OUR AREA INCLUDES ,F1
     30.1,17H TIMBERED ACRES, ,F10.1,18H PLANTABLE ACRES, ,F10.1,17H ACR
     4ES MANAGED AS/1H ,11HRANGE, AND ,F10.1,106H ACRES OF HIGH RECREATI
     5ON USE WHERE TIMBER YIELDS ARE INCIDENTAL AND NOT REGULATED. SEE P
     6AGE TYPE 5, 6, 7,/1H ,31HAND 14 FOR AREA CLASSIFICATION.)
       WRITE (6,530)
  530  FORMAT (1H0,70HTHE TIMBER RESOURCE OF THIS WORKING CIRCLE WILL BE
     1MANAGED AS FOLLOWS-   )
       DO 560 I=1,NWGP
       WRITE (6,550) (WGPNM(I,J),J=1,3),(WGPDES(I,K),K=1,20)
  550  FORMAT (1H ,15X,3A4,3H - ,20A4)
  560  CONTINUE
       WRITE (6,570)
  570  FORMAT (1H0,58HREGULATION OF THE CUT WILL BE BY AREA WITH A VOLUME
     1 CHECK.)
       WRITE (6,575)
  575  FORMAT (1H0,125HWITH THE DECISIONS AND AREAS ON PAGES TYPE 4 AND 1
     11 AND WITH BALANCED DISTRIBUTION OF AGE CLASSES, ALLOWABLE ANNUAL
     2CUT WOULD/1H ,14HBE AS FOLLOWS-)
       WRITE (6,580)
  580  FORMAT (1H0,64X,11HHUNDREDS OF/1H ,42X,5HACRES,19X,7HCU. FT.,17X,9
     1HM BD. FT.)
       WRITE (6,590)
  590  FORMAT (1H0,11X,17HREGENERATION CUTS,/)
       DO 605 I=1,NWGP
       K = POOR(I) * 0.1 + 0.5
       IF(REGN(I,3,K) .GT. 0.0) SANCUT(I) = SANCUT(I) * 2.0
       WRITE (6,600) (WGPNM(I,J),J=1,3),SANCUT(I),OPCU(I),OPBD(I)
  600  FORMAT (1H ,15X,3A4,11X,F11.1,14X,F11.1,14X,F11.1)
  605  CONTINUE
       WRITE (6,610)
  610  FORMAT (1H0,11X,18HFINAL REMOVAL CUTS,/)
       DO 615 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),SFNL(I),FNCU(I),FNBD(I)
  615  CONTINUE
       WRITE (6,620)
  620  FORMAT (1H0,11X,17HINTERMEDIATE CUTS,/)
       DO 625 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),ACINT(I),CUINT(I),BFINT(I)
  625  CONTINUE
       WRITE (6,630)
  630  FORMAT (1H0,11X,18HTOTAL FOR ONE YEAR,/)
       DO 635 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),SOPTA(I),SOPTC(I),SOPTB(I)
  635  CONTINUE
       WRITE (6,640) SIDLA,SIDLC,SIDLB
  640  FORMAT (1H0,11X,16HTOTAL ALL GROUPS,11X,F11.1,14X,F11.1,14X,F11.1)
       WRITE (6,650)
  650  FORMAT (1H0,1X,62HTOTAL ALL GROUPS DOES NOT INCLUDE DEFERRED GROUP
     1S, IF PRESENT.)
       WRITE (6,665)
  665  FORMAT (1H1,//,56X,18HPAGE TYPE 1, CONT.)
       WRITE (6,670)
  670  FORMAT (1H0,123HONLY COMMERCIAL VOLUMES ARE INCLUDED IN THE TABLES
     1 OF PAGE TYPE 1. CUTS ARE ASSIGNED TO BOARD FOOT TOTALS IF POSSIBL
     2E. THEY/1H ,124HAPPEAR IN CUBIC-FOOT TOTALS ONLY WHEN COMMERCIAL S
     3AWLOG CUTS ARE NOT POSSIBLE. AREAS OF INTERMEDIATE CUTS INCLUDE AC
     4REAGE OF/1H ,35HNONCOMMERCIAL SHOWN ON PAGE TYPE 2.)
       WRITE (6,680)
  680  FORMAT (1H0,125HACTUAL VOLUMES CUT DURING THE NEXT PERIOD COULD BE
     1 AS SHOWN ON PAGES TYPE 2 IF ALL POSSIBLE CULTURAL OPERATIONS, AS
     2INDICATED/1H ,68HBY WORK CODES, WERE PERFORMED. POTENTIAL ANNUAL C
     3UTS WOULD THEN BE--)
       WRITE (6,580)
       WRITE (6,590)
       DO 700 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),RGAC(I),RGCU(I),RGBD(I)
  700  CONTINUE
       WRITE (6,610)
       DO 705 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),FNAC(I),FINC(I),FINB(I)
  705  CONTINUE
       WRITE (6,620)
       DO 710 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),THAC(I),THCU(I),THBD(I)
  710  CONTINUE
       WRITE (6,630)
       DO 715 I=1,NWGP
       WRITE (6,600) (WGPNM(I,J),J=1,3),TOTAC(I),TOTCU(I),TOTBD(I)
  715  CONTINUE
       WRITE (6,640) ANNAC,ANNCU,ANNBD
       WRITE (6,665)
       WRITE (6,720)
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720 FORMAT (1H0,109HTHE FIRST TABLE, ABOVE, REPRESENTS YIELDS FROM ARE
   1A REGULATION WHEN VOLUME AND AREA GOALS HAVE BEEN ATTAINED.)
    WRITE (6,725)
725 FORMAT (1H0,50HTHE SECOND TABLE CAN REPRESENT AREA REGULATION IF-/
   11H ,8X,48H(1) VOLUME AND AREA GOALS HAVE NOT BEEN ATTAINED/1H ,8X,
   296H(2) WORK CODING IS SUCH THAT THE AREA VALUES OF THE SECOND TABL
   3E EQUAL AREAS OF THE FIRST TABLE.)
    WRITE (6,730)
730 FORMAT (1H0,87HIF NEITHER OF THESE ALTERNATIVES APPLY, YIELDS FROM
   1 AREA REGULATION WILL BE AS FOLLOWS-)
    WRITE (6,580)
    WRITE (6,590)
    DO 732 I=1,NWGP
    WRITE (6,600) (WGPNM(I,J),J=1,3),SANCUT(I),RACRG(I),RABOR(I)
732 CONTINUE
    WRITE (6,610)
    DO 734 I=1,NWGP
    WRITE (6,600) (WGPNM(I,J),J=1,3),SFNL(I),RACFN(I),RABOF(I)
734 CONTINUE
    WRITE (6,620)
    DO 736 I=1,NWGP
    WRITE (6,600) (WGPNM(I,J),J=1,3),ACINT(I),RACIT(I),RABOI(I)
736 CONTINUE
    WRITE (6,630)
    DO 738 I=1,NWGP
    WRITE (6,600) (WGPNM(I,J),J=1,3),SOPTA(I),RATC(I),RABT(I)
738 CONTINUE
    WRITE (6,640) SIOLA,SRACF,SRABO
    WRITE (6,665)
    WRITE (6,740)
740 FORMAT (1H0,//,1X,85HFORMULA COMPUTATION OF ALLOWABLE ANNUAL CUT.
   1CUBIC-FOOT VOLUMES INCLUDE SAWLOG TREES-)
    WRITE (6,745)
745 FORMAT (1H0,11X,79HHEYER FORMULA WITH M.A.I. FROM OPTIMUM YIELD TA
   1BLES AND COMPUTED GROWING STOCKS)
    WRITE (6,750)
750 FORMAT (1H0,42X,10HADJUSTMENT,12X,11HHUNDREDS OF/1H ,44X,6HPERIOD,
   116X,7HCU. FT.,17X,9HM BD. FT.,/)
    DO 755 I=1,NWGP
    IF(WGPNM(I,1) .EQ. 4HDEFE) GO TO 755
    WRITE (6,600) (WGPNM(I,J),J=1,3),ADJ(I),ALOWC(I),ALWBF(I)
755 CONTINUE
    WRITE (6,760) TOT(2),TOT(1)
760 FORMAT (1H0,15X,5HTOTAL,43X,F11.1,14X,F11.1)
    WRITE (6,765)
765 FORMAT (1H0,11X,65HMEAN ANNUAL INCREMENTS USED TO OBTAIN THE RESUL
   1TS TABULATED ABOVE)
    WRITE (6,750)
    DO 770 I=1,NWGP
    WRITE (6,600) (WGPNM(I,J),J=1,3),ADJ(I),CUMAI(I),BDMAI(I)
770 CONTINUE
    WRITE (6,775)
775 FORMAT (1H0,120HFORMULA COMPUTATIONS ARE BASED ON VOLUME AND AREA
   1COMPUTATIONS SUMMARIZED ON OTHER PAGES. VOLUME GOALS ARE ON PAGES
   2TYPE/1H ,120H4, 8, 9, 10, AND 11. ACTUAL AREAS AND VOLUMES ARE ON
   3PAGES TYPE 6, 7, 13, AND 14. CUBIC VOLUMES INCLUDE ALL TREES LARGE
   4R/1H ,68HAND OLDER THAN MINIMUM LIMITS FOR INCLUSION IN GROWING ST
   5OCK VOLUME.)
    WRITE (6,800)
800 FORMAT (1H0,124HSTANDS SELECTED FOR HARVEST AND REGENERATION WILL
   1INCLUDE THOSE CLASSED AS WORK INDEX 4, 5, OR 6. IT IS EXPECTED THA
   2T NEARLY/1H ,126HEQUAL AREAS WILL BE CUT ANNUALLY IN STANDS OF EAC
   3H SITE CLASS. IF THIS IS NOT DESIRABLE, FACTORS THAT INDICATE RELA
   4TIVE VOLUME/1H ,59HPRODUCTION (PAGE TYPE 12) MAY BE USED FOR AREA
   5ADJUSTMENTS.)
    WRITE (6,805)
805 FORMAT (1H0,100HIF WORK IS DONE DURING NEXT PERIOD AS SPECIFIED BY
   1 WORK INDEXES, PERIODIC ANNUAL INCREMENTS WILL BE-)
    WRITE (6,810)
810 FORMAT (1H0,44X,11HHUNDREDS OF/1H ,46X,7HCU. FT.,17X,9HM BD. FT.,/
   1)
    DO 820 I=1,NWGP
    WRITE (6,815) (WGPNM(I,J),J=1,3),PAICU(I),PAIBD(I)
815 FORMAT (1H ,15X,3A4,19X,F8.1,16X,F8.1)
820 CONTINUE
    RETURN
    END
```

Subroutine GIDE2

```
      SUBROUTINE GIDE2
C
C PRINT PAGE TYPE 2 - POTENTIAL WORK AND YIELDS FOR NEXT PERIOD.
C
      COMMON ADD,AGE(2),AGED,BA(2),BAS(2),BASD,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHD,DBHT,DEN(2),DEND,DENT,DMUS,FBA(2),
     2FCTR(2),FOM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMBR
     5,TMPD,TOT(2),TOTD,TOTT,TVL(2),VOM(2),VLUS,OMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKC/ ANNAC,ANNBD,ANNCU,FINB(5),FINC(5),FNAC(5),RGAC(5),
     1RGBD(5),RGCU(5),SAHP(5),SANCUT(5),SATH(5),SBFR(5),SBH(5),SBSV(5),
     2SCA(5,7),SCB(5,7),SCN(5),SCNB(5,7),SCNT(25),SCR(5),SCRB(5,7),
     3SCRT(25),SCU(5,7),SCUR(5),SFNL(5),SFR(5),SHL(5,7),SIOLA,SIOLB,
     4SIOLC,SOP(5,7),SOPTA(5),SOPTB(5),SOPTC(5),SSL(5,7),STBS(25),STFO
     5(25),STHP(25),STHR(25),STLV(25),STNC(25),STON(25),THAC(5),THBD(5),
     6THCU(5),TOTAC(5),TOTBD(5),TOTCU(5),SBM(5,7)
C
      DO 490 KA=1,NWGP
      SSUM = 0.0
      SSUM = SATH(KA) + SCUR(KA) + SBFR(KA) + SBSV(KA) + SBH(KA) +
     1SCR(KA) + SFR(KA) + SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
    5 FORMAT (1H1,//,60X,11HPAGE TYPE 2)
      WRITE (6,10)
   10 FORMAT (1H0,40X,46HPOTENTIAL WORK LOAD AND YIELDS FOR NEXT PERIOD)
      WRITE (6,15) (FORET(I), I=1,19)
   15 FORMAT (1H ,29X,18A4,A2)
      KOUNT = 0
      IF(SATH(KA) .EQ. 0.0) GO TO 100
      KOUNT = KOUNT + 1
      WRITE (6,20)
   20 FORMAT (1H0,/,41X,47HACRES OF COMMERCIAL THINNING DURING NEXT PERI
     1OD)
      IF(KA .EQ. 2) GO TO 30
      IF(KA .EQ. 3) GO TO 40
      IF(KA .EQ. 4) GO TO 50
      IF(KA .EQ. 5) GO TO 60
      WRITE (6,25)
   25 FORMAT (1H0,/,4X,5HBLOCK,12X,6HTYPE 1,13X,6HTYPE 2,13X,6HTYPE 3,13
     1X,6HTYPE 4,13X,6HTYPE 5,14X,5HTOTAL,/)
      MK = 1
      NK = 5
      GO TO 70
   30 WRITE (6,35)
   35 FORMAT (1H0,/,4X,5HBLOCK,12X,6HTYPE 6,13X,6HTYPE 7,13X,6HTYPE 8,13
     1X,6HTYPE 9,12X,7HTYPE 10,14X,5HTOTAL,/)
      MK = 6
      NK = 10
      GO TO 70
   40 WRITE (6,45)
   45 FORMAT (1H0,/,4X,5HBLOCK,11X,7HTYPE 11,12X,7HTYPE 12,12X,7HTYPE 13
     1,12X,7HTYPE 14,12X,7HTYPE 15,14X,5HTOTAL,/)
      MK = 11
      NK = 15
      GO TO 70
   50 WRITE (6,55)
   55 FORMAT (1H0,/,4X,5HBLOCK,11X,7HTYPE 16,12X,7HTYPE 17,12X,7HTYPE 18
     1,12X,7HTYPE 19,12X,7HTYPE 20,14X,5HTOTAL,/)
      MK = 16
      NK = 20
      GO TO 70
   60 WRITE (6,65)
   65 FORMAT (1H0,/,4X,5HBLOCK,11X,7HTYPE 21,12X,7HTYPE 22,12X,7HTYPE 23
     1,12X,7HTYPE 24,12X,7HTYPE 25,14X,5HTOTAL,/)
      MK = 21
      NK = 25
   70 DO 80 I=1,NBK
      WRITE (6,75) I,(OPEN(I,J),J=MK,NK),SOP(KA,I)
   75 FORMAT (1H ,4X,I2,10X,F11.1,5(8X,F11.1))
   80 CONTINUE
      WRITE (6,85) (STON(I),I=MK,NK),SATH(KA)
   85 FORMAT (1H0,3X,5HTOTAL,6(8X,F11.1))
  100 IF(SCUR(KA) .EQ. 0.0) GO TO 150
      KOUNT = KOUNT + 1
      WRITE (6,105)
  105 FORMAT (1H0,//,44X,39HHUNDREDS OF CU. FT. REMOVED BY THINNING)
      IF(KA .EQ. 2) GO TO 110
      IF(KA .EQ. 3) GO TO 115
      IF(KA .EQ. 4) GO TO 120
      IF(KA .EQ. 5) GO TO 125
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 130
  110 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 130
  115 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 130
  120 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 130
  125 WRITE (6,65)
      MK = 21
      NK = 25
  130 DO 135 I=1,NBK
      WRITE (6,75) I,(CMTH(I,J),J=MK,NK),SCU(KA,I)
  135 CONTINUE
      WRITE(6,85) (STNC(I),I=MK,NK),SCUR(KA)
  150 IF(SBFR(KA) .EQ. 0.0) GO TO 190
      KOUNT = KOUNT + 1
      WRITE (6,155)
  155 FORMAT (1H0,//,50X,29HM BD. FT. REMOVED BY THINNING)
      IF(KA .EQ. 2) GO TO 160
      IF(KA .EQ. 3) GO TO 165
      IF(KA .EQ. 4) GO TO 170
      IF(KA .EQ. 5) GO TO 175
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 180
  160 WRITE (6,35)
      MK = 6
      NK = 10
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      GO TO 180
  165 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 180
  170 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 180
  175 WRITE (6,65)
      MK = 21
      NK = 25
  180 DO 185 I=1,NBK
      WRITE (6,75) 1,(BFTH(I,J),J=MK,NK),SBM(KA,I)
  185 CONTINUE
      WRITE (6,85) (STPS(I),I=MK,NK),SBFR(KA)
  190 IF(KOUNT .LT. 3) GO TO 200
      SSUM = SBSV(KA) + SBH(KA) + SCR(KA) + SFR(KA) + SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  200 IF(SBSV(KA) .EQ. 0.0) GO TO 240
      KOUNT = KOUNT + 1
      WRITE (6,205)
  205 FORMAT (1H0,//,44X,39HM BO. FT. TO BE SALVAGED IN NEXT PERIOD)
      IF(KA .EQ. 2) GO TO 210
      IF(KA .EQ. 3) GO TO 215
      IF(KA .EQ. 4) GO TO 220
      IF(KA .EQ. 5) GO TO 225
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 230
  210 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 230
  215 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 230
  220 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 230
  225 WRITE (6,65)
      MK = 21
      NK = 25
  230 DO 235 I=1,NBK
      WRITE (6,75) 1,(SLVG(I,J),J=MK,NK),SSL(KA,1)
  235 CONTINUE
      WRITE (6,85) (STLV(1),I=MK,NK),SBSV(KA)
  240 IF(KOUNT .LT. 3) GO TO 250
      SSUM = SBH(KA) + SCR(KA) + SFR(KA) + SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  250 IF(SBH(KA) .EQ. 0.0) GO TO 290
      KOUNT = KOUNT + 1
      WRITE (6,255)
  255 FORMAT (1H0,//,41X,46HM BD. FT. TO BE HARVESTED BY REGENERATION CU
     1TS)
      IF(KA .EQ. 2) GO TO 260
      IF(KA .EQ. 3) GO TO 265
      IF(KA .EQ. 4) GO TO 270
      IF(KA .EQ. 5) GO TO 275
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 280
  260 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 280
  265 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 280
  270 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 280
  275 WRITE (6,65)
      MK = 21
      NK = 25
  280 DO 285 I=1,NBK
      WRITE (6,75) I,(CUTA(I,J),J=MK,NK),SCA(KA,I)
  285 CONTINUE
      WRITE (6,85) (STHR(I),I=MK,NK),SBH(KA)
  290 IF(KOUNT .LT. 3) GO TO 300
      SSUM = SCR(KA) + SFR(KA) + SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  300 IF(SCR(KA) .EQ. 0.0) GO TO 340
      KOUNT = KOUNT + 1
      WRITE (6,305)
  305 FORMAT (1H0,//,43X,42HHUNDREDS OF CU. FT. FROM REGENERATION CUTS)
      IF(KA .EQ. 2) GO TO 310
      IF(KA .EQ. 3) GO TO 315
      IF(KA .EQ. 4) GO TO 320
      IF(KA .EQ. 5) GO TO 325
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 330
  310 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 330
  315 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 330
  320 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 330
  325 WRITE (6,65)
      MK = 21
      NK = 25
  330 DO 335 I=1,NBK
      WRITE (6,75) 1,(PCFR(I,J),J=MK,NK),SCRB(KA,1)
  335 CONTINUE
      WRITE (6,85) (SCRT(I),I=MK,NK),SCR(KA)
  340 IF(KOUNT .LT. 3) GO TO 350
      SSUM = SFR(KA) + SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  350 IF(SFR(KA) .EQ. 0.0) GO TO 390
      KOUNT = KOUNT + 1
      WRITE (6,355)
  355 FORMAT (1H0,//,37X,54HM BD. FT. TO BE HARVESTED BY FINAL REMOVAL O
     1F OVERWOOD)
      IF(KA .EQ. 2) GO TO 360
      IF(KA .EQ. 3) GO TO 365
      IF(KA .EQ. 4) GO TO 370
      IF(KA .EQ. 5) GO TO 375
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 380
  360 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 380
  365 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 380
  370 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 380
  375 WRITE (6,65)
      MK = 21
      NK = 25
  380 DO 385 I=1,NBK
      WRITE (6,75) I,(CUTB(I,J),J=MK,NK),SCB(KA,I)
  385 CONTINUE
      WRITE (6,85) (STFO(I),I=MK,NK),SFR(KA)
  390 IF(KOUNT .LT. 3) GO TO 400
      SSUM = SCN(KA) + SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  400 IF(SCN(KA) .EQ. 0.0) GO TO 440
      KOUNT = KOUNT + 1
      WRITE (6,405)
  405 FORMAT (1H0,//,46X,35HHUNDREDS OF CU. FT. FROM FINAL CUTS)
      IF(KA .EQ. 2) GO TO 410
      IF(KA .EQ. 3) GO TO 415
      IF(KA .EQ. 4) GO TO 420
      IF(KA .EQ. 5) GO TO 425
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 430
  410 WRITE (6,35)
      MK = 6
      NK = 10
      GO TO 430
  415 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 430
  420 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 430
  425 WRITE (6,65)
      MK = 21
      NK = 25
  430 DO 435 I=1,NBK
      WRITE (6,75) I,(PDCFN(I,J),J=MK,NK),SCNB(KA,1)
  435 CONTINUE
      WRITE (6,85) (SCNT(I),I=MK,NK),SCN(KA)
  440 IF(KOUNT .LT. 3) GO TO 445
      SSUM = SAHP(KA)
      IF(SSUM .EQ. 0.0) GO TO 500
      WRITE (6,5)
      KOUNT = 0
  445 IF(SAHP(KA) .EQ. 0.0) GO TO 490
      WRITE (6,450)
  450 FORMAT (1H0,//,30X,59HACRES OF NONCOMMERCIAL THINNING DURING NEXT
     1PERIOD)
      IF(KA .EQ. 2) GO TO 460
      IF(KA .EQ. 3) GO TO 465
      IF(KA .EQ. 4) GO TO 470
      IF(KA .EQ. 5) GO TO 475
      WRITE (6,25)
      MK = 1
      NK = 5
      GO TO 48
  460 WRITE (6,35)
      MK = 6
      NK = 10
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      GO TO 480
  465 WRITE (6,45)
      MK = 11
      NK = 15
      GO TO 480
  470 WRITE (6,55)
      MK = 16
      NK = 20
      GO TO 480
  475 WRITE (6,65)
      MK = 21
      NK = 25
  480 DO 485 I=1,NBK
      WRITE (6,75) I,(HELP(I,J),J=MK,NK),SHL(KA,I)
  485 CONTINUE
      WRITE (6,85) (STHP(I),I=MK,NK),SAHP(KA)
  490 CONTINUE
  500 RETURN
      END
```

Subroutine BHPP

```
      SUBROUTINE BHPP
C
C LOCATION FOR ALL SPECIES - SPECIFIC STATEMENTS APPLICABLE TO BLACK
C HILLS PONDEROSA PINE.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUP,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NS1(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120), IJ
C
C SECTION 1 - FIND TOTAL CUBIC FOOT VOLUME.
C
   10 D2H = DBH(IK) * DBH(IK) * HT(IK)
      IF(D2H .GT. 6000.0) GO TO 11
      TOT(IK) = (0.00225 * D2H - 0.00074 * BAS(IK) + 0.03711) * DEN(IK)
      GO TO 12
   11 TOT(IK) = (0.00247 * D2H + 0.00130 * BAS(IK) - 1.40286) * DEN(IK)
   12 RETURN
C
C SECTION 2 - VOLUME CONVERSION FACTORS.
C MERCH. CU. FT. - TREES 6.0 INCHES D.B.H. AND LARGER TO 4-INCH TOP.
C BD. FT. - TREES 10.0 INCHES D.B.H. AND LARGER TO 8-INCH TOP.
C
   20 DO 21 J=1,2
      FCTR(J) = 0.0
   21 PROD(J) = 0.0
      DO 26 I=1,KNO
      IF(VDM(I) .LE. 4.99) GO TO 26
      IF(VDM(I) .GT. 6.7) GO TO 22
      FCTR(I) = 0.26612 * VDM(I) - 1.12689
      GO TO 24
   22 IF(VDM(I) .GT. 10.4) GO TO 23
      FCTR(I) = 3.46993 - 0.12017 * VDM(I) - 13.41984 / VDM(I)
      GO TO 24
   23 FCTR(I) = 0.99666 - 0.66932 / VDM(I)
   24 IF(VDM(I) .LE. 7.99) GO TO 26
      IF(VDM(I) .GT. 11.9) GO TO 25
      PROD(I) = 0.87783 * VDM(I) + 0.00660 * BA(I) - 7.27957
      GO TO 26
   25 PROD(I) = 5.10752 + 0.10712 * VDM(I) + 0.00185 * BA(I) - 36.20229
     1 / VDM(I)
   26 CONTINUE
      RETURN
C
C SECTION 3 - GROWTH FOR NEXT PERIOD.
C
   30 DO 35 I=1,2
      TMDY = AGE(I) + TIME
      IF(TMDY .LT. TEM) GO TO 35
      IF (HT(I).LE.0.) GO TO 31
      FDM(I) = 0.88511 * DBH(I) + 1.29735 * ALOG10(HT(I)) + 0.00119 * DB
     1H(I) * SITE + 62.37174 / SBAS - 1.56975
   31 IF(DBH(I) .GE. 10.0) GO TO 32
      FDN(I) = 0.00247 + 0.00124 * DBH(I) + 0.00028 * DBH(I) * DBH(I) +
     10.00000521 * SBAS * SBAS - 0.0000905 * DBH(I) * SBAS
      IF(FDN(I) .LT. 0.0) FDN(I) = 0.0
      FDN(I) = DEN(I) * (1.0 - FDN(I))
      MNK = FDN(I) + 0.5
      FDN(I) = MNK
      GO TO 33
   32 FDN(I) = DEN(I)
   33 FBA(I) = 0.0054542 * FDM(I) * FDM(I) * FDN(I)
      FHT(I) = 15.43021 + 1.107 * HT(I) - 0.08637 * AGE(I) - 304.12172 /
     1SITE - 0.02447 * SITE * SBAS / 100.0
      D2H = FDM(I) * FDM(I) * FHT(I)
      IF(D2H .GT. 6000.0) GO TO 34
      FVL(I) = (0.00225 * D2H - 0.00074 * FBA(I) + 0.03711) * FDN(I)
      GO TO 35
   34 FVL(I) = (0.00247 * D2H + 0.00130 * FBA(I) - 1.40286) * FDN(I)
   35 CONTINUE
      RETURN
C
C SECTION 4 - FUTURE UNTHINNED UNDERSTORY IF OVERSTORY REDUCED NOW.
C
   40 DMUS = 0.88511 * DBH(2) + 1.29735 * ALOG10(HT(2)) + 0.00119 * DBH(
     12) * SITE + 62.37174 / BAS(2) - 1.56975
      IF(DBH(2) .GE. 10.0) GO TO 41
      DNUS = 0.00247 + 0.00124 * DBH(2) + 0.00028 * DBH(2) * DBH(2) + 0.
     100000521 * BAS(2) * BAS(2) - 0.0000905 * DBH(2) * BAS(2)
      IF(DNUS .LT. 0.0) DNUS = 0.0
      DNUS = DEN(2) * (1.0 - DNUS)
      MNK = DNUS + 0.5
      DNUS = MNK
      GO TO 42
   41 DNUS = DEN(2)
   42 BAUS = 0.0054542 * DMUS * DMUS * DNUS
      HTUS = 15.43021 + 1.107 * HT(2) - 0.08637 * AGE(2) - 304.12172 / S
     1ITE - 0.02447 * SITE * BAS(2) / 100.0
      D2H = DMUS * DMUS * HTUS
      IF(D2H .GT. 6000.0) GO TO 43
      VLUS = (0.00225 * D2H - 0.00074 * BAUS + 0.03711) * DNUS
      GO TO 44
   43 VLUS = (0.00247 * D2H + 0.00130 * BAUS - 1.40286) * DNUS
   44 RETURN
C
C SECTION 5 - NEW D.B.H. AFTER THINNING.
C
   50 IF(PRET .LT. 50.0) GO TO 51
      DBHE = 0.73365 + 1.02008 * DBHO - 0.01107 * (PRET - 50.0) - 0.0001
     14 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 52
   51 PDBHE = 0.49401 + 0.71890 * ALOG10(DBHO) - 0.22530 * ALOG10(PRET)
     1 + 0.12616 * ALOG10(DBHO) * ALOG10(PRET)
      DBHE = 10.0 ** PDBHE
   52 RETURN
C
C SECTION 6 - CUBIC FEET AS BYPRODUCT OF SAWLOG CUT.
C
   60 ADD = VOL * (0.6180 + 26.7798 / DBH(KI) - 0.04034 * VOL)
      ADD = TVOL - ADD
      IF(ADD .LT. COMCU(KAK)) ADD = 0.0
      RETURN
C
C SECTION 7 - VOLUME IF THINNED NOW AND IF THINNED IN TIME YEARS.
C
   70 HT(KI) = HT(KI) + 7.64833 - 3.82286 * ALOG10(PRET)
      TEM = TBA(IK) / (0.0054542 * TDM(IK) * TDM(IK))
      D2H = TDM(IK) * TDM(IK)* HT(KI)
      IF(D2H .GT. 6000.0) GO TO 71
      TVL(IK) = (0.00225 * D2H - 0.00074 * TBA(IK) + 0.03711) * TEM
      GO TO 72
   71 TVL(IK) = (0.00247 * D2H + 0.00130 * TBA(IK) - 1.40286) * TEM
   72 RETURN
C
C SECTION 8 - STATUS AT END OF PERIOD IF THINNED AT START OF PERIOD.
C
   80 J = TIME / RINT(KAK)
      DO 83 I=1,J
      IF(TBA(1) .LE. 0.0) GO TO 83
      HT(1) = HT(1) + 7.64833 - 3.82286 * ALOG10(SAVE)
      FDM(1) = 1.0097*TDM(1)+0.0096*SITE-1.5766*ALOG10(TBA(1))+3.3021
      FHT(1) = 15.43021 + 1.107 * HT(1) - 0.08637 * AGE(KI) - 304.12172
     1/  SITE - 0.02447 * SITE * TBA(1) / 100.0
      MNK = (TBA(1) / (0.0054542 * TDM(1) * TDM(1))) + 0.5
      IF(TDM(1) .LT. 10.0) GO TO 81
      FDN(1) = MNK
      GO TO 82
   81 FDN(1) = 0.00247 + 0.00124 * TDM(1) + 0.00028 * TDM(1) * TDM(1) +
     10.00000521 * TBA(1) * TBA(1) - 0.0000905 * TDM(1) * TBA(1)
      IF(FDN(1) .LT. 0.0) FDN(1) = 0.0
      TEM = MNK
      NKM = TEM * (1.0 - FDN(1)) + 0.5
      FDN(1) = NKM
   82 FBA(1) = FDN(1) * 0.0054542 * FDM(1) * FDM(1)
      TDM(1) = FDM(1)
      TBA(1) = FBA(1)
      HT(1) = FHT(1)
      AGE(KI) = AGE(KI) + RINT(KAK)
   83 CONTINUE
      D2H = FDM(1) * FDM(1) * FHT(1)
      IF(D2H .GT. 6000.0) GO TO 84
      FVL(1) = (0.00225 * D2H - 0.00074 * FBA(1) + 0.03711) * FDN(1)
      GO TO 85
   84 FVL(1) = (0.00247 * D2H + 0.00130 * FBA(1) - 1.40286) * FDN(1)
   85 RETURN
C
C SECTION 9 - HEIGHT AND VOLUME BEFORE THINNING.
C
   90 IF(AGEO .GT. 55.0) GO TO 91
      HTSO = 0.01441 * AGEO * SITE - 0.12162 * AGEO - 1.50953
      GO TO 92
   91 HTSO = 0.59947 - 61.5019 / AGEO + 0.80522 * ALOG10(SITE) + 20.5252
     18 * ALOG10(SITE) / AGEO
      HTSO = 10.0 ** HTSO
   92 HTSO = HTSO + HTCUM
      D2H = DBHO * DBHO * HTSO
      IF(D2H .GT. 6000.0) GO TO 93
      TOTO = (0.00225 * D2H - 0.00074 * BASO + 0.03711) * DENO
      GO TO 94
   93 TOTO = (0.00247 * D2H + 0.00130 * BASO - 1.40286) * DENO
   94 RETURN
C
C SECTION 10 - HEIGHT AND TOTAL CUBIC FEET PER ACRE AFTER THINNING.
C
  100 ADDHT = 7.64833 - 3.82286 * ALOG10(PRET)
      HTCUM = HTCUM + ADDHT
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```
      HTST = HTSO + ADDHT
      O2H = OBHT * OBHT * HTST
      IF(O2H .GT. 6000.0) GO TO 101
      TOTT = 10.00225 * O2H - 0.00074 * BAST + 0.03711) * OENT
      GO TO 102
  101 TOTT = (0.00247 * O2H + 0.00130 * BAST - 1.40286) * DENT
  102 RETURN
C
C SECTION 11 - O.B.H. AT ENO OF PROJECTION PERIOO.
C
  110 OBHO = 1.0097*OBHT + 0.0096*SITE - 1.5766*ALOGIO(BAST) + 3.3021
      RETURN
C
C SECTION 12 - MORTALITY AS A PERCENTAGE OF INITIAL OENSITY.
C
  120 DENO = 0.00247 + 0.00124 * OBHT + 0.00028 * OBHT * OBHT + 0.000005
  121 * BAST * BAST - 0.0000905 * DBHT * BAST
      RETURN
      END
```

Subroutine LDGP

```
      SUBROUTINE LOGP
C
C LOCATION FOR ALL SPECIES - SPECIFIC STATEMENTS APPLICABLE TO LOOGEPOLE
C PINE IN COLO. ANO WYO.
C
      COMMON ADO,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,OATE(6),OBH(2),OBHE,OBHO,DBHT,OEN(2),OENO,OENT,OMUS,FBA(2),
     2FCTR(2),FOM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSO,
     3HTST,KAK,KND,MIN,MNK,NBK,NCMP,NSJB,NWGP,PDBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TOM(2),TEM,TIME,TMRR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VOM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),AOJ(5),AGETH(5,14),ALLCF(5,14),ALOWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),OBHTH(5,14),OELAY(5),OENTH(5,14),DLEV(5),FNBO(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBO(5),OPCU(5),PAIBO(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWO(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARS1(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),DPEN(7,27),PBRS1(7,14),POCFN(7,27
     2),POCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACS1(5,7,14),ACSP(5,7),GRBO(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120), IJ
C
C SECTION 1 - TOTAL CUBIC FOOT VOLUME.
C
   10 O2H = OBH(IK) * OBH(IK) * HT(IK)
      IF(O2H .GT. 7000.0) GO TO 11
      TOT(IK) = (-0.00577 - 0.00059 * BAS(IK) + 0.00276 * O2H) * DEN(IK)
      GO TO 12
   11 TOT(IK) = (0.00248 * O2H + 1.96336) * OEN(IK)
   12 RETURN
C
C SECTION 2 - VOLUME CONVERSION FACTORS.
C MERCH. CU. FT. - TREES 6.0 INCHES O.B.H. ANO LARGER TO 4-INCH TOP.
C BO. FT. - TREES 6.5 INCHES O.B.H. ANO LARGER TO 6-INCH TOP.
C
   20 OO 21 J=1,2
      FCTR(J) = 0.0
   21 PROO(J) = 0.0
      OO 26 I=1,KNO
      IF(VOM(I) .LE. 4.99) GO TO 26
      IF(VOM(I) .GT. 6.7) GO TO 22
      FCTR(I) = 0.31963 * VDM(I) - 1.42291
      GO TO 24
   22 IF(VOM(I) .GT. 9.8) GO TO 23
      FCTR(I) = 3.68255 - 0.14007 * VOM(I) - 13.54644 / VOM(I)
      GO TO 24
   23 FCTR(I) = 0.99503 - 0.58018 / VOM(I)
   24 IF(VOM(I) .LE. 7.99) GO TO 26
      IF(VDM(I) .GT. 10.0) GO TO 25
      PROO(I) = 0.00045 * BA(I) + 0.18091 * VOM(I) + 2.08874
      GO TO 26
   25 PROO(I) = 0.16583 + 3.74174 * ALOG10(VDM(I))
   26 CONTINUE
      RETURN
C
C SECTION 3 - GROWTH FOR NEXT PERIOO.
C
   30 OO 35 I=1,2
      TMOY = AGE(I) + TIME
      IF(TMOY .LT. TEM) GO TO 35
      IF(HT(I) .LE. 0.0) GO TO 31
      FDM(I) = 0.2631 + 0.95287 * DBH(I) + 0.0016 * OBH(I) * SITE + 16.4
     16662 / SBAS
      IF(OMR(I) .LE. 3.9) GO TO 31
      TEM = (FDM(I) - DBH(I)) * (1.0 - (0.192 * DMR(I) - 0.754))
      FDM(I) = OBH(I) + TEM
   31 DIE = 0.0
      IF(OEN(I) .GT. 1000.0) GO TO 32
      OIE = (3.81 * OMR(I) - 6.63) * 0.01
      IF(OIE .LT. 0.0) OIE = 0.0
      GO TO 33
   32 OIE = (8.64 + 3.28 * OMR(I)) * 0.01
   33 FDN(I) = 0.0
      IF(OBH(I) .GE. 10.0) GO TO 34
      FDN(I) = 0.05285 - 0.01346 * OBH(I) + 0.00226 * OBH(I) * OBH(I) +
     10.0000066 * SBAS * SBAS - 0.0001931 * DBH(I) * SBAS
      IF(FON(I) .LT. 0.0) FDN(I) = 0.0
   34 IF(OIE .LT. FON(I)) DIE = FDN(I)
      FDN(I) = DEN(I) * (1.0 - OIE)
      MNK = FON(I) + 0.5
      FON(I) = MNK
      FBA(I) = 0.0054542 * FDM(I) * FOM(I) * FDN(I)
      FHT(I) = 14.57349 + 1.101 * HT(I) - 0.09654 * AGE(I) - 333.37172 /
     1SITE - 0.04321 * SITE * SBAS / 100.0
      PCT = 1.0 - 0.0028 * OMR(I) * OMR(I) * OMR(I)
      CHNG = (FHT(I) - HT(I)) * PCT
      FHT(I) = HT(I) + CHNG
      D2H = FOM(I) * FDM(I) * FHT(I)
      IF(O2H .GT. 7000.0) GO TO 35
      FVL(I) = (0.00276 * D2H - 0.00059 * FBA(I) - 0.00577) * FON(I)
      GO TO 36
   35 FVL(I) = (0.00248 * D2H + 1.96336) * FON(I)
   36 CONTINUE
      RETURN
C
C SECTION 4 - FUTURE UNTHINNEO UNOERSTORY IF OVERSTORY REOUCEO NOW.
C
   40 DMUS = 0.2631 + 0.95287 * OBH(2) + 0.0016 * DBH(2) * SITE + 16.466
     162 / BAS(2)
      IF(DMR(2) .LE. 3.9) GO TO 41
      TEM = (DMUS - DBH(2)) * (1.0 - (0.192 * OMR(2) - 0.754))
      OMUS = OBH(2) + TEM
   41 DIE = 0.0
      IF(OEN(2) .GT. 1000.0) GO TO 42
      OIE = (3.81 * OMR(2) - 6.63) * 0.01
      IF(OIE .LT. 0.0) OIE = 0.0
      GO TO 43
   42 OIE = (8.64 + 3.28 * OMR(2)) * 0.01
   43 DNUS = 0.0
      IF(OBH(2) .GE. 10.0) GO TO 44
      DNUS = 0.05285 - 0.01346 * OBH(2) + 0.00226 * OBH(2) * OBH(2) + 0.
     10000066 * BAS(2) * BAS(2) - 0.0001931 * DBH(2) * BAS(2)
      IF(ONUS .LT. 0.0) DNUS = 0.0
   44 IF(DIE .LT. ONUS) DIE = ONUS
      DNUS = DEN(2) * (1.0 - DNUS)
      MNK = DNUS + 0.5
      ONUS = MNK
      BAUS = 0.0054542 * OMUS * DMUS * DNUS
      HTUS = 14.57349 + 1.101 * HT(2) - 0.09654 * AGE(2) - 333.37172 / S
     1ITE - 0.04321 * SITE * BAS(2) / 100.0
      PCT = 1.0 - 0.0028 * DMR(2) * OMR(2) * OMR(2)
      CHNG = (HTUS - HT(2)) * PCT
      HTUS = HT(2) + CHNG
      D2H = DMUS * DMUS * HTUS
      IF(O2H .GT. 7000.0) GO TO 45
      VLUS = (0.00276 * D2H - 0.00059 * BAUS - 0.00577) * ONUS
      GO TO 46
   45 VLUS = (0.00248 * D2H + 1.96336) * DNUS
   46 RETURN
C
C SECTION 5 - NEW D.B.H. AFTER THINNING.
C
   50 IF(PRET .LT. 50.0) GO TO 51
      DBHE = 0.44222 + 1.03170 * DBHO - 0.00816 * (PRET - 50.0) - 0.0000
     19 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 52
   51 PDBHE = 0.37321 - 0.17274 * ALOG10(PRET) + 0.79921 * ALOG10(OBHO)
     1+ 0.09315 * ALOG10(PRET) * ALOG10(DBHO)
      DBHE = 10.0 ** PDBHE
   52 RETURN
C
C SECTION 6 - CUBIC FEET AS BYPROOUCT OF SAWLOG CUT.
C
   60 AOO = VOL * (2.09342 + 2.98062 / DBH(KI) - 0.00542 * VOL)
      AOO = TVOL - AOO
      IF(AOO .LT. COMCU(KAK)) AOO = 0.0
      RETURN
C
C SECTION 7 - VOLUME IF THINNED NOW AND IF THINNEO IN TIME YEARS.
C
   70 HT(KI) = HT(KI) + 6.79950 - 3.41979 * ALOG10(PRET)
      TEM = TBA(IK) / (0.0054542 * TOM(IK) * TOM(IK))
      O2H = TOM(IK) * TDM(IK) * HT(KI)
      IF(D2H .GT. 7000.0) GO TO 71
      TVL(IK) = (0.00276 * O2H - 0.00059 * TBA(IK) - 0.00577) * TEM
      GO TO 72
   71 TVL(IK) = (0.00248 * O2H + 1.96336) * TEM
   72 RETURN
C
C SECTION 8 - STATUS AT END OF PERIOD IF THINNEO AT START OF PERIOO.
C
   80 J = TIME / RINT(KAK)
      DO 85 I=1,J
      IF(TBA(I) .LE. 0.0) GO TO 85
      HT(I) = HT(I) + 6.79950 - 3.41979 * ALOG10(SAVE)
      FOM(I) = 1.0222 * TDM(I) + 0.0151 * SITE - 1.2417 * ALOG10(TBA(I))
     1 + 2.1450
      IF(DMR(I) .LE. 3.9) GO TO 81
      TEM = (FOM(I) - TDM(I)) * (1.0 - (0.192 * OMR(I) - 0.754))
      FDM(I) = TDM(I) + TEM
   81 FHT(I) = 14.57349 + 1.101 * HT(I) - 0.09654 * AGE(KI) - 333.37172
     1/ SITE - 0.04321 * SITE * TBA(I) / 100.0
      PCT = 1.0 - 0.0028 * DMR(I) * DMR(I) * DMR(I)
      CHNG = (FHT(I) - HT(I)) * PCT
      FHT(I) = HT(I) + CHNG
      DIE = 0.0
      ITEM = TBA(I) / (0.0054542 * TDM(I) * TOM(I)) + 0.5
      TEM = ITEM
      IF(TEM .GT. 1000.0) GO TO 82
      OIE = (3.81 * DMR(I) - 6.63) * 0.01
      IF(OIE .LT. 0.0) OIE = 0.0
      GO TO 83
   82 DIE = (8.64 + 3.28 * DMR(I)) * 0.01
   83 FDN(I) = 0.0
      ITRE = (TBA(I) / (0.0054542 * TDM(I) * TDM(I))) + 0.5
```

```
      TRE = ITRE
      IF(TDM(1) .GE. 10.0) GO TO 84
      FDN(1) = 0.05285 - 0.01346 * TDM(1) + 0.00226 * TDM(1) * TDM(1) +
     10.0000066 * TBA(1) * TBA(1) - 0.0001931 * TDM(1) * TBA(1)
      IF(FDN(1) .LT. 0.0) FDN(1) = 0.0
   84 IF(DIE .LT. FDN(1)) DIE = FDN(1)
      FDN(1) = TRE * (1.0 - DIE)
      MNK = FDN(1) + 0.5
      FDN(1) = MNK
      FBA(1) = FDN(I) * 0.0054542 * FDM(1) * FDM(1)
      TDM(1) = FDM(I)
      TBA(1) = FBA(I)
      HT(1) = FHT(I)
      AGE(KI)  = AGE(KI) + RINT(KAK)
   85 CONTINUE
      D2H = FDM(1) * FDM(1) * FHT(1)
      IF(D2H .GT. 7000.0) GO TO 86
      FVL(1) = (0.00276 * D2H - 0.00059 * FBA(1) - 0.00577) * FDN(I)
      GO TO 87
   86 FVL(1) = (0.00248 * D2H + 1.96336) * FDN(I)
   87 RETURN
C
C SECTION 9 - HEIGHT AND VOLUME BEFORE THINNING.
C
   90 IF(AGEO .GT. 45.0) GO TO 91
      HTSO = 3.86111 - 0.05979 * AGEO + 0.01215 * AGEO * SITE
      GO TO 92
   91 HTSO = 0.33401 - 33.2866 / AGEO + 0.92341 * ALOG10(SITE) + 6.27811
     1* ALOG10(SITE) / AGEO
      HTSO = 10.0 ** HTSO
   92 HTSO = HTSO + HTCUM
      D2H = DBHO * DBHO * HTSO
      IF(D2H .GT. 7000.0) GO TO 93
      TOTO = (0.00276 * D2H - 0.00059 * BASO - 0.00577) * DENO
      GO TO 94
   93 TOTO = (0.00248 * D2H + 1.96336) * DENO
   94 RETURN
C
C SECTION 10 - HEIGHT AND TOTAL CUBIC FEET PER ACRE AFTER THINNING.
C
  100 ADDHT = 6.7995 - 3.41979 * ALOG10(PRET)
      HTCUM = HTCUM + ADDHT
      HTST = HTSO + ADDHT
      D2H = DBHT * DBHT * HTST
      IF(D2H .GT. 7000.0) GO TO 101
      TOTT = (0.00276 * D2H - 0.00059 * BAST - 0.00577) * DENT
      GO TO 102
  101 TOTT = (0.00248 * D2H + 1.96336) * DENT
  102 RETURN
C
C SECTION 11 - D.B.H. AT END OF PROJECTION PERIOD.
C
  110 DBHO = 1.0222*DBHT + 0.0151*SITE - 1.2417*ALOG10(BAST) + 2.1450
      RETURN
C
C SECTION 12 - MORTALITY AS A PERCENTAGE OF INITIAL DENSITY.
C
  120 DENO = 0.05285 - 0.01346 * DBHT + 0.00226 * DBHT * DBHT + 0.000006
     16 * BAST * BAST - 0.0001931 * DBHT * BAST
      RETURN
      END
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Subroutine SWPP

```
      SUBROUTINE SWPP
C
C LOCATION FOR ALL SPECIES - SPECIFIC STATEMENTS APPLICABLE TO PONDEROSA
C PINE IN ARIZONA AND NEW MEXICO.
C
      COMMON ADD,AGE(2),AGEO,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVOL,
     1CFVOL,DATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
     2FCTR(2),FDM(2),FDN(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
     3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,POBHE,PRET,PROD(2),REST,
     4SAVE,SBARB,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TMBR
     5,TMPO,TOT(2),TOTO,TOTT,TVL(2),VDM(2),VLUS,DMR(2)
      COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALUWC(5
     1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),BDMAI(5),BFAGE(5,15)
     2,BFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
     3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),DLEV(5),FNBD(5),
     4FNCU(5),GROWB(5,2,14),GROWC(5,2,14),GVLBF(5),GVLCU(5),INVL(5,3,14)
     5,NSI(5),OPBD(5),OPCU(5),PAIBD(5),PAICU(5),POOR(5),REGN(5,3,14),
     6RINT(5),SARSP(5),SBF(5),SHFLT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
     7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
     8WGNUM(5),WGPDES(5,20),WGPNM(5,3),SPNUM(5),TPR(5,7),PASP(5,7)
      COMMON ACBAR(7),ARBK(7),BARSI(7,14),BFTH(7,27),CMTH(7,27),CUTA(7,2
     17),CUTB(7,27),HELP(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
     2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SAFETY(7,35),SLVG(7,27),SPLT(
     37,27),TMTY(7),UNCML(7,27),PABR(7),PARTY(7,35)
      COMMON ACFNL(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
     1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
C
      COMMON /BLKD/ IJ,IK,KI,VOL,TVOL
C
      GO TO (10,20,30,40,50,60,70,80,90,100,110,120), IJ
C
C SECTION 1 - TOTAL CUBIC FOOT VOLUME.
C
   10 D2H = DBH(IK) * DBH(IK) * HT(IK)
      IF(D2H .GT. 5000.0) GO TO 11
      TOT(IK) = (0.53313 + 0.00033 * BAS(IK) + 0.00179 * D2H) * DEN(IK)
      GO TO 12
   11 TOT(IK) = (0.00237 * BAS(IK) + 0.00211 * D2H - 1.09356) * DEN(IK)
   12 RETURN
C
C SECTION 2 - VOLUME CONVERSION FACTORS.
C MERCH. CU. FT. - TREES 6.0 INCHES D.B.H. AND LARGER TO 4-INCH TOP.
C BD. FT. - TREES 10.0 INCHES D.B.H. AND LARGER TO VARIABLE TOP LIMIT.
C
   20 DO 21 J=1,2
      FCTR(J) = 0.0
   21 PROD(J) = 0.0
      DO 26 I=1,KNO
      IF(VDM(I) .LE. 4.99) GO TO 26
      IF(VDM(I) .GT. 6.5) GO TO 22
      FCTR(I) = 0.25222 * VDM(I) - 1.01119
      GO TO 24
   22 IF(VDM(I) .GT. 10.0) GO TO 23
      FCTR(I) = 3.02485 - 0.09957 * VDM(I) - 11.35814 / VDM(I)
      GO TO 24
   23 FCTR(I) = 1.03936 - 1.41034 / VDM(I)
   24 IF(VDM(I) .LE. 7.99) GO TO 26
      IF(VDM(I) .GT. 11.5) GO TO 25
      PROD(I) = 0.0028 * BA(I) + 0.04355 * VDM(I) * VDM(I) - 2.78326
      GO TO 26
   25 PROD(I) = 0.83943 + 0.20531 * VDM(I)
   26 CONTINUE
      RETURN
C
C SECTION 3 - GROWTH FOR NEXT PERIOD.
C
   30 DO 35 I=1,2
      TMDY = AGE(I) + TIME
      IF(TMDY .LT. TEM) GO TO 35
      IF(HT(I) .LE. 0.0) GO TO 31
      FDM(I) = 0.88511 * DBH(I) + 1.29735 * ALOG10(HT(I)) + 0.00119 *
     1DBH(I) * SITE + 62.37174 / SBAS - 1.56975
      IF(DMR(I) .LE. 3.5) GO TO 31
      TEM = (FDM(I) - DBH(I)) * (1.0 - (0.056 * DMR(I) - 0.197))
      FDM(I) = DBH(I) + TEM
   31 DIE = 0.0
      IF(DMR(I) .LT. 1.0) GO TO 32
      DIE = 20.66469 + 4.42271 * DMR(I) - 0.36374 * SITE + 3.87613 *
     1ALOG10(DEN(I))
      DIE = DIE * 0.01
      IF(DIE .LT. 0.0) DIE = 0.0
   32 FDN(I) = 0.0
      IF(DBH(I) .GE. 10.0) GO TO 33
      FDN(I) = 0.00247 + 0.00124 * DBH(I) + 0.00028 * DBH(I) * DBH(I) +
     10.00000521 * SBAS * SBAS - 0.0000905 * DBH(I) * SBAS
      IF(FDN(I) .LT. 0.0) FDN(I) = 0.0
   33 IF(DIE .LT. FDN(I)) DIE = FDN(I)
      FDN(I) = DEN(I) * (1.0 - DIE)
      MNK = FDN(I) + 0.5
      FDN(I) = MNK
      FBA(I) = 0.0054542 * FDM(I) * FDM(I) * FDN(I)
      FHT(I) = 15.43021 + 1.107 * HT(I) - 0.08637 * AGE(I) - 304.12172 /
     1SITE - 0.02447 * SITE * SBAS / 100.0
      PCT = 1.0 - 0.0002 * DMR(I) * DMR(I) * DMR(I)
      CHNG = (FHT(I) - HT(I)) * PCT
      FHT(I) = HT(I) + CHNG
      D2H = FDM(I) * FDM(I) * FHT(I)
      IF(D2H .GT. 5000.0) GO TO 34
      FVL(I) = (0.53313 + 0.00033 * FBA(I) + 0.00179 * D2H) * FDN(I)
      GO TO 35
   34 FVL(I) = (0.00237 * FBA(I) + 0.00211 * D2H - 1.09356) * FDN(I)
   35 CONTINUE
      RETURN
C
C SECTION 4 - FUTURE UNTHINNED UNDERSTORY IF OVERSTORY REDUCED NOW.
C
   40 DMUS = 0.88511 * DBH(2) + 1.29735 * ALOG10(HT(2)) + 0.00119 * DBH(
     12) * SITE + 62.37174 / BAS(2) - 1.56975
      IF(DMR(2) .LE. 3.5) GO TO 41
      TEM = (DMUS - DBH(2)) * (1.0 - (0.056 * DMR(2) - 0.197))
      DMUS = DBH(2) + TEM
   41 DIE = 0.0
      IF(DMR(2) .LT. 1.0) GO TO 42
      DIE = 20.66469 + 4.42271 * DMR(2) - 0.36374 * SITE + 3.87613 *
     1ALOG10(DEN(2))
      DIE = DIE * 0.01
      IF(DIE .LT. 0.0) DIE = 0.0
   42 DNUS = 0.0
      IF(DBH(2) .GE. 10.0) GO TO 43
      DNUS = 0.00247 + 0.00124 * DBH(2) + 0.00028 * DBH(2) * DBH(2) +
     10.00000521 * BAS(2) * BAS(2) - 0.0000905 * DBH(2) * BAS(2)
      IF(DNUS .LT. 0.0) DNUS = 0.0
   43 IF(DIE .LT. DNUS) DIE = DNUS
      DNUS = DEN(2) * (1.0 - DNUS)
      MNK = DNUS + 0.5
      DNUS = MNK
      BAUS = 0.0054542 * DMUS * DMUS * DNUS
      HTUS = 15.43021 + 1.107 * HT(2) - 0.08637 * AGE(2) - 304.12172 /
     1SITE - 0.02447 * SITE * BAS(2) / 100.0
      PCT = 1.0 - 0.0002 * DMR(2) * DMR(2) * DMR(2)
      CHNG = (HTUS - HT(2)) * PCT
      HTUS = HT(2) + CHNG
      D2H = DMUS * DMUS * HTUS
      IF(D2H .GT. 5000.0) GO TO 44
      VLUS = (0.53313 + 0.00033 * BAUS + 0.00179 * D2H) * DNUS
      GO TO 45
   44 VLUS = (0.00237 * BAUS + 0.00211 * D2H - 1.09356) * DNUS
   45 RETURN
C
C SECTION 5 - NEW D.B.H. AFTER THINNING.
C
   50 IF(PRET .LT. 50.0) GO TO 51
      DBHE = 0.73365 + 1.02008 * DBHO - 0.01107 * (PRET - 50.0) - 0.0001
     14 * (PRET - 50.0) * (PRET - 50.0)
      GO TO 52
   51 PDBHE = 0.49401 + 0.71890 * ALOG10(DBHO) - 0.22530 * ALOG10(PRET)
     1 + 0.12616 * ALOG10(DBHO) * ALOG10(PRET)
      DBHE = 10.0 ** PDBHE
   52 RETURN
C
C SECTION 6 - CUBIC FEET AS BYPRODUCT OF SAWLOG CUT.
C
```

```
   60 ADD = VOL * (1.40315 + 10.24272 / DBH(KI))
      ADD = TVOL - ADD
      IF(ADD .LT. COMCU(KAK)) ADD = 0.0
      RETURN
C
C SECTION 7 - VOLUME IF THINNED NOW AND IF THINNED IN TIME YEARS.
C
   70 HT(KI) = HT(KI) + 7.64833 - 3.82286 * ALOG10(PRET)
      TEM = TBA(IK) / (0.0054542 * TDM(IK) * TDM(IK))
      D2H = TDM(IK) * TDM(IK) * HT(KI)
      IF(D2H .GT. 5000.0) GO TO 71
      TVL(IK) = (0.53313 + 0.00033 * TBA(IK) + 0.00179 * D2H) * TEM
      GO TO 72
   71 TVL(IK) = (0.00237 * TBA(IK) + 0.00211 * D2H - 1.09356) * TEM
   72 RETURN
C
C SECTION 8 - STATUS AT END OF PERIOD IF THINNED AT START OF PERIOD.
C
   80 J = TIME / RINT(KAK)
      DO 84 I=1,J
      IF(TBA(1) .LE. 0.0) GO TO 84
      HT(1) = HT(1) + 7.64833 - 3.82286 * ALOG10(SAVE)
      FDM(1) = 1.0097 * TDM(I) + 0.0095 * SITE - 1.5766 * ALOG10(TBA(1))
     1 + 3.3021
      IF(OMR(1) .LE. 3.5) GO TO 81
      TEM = (FDM(1) - TDM(1)) * (1.0 - (0.056 * OMR(1) - 0.197))
      FDM(1) = TDM(1) + TEM
   81 FHT(1) = 15.43021 + 1.107 * HT(1) - 0.08637 * AGE(KI) - 304.12172
     1 / SITE - 0.02447 * SITE * TBA(1) / 100.0
      PCT = 1.0 - 0.0002 * OMR(1) * OMR(1) * OMR(1)
      CHNG = (FHT(1) - HT(1)) * PCT
      FHT(1) = HT(1) + CHNG
      DIE = 0.0
      IF(OMR(1) .LT. 1.0) GO TO 82
      ITEM = TBA(1) / (0.0054542 * TDM(1) * TDM(1)) + 0.5
      TEM = ITEM
      DIE = 20.66469 + 4.42271 * OMR(1) - 0.36374 * SITE + 3.87613 *
     1ALOG10(TEM)
      DIE = DIE * 0.01
      IF(DIE .LT. 0.0) DIE = 0.0
   82 FDN(1) = 0.0
      ITRE = (TBA(1) / (0.0054542 * TDM(1) * TDM(1))) + 0.5
      TRE = ITRE
      IF(TDM(1) .GE. 10.0) GO TO 83
      FDN(1) = 0.00247 + 0.00124 * TDM(1) + 0.00028 * TDM(1) * TDM(1) +
     10.00000521 * TBA(1) * TBA(1) - 0.0000905 * TDM(1) * TBA(1)
      IF(FDN(1) .LT. 0.0) FDN(1) = 0.0
   83 IF(DIE .LT. FDN(1)) DIE = FDN(1)
      FDN(1) = TRE * (1.0 - DIE)
      MNK = FDN(1) + 0.5
      FDN(1) = MNK
      FBA(1) = FDN(1) * 0.0054542 * FDM(1) * FDM(1)
      TDM(1) = FDM(1)
      TBA(1) = FBA(1)
      HT(1) = FHT(1)
      AGE(KI) = AGE(KI) + RINT(KAK)
   84 CONTINUE
      D2H = FDM(1) * FDM(1) * FHT(1)
      IF(D2H .GT. 5000.0) GO TO 85
      FVL(1) = (0.53313 + 0.00033 * FBA(1) + 0.00179 * D2H) * FDN(1)
      GO TO 86
   85 FVL(1) = (0.00237 * FBA(1) + 0.00211 * D2H - 1.09356) * FDN(1)
   86 RETURN
C
C SECTION 9 - HEIGHT AND VOLUME BEFORE THINNING.
C
   90 IF(AGED .GT. 55.0) GO TO 91
      HTSO = 0.01441 * AGED * SITE - 0.12162 * AGED - 1.50953
      GO TO 92
   91 HTSO = 0.59947 - 61.5019 / AGED + 0.80522 * ALOG10(SITE) + 20.5252
     18 * ALOG10(SITE) / AGED
      HTSO = 10.0 ** HTSO
   92 HTSO = HTSO + HTCUM
      D2H = DBHD * DBHD * HTSO
      IF(D2H .GT. 5000.0) GO TO 93
      TOTD = (0.53313 + 0.00033 * BASD + 0.00179 * D2H) * DEND
      GO TO 94
   93 TOTD = (0.00237 * BASD + 0.00211 * D2H - 1.09356) * DEND
   94 RETURN
C
C SECTION 10 - HEIGHT AND TOTAL CUBIC FEET PER ACRE AFTER THINNING.
C
  100 ADDHT = 7.64833 - 3.82286 * ALOG10(PRET)
      HTCUM = HTCUM + ADDHT
      HTST = HTSO + ADDHT
      D2H = DBHT * DBHT * HTST
      IF(D2H .GT. 5000.0) GO TO 101
      TOTT = (0.53313 + 0.00033 * BAST + 0.00179 * D2H) * DENT
      GO TO 102
  101 TOTT = (0.00237 * BAST + 0.00211 * D2H - 1.09356) * DENT
  102 RETURN
C
C SECTION 11 - D.B.H. AT END OF PROJECTION PERIOD.
C
  110 DBHD = 1.0097*DBHT + 0.0095*SITE - 1.5766*ALOG10(BAST) + 3.3021
      RETURN
C
C SECTION 12 - MORTALITY AS A PERCENTAGE OF INITIAL DENSITY.
C
  120 DEND = 0.00247 + 0.00124 * DBHT + 0.00028 * DBHT * DBHT + 0.000005
     121 * BAST * BAST - 0.0000905 * DBHT * BAST
      RETURN
      END
```

APPENDIX 2

An Application of TEVAP2

An example of what TEVAP2 can do is provided by the hypothetical situation described below and by reproductions of the computer records produced. The test forest, the mythical Bogus National Forest, is managed as one working circle. The working circle is subdivided into three blocks on the basis of topography, transportation system, and distribution of wood-using plants. Total areas of each block, interior tracts of other ownership, high-use recreation areas, and so forth, are known. The forest has not yet been subdivided into compartments; the AREA2 option of TEVAP2 is applicable.

Numerous decisions have been made concerning management objectives and how they may be attained. Past records of the forest and silvicultural characteristics of each species were considered during the planning process. Decisionmaking was assisted by computer simulation of forest activities (Myers 1973). The effects of changes in rotation length and other variables subject to control were examined. It was decided that the controls listed below would apply to timber management on the working circle. These controls are not recommendations for management of the species named; they are intended only to show the variability possible with TEVAP2. Controls applicable to any specific area and management objectives can be determined (Myers 1971, Myers 1973).

Working groups.

a. Ponderosa 1 — Ponderosa pine under two-cut shelterwood in remote areas of the forest.

b. Ponderosa 2 — Ponderosa pine under three-cut shelterwood where recreation use is heavy.

c. Lodgepole — Lodgepole pine clearcut in small patches with natural regeneration from serotinous cones.

Rotations.

a. Ponderosa 1 — 110 years, with final felling age of 130 years.

b. Ponderosa 2 — 110 years, with final felling age of 140 years, for all sites except that site 40 will be 90 years with final felling age of 120 years.

c. Lodgepole — 120 years.

Thinning.

a. Ponderosa 1 — Initial thinning at age 30 to level 120. Subsequent thinnings at 20-year intervals to level 100.

b. Ponderosa 2 — Initial thinning at age 30 to level 110. Subsequent thinnings at 20-year intervals to level 90.

c. Lodgepole — Initial thinning at age 30 to level 110. Subsequent thinnings at 30-year intervals to level 100.

Minimum site class to be managed for wood products.

a. Ponderosa 1 — Site index 50.

b. Ponderosa 2 — Site index 40.

c. Lodgepole — Site index 50.

Several decisions provided as inputs to the program are recorded on page type 4 of the output reproduced below. Other input data are recorded on pages of types 1, 8, and 11.

An inventory of the timber resource and analysis of the data were completed 5 years ago. At that time, summary cards with the items specified for data card type 9 were punched. The inventory file has increased annually through addition of records that describe thinning jobs, fires, and other changes affecting tracts of known area. The inventory file now consists of 251 records, 104 of which are job and similar reports; 147 sample "unknown" parts of the working circle. All inventory records are updated to a common time base annually (appendix 4).

Land books and other records provide the total number of acres in each block and the area occupied by nonforest vegetative and use types 28 to 33, inclusive. These acreages are recorded on pages type 5 and 6 of the output.

The situation described requires that data cards of all types except 11 through 16 be used.

Output pages reproduced below are in the order in which they might appear in a management plan, not in the order printed. For brevity, only two sheets each of pages type 8, 9, and 10 are reproduced. Complete output would include several sheets of each of these types, one for each site index class of each working group. Examples of pages produced with the other area options and with card types 11 through 16 appear in appendix 3.

A management guide can be produced annually, or more frequently, for distribution to appropriate land managers and staff. The example below required 91.0 seconds of central processor time for compilation and execution. After converting the source program to a binary deck, central processor time was 16.2 seconds for execution. The vast saving of time and money over conventional methods of plan preparation certainly should permit a timber manager to have an updated management plan whenever he wants one.

PAGE TYPE 1

GUIDE FOR MANAGEMENT BOGUS NATIONAL FOREST

BASED ON DATA CURRENT TO JANUARY 1, 1974

THE WORKING CIRCLE CONSISTS OF 884981.1 ACRES. OF THESE, 837181.7 ACRES ARE OWNED BY U.S. AND 47799.4 ACRES ARE INTERIOR TRACTS OF OTHER OWNERSHIP. OUR AREA INCLUDES 693717.3 TIMBERED ACRES, 110838.2 PLANTABLE ACRES, 16397.6 ACRES MANAGED AS RANGE, AND 6911.1 ACRES OF HIGH RECREATION USE WHERE TIMBER YIELDS ARE INCIDENTAL AND NOT REGULATED. SEE PAGE TYPE 5, 6, 7, AND 14 FOR AREA CLASSIFICATION.

THE TIMBER RESOURCE OF THIS WORKING CIRCLE WILL BE MANAGED AS FOLLOWS-
PONDEROSA 1 - TWO - CUT SHELTERWOOD WITH 20-YEAR REGENERATION PERIOD.
PONDEROSA 2 - THREE - CUT SHELTERWOOD WITH 30-YEAR REGENERATION PERIOD.
LODGEPOLE - CLEARCUTTING SMALL AREAS, SEEDING FROM SLASH.

REGULATION OF THE CUT WILL BE BY AREA WITH A VOLUME CHECK.

WITH THE DECISIONS AND AREAS ON PAGES TYPE 4 AND 11 AND WITH BALANCED DISTRIBUTION OF AGE CLASSES, ALLOWABLE ANNUAL CUT WOULD BE AS FOLLOWS-

	ACRES	HUNDREDS OF CU. FT.	M BD. FT.
REGENERATION CUTS			
PONDEROSA 1	2988.2	0.0	28294.4
PONDEROSA 2	7695.4	0.0	47770.7
LODGEPOLE	454.4	0.0	8564.2
FINAL REMOVAL CUTS			
PONDEROSA 1	2988.2	0.0	27507.4
PONDEROSA 2	3847.7	0.0	19852.0
LODGEPOLE	0.0	0.0	0.0
INTERMEDIATE CUTS			
PONDEROSA 1	11952.8	23217.5	5345.9
PONDEROSA 2	14460.7	16116.5	7772.6
LODGEPOLE	1363.1	773.3	4139.8
TOTAL FOR ONE YEAR			
PONDEROSA 1	17929.1	23217.5	61147.8
PONDEROSA 2	26003.9	16116.5	75395.3
LODGEPOLE	1817.5	773.3	12704.0
TOTAL ALL GROUPS	45750.5	40107.3	149247.1

TOTAL ALL GROUPS DOES NOT INCLUDE DEFERRED GROUPS, IF PRESENT.

PAGE TYPE 1, CONT.

ONLY COMMERCIAL VOLUMES ARE INCLUDED IN THE TABLES OF PAGE TYPE 1. CUTS ARE ASSIGNED TO BOARD FOOT TOTALS IF POSSIBLE. THEY APPEAR IN CUBIC-FOOT TOTALS ONLY WHEN COMMERCIAL SAWLOG CUTS ARE NOT POSSIBLE. AREAS OF INTERMEDIATE CUTS INCLUDE ACREAGE OF NONCOMMERCIAL SHOWN ON PAGE TYPE 2.

ACTUAL VOLUMES CUT DURING THE NEXT PERIOD COULD BE AS SHOWN ON PAGES TYPE 2 IF ALL POSSIBLE CULTURAL OPERATIONS, AS INDICATED BY WORK CODES, WERE PERFORMED. POTENTIAL ANNUAL CUTS WOULD THEN BE--

	ACRES	HUNDREDS OF CU. FT.	M BD. FT.
REGENERATION CUTS			
PONDEROSA 1	6226.0	29253.9	73149.3
PONDEROSA 2	5566.4	18871.4	43419.3
LODGEPOLE	447.4	0.0	7012.4
FINAL REMOVAL CUTS			
PONDEROSA 1	2600.9	32.1	4738.2
PONDEROSA 2	6494.1	3269.4	31464.6
LODGEPOLE	0.0	0.0	0.0
INTERMEDIATE CUTS			
PONDEROSA 1	13527.3	42761.9	3368.5
PONDEROSA 2	17632.3	22869.9	15422.3
LODGEPOLE	2357.7	9536.6	10187.6
TOTAL FOR ONE YEAR			
PONDEROSA 1	22354.2	72048.0	81256.0
PONDEROSA 2	29692.8	45010.7	90306.1
LODGEPOLE	2805.1	9536.6	17200.0
TOTAL ALL GROUPS	54852.2	126595.4	188762.1

PAGE TYPE 1, CONT.

THE FIRST TABLE, ABOVE, REPRESENTS YIELDS FROM AREA REGULATION WHEN VOLUME AND AREA GOALS HAVE BEEN ATTAINED.

THE SECOND TABLE CAN REPRESENT AREA REGULATION IF-
(1) VOLUME AND AREA GOALS HAVE NOT BEEN ATTAINED
(2) WORK CODING IS SUCH THAT THE AREA VALUES OF THE SECOND TABLE EQUAL AREAS OF THE FIRST TABLE.

IF NEITHER OF THESE ALTERNATIVES APPLY, YIELDS FROM AREA REGULATION WILL BE AS FOLLOWS-

	ACRES	HUNDREDS OF CU. FT.	M BD. FT.
REGENERATION CUTS			
PONDEROSA 1	2988.2	14040.6	35108.3
PONDEROSA 2	7695.4	26089.3	60026.2
LODGEPOLE	454.4	0.0	7120.9
FINAL REMOVAL CUTS			
PONDEROSA 1	2988.2	36.9	5443.8
PONDEROSA 2	3847.7	1937.1	18642.5
LODGEPOLE	0.0	0.0	0.0
INTERMEDIATE CUTS			
PONDEROSA 1	11952.8	52795.5	4158.9
PONDEROSA 2	14460.7	43604.1	29404.3
LODGEPOLE	1363.1	4337.0	4633.0
TOTAL FOR ONE YEAR			
PONDEROSA 1	17929.1	66873.0	44711.0
PONDEROSA 2	26003.9	71630.5	108073.0
LODGEPOLE	1817.5	4337.0	11753.9
TOTAL ALL GROUPS	45750.5	142840.5	164537.9

PAGE TYPE 1, CONT.

FORMULA COMPUTATION OF ALLOWABLE ANNUAL CUT. CUBIC-FOOT VOLUMES INCLUDE SAWLOG TREES-

HEYER FORMULA WITH M.A.I. FROM OPTIMUM YIELD TABLES AND COMPUTED GROWING STOCKS

	ADJUSTMENT PERIOD	HUNDREDS OF CU. FT.	M BD. FT.
PONDEROSA 1	30.0	141303.9	46849.7
PONDEROSA 2	30.0	123034.8	52369.7
LODGEPOLE	30.0	55601.2	22980.0
TOTAL		319939.9	122199.5

MEAN ANNUAL INCREMENTS USED TO OBTAIN THE RESULTS TABULATED ABOVE

	ADJUSTMENT PERIOD	HUNDREDS OF CU. FT.	M BD. FT.
PONDEROSA 1	30.0	153849.4	62386.7
PONDEROSA 2	30.0	183169.6	75746.3
LODGEPOLE	30.0	29323.4	12704.0

FORMULA COMPUTATIONS ARE BASED ON VOLUME AND AREA COMPUTATIONS SUMMARIZED ON OTHER PAGES. VOLUME GOALS ARE ON PAGES TYPE 4, 8, 9, 10, AND 11. ACTUAL AREAS AND VOLUMES ARE ON PAGES TYPE 6, 7, 13, AND 14. CUBIC VOLUMES INCLUDE ALL TREES LARGER AND OLDER THAN MINIMUM LIMITS FOR INCLUSION IN GROWING STOCK VOLUME.

STANDS SELECTED FOR HARVEST AND REGENERATION WILL INCLUDE THOSE CLASSED AS WORK INDEX 4, 5, OR 6. IT IS EXPECTED THAT NEARLY EQUAL AREAS WILL BE CUT ANNUALLY IN STANDS OF EACH SITE CLASS. IF THIS IS NOT DESIRABLE, FACTORS THAT INDICATE RELATIVE VOLUME PRODUCTION (PAGE TYPE 12) MAY BE USED FOR AREA ADJUSTMENTS.

IF WORK IS DONE DURING NEXT PERIOD AS SPECIFIED BY WORK INDEXES, PERIODIC ANNUAL INCREMENTS WILL BE-

	HUNDREDS OF CU. FT.	M BD. FT.
PONDEROSA 1	205554.6	83532.8
PONDEROSA 2	165101.4	57266.2
LODGEPOLE	39320.2	18864.7

PAGE TYPE 2

POTENTIAL WORK LOAD AND YIELDS FOR NEXT PERIOD
BOGUS NATIONAL FOREST

ACRES OF COMMERCIAL THINNING DURING NEXT PERIOD

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	14530.7	25657.5	0.0	40188.2
2	0.0	7247.6	18036.7	7136.5	0.0	32420.8
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	7247.6	32567.4	32794.0	0.0	72609.0

HUNDREDS OF CU. FT. REMOVED BY THINNING

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	116079.7	122260.1	0.0	238339.7
2	0.0	41244.0	115856.0	32179.6	0.0	189279.6
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	41244.0	231935.7	154439.7	0.0	427619.3

M BD. FT. REMOVED BY THINNING

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	0.0	33685.0	0.0	33685.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	33685.0	0.0	33685.0

PAGE TYPE 2

M BD. FT. TO BE HARVESTED BY REGENERATION CUTS

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	0.0	270723.4	200067.3	470790.7
2	0.0	0.0	0.0	153043.8	107658.3	260702.1
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	423767.2	307725.6	731492.9

HUNDREDS OF CU. FT. FROM REGENERATION CUTS

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	0.0	65682.1	97435.5	163117.6
2	0.0	0.0	623.6	65590.3	63207.5	129421.5
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	623.6	131272.4	160643.1	292539.1

M BD. FT. TO BE HARVESTED BY FINAL REMOVAL OF OVERWOOD

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	3839.6	0.0	14493.7	1079.5	19412.7
2	0.0	0.0	0.0	2098.1	25871.4	27969.5
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	3839.6	0.0	16591.7	26950.9	47382.2

HUNDREDS OF CU. FT. FROM FINAL CUTS

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	321.4	0.0	321.4
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	321.4	0.0	321.4

ACRES OF NONCOMMERCIAL THINNING DURING NEXT PERIOD

BLOCK	TYPE 1	TYPE 2	TYPE 3	TYPE 4	TYPE 5	TOTAL
1	8.9	29172.5	7287.6	3719.3	106.7	40295.0
2	515.6	7176.5	14486.2	191.2	0.0	22369.5
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	524.5	36348.9	21773.8	3910.5	106.7	62664.5

POTENTIAL WORK LOAD AND YIELDS FOR NEXT PERIOD
BOGUS NATIONAL FOREST

ACRES OF COMMERCIAL THINNING DURING NEXT PERIOD

BLOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	9277.3	27832.0	18554.7	0.0	55664.1
TOTAL	0.0	9277.3	27832.0	18554.7	0.0	55664.1

HUNDREDS OF CU. FT. REMOVED BY THINNING

BLOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	29262.5	149686.1	49750.5	0.0	228699.1
TOTAL	0.0	29262.5	149686.1	49750.5	0.0	228699.1

M BD. FT. REMOVED BY THINNING

BLOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	36938.4	117284.2	0.0	154222.6
TOTAL	0.0	0.0	36938.4	117284.2	0.0	154222.6

PAGE TYPE 2

M 8O. FT. TO 8E HARVESTEO 8Y REGENERATION CUTS

8LOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	393751.6	40441.5	434193.1
TOTAL	0.0	0.0	0.0	393751.6	40441.5	434193.1

HUNOREOS OF CU. FT. FROM REGENERATION CUTS

8LOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	162320.2	26393.6	188713.8
TOTAL	0.0	0.0	0.0	162320.2	26393.6	188713.8

M 8O. FT. TO 8E HARVESTEO 8Y FINAL REMOVAL OF OVERWOOO

8LOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	159386.7	155258.9	314645.6
TOTAL	0.0	0.0	0.0	159386.7	155258.9	314645.6

PAGE TYPE 2

HUNOREOS OF CU. FT. FROM FINAL CUTS

8LOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	32694.4	0.0	32694.4
TOTAL	0.0	0.0	0.0	32694.4	0.0	32694.4

ACRES OF NONCOMMERCIAL THINNING OURING NEXT PERIOO

BLOCK	TYPE 6	TYPE 7	TYPE 8	TYPE 9	TYPE 10	TOTAL
1	0.0	0.0	0.0	0.C	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0
3	27885.3	27832.0	46386.7	18554.7	0.0	120658.8
TOTAL	27885.3	27832.0	46386.7	18554.7	0.0	120658.8

PAGE TYPE 2

POTENTIAL WORK LOAD AND YIELDS FOR NEXT PERIOD
BOGUS NATIONAL FOREST

ACRES OF COMMERCIAL THINNING DURING NEXT PERIOD

BLOCK	TYPE 11	TYPE 12	TYPE 13	TYPE 14	TYPE 15	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	10704.7	0.0	0.0	10704.7
3	0.0	0.0	0.0	9277.3	0.0	9277.3
TOTAL	0.0	0.0	10704.7	9277.3	0.0	19982.0

HUNDREDS OF CU. FT. REMOVED BY THINNING

BLOCK	TYPE 11	TYPE 12	TYPE 13	TYPE 14	TYPE 15	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	95366.4	0.0	0.0	95366.4
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	95366.4	0.0	0.0	95366.4

M BD. FT. REMOVED BY THINNING

BLOCK	TYPE 11	TYPE 12	TYPE 13	TYPE 14	TYPE 15	TOTAL
1	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	26976.6	0.0	0.0	26976.6
3	0.0	0.0	0.0	74899.2	0.0	74899.2
TOTAL	0.0	0.0	26976.6	74899.2	0.0	101875.8

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PAGE TYPE 2

M BD. FT. TO BE HARVESTED BY REGENERATION CUTS

BLOCK	TYPE 11	TYPE 12	TYPE 13	TYPE 14	TYPE 15	TOTAL
1	0.0	0.0	0.0	53030.4	0.0	53030.4
2	0.0	0.0	0.0	17093.7	0.0	17093.7
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	0.0	0.0	70124.1	0.0	70124.1

ACRES OF NONCOMMERCIAL THINNING DURING NEXT PERIOD

BLOCK	TYPE 11	TYPE 12	TYPE 13	TYPE 14	TYPE 15	TOTAL
1	0.0	26.7	0.0	0.0	0.0	26.7
2	0.0	3568.2	0.0	0.0	0.0	3568.2
3	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	0.0	3594.9	0.0	0.0	0.0	3594.9

COMPARISON OF ACTUAL GROWING STOCK WITH GROWING STOCK GOAL
BOGUS NATIONAL FOREST

WORKING GROUP - PONDEROSA 1

THOUSANDS OF BOARD FEET IN TREES OF COMMERCIAL SIZE.

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME DIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	0.0	0.0	CORRECT
40	0.0	0.0	0.0	CORRECT
50	0.0	0.0	0.0	CORRECT
60	0.0	19470.8	-19470.8	DEFICIT
70	219.1	90747.8	-90528.7	DEFICIT
80	23320.2	177367.8	-154047.6	DEFICIT
90	24184.8	271217.4	-247032.6	DEFICIT
100	72120.8	308331.7	-236210.9	DEFICIT
110	130731.9	369272.1	-238540.2	DEFICIT
120	168771.6	187971.4	-19199.8	DEFICIT
130	350634.5	247209.1	103425.4	SURPLUS
140	145023.6	0.0	145023.6	SURPLUS
150	290472.7	0.0	290472.7	SURPLUS
TOTAL	1205479.1	1671588.1	-466109.0	

HUNDREDS OF MERCH. CUBIC FEET IN TREES 6.0 INCHES D.B.H. AND LARGER

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME DIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	3662.8	-3662.8	DEFICIT
40	209.1	113878.5	-113669.5	DEFICIT
50	134741.1	275738.6	-140997.5	DEFICIT
60	111286.5	401473.9	-290187.4	DEFICIT
70	207221.9	563672.9	-356451.0	DEFICIT
80	328000.1	626607.6	-298607.4	DEFICIT
90	249216.2	774133.4	-524917.2	DEFICIT
100	305525.6	766770.7	-461245.1	DEFICIT
110	685867.1	858922.5	-173055.3	DEFICIT
120	484648.6	374654.1	109994.5	SURPLUS
130	1093866.7	462076.5	631790.2	SURPLUS
140	362886.8	0.0	362886.8	SURPLUS
150	881757.3	0.0	881757.3	SURPLUS
TOTAL	4845227.1	5221591.5	-376364.4	

PAGE TYPE 3

COMPARISON OF ACTUAL GROWING STOCK WITH GROWING STOCK GOAL
BOGUS NATIONAL FOREST

WORKING GROUP - PONDEROSA 2

THOUSANDS OF BOARD FEET IN TREES OF COMMERCIAL SIZE.

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME DIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	0.0	0.0	CORRECT
40	0.0	0.0	0.0	CORRECT
50	0.0	0.0	0.0	CORRECT
60	0.0	27794.2	-27794.2	DEFICIT
70	0.0	108007.8	-108007.8	DEFICIT
80	0.0	211736.2	-211736.2	DEFICIT
90	31733.0	314599.1	-282866.0	DEFICIT
100	39451.6	336589.9	-297138.2	DEFICIT
110	105308.3	407927.4	-302619.1	DEFICIT
120	308808.7	245997.8	62810.9	SURPLUS
130	420828.4	264554.7	156273.7	SURPLUS
140	256587.7	150411.0	106176.8	SURPLUS
150	203603.3	0.0	203603.3	SURPLUS
TOTAL	1366321.2	2067618.0	-701296.8	

HUNDREDS OF MERCH. CUBIC FEET IN TREES 6.0 INCHES D.B.H. AND LARGER

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME DIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	5586.2	-5586.2	DEFICIT
40	0.0	144902.5	-144902.5	DEFICIT
50	123739.9	330913.0	-207173.1	DEFICIT
60	2816.4	457168.1	-454351.7	DEFICIT
70	96511.2	646813.8	-550302.6	DEFICIT
80	84675.3	710038.9	-625363.6	DEFICIT
90	304873.8	879182.0	-574308.1	DEFICIT
100	229096.0	793915.2	-564819.2	DEFICIT
110	477047.5	901361.7	-424314.2	DEFICIT
120	811752.2	478292.8	333459.4	SURPLUS
130	1113655.1	484954.9	628700.2	SURPLUS
140	521462.8	248656.7	272806.1	SURPLUS
150	512111.1	0.0	512111.1	SURPLUS
TOTAL	4277741.5	6081785.8	-1804044.4	

PAGE TYPE 3

COMPARISON OF ACTUAL GROWING STOCK WITH GROWING STOCK GOAL
BOGUS NATIONAL FOREST

WORKING GROUP - LOOGEPOLE

THOUSANOS OF 8OARO FEET IN TREES OF COMMERCIAL SIZE.

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME OIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	0.0	0.0	CORRECT
40	0.0	0.0	0.0	CORRECT
50	105.0	0.0	105.0	SURPLUS
60	0.0	23858.2	-23858.2	OEFICIT
70	0.0	43095.9	-43095.9	OEFICIT
80	0.0	60423.7	-60423.7	OEFICIT
90	0.0	74457.7	-74457.7	OEFICIT
100	65706.0	64740.7	965.3	SURPLUS
110	345274.6	79091.9	266182.7	SURPLUS
120	194711.9	0.0	194711.9	SURPLUS
130	203.8	0.0	203.8	SURPLUS
140	47947.6	0.0	47947.6	SURPLUS
150	0.0	0.0	0.0	CORRECT
TOTAL	653949.0	345668.1	308280.9	

HUNOREOS OF MERCH. CU8IC FEET IN TREES 6.0 INCHES O.8.H. ANO LARGER

AGE CLASS	ACTUAL GROWING STOCK	GROWING STOCK GOAL	VOLUME OIFFERENCE	STATUS OF ACTUAL VOLUME
10	0.0	0.0	0.0	CORRECT
20	0.0	0.0	0.0	CORRECT
30	0.0	1210.9	-1210.9	OEFICIT
40	0.0	30259.4	-30259.4	OEFICIT
50	511.3	66211.1	-65699.8	OEFICIT
60	82026.8	103965.8	-21939.1	OEFICIT
70	291.1	107232.3	-106941.2	OEFICIT
80	108525.3	143638.5	-35113.2	OEFICIT
90	0.0	173918.7	-173918.7	OEFICIT
100	152405.2	145383.9	7021.3	SURPLUS
110	822671.8	173694.5	648977.3	SURPLUS
120	458983.8	0.0	458983.8	SURPLUS
130	459.0	0.0	459.0	SURPLUS
140	107975.3	0.0	107975.3	SURPLUS
150	0.0	0.0	0.0	CORRECT
TOTAL	1733849.5	945515.1	788334.3	

PAGE TYPE 4

RECORO OF MANAGEMENT OECISIONS ANO CURRENT CONOITIONS
8OGUS NATIONAL FOREST

NUM8ER OF 8LOCKS - 3

NUM8ER OF COMPARTMENTS - 0

MINIMUM AGE FOR GROWING STOCK - 30

NUMBER OF WORKING GROUPS - 3

MINIMUM M 8O. FT. FOR GROWING STOCK - 1.5

LENGTH OF PLANNING PERIOO, YEARS - 10.

	W O R K I N G G R O U P		
	PONOEROSA 1	PONOEROSA 2	LOOGEPOLE
LOWEST SITE CLASS TO 8E MANAGEO	50.0	40.0	50.0
LENGTH OF CUTTING CYCLE, YEARS	20.0	20.0	30.0
LENGTH OF AOJUSTMENT PERIOO, YEARS	30.0	30.0	30.0
EXPECTEO OELAY IN REGENERATION, YEARS	0.0	0.0	10.0
STOCKING LEVEL FOR INITIAL THINNING	120.0	110.0	110.0
STOCKING LEVEL, SU8SEQUENT THINNINGS	100.0	90.0	100.0
MINIMUM COMMERCIAL CUT, M 8O. FT.	1.0	1.0	1.5
MINIMUM COMMERCIAL CUT, CU. FT.	2.4	2.4	2.4
LENGTH OF PREOICTION PERIOO, YEARS	10.0	10.0	10.0

CU8IC FEET IN HUNOREDS.

PAGE TYPE 5

AREAS OF TYPES IN WORKING CIRCLE
BOGUS NATIONAL FOREST

COVER TYPE	ACRES	*	COVER TYPE	ACRES	*	COVER TYPE	ACRES
1 PP1 0-30	26008.7	*	16	0.0	*	26 DEFOREST-B	30152.7
2 PP1 31-50	47591.3	*	17	0.0	*	27 DEFOREST-G	80685.5
3 PP1 51-100	90885.6	*	18	0.0	*	28 RECREATION	6911.1
4 PP1 101-40	113744.1	*	19	0.0	*	29 BARREN	581.6
5 PP1 141+	32807.4	*	20	0.0	*	30 BRUSHLAND	3390.2
6 PP2 0-30	65297.0	*	21	0.0	*	31 RANGE-HERB	16397.6
7 PP2 31-50	37109.4	*	22	0.0	*	32 PRIVATE	47799.4
8 PP2 51-100	83496.1	*	23	0.0	*	33 RIGHTS/WAY	5345.7
9 PP2 101-40	120605.5	*	24	0.0	*	34	0.0
10 PP2 141+	27832.0	*	25	0.0	*	35	0.0
11 LGP 0-30	3643.7	*					
12 LGP 31-50	3603.8	*					
13 LGP 51-100	10744.7	*					
14 LGP 101-40	30347.7	*					
15 LGP 141+	0.0	*					
						TOTAL AREA	884981.1

*************** ACRES BY WORKING GROUPS ***************

PONDEROSA 1	PONDEROSA 2	LODGEPOLE
311037.2	334340.2	48340.0

DEFORESTED ACRES - 110838.2

PAGE TYPE 6

TOTAL AREAS OF BLOCKS AND WORKING CIRCLE
BOGUS NATIONAL FOREST

BLOCK NO.	TOTAL ACRES	* PLANTABLE ACRES FOREST SOIL *			******** FOREST AND REGENERATING BY WORKING GROUPS *********		
		BRUSHY	GRASSY	TOTAL	PONDEROSA 1	PONDEROSA 2	LODGEPOLE
1	207509.0	11477.9	4066.0	15544.0	158149.3	0.0	10993.5
2	208389.3	84.5	11206.9	11291.4	152887.9	0.0	18778.4
3	469082.8	18590.3	65412.5	84002.8	0.0	334340.2	18568.0
TOTAL	884981.1	30152.7	80685.5	110838.2	311037.2	334340.2	48340.0

PAGE TYPE 7

OISTRI8UTION OF AREA 8Y SITE INOEX CLASS
8OGUS NATIONAL FOREST

8LOCK	SITE INOEX	OEFORESTEO ACRES	PONOEROSA 1	PONOEROSA 2	LOOGEPOLE
1	10	0.0	0.0	0.0	0.0
1	20	0.0	0.0	0.0	0.0
1	30	0.0	0.0	0.0	0.0
1	40	7407.5	0.0	0.0	0.0
1	50	4292.6	58842.8	0.0	40.0
1	60	3843.8	69782.9	0.0	3674.8
1	70	0.0	29523.6	0.0	7278.7
1	80	0.0	0.0	0.0	0.0
1	90	0.0	0.0	0.0	0.0
1	100	0.0	0.0	0.0	0.0
1	110	0.0	0.0	0.0	0.0
1	120	0.0	0.0	0.0	0.0
1	130	0.0	0.0	0.0	0.0
1	140	0.0	0.0	0.0	0.0
2	10	0.0	0.0	0.0	0.0
2	20	0.0	0.0	0.0	0.0
2	30	0.0	0.0	0.0	0.0
2	40	0.0	0.0	0.0	0.0
2	50	7278.7	79385.5	0.0	3568.2
2	60	222.2	55181.3	0.0	7229.8
2	70	3790.5	18321.0	0.0	7980.5
2	80	0.0	0.0	0.0	0.0
2	90	0.0	0.0	0.0	0.0
2	100	0.0	0.0	0.0	0.0
2	110	0.0	0.0	0.0	0.0
2	120	0.0	0.0	0.0	0.0
2	130	0.0	0.0	0.0	0.0
2	140	0.0	0.0	0.0	0.0

PAGE TYPE 7,CONT.,

8LOCK	SITE INOEX	OEFORESTEO ACRES	PONOEROSA 1	PONOEROSA 2	LOOGEPOLE
3	10	0.0	0.0	0.0	0.0
3	20	0.0	0.0	0.0	0.0
3	30	0.0	0.0	9277.3	0.0
3	40	0.0	0.0	83713.9	0.0
3	50	37198.3	0.0	74218.8	0.0
3	60	28072.0	0.0	102108.6	0.0
3	70	18732.5	0.0	65021.4	18568.0
3	80	0.0	0.0	0.0	0.0
3	90	0.0	0.0	0.0	0.0
3	100	0.0	0.0	0.0	0.0
3	110	0.0	0.0	0.0	0.0
3	120	0.0	0.0	0.0	0.0
3	130	0.0	0.0	0.0	0.0
3	140	0.0	0.0	0.0	0.0
TOTAL		110838.2	311037.2	334340.2	48340.0

PAGE TYPE 11

GROWING STOCK GOALS FOR WORKING CIRCLE

WORKING GROUP - PONDEROSA 1

BOGUS NATIONAL FOREST

SITE CLASS	ACRES	ROTATION AGE	CU. FT. TO BD. FT. LIMIT	CU. FT. TO ROTATION AGE	M BD. FT. ABOVE BD. FT. LIMIT
50.	148724.4	110.	311464.	1957760.	569556.
60.	128756.2	110.	275841.	2194825.	722268.
70.	51220.5	110.	113520.	1069007.	379764.
TOTALS	335627.1		700825.	5221592.	1671588.

CUBIC FEET IN HUNDREDS. TOTAL AREA INCLUDES ANY LOW SITE ACRES INCORRECTLY CLASSED AS OPERABLE TYPES.

PAGE TYPE 12

CONVERSION OF AREAS TO STANDARD ACRES

WORKING GROUP - PONDEROSA 1

BOGUS NATIONAL FOREST

SITE INDEX CLASS	TOTAL YIELD PER ACRE M BD. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
50.	15.2	148724.4	.65251	97044.1	1.53254
60.	23.3	128756.2	1.00000	128756.2	1.00000
70.	28.6	51220.5	1.22523	62756.6	.81618

SITE INDEX CLASS	TOTAL YIELD PER ACRE CU. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
50.	4111.0	148724.4	.73833	109807.1	1.35441
60.	5568.0	128756.2	1.00000	128756.2	1.00000
70.	6956.0	51220.5	1.24928	63988.8	.80046

PAGE TYPE 8

YIELOS PER ACRE OF MANAGEO, EVEN-AGED STANOS 8ASEO ON PREOETERMINEO STANOAROS FOR
SITE INOEX 70., 20.-YEAR CUTTING CYCLE
THINNING LEVELS= INITIAL - 110., SU8SEQUENT - 90.

WORKING GROUP - PONOEROSA 2

	ENTIRE STANO 8EFORE ANO AFTER THINNING							PERIOOIC CUT ANO MORTALITY				
STANO AGE (YEARS)	TREES NO.	8ASAL AREA SQ. FT.	AVERAGE O.8.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU. FT.	MERCHANT-A8LE VOLUME CU. FT.	SAWTIM8ER VOLUME M 8O. FT.	TREES NO.	8ASAL AREA SQ. FT.	TOTAL VOLUME CU. FT.	MERCHANT-A8LE VOLUME CU. FT.	SAWTIM8ER VOLUME M 8O. FT.
30.	950	119	4.8	25	1188	312.	0.000					
30.	417	74	5.7	26	799	312.	0.000	533	45	389	0.	0.000
40.	413	104	6.8	35	1502	1020.	0.000					
50.	406	131	7.7	44	2370	1900.	1.160					
50.	215	85	8.5	45	1568	1364.	1.160	191	46	802	536.	0.000
60.	214	105	9.5	51	2221	2034.	3.900					
70.	213	126	10.4	58	3043	2829.	8.150					
70.	132	90	11.2	59	2240	2098.	7.050	81	36	803	731.	1.100
80.	132	107	12.2	65	2969	2796.	10.820					
90.	132	124	13.1	69	3722	3519.	14.800					
90.	85	90	13.9	70	2737	2596.	11.380	47	34	985	923.	3.420
100.	85	103	14.9	74	3355	3193.	14.980					
110.	85	116	15.8	78	3975	3794.	18.780					
110.	27	45	17.5	80	1593	1527.	7.960	58	71	2382	2267.	10.820
120.	27	53	19.0	83	1960	1884.	10.460					
130.	27	61	20.4	86	2341	2256.	13.180					
130.	9	24	22.0	87	928	896.	5.440	18	37	1413	1360.	7.740
140.	9	28	24.0	90	1138	1102.	7.080					
							TOTAL YIELOS			7912	6919.	30.160

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELOS-- 240. CU8IC FEET ANO 1000. 8OARO FEET

PAGE TYPE 9

GROWING STOCK OF MANAGEO, REGULATEO, EVEN-AGEO STANOS
SITE INOEX 70., 20.-YEAR CUTTING CYCLE
OENSITY LEVEL- 110. ANO 90.

WORKING GROUP - PONOEROSA 2

VOLUMES PRESENT PER ACRE AT ENO OF EACH YEAR

MERCHANTABLE CUBIC FEET

	YEAR									
OECAOE	0	1	2	3	4	5	6	7	8	9
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	312.0	382.8	453.6	524.4	595.2	666.0	736.8	807.6	878.4	949.2
4	1020.0	1108.0	1196.0	1284.0	1372.0	1460.0	1548.0	1636.0	1724.0	1812.0
5	1364.0	1431.0	1498.0	1565.0	1632.0	1699.0	1766.0	1833.0	1900.0	1967.0
6	2034.0	2113.5	2193.0	2272.5	2352.0	2431.5	2511.0	2590.5	2670.0	2749.5
7	2098.0	2167.8	2237.6	2307.4	2377.2	2447.0	2516.8	2586.6	2656.4	2726.2
8	2796.0	2868.3	2940.6	3012.9	3085.2	3157.5	3229.8	3302.1	3374.4	3446.7
9	2596.0	2655.7	2715.4	2775.1	2834.8	2894.5	2954.2	3013.9	3073.6	3133.3
10	3193.0	3253.1	3313.2	3373.3	3433.4	3493.5	3553.6	3613.7	3673.8	3733.9
11	1527.0	1562.7	1598.4	1634.1	1669.8	1705.5	1741.2	1776.9	1812.6	1848.3
12	1884.0	1921.2	1958.4	1995.6	2032.8	2070.0	2107.2	2144.4	2181.6	2218.8
13	896.0	916.6	937.2	957.8	978.4	999.0	1019.6	1040.2	1060.8	1081.4
14	1102.0									

THOUSANOS OF BOARO FEET

0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	.116	.232	.348	.464	.580	.696	.812	.928	1.044
5	1.160	1.434	1.708	1.982	2.256	2.530	2.804	3.078	3.352	3.626
6	3.900	4.325	4.750	5.175	5.600	6.025	6.450	6.875	7.300	7.725
7	7.050	7.427	7.804	8.181	8.558	8.935	9.312	9.689	10.066	10.443
8	10.820	11.218	11.616	12.014	12.412	12.810	13.208	13.606	14.004	14.402
9	11.380	11.740	12.100	12.460	12.820	13.180	13.540	13.900	14.260	14.620
10	14.980	15.360	15.740	16.120	16.500	16.880	17.260	17.640	18.020	18.400
11	7.960	8.210	8.460	8.710	8.960	9.210	9.460	9.710	9.960	10.210
12	10.460	10.732	11.004	11.276	11.548	11.820	12.092	12.364	12.636	12.908
13	5.440	5.604	5.768	5.932	6.096	6.260	6.424	6.588	6.752	6.916
14	7.080									

PAGE TYPE 10

OISTRIBUTION OF AREA AND GROWING STOCK GOALS

FOR SITE INOEX CLASS- 70., ROTATION- 110., AND 82768.3 ACRES OF THIS SITE CLASS AND GROUP

WORKING GROUP - PONOEROSA 2

AGE CLASS	ACRES IN CLASS	HUNOREOS OF CU. FT.	M 8O. FT.
1- 10	7524.4	0.0	0.0
11- 20	7524.4	0.0	0.0
21- 30	7524.4	2347.6	0.0
31- 40	7524.4	52776.1	0.0
41- 50	7524.4	109133.8	0.0
51- 60	7524.4	130360.1	18988.6
61- 70	7524.4	180446.3	46105.7
71- 80	7524.4	186748.0	68648.8
81- 90	7524.4	233357.8	95311.5
91-100	7524.4	220039.6	100525.9
101-110	7524.4	248068.0	120300.0
111-120	0.0	129671.7	70240.2
121-130	0.0	146921.3	84137.8
131-140	0.0	75943.7	47719.7
141-150	0.0	0.0	0.0
TOTALS	82768.3	1715814.1	651978.3

PAGE TYPE 11

GROWING STOCK GOALS FOR WORKING CIRCLE

WORKING GROUP - PONOEROSA 2

8OGUS NATIONAL FOREST

SITE CLASS	ACRES	ROTATION AGE	CU. FT. TO 8O. FT. LIMIT	CU. FT. TO ROTATION AGE	M 8O. FT. A8OVE 8O. FT. LIMIT
40.	83713.9	90.	202588.	698039.	162433.
50.	109459.9	110.	221693.	1478694.	481059.
60.	128703.7	110.	263048.	2189238.	772147.
70.	82768.3	110.	175025.	1715814.	651978.
TOTALS	413923.3		862354.	6081786.	2067618.

CU8IC FEET IN HUNOREOS. TOTAL AREA INCLUOES ANY LOW SITE ACRES INCORRECTLY CLASSEO AS OPERA8LE TYPES.

PAGE TYPE 12

CONVERSION OF AREAS TO STANDARD ACRES

WORKING GROUP - PONDEROSA 2

BOGUS NATIONAL FOREST

SITE INDEX CLASS	TOTAL YIELD PER ACRE M BD. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
40.	8.7	83713.9	.48930	40961.4	2.04373
50.	17.8	109459.9	1.00000	109459.9	1.00000
60.	23.0	128703.7	1.29673	166894.5	.77117
70.	30.2	82768.3	1.69820	140557.1	.58886

SITE INDEX CLASS	TOTAL YIELD PER ACRE CU. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
40.	2373.0	83713.9	.57305	47972.3	1.74505
50.	4141.0	109459.9	1.00000	109459.9	1.00000
60.	5550.0	128703.7	1.34026	172495.9	.74613
70.	6919.0	82768.3	1.67085	138293.7	.59850

PAGE TYPE 8

YIELDS PER ACRE OF MANAGED, EVEN-AGED STANDS BASED ON PREDETERMINED STANDARDS FOR
SITE INDEX 70., 30.-YEAR CUTTING CYCLE
THINNING LEVELS* INITIAL - 110., SUBSEQUENT - 100.

WORKING GROUP - LODGEPOLE

	ENTIRE STAND BEFORE AND AFTER THINNING							PERIODIC CUT AND MORTALITY				
STAND AGE (YEARS)	TREES NO.	BASAL AREA SQ. FT.	AVERAGE D.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU. FT.	MERCHANT-ABLE VOLUME CU. FT.	SAWTIMBER VOLUME M BD. FT.	TREES NO.	BASAL AREA SQ. FT.	TOTAL VOLUME CU. FT.	MERCHANT-ABLE VOLUME CU. FT.	SAWTIMBER VOLUME M BD. FT.
30.	1000	126	4.8	28	1674	341.	0.000					
30.	432	71	5.5	29	1018	341.	0.000	568	55	656	0.	0.000
40.	430	99	6.5	37	1812	1186.	0.000					
50.	429	128	7.4	41	2647	2158.	0.000					
60.	428	153	8.1	49	3728	3264.	13.510					
60.	227	96	8.8	50	2389	2175.	8.900	201	57	1339	1089.	4.610
70.	225	115	9.7	56	3228	2993.	12.570					
80.	224	137	10.6	61	4184	3934.	16.750					
90.	224	159	11.4	65	5112	4826.	21.060					
90.	125	100	12.1	66	3220	3049.	13.580	99	59	1892	1777.	7.480
100.	125	117	13.1	69	3922	3728.	17.040					
110.	125	134	14.0	72	4631	4416.	20.630					
120.	125	151	14.9	75	5397	5160.	24.590					
							TOTAL YIELDS			9284	8026.	36.680

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS-- 240. CUBIC FEET AND 1500. BOARD FEET

PAGE TYPE 9

GROWING STOCK OF MANAGED, REGULATED, EVEN-AGED STANDS
SITE INDEX 70., 30.-YEAR CUTTING CYCLE
DENSITY LEVEL- 110. AND 100.

WORKING GROUP - LODGEPOLE

VOLUMES PRESENT PER ACRE AT END OF EACH YEAR

MERCHANTABLE CUBIC FEET

	YEAR									
DECADE	0	1	2	3	4	5	6	7	8	9
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	341.0	425.5	510.0	594.5	679.0	763.5	848.0	932.5	1017.0	1101.5
4	1186.0	1283.2	1380.4	1477.6	1574.8	1672.0	1769.2	1866.4	1963.6	2060.8
5	2158.0	2268.6	2379.2	2489.8	2600.4	2711.0	2821.6	2932.2	3042.8	3153.4
6	2175.0	2256.8	2338.6	2420.4	2502.2	2584.0	2665.8	2747.6	2829.4	2911.2
7	2993.0	3087.1	3181.2	3275.3	3369.4	3463.5	3557.6	3651.7	3745.8	3839.9
8	3934.0	4023.2	4112.4	4201.6	4290.8	4380.0	4469.2	4558.4	4647.6	4736.8
9	3049.0	3116.9	3184.8	3252.7	3320.6	3388.5	3456.4	3524.3	3592.2	3660.1
10	3728.0	3796.8	3865.6	3934.4	4003.2	4072.0	4140.8	4209.6	4278.4	4347.2
11	4416.0	4490.4	4564.8	4639.2	4713.6	4788.0	4862.4	4936.8	5011.2	5085.6
12	5160.0									

THOUSANDS OF BOARD FEET

0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.000	1.351	2.702	4.053	5.404	6.755	8.106	9.457	10.808	12.159
6	8.900	9.267	9.634	10.001	10.368	10.735	11.102	11.469	11.836	12.203
7	12.570	12.988	13.406	13.824	14.242	14.660	15.078	15.496	15.914	16.332
8	16.750	17.181	17.612	18.043	18.474	18.905	19.336	19.767	20.198	20.629
9	13.580	13.926	14.272	14.618	14.964	15.310	15.656	16.002	16.348	16.694
10	17.040	17.399	17.758	18.117	18.476	18.835	19.194	19.553	19.912	20.271
11	20.630	21.026	21.422	21.818	22.214	22.610	23.006	23.402	23.798	24.194
12	24.590									

PAGE TYPE 10

DISTRIBUTION OF AREA AND GROWING STOCK GOALS

FOR SITE INDEX CLASS- 70., ROTATION- 120., AND 35227.4 ACRES OF THIS SITE CLASS AND GROUP

WORKING GROUP - LODGEPOLE

AGE CLASS	ACRES IN CLASS	HUNDREDS OF CU. FT.	M BD. FT.
0	2935.6		
1- 10	2935.6	0.0	0.0
11- 20	2935.6	0.0	0.0
21- 30	2935.6	1001.0	0.0
31- 40	2935.6	23653.7	0.0
41- 50	2935.6	50510.2	0.0
51- 60	2935.6	78011.0	20063.2
61- 70	2935.6	77057.0	32052.5
71- 80	2935.6	103056.2	43649.7
81- 90	2935.6	124672.7	53934.6
91-100	2935.6	100470.0	45452.1
101-110	2935.6	120548.1	55819.3
111-120	0.0	0.0	0.0
121-130	0.0	0.0	0.0
131-140	0.0	0.0	0.0
141-150	0.0	0.0	0.0
TOTALS	35227.4	678980.0	250971.3

AGE CLASS ZERO REPRESENTS CLEARCUT ACRES NOT YET REFORESTED BECAUSE OF DELAY OF 10. YEARS EXPECTED AFTER SCHEDULED REGENERATION CUTTING.

PAGE TYPE 11

GROWING STOCK GOALS FOR WORKING CIRCLE

WORKING GROUP - LODGEPOLE

BOGUS NATIONAL FOREST

SITE CLASS	ACRES	ROTATION AGE	CU. FT. TO BD. FT. LIMIT	CU. FT. TO ROTATION AGE	M BD. FT. ABOVE BD. FT. LIMIT
50.	6640.6	120.	12502.	74084.	24933.
60.	12655.7	120.	21157.	192451.	69764.
70.	35227.4	120.	81825.	678980.	250971.
TOTALS	55005.2		115483.	945515.	345668.

CUBIC FEET IN HUNDREDS. TOTAL AREA INCLUDES ANY LOW SITE ACRES INCORRECTLY CLASSED AS OPERABLE TYPES.

PAGE TYPE 12

CONVERSION OF AREAS TO STANDARD ACRES

WORKING GROUP - LODGEPOLE

BOGUS NATIONAL FOREST

SITE INDEX CLASS	TOTAL YIELD PER ACRE M BD. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
50.	17.7	6640.6	.73682	4892.9	1.35718
60.	24.1	12655.7	1.00000	12655.7	1.00000
70.	36.7	35227.4	1.52262	53638.0	.65676

SITE INDEX CLASS	TOTAL YIELD PER ACRE CU. FT.	ACRES IN SITE CLASS	REDUCTION FACTOR	AREA IN STANDARD ACRES	EQUIVALENT OF STANDARD ACRE IN SITE ACRES
50.	4386.0	6640.6	.72700	4827.7	1.37551
60.	6033.0	12655.7	1.00000	12655.7	1.00000
70.	8026.0	35227.4	1.33035	46864.7	.75168

PAGE TYPE 13

VOLUMES OF BLOCKS AND WORKING CIRCLE
BOGUS NATIONAL FOREST

	TOTALS	BLOCK NO. 1	BLOCK NO. 2	BLOCK NO. 3	BLOCK NO. 4	BLOCK NO. 5	BLOCK NO. 6	BLOCK NO.
PONDEROSA 1								
TOTAL CU. FT.	6364169.1	3409318.4	2954850.7	0.0				
MERCH. CU. FT.	4845227.1	2592262.9	2252964.3	0.0				
M BD. FT.	1205479.1	715735.4	489743.7	0.0				
PONDEROSA 2								
TOTAL CU. FT.	5554914.0	0.0	0.0	5554914.0				
MERCH. CU. FT.	4277741.5	0.0	0.0	4277741.5				
M BD. FT.	1366321.2	0.0	0.0	1366321.2				
LODGEPOLE								
TOTAL CU. FT.	1966950.4	334040.0	767312.2	865598.1				
MERCH. CU. FT.	1733849.5	306054.2	619582.1	808213.2				
M BD. FT.	653949.0	129110.3	184678.6	340160.1				
TOTAL VOLUME OF BLOCK								
TOTAL CU. FT.	13886033.4	3743358.4	3722162.9	6420512.1				
MERCH. CU. FT.	10856818.1	2898317.1	2872546.4	5085954.6				
M BD. FT.	3225749.3	844845.7	674422.3	1706481.3				

CUBIC FEET IN HUNDREDS, BOARD FEET IN THOUSANDS

TOTAL AREAS AND VOLUMES OF BLOCKS AND WORKING CIRCLE
BOGUS NATIONAL FOREST

BLOCK NO.	TYPE NO.	TOTAL ACRES	TOTAL CU. FT.	MERCH. CU. FT.	M BD. FT.	ACRES LOW SITE	NUMBER OF RECORDS
1	1	7287.6	0.0	0.0	0.0	0.0	5.
1	2	33114.0	301634.2	38789.0	0.0	0.0	15.
1	3	29385.8	611637.3	351176.3	7119.8	0.0	16.
1	4	70027.4	1958300.3	1708379.5	534544.8	0.0	31.
1	5	18334.5	537746.6	493918.0	174070.8	0.0	8.
1	6	0.0	0.0	0.0	0.0	0.0	0.
1	7	0.0	0.0	0.0	0.0	0.0	0.
1	8	0.0	0.0	0.0	0.0	0.0	0.
1	9	0.0	0.0	0.0	0.0	0.0	0.
1	10	0.0	0.0	0.0	0.0	0.0	0.
1	11	3630.4	0.0	0.0	0.0	0.0	1.
1	12	35.6	925.3	511.3	105.0	0.0	2.
1	13	0.0	0.0	0.0	0.0	0.0	0.
1	14	7327.5	333114.7	305542.9	129005.2	0.0	5.
1	15	0.0	0.0	0.0	0.0	0.0	0.
1	16	0.0	0.0	0.0	0.0	0.0	0.
1	17	0.0	0.0	0.0	0.0	0.0	0.
1	18	0.0	0.0	0.0	0.0	0.0	0.
1	19	0.0	0.0	0.0	0.0	0.0	0.
1	20	0.0	0.0	0.0	0.0	0.0	0.
1	21	0.0	0.0	0.0	0.0	0.0	0.
1	22	0.0	0.0	0.0	0.0	0.0	0.
1	23	0.0	0.0	0.0	0.0	0.0	0.
1	24	0.0	0.0	0.0	0.0	0.0	0.
1	25	0.0	0.0	0.0	0.0	0.0	0.
1	26	11477.9	0.0	0.0	0.0	0.0	7.
1	27	4066.0	0.0	0.0	0.0	0.0	5.

PAGE TYPE 14, CONT.

BLOCK NO.	TYPE NO.	TOTAL ACRES	TOTAL CU. FT.	MERCH. CU. FT.	M BD. FT.	ACRES LOW SITE	NUMBER OF RECORDS
2	1	18721.1	0.0	0.0	0.0	0.0	13.
2	2	14477.3	248077.6	96161.2	0.0	0.0	8.
2	3	61499.8	1174498.1	850074.1	112725.0	0.0	29.
2	4	43716.7	1092254.9	918889.8	260616.8	0.0	21.
2	5	14472.9	440020.1	387839.3	116401.9	0.0	6.
2	6	0.0	0.0	0.0	0.0	0.0	0.
2	7	0.0	0.0	0.0	0.0	0.0	0.
2	8	0.0	0.0	0.0	0.0	0.0	0.
2	9	0.0	0.0	0.0	0.0	0.0	0.
2	10	0.0	0.0	0.0	0.0	0.0	0.
2	11	0.0	0.0	0.0	0.0	0.0	0.
2	12	3568.2	40874.4	0.0	0.0	0.0	1.
2	13	10744.7	433035.0	343248.3	65706.0	0.0	4.
2	14	4465.5	293402.8	276333.8	118972.7	0.0	3.
2	15	0.0	0.0	0.0	0.0	0.0	0.
2	16	0.0	0.0	0.0	0.0	0.0	0.
2	17	0.0	0.0	0.0	0.0	0.0	0.
2	18	0.0	0.0	0.0	0.0	0.0	0.
2	19	0.0	0.0	0.0	0.0	0.0	0.
2	20	0.0	0.0	0.0	0.0	0.0	0.
2	21	0.0	0.0	0.0	0.0	0.0	0.
2	22	0.0	0.0	0.0	0.0	0.0	0.
2	23	0.0	0.0	0.0	0.0	0.0	0.
2	24	0.0	0.0	0.0	0.0	0.0	0.
2	25	0.0	0.0	0.0	0.0	0.0	0.
2	26	84.5	0.0	0.0	0.0	0.0	2.
2	27	11206.9	0.0	0.0	0.0	0.0	8.

BLOCK NO.	TYPE NO.	TOTAL ACRES	TOTAL CU. FT.	MERCH. CU. FT.	M BD. FT.	ACRES LOW SITE	NUMBER OF RECORDS
3	1	0.0	0.0	0.0	0.0	0.0	0.
3	2	0.0	0.0	0.0	0.0	0.0	0.
3	3	0.0	0.0	0.0	0.0	0.0	0.
3	4	0.0	0.0	0.0	0.0	0.0	0.
3	5	0.0	0.0	0.0	0.0	0.0	0.
3	6	65297.0	0.0	0.0	0.0	0.0	12.
3	7	37109.4	619749.3	123739.9	0.0	0.0	4.
3	8	83496.1	997668.7	717972.8	71184.7	0.0	9.
3	9	120605.5	3262467.2	2923917.6	1091533.2	9277.3	13.
3	10	27832.0	675028.8	512111.1	203603.3	0.0	3.
3	11	13.3	0.0	0.0	0.0	0.0	1.
3	12	0.0	0.0	0.0	0.0	0.0	0.
3	13	0.0	0.0	0.0	0.0	0.0	0.
3	14	18554.7	865598.1	808213.2	340160.1	0.0	2.
3	15	0.0	0.0	0.0	0.0	0.0	0.
3	16	0.0	0.0	0.0	0.0	0.0	0.
3	17	0.0	0.0	0.0	0.0	0.0	0.
3	18	0.0	0.0	0.0	0.0	0.0	0.
3	19	0.0	0.0	0.0	0.0	0.0	0.
3	20	0.0	0.0	0.0	0.0	0.0	0.
3	21	0.0	0.0	0.0	0.0	0.0	0.
3	22	0.0	0.0	0.0	0.0	0.0	0.
3	23	0.0	0.0	0.0	0.0	0.0	0.
3	24	0.0	0.0	0.0	0.0	0.0	0.
3	25	0.0	0.0	0.0	0.0	0.0	0.
3	26	18590.3	0.0	0.0	0.0	0.0	4.
3	27	65412.5	0.0	0.0	0.0	0.0	13.
TOTALS		804555.5	13886033.4	10856818.1	3225749.3	9277.3	251.

CUBIC FEET IN HUNDREDS, BOARD FEET IN THOUSANDS

APPENDIX 3

Alternative Outputs

Reproduced below are examples of the type 5 pages produced by optional subroutine MAPS. MAPS produces two type 5 pages for each compartment if maps are desired, and a single type 5 page per compartment if map output is suppressed.

Subroutine AREA1 prints a type 5 page with two compartments per page. An example is not given; the format for each compartment is the same as the top half of the page without maps produced by MAPS.

Type 6 pages produced by MAPS and AREA1 are not reproduced because they do not differ in format from the page type 6 of AREA2 in appendix 2.

PAGE TYPE 5

BOGUS NATIONAL FOREST

TYPE MAP OF COMPARTMENT NO. 206 BLOCK NO. 1

```
                      5 5
            5 5 5 5 5 5 5               3 3323232 3 3
  5 5 5 5 5 5 5 5 5 5 5 5 5       5 5 5 3 3323232 3 3 3 3
3 5 5 5 5 5 5 5 5 5 5 5 5 5 5   3 3 5 5 5 53232323131 3 3 3 3
3 5 5 5 5 5 5 5 5 5 3 5 5 5 5 5 3 5 5 5 5 5 5 3 3 3 3 33131323232
3 5 5 5 5 5 5 5 5 3 3 5 5 5 5 5 5 5 5 5 5 3 3 3 4 4 3 3 3 4 33232
  3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 3 3 3 3 3 3 3 4 4 3 3 332
  3 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 3 3 3 3 3 3 3
    5 5 5 5 5 5 5 5 5 4 4 4 4 5 5 5 5 3 3 3 3 5 3
      5 5 5 5 5 5 5 5 3 3 4 4 5 5 5 5 3     5
      5 5 5 5 5 5 5 5 5 3 4 4 5 5   5
        5 5 5 5 5 5 5 5     4
          5     5
```

	COVER TYPE	ACRES	*	COVER TYPE		ACRES	*		COVER TYPE	ACRES
1	PP1 0-30	0.0	*	16		0.0	*	26	DEFOREST-B	0.0
2	PP1 31-50	0.0	*	17		0.0	*	27	DEFOREST-G	0.0
3	PP1 51-100	280.0	*	18		0.0	*	28	RECREATION	0.0
4	PP1 101-40	62.2	*	19		0.0	*	29	BARREN	0.0
5	PP1 141+	742.2	*	20		0.0	*	30	BRUSHLAND	0.0
6	PP2 0-30	0.0	*	21		0.0	*	31	RANGE-HERB	17.8
7	PP2 31-50	0.0	*	22		0.0	*	32	PRIVATE	66.7
8	PP2 51-100	0.0	*	23		0.0	*	33	RIGHTS/WAY	0.0
9	PP2 101-40	0.0	*	24		0.0	*	34		0.0
10	PP2 141+	0.0	*	25		0.0	*	35		0.0
11	LGP 0-30	0.0	*							
12	LGP 31-50	0.0	*							
13	LGP 51-100	0.0	*							
14	LGP 101-40	0.0	*							
15	LGP 141+	0.0	*							

TOTAL AREA 1168.9

*************** ACRES BY WORKING GROUPS ***************

PONDEROSA 1	PONDEROSA 2	LODGEPOLE
1084.4	0.0	0.0

DEFORESTED ACRES - 0.0

PAGE TYPE 5

BOGUS NATIONAL FOREST

SUBCOMPARTMENT MAP OF COMPARTMENT NO. 206 BLOCK NO. 1

```
                      1 1
            2 2 2 1 1 1 1               3 3       4 4
  5 5 5 5 5 2 2 2 1 1 1 1 1       6 6 6 3 3       4 4 4 4
7 5 5 5 5 5 2 2 2 2 1 1 1 1 1   8 8 6 6 6 6           4 4 4 4
7 5 5 5 5 2 2 2 2 2 9 1 1 1 1 1 8 6 6 6 6 6 61010 4 4 4
7 5 5 5 5 2 2 2 2 9 9 1 1 1 1 1 6 6 6 6 61010101111 4 4 41213
  7 5 5 5 2 2 2 21414 1 1 1 1 6 6 6 6 6 610101010 4 4 41212131313
  7 5 51414 214141414 1 1 1 1 6 6 6 6 6101010101010 4
    5 51414141414141415151515 6 6 6 6101010101610
     141414141414141417171515 6 6 6 610    16
     141414141414141414171515 6 6   6
       1414141414141414    15
         14    14
```

SUBCOMP.	COVER TYPE	ACRES	*	SUBCOMP.	COVER TYPE	ACRES
1	5. PP1 141+	151.1	*	10	3. PP1 51-100	93.3
2	5. PP1 141+	106.7	*	11	4. PP1 101-40	8.9
3	3. PP1 51-100	17.8	*	12	4. PP1 101-40	13.3
4	3. PP1 51-100	88.9	*	13	3. PP1 51-100	17.8
5	5. PP1 141+	111.1	*	14	5. PP1 141+	186.7
6	5. PP1 141+	177.8	*	15	4. PP1 101-40	40.0
7	3. PP1 51-100	22.2	*	16	5. PP1 141+	8.9
8	3. PP1 51-100	13.3	*	17	3. PP1 51-100	13.3
9	3. PP1 51-100	13.3	*			

TOTAL AREA 1084.4

*************** ACRES BY WORKING GROUPS ***************

PONDEROSA 1	PONDEROSA 2	LODGEPOLE
1084.4	0.0	0.0

DEFORESTED ACRES - 0.0

PAGE TYPE 5

BOGUS NATIONAL FOREST

TYPE AREAS OF COMPARTMENT NO. 206 BLOCK NO. 1

COVER TYPE	ACRES	*	COVER TYPE	ACRES	*	COVER TYPE	ACRES
1 PP1 0-30	0.0	*	16	0.0	*	26 DEFOREST-B	0.0
2 PP1 31-50	0.0	*	17	0.0	*	27 DEFOREST-G	0.0
3 PP1 51-100	280.0	*	18	0.0	*	28 RECREATION	0.0
4 PP1 101-40	62.2	*	19	0.0	*	29 BARREN	0.0
5 PP1 141+	742.2	*	20	0.0	*	30 BRUSHLAND	0.0
6 PP2 0-30	0.0	*	21	0.0	*	31 RANGE-HERB	17.8
7 PP2 31-50	0.0	*	22	0.0	*	32 PRIVATE	66.7
8 PP2 51-100	0.0	*	23	0.0	*	33 RIGHTS/WAY	0.0
9 PP2 101-40	0.0	*	24	0.0	*	34	0.0
10 PP2 141+	0.0	*	25	0.0	*	35	0.0
11 LGP 0-30	0.0	*					
12 LGP 31-50	0.0	*					
13 LGP 51-100	0.0	*					
14 LGP 101-40	0.0	*					
15 LGP 141+	0.0	*					

TOTAL AREA 1168.9

BOGUS NATIONAL FOREST

SUBCOMPARTMENTS OF COMPARTMENT NO. 206 BLOCK NO. 1

SUBCOMP.	COVER TYPE	ACRES	*	SUBCOMP.	COVER TYPE	ACRES
1	5. PP1 141+	151.1	*	10	3. PP1 51-100	93.3
2	5. PP1 141+	106.7	*	11	4. PP1 101-40	8.9
3	3. PP1 51-100	17.8	*	12	4. PP1 101-40	13.3
4	3. PP1 51-100	88.9	*	13	3. PP1 51-100	17.8
5	5. PP1 141+	111.1	*	14	5. PP1 141+	186.7
6	5. PP1 141+	177.8	*	15	4. PP1 101-40	40.0
7	3. PP1 51-100	22.2	*	16	5. PP1 141+	8.9
8	3. PP1 51-100	13.3	*	17	3. PP1 51-100	13.3
9	3. PP1 51-100	13.3	*			

TOTAL AREA 1084.4

*************** ACRES BY WORKING GROUPS ***************

PONDEROSA 1	PONDEROSA 2	LODGEPOLE
1084.4	0.0	0.0

DEFORESTED ACRES - 0.0

APPENDIX 4

An Example of Record Maintenance

Program GROW, listed below, is an example of the assistance provided by computers in the maintenance of records. Its purpose is to update inventory records if thinning or other change has not required replacement with a new record. New inventory data and updated data can then be combined for input to TEVAP2. The new management plan produced will be based on the most recent estimates of forest condition for all plots or subcompartments. The plan can be produced during the winter, between growing seasons, before it is needed to guide the next season's work.

Inputs to GROW are always original records, not the results of previous projections. A 9999 is punched instead of the year of record on inventory cards with updated information. Records with very large values for year will not be processed by the program. Accidental mixture of original and updated records will not be perpetuated for use by TEVAP2. This feature requires that two sets of inventory records be prepared for each working circle:

1. A permanent file of original data that is revised only by replacement of records. This file is revised continuously as work and inventory reports are submitted, and is the input file for GROW.

2. A temporary file consisting of data updated by GROW and of duplicates of original data that are too new to need updating. This file contains the inventory records to be used by TEVAP2.

Use of two files increases the complexity of the record system, but avoids the compounding of projection errors.

Linear projections are used in GROW because other forms of the relationships are unknown. For example, a 2-year increase in diameter is assumed to equal two-tenths of the increase projected by an equation developed for a 10-year period. Projection periods, the variable TIME in TEVAP2, should, therefore, be kept short, especially for fast-growing species.

GROW produces three kinds of output:

1. An inventory card with updated data is punched for direct use or for transfer to magnetic tape. Alternatively, the logical unit assigned to the punch may be assigned to a

tape drive. Card images of the temporary inventory file are then written directly onto tape.

2. A copy of the card or card image may be printed, if desired. A nonzero value of DUPL is read to obtain the printed record.

3. A record of the number of cards processed is written after all other operations have been executed. The total does not include any previously updated records accidentally mixed with original data.

As listed, the relationships in GROW apply to ponderosa pine in the Black Hills. Similar programs can be prepared for other species by replacing the species-specific statements with equivalents from section 3 of the appropriate species-specific subroutine of TEVAP2. Even the dwarf mistletoe rating can be updated. For lodgepole pine (Myers et al. 1971):

```
    IF (DMR .LE. 1.0) GO TO 100
    DMR = DMR + 0.07 * RINT(I)
    GO TO 105
100 DMR = DMR + (0.03 + 0.038 * DMR) *
    RINT(I)
```

```
      PROGRAM GROW
     1(INPUT,OUTPUT,PUNCH,TAPE5=INPUT,TAPE6=OUTPUT,TAPE7=PUNCH,TAPE4=TAP
     2E5)
C
C TO UPDATE INVENTORY IF NO CHANGES EXCEPT NORMAL GROWTH HAVE OCCURRED.
C
C DEFINITIONS OF VARIABLES NOT ALREADY OEFINED IN PROGRAM TEVAP.
C
C     ADD = NUMBER OF YEARS TO PROJECT INVENTORY DATA.
C     ANO = YEAR AFTER LAST GROWING SEASON TO BE PROJECTEO.
C     OUPL = INDEX TO PRINT (1) OR UMIT (BLANK OR D) NEW DATA.
C     NBR = NUMBER OF INVENTORY CAROS PROCESSEO.
C
      DIMENSION AGE(2),BAS(2),DATE(6),OBH(2),OEN(2),DMR(2),FAG(2),
     1FDEN(2),FDM(2),FOMR(2),FHT(2),FORET(19),HT(2),JDMR(2),JFAG(2),
     2JFDEN(2),JFDM(2),JFHT(2)
C
      KNTR = D
      NBR = D
C
C READ VALUES COMMON TO ALL CAROS.
C
      READ (5,I) (FORET(I),I=1,19)
    1 FORMAT (IBA4,A2)
      READ (5,5) (DATE(I),I=1,6)
    5 FORMAT (6A4)
      READ (5,1D) RINT,DUPL,ANO,NBK
   10 FORMAT (3F4.0,I4)
C
C INITIALIZE VARIABLES RECOMPUTEO FOR EACH INVENTORY CARD.
C
   15 OO 20 I=1,2
      DMR(I) = O.D
      FAG(I) = D.D
      FDEN(I) = D.D
      FDM(I) = D.0
      FDMR(I) = O.D
      FHT(I) = O.D
      JDMR(I) = D
      JFAG(I) = D
      JFOEN(I) = D
      JFDM(I) = D
      JFHT(I) = D
   2D CONTINUE
      SBAS = D.D
C
C READ INVENTORY CAROS. LAST CARD IS BLANK TO STOP PROCESSING.
C INVENTORY RECORDS ARE ORIGINAL OATA, NOT RESULTS OF PREVIOUS
C PROJECTIONS. VARIABLE WHEN IS ACTUAL OATE, NOT OUMMY AODEO BY THIS
C PROGRAM.
C
      READ (4,25) IBK,KOMP,ISUB,QTR1,QTR2,SECT,TOWN,RANG,SITE,STRY,
     1NTYP,WORK,FISC,OBH(1),HT(1),DEN(1),AGE(1),DMR(1),DBH(2),HT(2),DEN(
     22),AGE(2),OMR(2),ACRE,WHEN
   25 FORMAT (I2,I4,I3,3A3,2A4,F3.0,F1.0,I2,F1.0,F4.D,F3.1,F3.D,F5.D,F3.
     10,F2.1,F3.I,F3.D,F5.0,F3.0,F2.I,F5.1,F4.0)
C
C DETERMINE IF GROWTH PROJECTION CAN BE MAOE.
C
      IF(IBK .LE. D .OR. IBK .GT. NBK) GO TO 130
      JFISC = FISC
```

```
C
C TEST DATE OF DATA SO PROJECTED DATA WILL NOT BE PROJECTED AGAIN.
C
      IF(WHEN .GE. 2000.0) GO TO 15
      NBR = NBR + 1
      ADD = ANO - WHEN
      IF(ADD .EQ. 0.0) GO TO 75
      IF(DEN(1) .EQ. 0.0 .OR. DBH(1) .EQ. 0.0) GO TO 75
C
C COMPUTE FUTURE STAND VALUES.
C
      BAS(1) = 0.0054542 * DBH(1) * DBH(1) * DEN(1)
      BAS(2) = 0.0054542 * DBH(2) * DBH(2) * DEN(2)
      SBAS = BAS(1) + BAS(2)
      DO 35 I=1,2
      IF(DBH(I) .EQ. 0.0) GO TO 35
      IF(DEN(I) .EQ. 0.0) GO TO 35
      FAG(I) = AGE(I) + ADD
      IF(DBH(I) .GE. 10.0) GO TO 28
      FDEN(I) = 0.00247 + 0.00124 * DBH(I) + 0.00028 * DBH(I) * DBH(I) +
     10.00000521 * SBAS * SBAS - 0.0000905 * DBH(I) * SBAS
      IF(FDEN(I) .LT. 0.0) FDEN(I) = 0.0
      FDEN(I) = DEN(I) * (1.0 - FDEN(I))
      GO TO 30
   28 FDEN(I) = DEN(I)
   30 FDM(I) = 0.88511 * DBH(I) + 1.29735 * ALOG10(HT(I)) + 0.00119 * DB
     1H(I) * SITE + 62.37174 / SBAS - 1.56975
      FHT(I) = 15.43021 + 1.107 * HT(I) - 0.08637 * AGE(I) - 304.12172 /
     1SITE - 0.02447 * SITE * SBAS * 0.01
   35 CONTINUE
C
C CHANGE ORIGINAL VALUES TO THOSE EXPECTED IN ADD YEARS.
C
      TEM = ADD / RINT
      DO 40 I=1,2
      FDEN(I) = DEN(I) + (FDEN(I) - DEN(I)) * TEM
      FDM(I) = DBH(I) + (FDM(I) - DBH(I)) * TEM
      FHT(I) = HT(I) + (FHT(I) - HT(I)) * TEM
   40 CONTINUE
C
C CHANGE TYPE CODES AS NEEDED.  REPLACE NTYP = 1 TO NTYP = 5 WITH
C VALUES OF NTYP APPROPRIATE TO SPECIES AND WORKING GROUP.
C
      J = 1
      IF(STRY .GT. 0.0) J = 2
      IF(FAG(J) .GT. 30.0) GO TO 45
      NTYP = 1
      GO TO 65
   45 IF(FAG(J) .GT. 50.0) GO TO 50
      NTYP = 2
      GO TO 65
   50 IF(FAG(J) .GT. 100.0) GO TO 55
      NTYP = 3
      GO TO 65
   55 IF(FAG(J) .GT. 140.0) GO TO 60
      NTYP = 4
      GO TO 65
   60 NTYP = 5
C
C CONVERT TO FIXED POINT FOR PUNCHING. RETAIN NECESSARY DECIMALS.
C
   65 DO 70 I=1,2
      JDMR(I) = FDMR(I) * 10.0 + 0.5
      JFAG(I) = FAG(I) + 0.5
      JFDEN(I) = FDEN(I) + 0.5
      JFDM(I) = FDM(I) * 10.0 + 0.5
      JFHT(I) = FHT(I) + 0.5
      FAG(I) = JFAG(I)
      FDEN(I) = JFDEN(I)
      FDM(I) = JFDM(I)
      FDM(I) = FDM(I) * 0.1
      FDMR(I) = JDMR(I)
      FDMR(I) = FDMR(I) * 0.1
      FHT(I) = JFHT(I)
   70 CONTINUE
      GO TO 85
   75 DO 80 I=1,2
      FAG(I) = AGE(I)
      FDEN(I) = DEN(I)
      FDM(I) = DBH(I)
      FDMR(I) = DMR(I)
      FHT(I) = HT(I)
      JDMR(I) = DMR(I) * 10.0 + 0.5
      JFAG(I) = AGE(I)
      JFDEN(I) = DEN(I)
      JFDM(I) = DBH(I) * 10.0 + 0.5
      JFHT(I) = HT(I)
   80 CONTINUE
   85 JSITE = SITE
      JSTRY = STRY
      JWORK = WORK
      JACRE = ACRE * 10.0 + 0.5
      JWHN = 9999
C
C PUNCH REPLACEMENT FOR INVENTORY CARD, USING NEW DATA.
C
      WRITE (7,90) IBK,KOMP,ISUB,QTR1,QTR2,SECT,TOWN,RANG,JSITE,JSTRY,NT
     1YP,JWORK,JFISC,JFDM(1),JFHT(1),JFDEN(1),JFAG(1),JDMR(1),JFDM(2),JF
     2HT(2),JFDEN(2),JFAG(2),JDMR(2),JACRE,JWHN
   90 FORMAT (I2,I4,I3,3A3,2A4,I3,I1,I2,I1,I4,2I3,I5,I3,I2,2I3,I5,I3,I2,
     1I5,I4)
C
C PRINT RECORD OF NEW INVENTORY DATA, IF DESIRED.
C
```

```
      IF(OUPL .EQ. 0.0) GO TO 15
      IF(KNTR .EQ. 50) KNTR = 0
      IF(KNTR .NE. 0) GO TO 120
      WRITE (6,100) (DATE(K),K=1,6)
  100 FORMAT (1H1,//,43X,39HRESULTS OF PROJECTION OF INVENTORY DATA/1H ,
     142X,18HOATA PROJECTED TO ,6A4)
      WRITE (6,105) (FORET(I),I=1,19)
  105 FORMAT (1HO,8X,18A4,A2)
      WRITE (6,110)
  110 FORMAT (1HO,53X,29H**********OVERSTORY**********,1X,29H**********UN
     1DERSTORY**********,10X,5HORIG./1H ,2X,5HBLOCK,2X,4HCOMP,2X,4HSUBC,
     22X,4HSITE,2X,5HSTORY,2X,4HTYPE,2X,4HWORK,3X,4HFISC,3X,3HDBH,3X,2HH
     3T,3X,5HTREES,3X,3HAGE,2X,3HOMR,3X,3HOBH,3X,2HHT,3X,5HTREES,3X,3HAG
     4E,2X,3HOMR,4X,4HAREA,3X,4HOATE)
      WRITE (6,115) IBK,KOMP,ISUB,SITE,STRY,NTYP,WORK,FISC,FDM(1),FHT(1)
     1,FOEN(1),FAG(I),OMR(1),FDM(2),FHT(2),FDEN(2),FAG(2),OMR(2),ACRE,WH
     2EN
  115 FORMAT (1HO,3X,I2,5X,I3,3X,I2,F7.0,F6.0,4X,I2,F7.0,F7.0,F6.1,F6.1,
     1F8.0,F6.0,F4.1,F6.1,F6.1,F8.0,F6.0,F4.1,F9.1,F7.0)
      KNTR = KNTR + 1
      GO TO 15
  120 WRITE (6,125) IBK,KOMP,ISUB,SITE,STRY,NTYP,WORK,FISC,FDM(1),FHT(1)
     1,FDEN(1),FAG(1),OMR(1),FDM(2),FHT(2),FDEN(2),FAG(2),OMR(2),ACRE,WH
     2EN
  125 FORMAT (1H ,3X,I2,5X,I3,3X,I2,F7.0,F6.0,4X,I2,F7.0,F7.0,F6.1,F6.1,
     1F8.0,F6.0,F4.1,F6.1,F6.1,F8.0,F6.0,F4.1,F9.1,F7.0)
      KNTR = KNTR + 1
      GO TO 15
C
C RECORO THAT THE CHANGES WERE MADE.
C
  130 IF(OUPL .EQ. 0.0) GO TO 140
      WRITE (6,135) NBR
  135 FORMAT(1HO,//,5X,27HNUMBER OF CAROS REPUNCHEO- ,I5)
      GO TO 200
  140 WRITE (6,145)
  145 FORMAT (1H1,////,43X,38HRECORO OF PROJECTION OF INVENTORY OATA)
      WRITE (6,150) (FORET(I),I=1,19)
  150 FORMAT (1HO,/,43X,16HSOURCE OF OATA- ,18A4,A2)
      WRITE (6,155) (OATE(I),I=1,6)
  155 FORMAT (1HO,/,43X,18HOATA AOJUSTEO TO- ,6A4)
      WRITE (6,160) NBR
  160 FORMAT (1HO,/,5X,27HNUMBER OF CAROS REPUNCHEO- ,I5)
  200 CALL EXIT
      END
```

RESULTS OF PROJECTION OF INVENTORY OATA
OATA PROJECTEO TO JANUARY 2, 1974

ROGUS NATIONAL FOREST

								**********OVERSTORY**********					**********UNOERSTORY**********						ORIG.
BLOCK	COMP	SUBC	SITE	STORY	TYPE	WORK	FISC	OBH	HT	TREES	AGE	OMR	OBH	HT	TREES	AGE	OMR	AREA	OATE
1	1	1	40.	0.	3	2.	1974.	5.9	33.0	811.	82.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
1	1	2	60.	0.	4	0.	-0.	12.5	59.0	125.	125.	0.0	0.0	0.0	0.	0.	0.0	0.0	1968.
1	1	7	40.	0.	5	4.	1976.	9.4	48.0	315.	153.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
1	2	5	50.	1.	3	5.	1974.	12.7	59.0	2.	128.	0.0	5.4	44.0	615.	78.	0.0	8.9	1966.
1	2	9	70.	0.	4	4.	1974.	14.9	85.0	70.	138.	0.0	6.9	63.0	125.	78.	0.0	173.3	1966.
1	2	13	60.	0.	26	1.	1974.	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
1	3	1	50.	1.	3	6.	1974.	12.3	49.0	2.	126.	0.0	5.4	34.0	846.	77.	0.0	364.4	1967.
1	3	6	70.	0.	26	1.	1975.	0.0	0.0	0.	0.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
1	3	10	60.	0.	3	0.	-0.	11.0	62.0	204.	98.	0.0	0.0	0.0	0.	0.	0.0	320.0	1968.
1	6	1	60.	0.	4	0.	-0.	10.4	63.0	235.	108.	0.0	0.0	0.0	0.	0.	0.0	0.0	1966.
1	7	10	50.	0.	3	2.	1975.	5.4	32.0	653.	54.	0.0	0.0	0.0	0.	0.	0.0	0.0	1968.
1	9	14	50.	0.	3	2.	1977.	6.4	34.0	417.	56.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
2	98	1	50.	0.	2	0.	-0.	4.6	22.0	597.	38.	0.0	0.0	0.0	0.	0.	0.0	0.0	1966.
2	98	4	60.	0.	3	2.	1974.	6.4	51.0	1083.	77.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
2	98	13	60.	0.	4	0.	-0.	10.7	68.0	238.	133.	0.0	0.0	0.0	0.	0.	0.0	0.0	1966.
2	99	4	60.	0.	1	0.	-0.	0.0	3.0	580.	10.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
2	100	2	50.	0.	4	0.	-0.	9.6	57.0	203.	123.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
2	100	4	50.	0.	1	0.	-0.	3.1	14.0	1968.	25.	0.0	0.0	0.0	0.	0.	0.0	17.8	1969.
2	100	5	60.	0.	3	4.	1975.	12.0	59.0	198.	89.	0.0	5.5	50.0	288.	69.	0.0	0.0	1965.
2	100	7	60.	0.	4	0.	-0.	10.8	71.0	238.	129.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
2	100	9	60.	0.	4	6.	1974.	12.7	71.0	3.	129.	0.0	7.3	54.0	498.	79.	0.0	0.0	1965.
2	100	16	50.	0.	5	4.	1977.	14.0	61.0	101.	148.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
2	101	2	50.	1.	3	0.	-0.	12.6	57.0	1.	129.	0.0	8.2	48.0	289.	89.	0.0	0.0	1965.
2	102	2	50.	1.	2	6.	1978.	14.5	56.0	10.	125.	0.0	2.5	25.0	2942.	41.	0.0	8.9	1968.
2	102	9	60.	0.	4	5.	1974.	14.3	66.0	44.	135.	0.0	7.3	43.0	342.	65.	0.0	53.3	1969.
3	202	1	40.	0.	5	4.	1988.	11.7	50.0	76.	157.	0.0	0.0	0.0	0.	0.	0.0	66.7	1968.
3	208	2	60.	0.	5	5.	1979.	12.4	75.0	76.	155.	0.0	4.5	51.0	672.	75.	0.0	0.0	1969.
3	207	10	70.	0.	5	4.	1978.	17.7	90.0	36.	157.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	203	11	60.	0.	3	2.	1976.	5.8	55.0	976.	85.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	203	9	60.	0.	4	0.	-0.	7.8	67.0	370.	112.	0.0	0.0	0.0	0.	0.	0.0	0.0	1967.
3	203	7	60.	0.	4	2.	1978.	9.8	64.0	387.	119.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	203	5	50.	0.	5	6.	1979.	14.2	60.0	35.	165.	0.0	3.3	31.0	2194.	55.	0.0	40.0	1969.
3	203	3	70.	0.	3	2.	1976.	8.6	67.0	441.	89.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	203	2	60.	0.	4	2.	1977.	8.8	66.0	390.	114.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	203	1	50.	0.	5	4.	1988.	11.9	57.0	124.	148.	0.0	0.0	0.0	0.	0.	0.0	31.1	1968.
3	202	9	60.	0.	3	2.	1979.	3.1	41.0	4665.	59.	0.0	0.0	0.0	0.	0.	0.0	0.0	1965.
3	202	8	50.	0.	4	0.	-0.	10.7	58.0	67.	119.	0.0	2.7	29.0	1084.	49.	0.0	0.0	1965.
3	202	7	60.	0.	3	2.	1988.	5.6	33.0	844.	56.	0.0	0.0	0.0	0.	0.	0.0	13.3	1968.

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Myers, Clifford A.
1973. Computerized preparation of timber management plans: TEVAP2. USDA For. Serv. Res. Pap. RM-115, 72 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Presents computer programs, written in FORTRAN IV, for analysis of inventory data, and computation of actual and optimum growing stocks and allowable cuts, and other values needed for forest management planning. Computed volumes and areas are summarized in a timber management plan. Effects of cultural operations and other changes are accounted for in computation of both actual and optimum conditions. Supersedes Research Paper RM-63.

Oxford: 624:U681.3. **Keywords:** Allowable cut, forest management, timber management, *Pinus ponderosa, Pinus contorta.*

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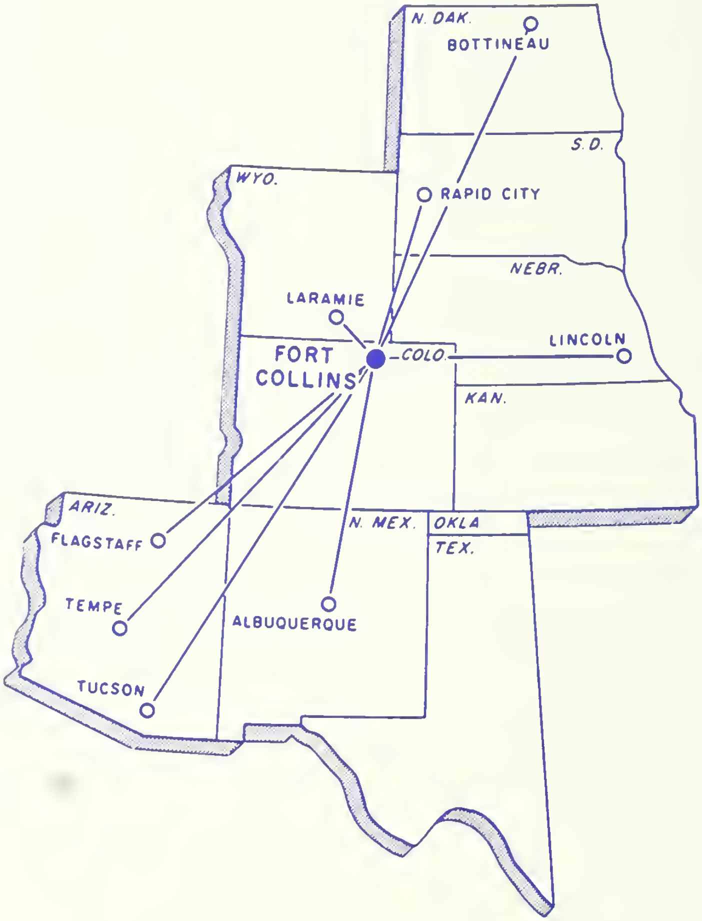
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Cost Analysis of Experimental Treatments on Ponderosa Pine Watersheds

by James M. Turner and Frederic R. Larson

USDA Forest Service Research Paper RM-116
March 1974

Rocky Mountain Forest and Range Experiment Station
Forest Service, U.S. Department of Agriculture, Fort Collins, Colorado 80521

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Abstract

A regression model predicts thinning and piling costs as a function of the degree of timber basal area removed. Thinning costs are related to basal area removed noncommercially, while piling costs are related to total basal area removals including commercial logging. Sensitivity analyses indicate that the piling predictive models are representative for all but the most extreme conditions of slope steepness likely to be encountered in the Southwest. If thinning involved removal of trees larger than 8 inches in diameter, cost variability may be greater than that accounted for by the thinning model.

Oxford: 641:116. **Keywords:** Forest conversion, forest economics, watershed management, *Pinus ponderosa.*

The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U. S. Department of Agriculture to the exclusion of others that may be suitable.

USDA Forest Service
Research Paper RM-116

March 1974

Cost Analysis of Experimental Treatments on Ponderosa Pine Watersheds

by

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CONTENTS

Cost Analysis of Experimental Treatments on Ponderosa Pine Watersheds

James M. Turner and Frederic R. Larson

The purpose of the Beaver Creek Pilot Watershed project is to evaluate the effects of vegetative changes on water, sediment, soil, forage, recreation, and wildlife yields, and to determine the subsequent risks from fire, insects, and disease. Located just south of Flagstaff, Arizona, this project is currently developing multiple use production data for alternative land management practices. A wide range of vegetation treatments have been experimentally tested on watersheds in both the juniper and ponderosa pine zones.

This report contains an analysis of treatment costs in the ponderosa pine zone to provide relationships for economic evaluations and estimation of project planning costs. The estimates include costs of precommercial thinning and slash disposal, by Forest Service crews (force account work), but not costs of commercial product removals. If thinning and piling activities are to be accomplished as sale purchaser work, or by contract, these estimates will also be useful for determining contract costs.

The activities and costs may be much the same as those required for present operational management, but the experimental treatments are more extensive. For example, where budget limitations restrict present management practices to slash piling in fuelbreaks only, the experimental treatments to date involved slash removal wherever timber was cut. A cost model which distinguishes between per-acre thinning and per-acre piling costs is thus suitable for both experimental and present management applications.

The system for collecting cost data was designed by Worley et al. (1965). Two papers have been published summarizing cost factors in the juniper vegetation type (Miller and Johnsen 1970, Miller 1971), and a third concerns the clearcutting of ponderosa pine (Miller and Larson 1973). This report combines data from the above pine clearcut treatment with that from four other treatments to form a basis for predicting costs for operations likely to be encountered in ponderosa pine watershed treatments. These five treatments encompass a wide range of configurations and degrees of vegetation removal, thereby providing a good cross section of activities and forest conditions which determine cost.

The study area contains cutover, unevenaged stands comprised of 85 percent ponderosa pine and 15 percent woodland species, primarily Gambel oak and alligator juniper. Ponderosa pine averaged 2,000 cubic feet in volume and 110 square feet in basal area per acre.

The objectives of this report are to:

1. Present and compare costs for jobs encountered in experimental treatments of the southwestern ponderosa pine vegetation type.
2. Develop a cost prediction model for experimental and operational applications.
3. Use a sensitivity analysis to test the effects of labor, equipment, materials, slope steepness, and stand density on treatment cost.

Summary of Treatment Prescriptions

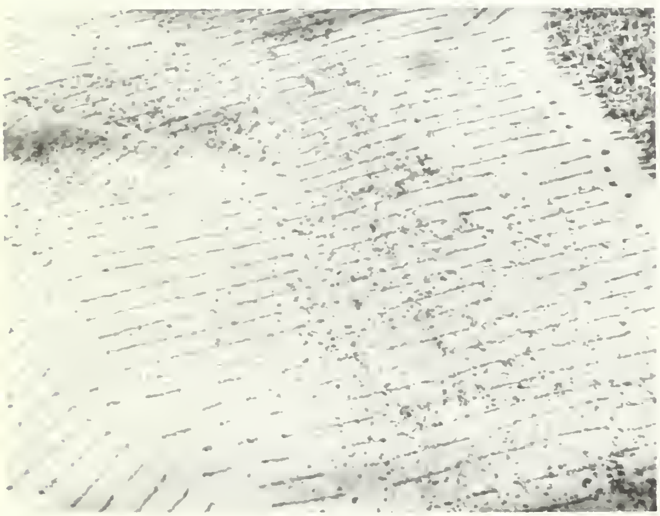
Regular 1/3 Stripcut, Watershed 9 (1,121 Acres, Treated in 1968)

Trees were cut in a pattern of alternating cut and leave strips oriented to the direction of landslope. The cut and leave strips, 60 and 120 feet wide, respectively, are regular in shape with few or no trees left in the cut strip. The leave strips were untreated, so only one-third of the watershed was harvested and treated. Saw logs and poles were harvested; the slash was piled in windrows in the cut strips and burned (fig. 1).

Figure 1.—The regular pattern of cut strips on watershed 9.

Clearcut, Watershed 12
(455 Acres, Treated in 1967)

This treatment required complete removal of trees. The harvest included saw logs and poles. All slash and debris were windrowed in such a way as to trap and retain snow, and increase the watershed's drainage efficiency (fig. 2).



Irregular 1/3 Stripcut, Watershed 14
(1,350 Acres, Treated in 1970)

This pattern also consists of alternate cut and leave strips, which average 60 and 120 feet in width, respectively. Width of the clearcut strip varied as much as 50 percent (± 30 feet) in order to provide an esthetically pleasing, irregular pattern of elongated openings. The leave strips were thinned to 80 ft^2 basal area in a manner designed to improve timber production, while at the same time retaining sufficient density to encourage trapping and retention of snow in the adjacent cut strips. The harvest included saw logs, poles, pulpwood, and firewood. The slash was pushed into piles and burned. Spacers of uncut trees were left at intervals in the cut strips to break up visual continuity. Gambel oaks under 15 inches diameter at breast height were also left in the cut strips. The strips were generally oriented in the direction of landslope to facilitate water transport into stream channels (fig. 3).

Figure 3.—The cut strips of varying widths on watershed 14.

◄ Figure 2.—The clearcut area and slash windrowed to trap and retain snow on watershed 12.

Irregular 1/2 Stripcut, Watershed 16 (252 Acres, Treated in 1971)

This treatment is similar to the irregular 1/3 stripcut, except that both cut and leave strips were 60 ± 30 feet in width. Again, Gambel oak and spacers of ponderosa pine were left to break up the continuity of long cut strips. Leave strips were thinned to 80 ft^2 of basal area per acre to encourage timber growth. The harvest included saw logs, poles, and pulpwood.

Severe Thin, Watershed 17 (300 Acres, Treated in 1969)

After severe thinning, the remaining stand consisted of even-aged groups of ponderosa pine with crown density of 10 to 20 percent, and basal area of 25 ft^2 per acre. In addition to the pine, 5 to 10 ft^2 per acre of Gambel oak were left. The harvest included saw logs and poles; slash was piled in strategically arranged windrows for snow trapping and retention, and for water runoff (fig. 4).

Scope and Methodology

The data collection system developed by Worley et al. (1965) consisted of keeping daily time and material records for all jobs, such as thinning. The data are daily physical measures, such as hours of labor, hours of equipment rental, gallons of paint, rolls of flagging, etc., by job. Physical input-output data were collected rather than dollar costs and returns because it is easier to generalize from the former. The basic physical requirements for a given job are constant, and when multiplied by current wage rates and unit costs yield updated dollar cost estimates.

The approach used is quite similar to time-motion analysis aggregated to a daily basis. This strategy was chosen because the variability of conditions in the woods is far greater than under more closely controlled plant conditions. It is expected that widely varying factors such as soil, slope, and stand characteristics do affect treatment costs, and a later section explores these sources of variation.

Summary of Costs

Each watershed treatment is separated into operations, or jobs, to allow detailed examination of the component costs. Individual jobs

Figure 4.—A severely thinned stand on watershed 17. Stands were thinned to a residual basal area of 25 square feet per acre.

encountered in the five treatments, in order of occurrence and by watershed, are listed in table 1. The component costs, consisting of supervision, labor, equipment, and materials, expressed on a per unit of material or per hour of labor and equipment, are given in table 2.

For practical purposes a distinction is made in this analysis between per-treatment-acre and per-watershed-acre costs. Because jobs such as thinning are not applied to the entire watershed, costs may be prorated over those acres actually treated (per-treatment-acre cost) or over the entire watershed (per-watershed-acre cost). For detailed analyses of each job, per-treatment-acre cost is appropriate for between-watershed comparisons and for extrapolating these costs to

Table 1.--Component jobs in the treatment of five Beaver Creek watersheds (see summary of treatment prescriptions for descriptions of watershed treatments)

Component job	Watershed--				
	9	12	14	16	17
Road and strip layout	X		X	X	
Marking			X	X	X
Log sale administration	X		X	X	
Pulp sale administration			X		
Clearing and thinning	X	X	X	X	X
Slash piling	X	X	X	X	X
Slash burning	X		X		
Chemical application		X			
Erosion control	X		X		

Table 2.--Component costs adapted for this analysis

Personnel	
GS grade	Hourly rate[1]
1	$2.58
2	2.93
3	3.30
4	3.72
5	4.15
6	4.63
7	5.13
8	5.68
9	6.27
Equipment	**Cost per hour**
TD-340	[2] 7.40
TD-15	[2] 14.91
D-6	[2] 13.42
D-7	[2] 16.64
Rubber tired dozer	[2] 8.59
Chain saw	[3] .42
Mist blower	[4] .30
Materials	**Cost per unit**
Flagging (roll)	[5] .22
Paint (gallon)	[5] 2.65
Grass seed (pound)	[6] .467
Diesel fuel oil, #2 (gallon)	[7] .17
Ponderosa pine seedlings (seedling)	[6] .046
Chemicals (gallon)	[5] .423

[1]GS grades taken from USDA General Schedule 5 U.S.C. 5332 (a) at step 1 level plus 18 percent overhead as of January 1972.

[2]Written communication from Roland L. Barger, Rocky Mountain Forest and Range Experiment Station. Consists of fixed and variable costs of operation without the operator.

[3]Obtained from Timber Staff Specialist at the Long Valley Ranger District, Coconino National Forest.

[4]Based on chain saw cost with adjustments for time of operation and maintenance.

[5]Obtained from the General Services Administration supply catalog.

[6]Obtained from Coconino National Forest records.

[7]General Services Administration price delivered to Happy Jack, Arizona.

other types of treatments. In addition, average per-watershed-acre cost was computed by multiplying each job cost by the number of acres per job and dividing by the total acres in the watershed. These costs are provided for comparing total treatment costs:

Watershed	Cost less travel
9	$26.94
12	79.95
14	44.58
16	66.79
17	58.91

The predictive models developed in this paper use per-watershed-acre units because the data collection system recognizes a uniform treatment pattern applied over the total watershed. On a per-treatment-acre basis, the cleared strip treatment (watershed 9) is similar to the clearcut (watershed 12). However, the per-watershed-acre treatment cost on watershed 9 is less because only one-third of the area was treated, or only one-third of the trees per acre were removed.

Table 3 presents the basic physical requirements in hours of supervision, labor, and equipment for each job and watershed on a treated-acre basis. These data are converted to the treated-acre dollar costs in table 4 by applying the unit costs in table 2. Material costs were presented directly in dollars in table 4 because the variety of items, such as rolls of flagging and gallons of paint, prevented expression in common units and because materials are a small percentage of total cost.

Tables 3 and 4 indicate that the strip layout jobs on watersheds 9, 14, and 16 covered a greater percent of the area than was actually cleared. This is due to crews surveying the total watershed for proper strip placements.

Major patterns discernible from table 4 involve the two largest jobs: clearing and/or thinning,[2] and slash piling. The clearing operations on watersheds 9 and 12 are quite consistent where both involve 100 percent removals on the treated acres. Because watersheds 14, 16, and 17 were thinned to various degrees, however, lesser degrees of removal were involved on a treatment-acre basis. The corresponding

[2]*In this report, "clearing" refers to complete removal of all trees and "thinning" refers to partial tree removals. It should be noted that the cleared strips in Watersheds 9, 14, and 16, and the Watershed 12 clearcut are for experimental purposes, and do not reflect current National Forest operational cutting practices in the Southwest.*

Table 3.--Supervision, labor, and equipment hours required to treat five Beaver Creek watersheds (WS)

Watershed treatment and job	Area treated	Portion of watershed treated	Time required per treated acre		
			Supervision	Labor	Equipment
	Acres	*Percent*	- - - - - - *Hours* - - - - - -		
WS-9: REGULAR 1/3 STRIPCUT	1141	100.0			
Road layout	3	.3	0	9.57	0
Strip layout	1141	100.0	0.03	.47	0
Log sale administration	219	19.2	0	1.01	0
Clearing cut strips	338	29.6	1.87	9.28	8.74
Slash piling	285	25.0	0	2.64	1.49
Slash burning	1121	97.9	.08	.34	.01
Erosion control	3	.3	0	7.00	0
WS-12: CLEARCUT	455	100.0			
Clearing cut strips	455	100.0	1.95	9.07	9.02
Slash piling	447	98.2	0	2.87	1.33
Chemical application	147	32.4	.88	2.95	2.02
WS-14: IRREGULAR 1/3 STRIPCUT	1350	100.0			
Strip layout	1310	97.0	0	.33	0
Marking	1310	97.0	.08	.33	0
Log sale administration	1310	97.0	.27	.20	0
Pulp sale administration	460	34.1	.13	.07	0
Clearing and thinning	1222	90.5	.35	4.91	3.91
Slash piling	1157	85.7	.03	1.94	1.67
Slash burning	1310	97.0	.03	.37	.02
Erosion control	35	2.6	.42	1.71	0
WS-16: IRREGULAR 1/2 STRIPCUT	252	100.0			
Strip layout	247	98.0	.33	.58	0
Marking	247	98.0	.23	.41	0
Log sale administration	247	98.0	1.57	.02	0
Clearing and thinning	247	98.0	1.41	5.72	5.74
Slash piling	247	98.0	.95	1.38	1.15
WS-17: SEVERE THIN	300	100.0			
Marking	300	100.0	0	.14	0
Thinning	294	98.0	.67	8.39	8.00
Slash piling	257	85.7	0	2.82	1.13

Table 4.--Treatment costs for five Beaver Creek watersheds (WS)

Watershed treatment and job	Area treated	Portion of watershed treated	Treated-acre cost: Supervision	Labor	Equipment	Material	Total
	Acres	*Percent*					
WS-9: REGULAR 1/3 STRIPCUT	1141	100.0					
Road layout	3	.3	0	$52.69	0	$0.84	$53.53
Strip layout	1141	100.0	$0.17	2.65	0	.05	2.87
Log sale administration	219	19.2	0	6.08	0	0	6.08
Clearing cut strips	338	29.6	7.82	34.55	$3.67	0	46.04
Slash piling	285	25.0	0	9.85	19.10	0	28.95
Slash burning	1121	97.9	.44	1.29	.13	0	1.86
Erosion control	3	.3	0	26.04	0	0	26.04
WS-12: CLEARCUT	455	100.0					
Clearing	455	100.0	7.62	33.75	3.79	0	45.16
Slash piling	447	98.2	0	10.72	18.67	0	29.39
Chemical application	147	32.4	4.52	10.98	.60	2.22	18.32
WS-14: IRREGULAR 1/3 STRIPCUT	1350	100.0					
Strip layout	1310	97.0	0	1.52	0	.04	1.56
Marking	1310	97.0	.41	1.51	0	0	1.92
Log sale administration	1310	97.0	1.43	.74	0	0	2.17
Pulp sale administration	460	34.1	.71	.28	0	0	.99
Clearing and thinning	1222	90.5	1.80	18.27	1.64	0	21.71
Slash piling	1157	85.7	.18	7.22	12.41	0	19.81
Slash burning	1310	97.0	.17	1.49	.15	.04	1.85
Erosion control	35	2.6	2.19	6.20	0	4.67	13.06
WS-16: IRREGULAR 1/2 STRIPCUT	252	100.0					
Strip layout	247	98.0	1.23	1.94	0	.11	3.28
Marking	247	98.0	.86	1.38	0	.24	2.48
Log sale administration	247	98.0	5.86	.10	0	0	5.96
Clearing and thinning	247	98.0	5.26	21.25	2.41	0	28.92
Slash piling	247	98.0	3.56	6.76	17.18	0	27.50
WS-17: SEVERE THIN	300	100.0					
Marking	300	100.0	0	1.10	0	.03	1.13
Thinning	294	98.0	2.47	28.73	3.36	.50	35.06
Slash piling	257	85.7	0	9.82	17.52	0	27.34

lower costs for clearing and thinning on these watersheds suggest a direct relationship between cost and degree of timber removals. This idea is developed further in the predictive models section.

The slash piling costs are similar for all watersheds except watershed 14, where piling costs were less. Thirty-five percent of watershed 14 was commercially logged for pulpwood. The commercial removal of trees 8 to 11 inches d.b.h. reduced Forest Service costs.

Finally, it should be noticed that travel costs are not included. Since travel costs are a function of distance or time required to reach the working site, an additional means of estimating travel cost is required. Travel costs to watersheds 9, 12, and 14 consistently accounted for about 14 percent of the total costs. The Beaver Creek watersheds were an hour's drive (round trip) from the Ranger Station, so that traveling occupied 1/8 or 12.5 percent of a working day. The similarity between the two percentages indicates the labor intensiveness of the watershed treatments, and provides a rule-of-thumb for rough approximations of the expected proportion of travel cost to total cost if distance is known.

Predictive Models (Regression)

The two major components, cutting (clearing and/or thinning) and piling, are basic to any watershed treatment. They comprise an acreage-weighted average of 88 percent of the total treatment costs per acre for all watersheds. Cutting and piling activities are thus the mainstay of a cost predictor where costs are related to timber removals. The cutting activities are related only to basal area removed noncommercially. On the other hand, the piling activity follows both the commercial logger and the thinning crew, so piling costs are related to total basal area removed per acre from the watershed.

Table 5 contains the cutting and piling costs per watershed acre and the respective rates of timber removals per watershed acre to which they apply. In most cases, the commercial logging operation accounted for about 50 percent of the total removals. In the watershed 9 stripcut, for example, 32 percent of the total basal area was removed overall, with about half of that being removed commercially. However, a concerted effort on watershed 14 to fully utilize the timber through the sale of pulp and cordwood increased the commercial share. Thus the proportion of commercially valuable timber depends on management intensity. Also, sites of differing quality may have differing proportions of commercially usable timber. The proportion will also vary with time.

An initial, intensified watershed treatment removes undesirable trees even on poor sites, and puts the stand in good growing stock condition. Further harvests will benefit by having greater proportions of commercially usable timber. Hence, it is not only desirable but necessary to separate the cost model into two parts, cutting and piling activities, to emphasize the difference between commercial and noncommercial timber removals. Only then can differences in site quality, management intensity, and product flows over time be incorporated into the cost estimates.

Table 5.--Summary of per-watershed-acre cutting and piling costs vs. basal area of timber removals per watershed acre

Treatment	Average noncommercial basal area removed/acre (X)	Cutting costs (Y)	Average total basal area removed/acre (X)	Piling costs (Y)
	Ft^2		Ft^2	
WS-9: REGULAR 1/3 STRIPCUT	18	$13.64	38	$7.23
WS-12: CLEARCUT	56	45.16	105	28.87
WS-14: IRREGULAR 1/3 STRIPCUT	22	19.65	61	16.98
WS-16: IRREGULAR 1/2 STRIPCUT	36	28.35	78	26.95
WS-17: SEVERE THIN	47	34.36	90	23.42

The relationship between cutting costs and noncommercial basal area removed is presented in figure 5. Correlation analysis obtained a coefficient of determination (r^2) of 0.98, and a t test showed the y intercept not to be significantly different from the origin at the 0.05 level of significance. On the assumption, therefore, that no removal incurs no cost, the line is forced through the origin. The relationship $C_1 = 0.79BA_1$ is obtained where C_1 is cost per watershed-acre and BA_1 is the noncommercial basal area removed per watershed acre. This implies that it costs $0.79 to cut noncommercial trees equivalent to 1 ft^2 of basal area from an acre.

A similar relationship was found for piling costs versus total removals (fig. 6). In this case, r^2 is 0.88, and again the intercept is not significantly different from zero at the 0.05 level. The relation is $C_2 = 0.28BA_2$ where C_2 is the predicted piling cost per watershed acre and BA_2 is total basal area removed per watershed acre. Again this implies that it costs $0.28 to pile the slash accumulated per square foot of basal area removed by commercial and noncommercial operations.

Both basal area removals and costs are on a watershed-acre basis and the regression coefficients are the average cost per ft^2 of basal area removed. Since the regression passes through the origin, the coefficients are also equal to the average cost per ft^2 of basal area removed on a treated-acre basis.

The relationship derived thus far for the sum of cutting and piling costs is $C = 0.79BA_1 + 0.28BA_2$. An operationally suitable model would first have to be adjusted for the 12 percent of miscellaneous costs such as sale administration, marking, and other jobs. Thus, $C = 1.12\ (0.79BA_1 + 0.28BA_2) = 0.88BA_1 + 0.31BA_2$.

Typical ponderosa pine stands on Beaver Creek are lightly to moderately stocked. Although isolated patches of heavily stocked stands were cleared or thinned (notably on watershed 14), daily cost data were not identified closely enough on maps to determine cost-stocking relationships. Further research is needed to verify the model in heavily stocked stands, although no significant density-related economies or diseconomies of scale were noted.

Additional models were derived from data in table 3 converted to a per-watershed-acre basis (table 6). These models predict man-hours (supervision plus labor) and equipment hours for the cutting and piling activities. These are useful in that the managers are able to estimate cost from wage and equipment rental rates appropriate to the situation. The models (figs. 7, 8) are all linear with intercepts not significantly different from zero so they are fitted through the origin.

Table 6.--Summary of man- and equipment-hour requirements versus average basal area of timber removals per watershed acre

Treatment	Average basal area removed/acre: Noncommercial	Average basal area removed/acre: Total	Man-hours	Equipment hours
WS-9: REGULAR 1/3 STRIPCUT				
Cutting	18		3.30	2.59
Piling		38	.66	.37
WS-12: CLEARCUT				
Cutting	56		11.02	9.02
Piling		105	2.82	1.31
WS-14: IRREGULAR 1/3 STRIPCUT				
Cutting	22		4.76	3.54
Piling		61	1.69	1.43
WS-16: IRREGULAR 1/2 STRIPCUT				
Cutting	36		6.99	5.63
Piling		78	2.28	1.13
WS-17: SEVERE THIN				
Cutting	47		8.88	7.84
Piling		90	2.42	.97

The relationship obtained for man-hours of cutting time versus basal area removed noncommercially is $MH_1 = 0.20\ BA_1$ (fig. 7). Total predicted man-hours (MH_1) is composed of 18 percent supervision and 82 percent labor averaged over all watersheds. The equipment hours (EH_1) (fig. 7) were estimated by the relation $EH_1 = 0.16BA_1$. This estimate is based on the use of medium-sized power saws with brush bars, as are typically used by Forest Service thinning crews.

The relationships obtained for man-hours of piling time (MH_2) versus total basal area removed (fig. 8) is $MH_2 = 0.027BA_2$. For piling, the total predicted man-hours is composed of 10 percent supervision and 90 percent labor averaged over all watersheds. The equipment hours (EH_2) (fig. 8) were estimated by the relationship $EH_2 = 0.012BA_2$. This estimate of equipment hours is based on the use of medium-sized crawler tractors (TD-15, D6, D7). The use of other machines (Larson and Miller 1973) or improved equipment and methods may change the relationship. Watershed 14 was excluded from the equipment hours' prediction equation because a very intensive slash cleanup operation was prescribed and two tractors were used; a small tractor to pull slash out of thinned stands and a medium-sized tractor to

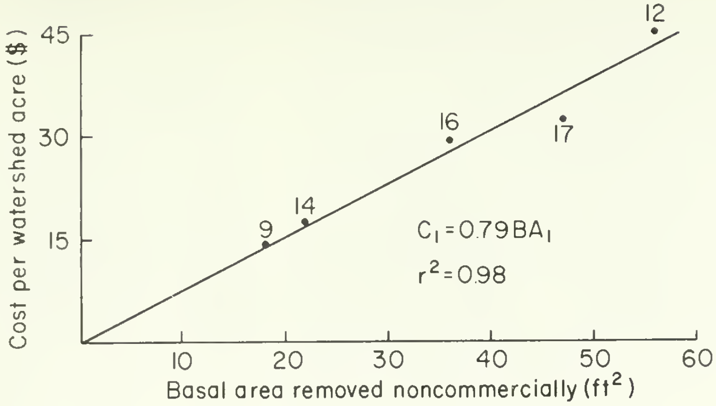


Figure 5.—Relationship between cutting cost and noncommercial basal area removals.

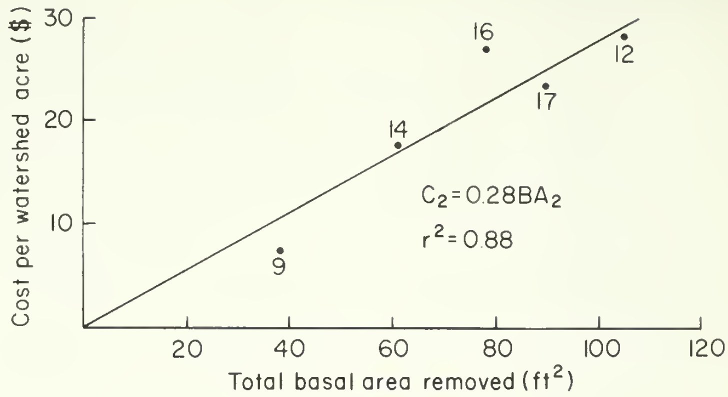


Figure 6.—Relationship between piling cost and total basal area removals.

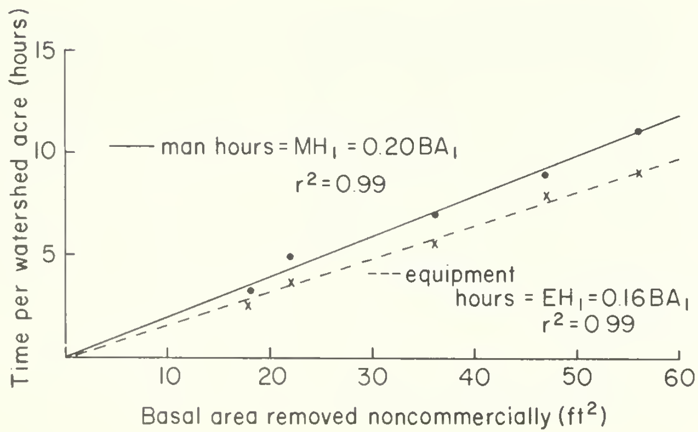


Figure 7.—Relationship between man and equipment hours for cutting and noncommercial basal area removals.

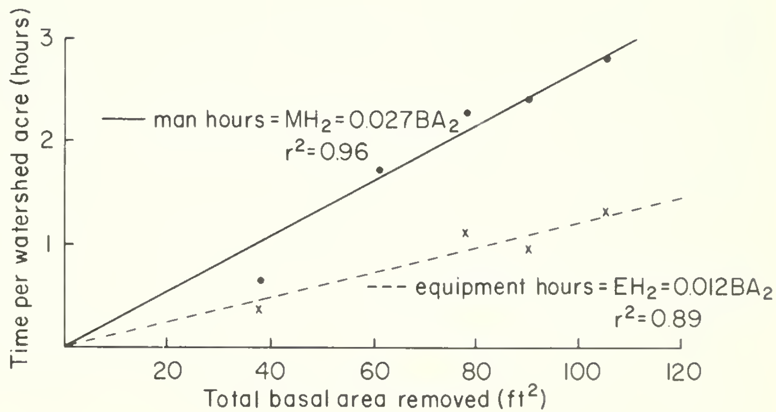


Figure 8.—Relationship between man and equipment hours for piling and total basal area removals.

pile this slash plus that in the cut-strips. Thus, some slash was handled twice and a proportion of the area was covered by both tractors.

Tabulated labor and equipment hours, for both cutting and piling operations at different levels of basal area removed (table 7), can be used in lieu of the predictive equations presented on page 8.

Table 7.--Hours per acre of labor and equipment required for cutting and piling activities as a function of basal area removals

Noncommercial basal area removed (Ft^2)	Cutting		Total basal area removed (Ft^2)	Piling	
	Labor	Equipment		Labor	Equipment
5	1.0	0.8	10	0.27	0.12
10	2.0	1.6	20	.54	.24
15	3.0	2.4	30	.81	.36
20	4.0	3.2	40	1.08	.48
25	5.0	4.0	50	1.35	.60
30	6.0	4.8	60	1.62	.72
35	7.0	5.6	70	1.89	.84
40	8.0	6.4	80	2.16	.96
45	9.0	7.2	90	2.43	1.08
50	10.0	8.0	100	2.70	1.20
55	11.0	8.8	110	2.97	1.32
60	12.0	9.6	120	3.24	1.44

Sensitivity Analysis

Each of the points in figures 5 and 6 is subject to wide fluctuation. It was anticipated that the sources of variation would be many and confounding. Thus, a more generalized indicator of cost was necessary so that many of these underlying sources such as labor, equipment, topography, and stand characteristics would average out over a large watershed. The degree of timber removals is an indicator of average cost. The variance of that cost is a function of daily variations, which in turn are related to the above sources encountered on a given day. The fact that the relationships obtained were meaningful indicates the merit of this approach.

Possible causes of cost variation were examined by sensitivity analysis to judge whether the addition of these causative factors would enhance the predictive power of the model. The first part of the sensitivity analysis is devoted to the influence of labor productivity and type of machinery used as general indicators of variability in costs. The second portion examines probable causes of variability as related to steepness of slope, size class, and distribution of trees.

Variation in Cost Due to Labor and Equipment

For each watershed, data were collected on a daily basis for all labor, equipment, and materials inputs (table 2). This information was examined by sensitivity analysis to determine daily variability within and between watersheds. The formula used for this analysis was developed by Miller (1971):

$$\text{Sensitivity Index (SI)} = \frac{\bar{Y}_i \; S_i}{\sum_i (\bar{Y}_i \; S_i)}$$

where

$\bar{Y}_i$ = the average cost per acre, and

S_i = the standard deviation of daily costs for the i^{th} component, job, or watershed.

The entire sensitivity analysis is restricted to the cutting and piling operations and their component costs. Tests for sensitivity comparing jobs within each watershed indicate that, of the total variation in cost, cutting and piling on the average account for 95 percent. The cutting and piling operations are also common to all treatments.

Table 8 summarizes the sensitivity analyses. Variation around total cost per job acre (standard deviation) is a measure of the range of forest and working conditions and equipment used. In this case, the variation is substantial. A comparison between watersheds indicates where cutting and piling costs vary most relative to the other watersheds.

The two major trends indicated clearly by the component analysis in table 8 are that labor is responsible for most variation in the cutting operation, while the equipment component varies most in the piling operation. In the case of cutting activities, WS-9 shows the greatest variation. This may be due to slope, since WS-9 has more rugged terrain than the other watersheds. Conversely, WS-17, with relatively flat contours and uniform stand composition, has the least cutting cost variation.

Commercial pulpwood harvesting on WS-14 and WS-16 not only decreased cutting costs considerably, but also reduced variability of cost for cutting operations in the remaining stands. Cost variability was higher when cutting trees 8 inches and larger in diameter (table 8) because sawyers used power saws equipped with brush-cutting bars normally used for routine thinning work. These saws are unwieldy for felling larger trees.

Table 8.--Sensitivity analysis for clearing, thinning, and slash piling on five watersheds, showing average cost per job acre, standard deviation (SD), and sensitivity index (SI)[1]

Watershed	Supervision			Labor			Equipment			Total		
	Cost	SD	SI	Cost	SD	SI	Cost	SD	SI	Cost[2]	SD	SI
			Pct			*Pct*			*Pct*			*Pct*
WS-9: REGULAR 1/3 STRIPCUT												
Clearing	$7.82	$18.40	9.9	$34.55	$37.60	89.4	$3.67	$2.90	0.7	$46.05	$53.80	57.4
Piling	--	--	--	--	--	--	--	--	--	27.31	17.30	22.0
WS-12: CLEARCUT												
Clearing	7.62	5.90	6.1	33.75	20.70	92.9	3.79	2.10	1.0	45.16	26.60	27.8
Piling	--	--	--	--	--	--	--	--	--	29.40	30.60	42.0
WS-14: IRREGULAR 1/3 STRIPCUT												
Thin & clear	1.80	.80	1.4	18.27	6.00	97.9	1.64	.50	.7	21.73	7.10	3.6
Piling	.18	.80	.1	7.22	3.70	28.9	12.41	5.30	71.0	19.83	8.70	8.0
WS-16: IRREGULAR 1/2 STRIPCUT												
Thin & Clear	5.26	2.20	5.3	21.25	9.50	93.5	2.41	1.00	1.2	28.93	12.80	8.6
Piling	2.85	3.00	3.1	5.42	4.80	9.5	16.08	14.90	87.4	24.37	20.70	23.5
WS-17: SEVERE THIN												
Thinning	2.47	.60	2.1	28.73	2.70	96.7	3.36	.20	1.2	35.08	3.20	2.6
Piling	--	--	--	--	--	--	--	--	--	13.64	7.00	4.5

Note: "--" means not enough data for sensitivity analysis.

[1]All sources of variation accounted for; sensitivity indexes (SI) add to 100 percent for both within watershed and between watershed comparisons.

[2]May not add to total for the job in table 4 because downtime, a valid component of overall cost, is not pertinent to the sensitivity analysis and is not included.

Costs vary more for equipment than for labor in the piling jobs (table 8). Total average costs for piling are consistent between watersheds, but variation is considerable; the sensitivity analysis indicates that costs on WS-12 vary most. Piling costs on WS-12 varied because two different crawler tractors and a rubber-tired dozer were used. A small tractor with automatic transmission and hydraulic dozer was twice as efficient as the large tractor with manual shift and cable dozer, and was 6 percent more efficient than a rubber-tired dozer. Costs on WS-12 are discussed further in Miller and Larson (1973).

Variation in Cutting Costs Due to Slope and Stand Characteristics

To test the effects of slope and stand characteristics, it was necessary to characterize the daily observations by type of terrain and stands encountered that day. Work progress was mapped by units which required up to 2 weeks to be treated. Physical inventory data were used to characterize each working unit, and the daily costs for that unit were averaged as being typical of those inventory conditions. The working units were classified into eight strata on the basis of slope and number of trees in two aggregated size classes: (1) slopes greater than or less than 15 percent, (2) more or less than 50 trees per acre in the 8- to 11-inch diameter class, and (3) more or less than 750 trees per acre in the 1- to 11-inch diameter class. Stratification thus accounts for slope, density, and tree size class distribution. In addition, the two-stand composition criteria emphasize any cost differences when a thinning or slashing operation requires removal of larger trees normally removed by a commercial pulpwood operation. Once again, only the cutting and piling activities are included in the analysis.

Pulpwood harvesting greatly affected costs by leaving only a stand of uniformly small trees for thinning crews. WS-14 cutting costs were very consistent, and the sensitivity index showed evenly distributed variance between strata (table 8). The partial pulpwood sale minimized the effect of stand composition, leaving only the effects of slope. Because costs per acre were still quite consistent, both the Beaver Creek data and intuition suggest the inclusion of slope as a variable for determining cutting costs only in extreme cases where slope exceeds 30 percent.

Analysis of data from watersheds 9 and 12, which did not have pulpwood sales, showed that cutting costs are affected by the number of trees with diameters exceeding 8 inches. This implies that the introduction of tree diameter as a variable helps explain variation in cost.

Variation in Piling Costs Due to Slope and Stand Characteristics

The sensitivity analysis for piling costs was not conclusive. It was thought that piling activities would be sensitive to slope, but the per-acre piling costs did not show this difference. The sensitivity index varied widely, however, which indicates that an unexplained factor, perhaps type and maneuverability of the dozer used (Miller and Larson 1973), is still causing variance.

Sensitivity Analysis Summary

The sensitivity analysis identified significant variation in daily per-acre costs due to the labor input in cutting activities and the machinery input in piling activities. Further analysis of the cutting operation rejected steepness of slope as a causal factor, and showed significance only for trees exceeding 8 inches in diameter. The analysis for the piling operation was unable to distinguish the effect of slope, and there were no discernible trends to suggest ways to improve the cost model.

Summary and Conclusions

Forest Service costs are summarized for five experimental watershed treatments in Arizona that differed in configuration and degree of timber removals. Data from the five watersheds were used to develop regressions which predict man and equipment hours, and treatment cost as a function of basal area removed. Clearing and thinning costs are related to the basal area removed noncommercially, while piling costs are related to total basal area removals including commercial logging. These relationships were then expressed as man and equipment hours of cutting and piling time to give regressions expressed in physical constants which can be updated with current wage and equipment operation rates.

The use of basal area removals as an indication of cost implicitly averages out a number of forest conditions, such as steepness of slope, which might affect costs. A sensitivity analysis was performed to measure the extent to whic this averaging occurs, and to investigate possibl avenues for refinement of the model. Thi analysis, which was focused on the variance in daily input requirements, showed that each o the data points in the cost relation does have a wide range of variation. It also revealed signif icant variation in daily per-acre costs due to the labor input in cutting activities and the machinery input in piling activities. Further analysis of the cutting operation rejected steepness of slope as a causal factor, and showed significance only for trees exceeding 8 inches in diameter which normally would be removed commercially for pulpwood. The analysis for the piling operation was unable to isolate a slope effect, and there were no discernible trends to suggest improvement of the cost model.

Additional cost data from heavily stocked stands with high rates of timber removals are needed to extend the model over the range of removals likely to be encountered in areas outside Beaver Creek.

A conceptual framework has been provided which explains the nature of watershed treatment costs, but which is also useful for planning purposes as well. The system can be applied in project planning where costs for timber stand improvement work must be estimated. Other applications include cost estimates in evaluating the effectiveness of alternative timber management prescriptions in multiple-use planning.

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1974. Cost analysis of experimental treatments on ponderosa pine watersheds. USDA For. Serv. Res. Pap. RM-116, 12 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

A regression model predicts thinning and piling costs as a function of the degree of timber basal area removed. Thinning costs are related to basal area removed noncommercially, while piling costs are related to total basal area removals including commercial logging. Sensitivity analyses indicate that the piling predictive models are representative for all but the most extreme conditions of slope steepness likely to be encountered in the Southwest. If thinning involved removal of trees larger than 8 inches in diameter, cost variability may be greater than that accounted for by the thinning model.

Oxford: 641:116. **Keywords:** Forest conversion, forest economics, watershed management, *Pinus ponderosa*.

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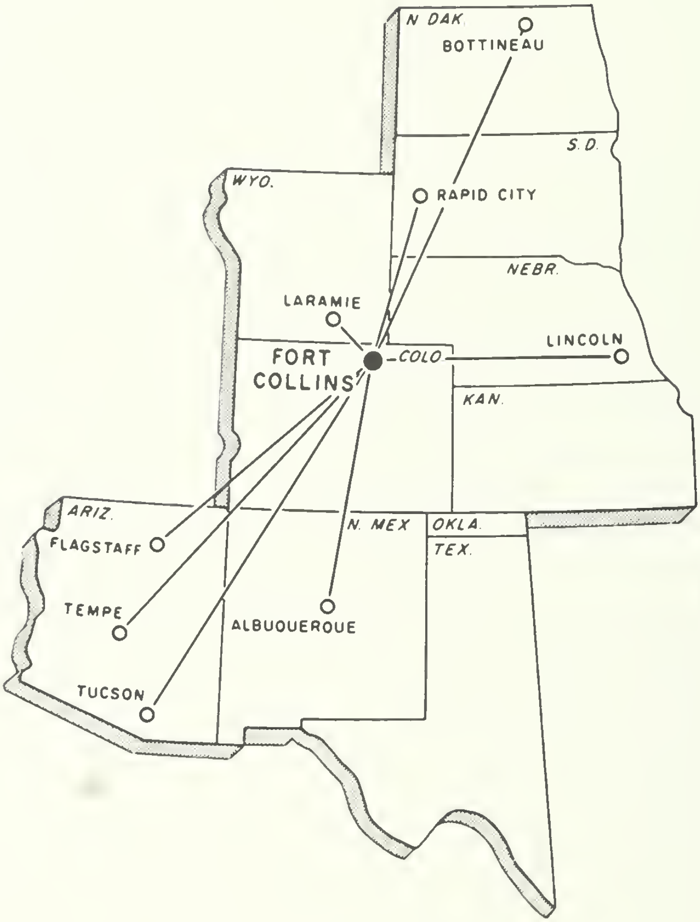
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MANAGEMENT OF PHREATOPHYTE AND RIPARIAN VEGETATION FOR MAXIMUM MULTIPLE USE VALUES

by Jerome S. Horton and C. J. Campbell

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ABSTRACT

Summarizes the status of our knowledge about environmental relations of vegetation along water courses in the southwestern United States, and impacts of vegetation management to reduce evapotranspiration on other resource values. Reviews the literature on measurement and evaluation of water losses from moist-site vegetation, ecological relationships, other resource uses of phreatophyte and riparian areas, and control methods. Suggests approaches to management of moist-site areas by zones based primarily on water table depth, elevation, and tree species.

Oxford: 116.25:181.31. **Keywords:** Phreatophytes, riparian vegetation, water yield improvement.

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Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Use Values

by

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Contents

Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Use Values

Jerome S. Horton and C. J. Campbell

Human impact upon the vegetation along the streams and rivers of the southwestern United States began with the development of relatively stable Indian cultures many centuries ago. This impact was intensified with the exploration and development of the Spanish and Mexican cultures. However, major changes came with the arrival of the Anglo-American pioneers who began to develop extensive civilizations along the river flood plains involving the removal of trees and clearing of land for agriculture and houses. Diversion of water from the streams and rivers for irrigation created water shortages in a comparatively short time. Large irrigation projects altered the water regime along the rivers and, consequently, the phreatophyte vegetation occupying flood-plain zones. In contrast, man changed the vegetation along mountain streams only in meadows and the larger valleys, or where water was impounded by dams and diverted away from the normal stream channel.

Soon after major irrigation systems were developed, the problem of water shortage again became paramount in the minds of engineers and planners. Investigations into the problem of water losses were started in southern California during the dry years of the late 1920's when the California Division of Water Resources (1930, 1933), in cooperation with several U.S. Government agencies, started research to determine water losses from moist-site vegetation. This work included lysimeter or tank studies, riparian reach studies, and surveys of water-losing areas as well as studies of irrigation losses. This same extensive cooperative approach was used in surveys carried on later in New Mexico on the Rio Grande (National Resources Committee 1938), and on the Pecos River (National Resources Planning Board 1942). These early studies furnished much of the data used by Blaney and Criddle (1962) in developing their method of predicting consumptive use for river basins and flood plains.

The U.S. Geological Survey was one of the first agencies to become intensely interested in research in water losses from river flood plains of the Southwest (Robinson 1958). It had been concerned with this problem since Meinzer (1923) had coined the word "phreatophyte" from the Greek meaning "well plant," and wrote the first major article dealing with phreatophytes in the Southwest. USGS work, which consisted of many detailed studies including tanks, reach studies, surveys, and analysis of water losses, has continued to the present. The U.S. Bureau of Reclamation has also carried on or sponsored extensive research in determination of water losses from phreatophytes to aid in development of their action programs.

In Arizona, New Mexico, and Texas, the water losses along the rivers became of particular interest as the introduced saltcedar (Tamarix chinensis Lour.[2]) spread vigorously in the reservoir deltas and along the major rivers. This spread was viewed with considerable alarm, and efforts were made to develop methods of control. The research approach was twofold: (1) to initiate studies to evaluate water losses to determine if clearing programs could be justified, and (2) to develop means of controlling saltcedar. In many cases, this research was done

[2] *The authors agree with Baum (1967) in rejecting the use of the name* Tamarix pentandra *(Pall.) for saltcedar.*

Phreatophyte vegetation growing along the Salt River near Granite Reef Dam, Arizona:

1. Tamarisk and associated seepwillow on the islands and along the river in the foreground
2. Tamarisk and Bermudagrass, in the old river channel parallel to the road.
3. Cattail (Typha spp.).
4. Mesquite.
5. Arrowweed.
6. Cottonwood.
7. Desert scrub.

hurriedly without sufficient safeguards to insure reliable data. While much of the data indicate the magnitude of water losses, they did not give the information needed for accurate application to irrigation planning and control measures, or to adequately assess other management alternatives.

In response to the needs for more detailed research in the riparian and phreatophyte zones of the Southwest, a project was set up in 1955 by the Rocky Mountain Forest and Range Experiment Station (USDA Forest Service) at Tempe, Arizona, to intensify the study of (1) ways of measuring and evaluating water losses from the different species in moist-site vegetation, and (2) the ecological relationships of moist-site vegetation to develop optimum management procedures.

For many years, flood-plain management consisted of attempts to control or completely eliminate undesirable phreatophytes for water salvage, even though some thoughts were given to other resource uses (Bowser 1952). More recently, interest has increased in preservation or development of the wildlife, recreation, and esthetic values of these areas. It therefore becomes increasingly important to determine the effects of phreatophyte clearing upon the other resources involved. We can no longer justify rather casually the clearing and destruction of phreatophyte vegetation to save water.

Thus, much more detailed information is needed on the actual evapotranspiration losses from individual plants and from different types of phreatophyte cover, as well as on the ecology and life history of the important species. Alternate management practices must also be known to properly manage these areas for optimum use of all resources inherent in phreatophyte vegetation.

The value of riparian vegetation along mountain streams is rapidly increasing for various resource uses, particularly those related to recreation. Careful management to allow for increased use without deterioration of the vegetation or water quality is imperative in many areas. Measures to prevent excessive flood damage, trampling of streamsides, and water pollution are examples of the problems facing managers of this zone.

MEASUREMENT AND EVALUATION OF WATER LOSSES FROM MOIST-SITE VEGETATION

The need for proper evaluation of water losses from moist-site vegetation, and of the possibilities of water salvage by vegetation removal or manipulation, require research aimed not only at determining water losses from individual plants under different environmental conditions but also at evaluating stream-reach losses and the effect of vegetation removal.

Measurements of evapotranspiration losses from individual plants started many years ago, often using plants grown in containers. Most of these early studies were limited in scope. With time and experience the containers became more refined and detailed, until very elaborate lysimeters were built which measured changes in the environment and in soil water. However, because it has long been recognized that plants in containers are not growing naturally, many other methods have been tried to determine actual transpiration losses from the individual plant or cut shoot. For instance, the plastic evapotranspiration tent was developed to measure water losses from the phreatophytes. Also in recent experiments, the Scholander pressure chamber "bomb" has been used in riparian vegetation as an indicator of water availability. The bomb, however, does not measure transpiration losses.

Values of many of these approaches for measurement and evaluation of water losses from moist-site vegetation have been discussed by the Pacific Southwest Inter-Agency Committee (1966).

Tanks and Evapotranspirometers

The first major studies to determine water losses from specific moist-site wildland species were done by the use of metal cylindrical tanks varying from 2 to 10 ft in diameter, depending on the species to be studied. In all cases, these tanks were maintained with a specified water table varying from 2 to 6 ft below the soil surface, again depending on the objectives of the study and the species to be used.

Plants grown in small tanks may respond very differently from mature plants in the field. They are subject to very different environmental conditions which affect the water-loss readings. Unfortunately, these tank data are all that are available for many species under different climatic and water-table depth conditions.

The studies started by the California Division of Water Resources in 1927, using willow, cattails, and several species of grasses and rushes, showed that water losses from these riparian plants may be equal or greater than evaporation as measured from a Weather Bureau pan close by (Young and Blaney 1942). Use of water increased markedly as depth to the water table decreased. One of their studies demonstrated that tanks should not be isolated and thereby receive advected heat from the side (Taylor and Nickle 1933). Tules (cattails) grown in an isolated tank lost about three times as much water as those in a tank placed in a dense cover of the same species. This fact was not always considered in later studies or in the evaluation of the tank data relative to water losses from river reaches.

The extensive survey of water resources and water losses carried out cooperatively in the Upper Rio Grande during the middle 1930's (Blaney and others 1938) included tank studies of many agricultural crops and some marshland species but no true phreatophyte or riparian species.

The Pecos River survey in 1939-40 included tanks that were planted to saltcedar, sacaton (Sporobolus airoides), and saltgrass (Distichlis stricta) at Carlsbad, New Mexico (Blaney and others 1942). This installation used small metal tanks large enough for only one saltcedar shrub and not well buffered from the influences of radiation and wind from the sides. There was no replication and the study was run for only one season which did not allow sufficient time for development of the shrubs.

The flood plain of the upper Gila River, Graham County, Arizona, was studied first by Turner and Halpenny (1941) of the U.S. Geological Survey who established tanks near Safford, planted to saltcedar and seepwillow (Baccharis glutinosa). More shrubs were used in each tank but they were not well buffered and were operated for only one season.

A second and more extensive study of the upper Gila River by the same agency included a detailed tank study established at Glenbar, Arizona (Gatewood and others 1950). These tanks had large single shrubs planted in duplicates at different water-table depths. The readings during the first year are very comparable to the Carlsbad readings. During the second year, however, growth was vigorous and the water losses were very high, probably much too high for typical saltcedar. Unfortunately, the study was terminated by flooding at the end of the second summer. The vigorous second-year growth plus some increased radiation received by partially exposed tanks probably make these readings of water loss too high.

Due to the relatively small size and known inaccuracies of the metal tanks, large plastic-lined evapotranspirometers were designed and built to study water losses from phreatophytes. A block of soil was excavated in alluvium measuring about 1,000 ft^2 in surface area and 8 to 15 ft deep. The hole was lined with heavy plastic. Various means were added to measure the water depth, and to allow pumping and draining of contained water if desired. After these controls were installed, the tank was filled with the excavated soil.

The large area of the research installation and the ability to completely buffer the study plants to a large extent removed the problem of isolation. The elaborate method of adding water to the water table to compensate for evapotranspiration allowed accurate operation and data collection without disturbance of the plant cover. The greater depth of soil and the longer study period produced a more mature cover and a more representative simulation of natural conditions. The greatest difficulty encountered was the accumulation of salt in the water table which, unexpectedly, greatly reduced growth and water losses.

The first of these large plastic-lined tank installations was built in 1959 for saltcedar studies at Buckeye, Arizona, by the Geological Survey in cooperation with the Bureau of Reclamation (van Hylckama 1974). No records of evapotranspiration loss were published until the third growing season. At this time, the cover was nearly mature and beginning to reach the pattern of vigorous spring growth and a more or less dormant summer period. The readings in the Buckeye tanks show a very definite relationship of depth to water table. Saline conditions in the ground water were concluded to have reduced the evapotranspiration losses very markedly.

Another set of large plastic-lined tanks was built in 1961 for saltcedar studies by the Bureau of Reclamation near Bernardo, New Mexico (Pacific Southwest Inter-Agency Committee 1962). These evapotranspirometers were designed to control the difficulties caused by increased salt contents in the soil water. They were flushed yearly to reduce salt effect from accumulations in the ground water. The Bernardo tanks show a different water loss/water-table depth relationship, which appears to contradict some of the other studies. The 3-ft water-table tanks, (2 ft less than the shallowest Buckeye tank) showed rather consistently a reduction not only in water loss but also in the development of a vegetation cover (personal communication, Bureau of Reclamation, Albuquerque, New Mexico).

One interesting result of the Bernardo study was the reaction of the plants to a water-table change from a 5.6-ft depth down to 9 ft. When the water table was dropped rapidly by pumping, the amount of water loss was almost cut in half. In the next year, however, the root system apparently recovered and even at the 9-ft depth it was using nearly as much water as it had at the shallower depth. The tank in which the water table was lowered by plant water use showed a less dramatic reaction.

The Bernardo tanks appear to demonstrate the shallow water-table depths are not optimum for tamarisk, and that when the root system is developed, the water loss from the deeper water tables may be very close to losses from shallower depths if the ground water is reasonably free of excess salt.

There were two other Geological Survey evapotranspirometer installations — one at Yuma, Arizona, which studied arrowweed (Pluchea sericea), saltbush (Atriplex sp.), and Bermudagrass (Cynodon dactylon) (McDonald and Hughes 1968) and one near Winnemucca in northern Nevada which used Great Basin wetland species (Robinson 1970). The results of the latter are not considered applicable in the phreatophyte areas of the Southwest.

Based on the tank data, a mature, dense, unbroken stand of saltcedar growing in the Buckeye area without excessive salts in the soil will utilize 6 to 7 ft of water per year. At the elevation of Glenbar and Safford, Arizona, the figure is probably in the neighborhood of 5 to 6 ft per year. At Carlsbad, the water loss is probably about the same or slightly less. At the higher elevations of Bernardo, the annual water losses would be about 4 or 4.5 ft.

These figures are not conclusive, of course, but they are reasonably consistent. These losses are for dense, mature saltcedar which usually constitutes a relatively small proportion of a flood-plain area. As the vegetation is reduced, the water losses are likewise reduced, so that a comparatively small portion of a flood plain would consume these high amounts of water.

All studies comparing grass with saltcedar used tanks maintained at shallow water-table depths. At these depths the water loss includes a large percentage of evaporation from the soil. Saltcedar growing where the water is close to the surface does not mature into a vigorous stand. Likewise, grass does not develop at water tables optimum for saltcedar growth. Thus, direct comparisons are difficult.

In conclusion, these tank data, in spite of their weaknesses and perhaps inaccuracies, are the most detailed that are available on water losses from saltcedar. In other vegetation types, measured water losses from the tanks have been carefully compared with losses computed by various energy-budget and other types of approaches (van Bavel 1966). These results show that a carefully controlled tank or lysimeter is the only way known at present to accurately and completely measure the water losses from a plant or group of plants (Harrold 1966). Consequently, unless newer techniques prove satisfactory, use of the tank approach will continue to be desirable if more detail is necessary on the actual water losses from phreatophyte vegetation. Carefully designed instrumentation may produce better and faster results at less cost in the long run than initially cheaper and less accurate types of research efforts.

Application of Tank Moisture-Loss Data

Tank data were often used directly to estimate water losses from flood plains (National Resources Committee 1938, National Resources Planning Board 1942, Gatewood and others 1950). Because the tank data, however, were only for a limited set of conditions, it was reasoned that water loss could be predicted from any area if values and vegetation response were known. For many years, attempts have been made to predict moisture losses solely from environmental factors. Essentially these approaches utilize a basic formula which states the relationship of evaporation of water to energy from the sun. Some of these formula approaches are very simple and include only temperature and day length. Later formulas use additional factors such as humidity, wind movement, radiation, and vegetation response (Criddle 1966, Jensen 1966, Cruff and Thompson 1967).

Probably the most widely used approach, especially in river basin studies in the West, is the Blaney-Criddle formula (Blaney 1952a, 1952b; Blaney and Criddle 1962). Essentially it is similar to other formulas (Thornthwaite and Mather 1957, Penman 1963), but requires a crop or vegetation factor (K) as well as information on temperature and day length. As originally prepared by Blaney and Morin (1942), humidity was also used but this factor was dropped in the more recent applications. The energy factor is computed from temperature and day length. The vegetation factor (K) varies with such factors as species, percentage of cover, and season; to a large extent it is based upon data from tank studies. The Blaney-Criddle method has many of the weaknesses of the other empirical formulas but it is simpler and, if vegetation data are available, predictions are usually closer to the actual water loss than by any other formula. Rantz (1969) improved the applicability of this formula to phreatophyte areas.

Evapotranspiration Tent

Very little work has been done with the measurement of transpiration directly from phreatophyte plant parts, with the exception of the development and use of the evapotranspiration tent. This method, developed by the USDA Forest Service at Tempe, Arizona, was used first as a laboratory procedure for measuring the transpiration of potted plants under controlled light, humidity, and temperature (Decker and Wetzel 1957). Air was forced into the chamber containing the plant and the change in humidity between the inlet and the outlet was measured by an infrared gas analyzer which served as an accurate hygrometer. This method worked very well in the laboratory under uniform temperature and light conditions.

A field apparatus was developed with a frameless cylindrical 10- by 10-ft tent made of transparent plastic film. This film was thrown over the plant and inflated by ventilating blowers. The humidity of the airstream entering and leaving the tent was again measured with the infrared analyzer, which was later replaced with a more simple hygrometer. Field observations were made along the Salt River near Granite Reef Dam, Arizona, on transpiration rates of isolated shrubs of tamarisk surrounded by Bermudagrass sod. Evapotranspiration of tamarisk-Bermudagrass stands increased linearly with the amount of tamarisk, with the larger shrubs using two to three times as much water as Bermudagrass sod (Decker and others 1962).

Campbell (1966) compared undisturbed tamarisk shrubs in a high water-table grassy site with those cut at 1 ft from the ground, and found that evapotranspiration decreased approximately 50 percent due to cutting. These results are similar to those from the shorn Buckeye tanks reported by van Hylckama (1970).

The artificial microclimate formed by the enclosed evapotranspiration tent became apparent in a study on the Gila River west of Safford, Arizona; mesquite (Prosopis juliflora) and tamarisk shrubs growing with deep water tables were defoliated after 8 hours inside the evapotranspiration tent. This indicated a very serious enclosure effect which had not been apparent in the Salt River studies where high water tables and, therefore, sufficient surplus water kept the plants alive. Mace (1968) redesigned the evapotranspiration tent to increase the amount of ventilation because he determined that the serious enclosure effect was due in part to poor ventilation inside the tent rather than entirely to the greenhouse effect of the plastic. However, there is still a serious question about the use of the evapotranspiration tent and its effectiveness in determining rates of water loss in the field, even though Decker and others (1962) felt that the enclosure effect would be more or less similar when rates of transpiration between species were being compared. The enclosure effect has been questioned by Lee (1966) and again by Mace and Thompson (1969).

Sebenik and Thames (1967) used the tent modified by Mace in 1966 to measure evapotranspiration from tamarisk on the San Pedro River. Their water-loss figures are among the highest published, probably due in large part to the enclosure effect.

As a result of these studies, the evapotranspiration tent is not now recommended until the enclosure effects have been critically evaluated.

Heat-Pulse Meter

Swanson (1962) helped develop instrumentation for detecting the movement of sap in the stems of conifers. A correlating run with the evapotranspiration tent (Skau and Swanson 1963, Decker and Skau 1964) indicated sap flow might possibly be used to measure the rate of transpiration. One difficulty, and as yet unresolved, is the determination of the amount of moisture moving upwards in the stream of water because the instrument records only the rate of movement, not the amount which is flowing. Unfortunately, the heat-pulse meter is better adapted to use in conifers than in hardwood species because of the greater homogeneity of wood of conifers, but by using more sampling points, the technique was thought to be applicable to measurement of sap flow in hardwood. Forest Service results indicate, however, that variability of sap flow is too great. Sap velocity in mesquite is highly variable from hour to hour, and appears to lag actual transpiration well into the night.

Because of these environmental influences and apparent inherent variability of sap flow it can be concluded that in mesquite, and perhaps in all hardwoods, techniques of integrating a number of sap-velocity measurements in the cross section of a trunk are too crude to warrant interpretations of transpiration rates.

Pressure Chamber

Considerable work has been reported in recent years on techniques for determining moisture stress in plants. The use of the pressure-bomb technique in watershed management research is now being evaluated by the Forest Service. The pressure bomb (Scholander and others 1964, 1965; Boyer 1967, Kaufmann 1968) appears to be an effective field and laboratory method for determining an index of leaf-water potential and internal water stress of some plants. The technique consists of placing a leafy shoot, or single leaf, inside a steel chamber with the cut end exposed to the atmosphere. Pressure of dry nitrogen is increased within the chamber until xylem sap begins to bubble out from the cut end, at which time the pressure is recorded. This technique is particularly suited to field conditions because of rapidity of measurements, and low cost and dependability of equipment (Waring and Cleary 1967). Because the pressure needed to force water from leaf cells to the cut xylem surface is basically a function of leaf-water potential, predawn pressure-bomb readings can be considered an index to soil-moisture availability within the root zone.

Bomb measurements are influenced by osmotic potential of the xylem sap, resistance to xylem movement of water, loss of water to voids in the xylem, the rate nitrogen is released into the pressure chamber, precision of the low-pressure gage, and elapsed time between twig removal and bomb reading (Campbell and Pase 1972). Even with these sources of error, a high degree of consistency between successive readings is usually characteristic of the bomb technique because the internal plant-water status tends to integrate the effects of myriad environmental factors. For example, if soil moisture is limiting but atmospheric stress is low, then the bomb reading will also be relatively low. A change of either parameter, however, will cause the bomb reading to change. Other environmental influences such as vapor-pressure deficit, wind, temperature, phenology, and physiology are integrated into every bomb reading. Bomb data are not repeatable with the same degree of consistency within and among all species; therefore a precursor to any "bomb" study is species selection.

The pressure-bomb technique to determine water requirements appears to be a useful tool in watershed management. While this instrument does not give the amount of water being lost, it can readily segregate those plants which have water available to them and are obtaining their water from the deeper water supplies during a period of drought. Thus, vegetated areas with available water can be readily determined by use of this technique. In a central Arizona chaparral community, the pressure chamber was used to evaluate moisture-stress changes in birchleaf mountainmahogany (Cercocarpus betuloides) under several pruning regimes (Campbell and Pase 1972). Removal of 22 and 36 percent leaf mass of mountain-mahogany had little effect on plant-moisture stress. Removal of 41 and 66 percent leaf mass caused highly significant decreases of 6 and 8 bars tension, respectively. Based on this reduced internal plant-moisture stress, it is assumed that water will not be removed from the soil as rapidly or in as large amounts as occurred before pruning.

Phreatophyte Flood-Plain Reaches

Research in phreatophyte water losses was aimed at determining the effect of vegetation clearing upon water yield. Because of the high cost of research studies, many early attempts were made to use indirect methods to estimate savings.

Data from tanks planted to phreatophyte species have been widely used for this purpose. Sometimes the amount of possible water salvage has been increased by using the maximum figures of water loss from tanks. Gatewood and others (1950), averaging six different methods, estimated that total use of water along a section of the Gila River in Graham County, Arizona, during a study in 1943 and 1944 was 28,350 acre-ft (including precipitation) of water from 9,303 acres of bottomland vegetation. This amounts to about 3 acre-ft per acre of phreatophytes. Data derived from the Glenbar tank study (one of the six methods used) indicated that the total water loss was approximately 18.7 percent higher than the average of the six methods. Inasmuch as saltcedar was the principal vegetation, the high water-loss figures obtained from the saltcedar tanks could explain the high estimate of water loss by this method. The authors state that a large percentage of the water loss could be saved by clearing the phreatophytes, but they made no estimate of the actual amounts.

Turner and Skibitzke (1952) estimated that the clearing of a 2,000-ft channel along the Salt and Gila Rivers in Arizona would save somewhat less than 1 acre-ft per acre.

In contrast, Blaney and others (1942) concluded from the short-lived tank study at Carlsbad that saltcedar along the riverbeds would use 6 ft of water per year and, away from the river, about 5 ft. This figure was used in the hearing on the proposed phreatophyte control along the Pecos River. Testimony was given that phreatophytes, principally tamarisk, would consume 5 to 6 acre-ft of water, and about half of this water could be saved by clearing (U.S. Senate 1963).

Unfortunately, there are few actual figures of water savings after phreatophyte clearing. However, a recent study conducted along the Gila River in Graham County, Arizona, gives some preliminary indication of amounts of salvage (Culler 1970). In one study reach, 1,720 untreated acres lost an average of 21 acre-ft of water per day for a 6-month period (February through July), or an average water loss of 2.2 acre-ft per acre. Even assuming that water loss would be less for the August through January period, the measured water loss is still somewhat more than the 3.0 acre-ft per acre per year estimated as total water loss for approximately the same reach by Gatewood and others (1950).

Subsequently, the study reach was completely cleared and computed evapotranspiration declined to 13 acre-ft per day, a water savings of 8 acre-ft per day or an average of 0.8 ft depth per acre for the 6-month period. Only 45 percent of the area was under dense phreatophyte canopy of tamarisk and mesquite, with the remainder open vegetation. Even if this amount of water savings is credited solely to the area of dense cover, the amount would be only 1.8 acre-ft per acre of cleared dense phreatophyte vegetation, far less than 2.5 to 3.0 acre-ft estimated for the Pecos River (U.S. Senate 1963) at approximately the same climatic conditions. The actual savings probably was closer to 0.8 than 1.8 acre-ft, and this amount would decline as replacement vegetation became established (Culler 1970).

Riparian Reaches

Only a few estimates of evapotranspiration have been obtained from riparian reaches, and these data, like phreatophyte water-loss data, are not necessarily transferable to other sectors (table 1). Plant-species diversity (frequency, composition, and age) and highly variable environments create a situation where no completely satisfactory method has been developed.

Table 1.--Summary of studies in elevation zone below 4,300 ft, with estimate of ET (evapotranspiration) per acre of flood plain

Reach, elevation range, and area	Length of channel	Dominant vegetation type	Depth to water table	Estimated ET per acre of channel	Savings after treatment	Comments
	Miles			*Acre-ft*		
SYCAMORE CREEK						
(1,400-1,760 ft) 1,400 acres	10	Mesquite-burrobrush	20 ft (approximate)	1.1	--	Inflow-outflow technique, vegetation not treated.
AGUA FRIA (1,600-4,000 ft) 3,230 acres	61	Mesquite	0-2 ft,(36%) 5-6 ft,(22%) 10-20ft,(42%)	1.8	--	ET estimated on basis of depth to ground water and areal density. Vegetation not treated.
COTTONWOOD WASH (4,000-4,300 ft) 22 acres	1.5	Cottonwood	2-3 ft	3.6	1.7	Inflow-outflow technique, vegetation eradicated on one sector. Control sector above treatment area.
MONROE CANYON (2,000-2,500 ft) 38 acres	1.3	Oak, maple, bigcone Douglas-fir, alder, willow		4.2-5.0	.5	Paired watersheds, Monroe Canyon vegetation treated following calibration period; Volfe Canyon used as control watershed.

In certain areas, stream-gaging stations have been used above and below stream reaches. A water-budget analysis can then be used to estimate evapotranspiration by total inflow minus outflow, corrected for such factors as deep drainage and soil-moisture storage (table 1).

Thomsen and Schumann (1968) used the water-budget analysis to study water resources of Sycamore Creek, Maricopa County, Arizona. In a 5-year period, water-budget analysis indicated water loss from the channel on the lower 10 miles of Sycamore Creek averaged 1,500 acre-ft. In this channel and flood plain, riparian vegetation covered about 1,400 acres, with denser vegetation in the lower half where depth to the water table was usually less than 20 ft. In the upper half of the area where the vegetation was less dense, the water table was generally more than 20 ft deep. Average evapotranspiration loss from the 10-mile reach was estimated to be 1.1 acre-ft per acre; of this, transpiration rather than evaporation probably accounted for most of the loss. Thus, a large percentage of this loss would, perhaps, be saved following vegetation removal.

Anderson (1970) measured channel losses from a natural flow regimen in part of the Agua Fria drainage, and estimated maximum possible losses that might result in the same reaches if additional water became available as a result of modification of upland chaparral vegetation. His theory was that the watershed treatment would increase streamflow and raise the level of ground water. This increased flow would cause increases in flood-plain vegetation density and thus evapotranspiration losses would increase. Also, the additional water would change the flow regimen in some channel sectors from ephemeral to perennial. Results indicate the 61 miles of reach contained about 3,230 acres of variously vegetated flood plain, including many acres classified as bare soil. Present annual evapotranspiration losses were estimated at 5,750 acre-ft or about 1.8 acre-ft per acre of channel and flood plain. If the expected increase in water yield occurs, Anderson estimates total possible water loss from this zone would reach nearly 3 acre-ft per acre per year.

Bowie and Kam (1968) used soil-water budget analysis and transpiration-well data on Cottonwood Wash in northwestern Arizona to indicate effects of removing riparian vegetation from a 1.5-mile section of stream channel. The average amount of water saved after removing about 22 acres of cottonwood (Populus fremontii), willow (Salix sp.), and seepwillow was estimated at 1.7 acre-ft per acre, or a savings of 6 percent of inflow. Transpiration-well data indicated vegetation eradication near the shallow wells may reduce water use by as much as 90 percent. Re-growth of shrub-type vegetation, such as seep-willow, reduced the water savings effected by the removal of tree-type vegetation. Water quality did not change significantly downstream following treatment.

Watershed studies in the woodland-riparian zones of Monroe Canyon in the San Gabriel Mountains of southern California exemplify a successful application of water-budget analysis and effect of vegetation treatment (Rowe 1963). Volfe Canyon, an adjoining untreated watershed, was used as a control. Along the lower reaches of Monroe Canyon, 38 acres of woodland-riparian vegetation was removed; of this, only about 3.8 acres were riparian species with the rest composed of woodland species common to adjacent canyon slopes. Following treatment, the flow from Monroe was 17.4 acre-ft more than would have occurred had it not been treated. This increased yield was about 0.5 acre-ft per acre treated. Chemical analysis revealed no changes in chemical content or total solids due to treatment. Removal of canyon-bottom vegetation and the resultant insolation of the stream channel did result in an appreciable higher concentration of green algae, especially in the summer. Rowe stipulates conditions necessary for increased water yields to occur: (1) water supply must be adequate to exceed evapotranspiration losses after treatment, (2) the water table or zone of saturation must be within reach of the heavy water-using woodland-riparian vegetation, and (3) the canyon-bottom soils overlaying the water table must be of sufficient extent and depth to permit reduction in evapotranspiration if the deep-rooted vegetation is eliminated.

The few riparian treatments performed indicated rather consistent increased water yields were obtained following riparian treatments. Two reach studies (table 1) indicate a water savings of about 1.1 acre-ft per acre after removal of flood-plain vegetation. Two other studies predicted that reduction of evapotranspiration losses of about the same amount might occur if the denser vegetation on the flood plain were removed. In summary, a working hypothesis somewhere between 1 and 2 acre-ft of water savings is as close an approximation as possible with the limited data available. These water yields would have to be weighed against losses or gains from other resources such as wildlife habitat and food, fish habitat, recreation, and esthetics for evaluation of possible benefits (Campbell 1970).

Ground-Water Wells

Ground-water wells have often been used to evaluate evapotranspiration losses from flood-plain reaches. These data indicate the changes in water level, which can be interpreted to give rough estimates of the ground-water losses by phreatophytes. However, the data are subject to wide fluctuation due to the characteristics of the alluvial material in which the ground water occurs. It is recommended that ground-water wells be used only for monitoring changes in the water-table levels and to evaluate the success of clearing operations. It is doubtful that they will give an accurate indication of the amount of water losses. In most studies, there have not been sufficient wells to give a good statistical indication of changes and some of the studies have been severely criticized because the conclusions were reached with too few wells.

Theis and Conover (1951) proposed that a series of ground-water wells could be used to determine water losses in an area of phreatophytes. They would first measure the normal ground-water conditions then remove the phreatophytes and determine water-level changes. The next step would be to pump the water out to equal the water losses of the plants and measure the rate of pumping. Tests of this type on the Salt River showed that removal of saltcedar did reduce diurnal fluctuations (Gary 1962). Later, thirty-nine 3-inch wells within a 20-ft radius were installed, but variation between wells was too great to accurately measure the rapidly changing ground-water level created by pumping (Gary and Campbell 1965).

Use of Energy Measurements

Energy measurements have often been used to determine evapotranspiration losses and it has been found possible, with the use of sophisticated and expensive instruments to accurately predict the amount of evapotranspiration losses from homogeneous vegetation surfaces. The different methods and approaches are thoroughly discussed in Conference Proceedings of both the American Society of Civil Engineers (1966) and American Society of Agricultural Engineers (1966).

Unfortunately, comparatively little work has been done in forest or other irregular or discontinuous types of cover. In phreatophyte areas, research is needed to determine the so-called "oasis effect" — the advective energy relationships between the transpiring area and the surrounding desert or semiarid climate. These irregularities of energy input and output are extremely difficult to evaluate. There is no present research which studies these phenomena in relation to phreatophyte cover, but the results of the studies on agricultural cropland would indicate that there should be possibilities of determining evaporation losses from larger areas of phreatophyte vegetation. Likewise, there are possibilities of developing methods such as remote sensing, laser beams, and infrared film to measure moisture content of the air surrounding the phreatophyte zone. Research should be pushed aggressively in search of new approaches.

ECOLOGICAL RELATIONSHIPS

To properly manage riparian and phreatophyte zones requires a knowledge of (1) the present community relationships, (2) the possibility of developing different vegetation types, and (3) the individual reactions of the various species that occupy the zone or that might be introduced under management.

Community Changes

As has been pointed out previously, drastic changes have occurred in the vegetation of the moist-site areas of Arizona and New Mexico. Changes in land use and water regime have been marked with striking results on many of the vegetation communities, particularly flood-plain areas.

Phreatophyte Flood Plains

The original vegetation of the flood-plain areas was dependent primarily on the nearly continuous water supply available to plant roots. Records and reports from early travelers indicate the rivers flowed rather constantly and the water tables were high in much of the valley areas. In the more saline areas were large patches of salt-tolerant grasses, surrounded by saltbushes and other salt-tolerant plants.

The early pioneers used the cottonwood, mesquite, and other trees and larger shrubs for fuel and building materials. In the Arizona desert, the lands dominated by mesquite were some of the best soils in the valley and were soon cleared for farming. Along the Rio Grande, the first and finest farmland was created by removal of cottonwood.

The Old World tamarisk, or saltcedar, found conditions ideal for rapid invasion of the flood-plain areas. First introduced into the United States as an ornamental, tamarisk was sold at nurseries in the East as early as 1823 (Horton 1964). By 1856 it was being sold in nurseries in California. In 1901, it was recorded as a naturalized shrub along the Salt River at Tempe. In the early 1900's, Thornber (1916) stressed the desirability of using Tamarix of several different

Tamarisk growing on the flood plain of the Gila River near Safford, Arizona.

species around buildings, for hedge rows, and in general plantings in the hot desert areas.

In the 1920's, saltcedar was beginning to spread along the Rio Grande, and other rivers such as the Gila, Salt, Pecos, and Colorado (Robinson 1965). By the 1940's, these river flood plains were to a large extent covered with a solid, unbroken stand of almost impenetrable saltcedar. Now it is found along many smaller streams, around springs, by roadsides, and in other areas that have sufficient moisture to germinate and establish the seeds.

Along some flood-plain reaches, dropping water tables have reduced the stand of saltcedar, because ground water is now apparently out of reach of its roots. In the Phoenix area, where in the 1940's a dense stand of saltcedar extended along the Salt River from east of Mesa through Tempe and Phoenix to the junction with the Gila, the shrubs are now growing as widely spaced desert-type plants. The remaining shrubs depend on floodflows or rain for survival. In dry periods, these shrubs will make almost no growth, and tend to drop their leaves. They leaf out very quickly when water becomes available, however. Fires burning through these areas kill a fairly large number of plants and create an even more open stand. It is probable, in this desert climate, that the shrubs must be spaced 15 or 20 feet or more apart to be able to have sufficient root systems to withstand lengthy droughts. A heavy, dense stand will survive only where the water tables are within 15 or 20 ft of the surface. Much of the lands originally dominated by saltcedar have also been converted into farms or industrial use near the towns and cities.

In spite of the major changes along the flood plains of the Southwest, there are still large areas occupied by wildland vegetation, but usually altered by man. Marks (1950), who studied the vegetation and soil relations of the lower Colorado desert, included considerable information on the communities along the lower Gila River. At that time, the bottom lands were dominated by an arrowweed-saltcedar community with other species such as seepwillow, screwbean mesquite (Prosopis pubescens), and saltbush. Along the river channels, cottonwood and willow were found. Scattered through the valley bottoms were saline communities dominated by Sueda and Allenrolfea. Above the bottom land occurred the most conspicuous of the valley communities — that dominated by mesquite. These lands are usually suitable for farming, and therefore a large percentage has been cleared. Mixed with the mesquite or at somewhat higher elevation was a community of Atriplex polycarpa.

Haase (1972), in his study of the lower Gila River, indicates that saltcedar occupies about 50 percent of the total bottom-land area. Under present conditions he feels that this dominance will not be changed unless there is some marked fluctuation in the water table or in other environmental conditions. His analysis and breakdown of the communities is very similar to Marks (1950).

Somewhat similar communities were studied along the Salt River above Granite Reef Dam east of Tempe (Gary 1965). The saltcedar communities were separate and distinct from the arrowweed, and occupied sites with shallower water tables and a silt loam soil, contrasted to the sandy loam found under the arrowweed and mature mesquite. Though there are a few cottonwood trees, these were not significant enough to be included in the analysis.

Along the Rio Grande, Campbell and Dick-Peddie (1964) found that saltcedar was the major dominant in southern New Mexico, but as one progressed up the river there was more cottonwood, Russian-olive (Elaeagnus angustifolia), and other species. These authors observed that cottonwood assumes dominance over saltcedar if cottonwood is left to develop into a full tree without disturbance. In mature stands of cottonwood, saltcedar grows only in natural openings and along the outer edge of the cottonwood stand.

Mesquite Washes

Many ephemeral streams below 3,500 ft contain broad alluvial flood plains and terraced bottoms that support high densities of deep-rooted trees and shrubs such as mesquite, blue paloverde (Cercidium floridum), catclaw acacia (Acacia greggii), burrobrush (Hymenoclea monogyra), and wolfberry (Lycium andersonii). These ephemeral streams, arroyos, and dry washes, predominately lined with mesquite, provide a certain amount of protective cover for cattle and wildlife. However, the deep-rooted trees also remove unknown quantities of water from the water table. Since the trees depend on deep water supplies, removal of the trees would eliminate transpirational losses from the aquifer. On-site precipitation, which is usually less than 15 inches, would continue to be lost because of high soil-surface evaporation.

Old mesquite growing near Granite Reef Dam, Arizona.

Mesquite in some areas may be extensive enough to warrant commercial harvesting. Mesquite makes excellent charcoal briquettes and is one of the better fireplace woods. A minor use of mesquite wood is for fenceposts.

From 2,500 to 3,500 ft, cottonwood and sycamore sometimes codominate with acacia and mesquite, forming an almost impenetrable understory. These trees use water from alluvium supplies but also provide channel stabilization and potential recreation sites.

Cottonwood Communities

Riparian communities between 3,500 and 7,000 ft, in general, contain the greatest number of species, the greatest percentages of cover, and will probably require the most planning before sound management practices can be developed. Cottonwood, ash (Fraxinus pennsylvanica), sycamore (Platanus wrightii), oak (Quercus sp.), and walnut (Juglans major) are typical trees in this sector.

Cottonwood reaches its maximum density in these altitudes in the alluvial valleys, such as the Verde River, Cottonwood Wash, and

Cottonwoods growing in dense stand along the Verde River in Arizona.

Carrizo Creek, Arizona. Most of the vegetation in large valleys was extensively altered in pioneer days for fuel and building materials.

Composition of streamside vegetation is continually changing. On the Rio Grande, Wislizenus 1847), Abert (1848), Gregg (1856), Metcalfe (1902), Watson (1912), and Campbell and Dick-Peddie (1964) all indicate successive changes in vegetation, primarily because of the influence of man. Watson (1912) reported the cottonwood trees were small because native ranchers used the wood for fuel. The growth rates and number of tree species were apparently not sufficient to supply the demand created by the localized settlers at this time. Construction of dams, irrigation canals and ditches, and drainage of marshes in the twentieth century have further changed the community complex.

The Santa Cruz and San Pedro Rivers in Arizona and Guadalupe Canyon in southwestern New Mexico are distinctly unique in the Southwest because they form a continuous ribbon of riparian plants from the State of Sonora, Mexico, into the continental United States. Because of a similarity of climate and lack of geographical barriers, many species of birds and reptiles common to Mexico follow these channels into the United States.

Sycamore-Dominated Ephemeral Streams

Along Sycamore Creek, near Sunflower, Arizona, Campbell and Green (1968) subdivided stream-channel vegetation into two major types, riparian and pseudoriparian, with both types extending ribbonlike from 1,500-ft elevations to 5,500 ft. Riparian species are obligate and pseudoriparian facultative. Thus, pseudoriparian species extend from adjacent slopes into the riparian zone where growing conditions are more favorable. Alder (Alnus spp.), willow, cottonwood, and sycamore are examples of riparian species; these plants grow only where additional ground or surface water occurs. Examples of pseudoriparian species are mesquite, oak, and acacia. These plants grow faster and taller on sites where ground or surface water supplements local precipitation, but they also germinate and grow on surrounding hillsides.

On Sycamore Creek, the riparian species are diffused and spread rather evenly up or down the channel. Pseudoriparian species, however, particularly the shrubs, show a distinct zonation along the channel at about the 3,000-ft elevation. Adjacent to the stream and at the same elevation there is an abrupt ecotone between

Sycamores growing along Sycamore Creek near Sunflower, Arizona.

desert and chaparral vegetation types. Most shrub species have a wider ecological amplitude than trees with respect to variation in soil moisture. Ninety-five percent of the shrub species occur on both relatively mesic and xeric sites, and are thus classified as pseudoriparian, versus only 52 percent of the trees.

Manmade disturbances in this zone are relatively minor. The frequent floods have a greater effect. Disturbances in the flood-prone channel cause species to form mosaics of seral stages of communities, with different combinations of species dominating each stage.

Perennial Streams

Canyons of the major rivers, including the Colorado, Rio Grande, Salt River (above Roosevelt Reservoir), and the Gila (above the confluence of the Blue), have thin strips of vegetation along the edges composed of some scattered trees but mostly shrubs including saltcedar. Floodflows remove young trees and shrubs at periodic intervals, but reestablishment is rapid. Due to the large ratio of open water to vegetation, however, transpiration causes a minor percentage of the total water losses and, therefore, management of vegetation for water savings could rarely be justified.

Side streams at the higher altitudes are usually alder dominated. Most of them are not altered by man except for recreational use, development of campgrounds and roads, and fishing.

Alders lining the streambanks of Oak Creek Canyon near Sedona, Arizona.

Species Characteristics

An important characteristic of any species in its relation to the community is its ability to establish itself naturally (or after planting, if an introduced species). Many phreatophyte species, such as saltcedar, cottonwood, and willow, are spread primarily by abundant windborne seeds. When they fall on water or moist soil they can germinate quickly. Seeds of these species will usually lose viability rapidly and unless they germinate within 2 to 4 months will lose their capacity to do so (Horton and others 1960). Though the seed will germinate very rapidly, the new seedlings require wet soils for several weeks to be able to develop sufficient roots for survival. These species thrive best in an open situation such as along sandbars or areas disturbed by floodflows and, when conditions are ideal, invasion will be rapid.

Seed germination of mesquite and associates is not dependent on such rigid soil-moisture conditions. While germination may be started by floodflow, especially in gravel washes, they seem to be spread more by cattle and rodent activity (Glendening and Paulsen 1955). Thus, mesquite has spread into the grassland and hillsides of southern Arizona where summer rains are more frequent (Schuster 1969). In the drier areas of central Arizona, however, the species is more common above deeper ground-water tables.

Root systems of phreatophyte species vary greatly. Mesquite is extremely deep rooted; Kearney and Peebles (1951) report it penetrates as much as 60 ft into the alluvium. Saltcedar can also be deep rooted. Seepwillow is relatively shallow rooted, growing only where the ground water is close to the surface (Gary 1963).

Arrowweed shrubs send out lateral roots just below the surface of the soil which sprout to form dense clusters over relatively large areas (Gary 1963). Some seedlings of this species have been noted, but it is felt that the dense thickets are caused by lateral spread.

After burning or cutting, saltcedar shrubs redevelop rapidly; the sprouts from the root crown will grow as much as 10 or 12 ft in a year under favorable conditions. In the study of the effect of grazing, cattle removed approximately 50 percent of the foliage produced but the shrubs still grew vigorously (Gary 1960). During the second year the stand became so dense and heavy that cattle would not enter the area.

In another study, Campbell (1966) found that even biweekly cutting of saltcedar at a height of 12 inches above the ground did not kill the plants. However, if all foliage was removed from the stump at 2-week intervals, 92 percent of the plants died the first season and the remainder died after retreatment the following year. Thus, in areas where there is sufficient water and grass, heavy use of saltcedar by cattle is desirable. Because mowed saltcedar grows so rapidly, cattle or sheep must use it excessively to keep the crowns within reach.

All of the aboveground portions of saltcedar will develop adventitious roots and form new shrubs if kept wet in moist soil. Gary and Horton (1965) found that 100 percent of stem cuttings would sprout at all times of the year if they are kept moist and warm. Root cuttings did not sprout. If stem cuttings are allowed to dry, even as little as 1 day, the sprouting ability is very quickly reduced. This rooting ability is important in mechanical clearing because, if the operation is done when the ground is moist, a large portion of the plant parts that are buried will develop new shrubs.

Taxonomy of Tamarix

The taxonomy of saltcedar has long been confused. The first plants introduced into the United States were usually called Tamarix gallica L.; later the nursery catalogs began to carry the name Tamarix germanica L. (Horton 1964). There is no way of knowing what species of plants were actually introduced. The early floras usually listed Tamarix gallica as the introduced species.

McClintock (1951) reported that there were four species of pentamerous tamarisk in the United States. She stated that T. gallica was a rather rare shrub in the West and that the common aggressive western saltcedar should be classified as T. pentandra Pall. rather than T. gallica. She indicated that T. chinensis Lour. was a synonym of T. pentandra. Two other species were listed as ornamentals found occasionally as naturalized plants.

Baum (1967), after extensive study of the genus Tamarix at the Hebrew University, Jerusalem, abandoned the name T. pentandra, and divided the western pentamerous tamarisk (saltcedar) into several species after examining material from various American herbaria. In 1968, the USDA Forest Service at the Forest Hydrology Laboratory started a study of Tamarix taxonomy; individual shrubs were grown from cuttings collected at various locations in the United States and the Old World to check on the growth characteristics and validity of the speciation as outlined by Baum. Their plantings have indicated that while there is variation in the growth habits and phenology of saltcedar, the botanical differences are not significant or constant enough to warrant species separation.

Thus, the aggressive saltcedar should be considered as one species. Due to the fact that the name Tamarix pentandra is not held to be legitimate, another name must be used. The oldest synonym applied to the aggressive pentamerous tamarisk group is Tamarix chinensis; thus by the rules of botanical nomenclature, this name should now be used for the species so commonly naturalized in the West.

OTHER RESOURCE USES OF PHREATOPHYTE AREAS

The emphasis on use and management of phreatophyte areas has recently changed from water salvage to the possible development of other management alternatives. The tangible resource uses, such as the removal of shrubs and trees to develop farmlands or to use these areas for grazing, are relatively easy to justify and to determine the economic values involved. Many intangible resources are very difficult to evaluate, however, including recreation, wildlife, and preservation of natural areas. Determining the most desirable alternative is sometimes very difficult because the resources involved are so often backed by single users who feel that their resource overshadows all the others. Multiple-use management, however, must consider the following resources in addition to water salvage.

Development of Farms and Grazing Lands

Along most of the flood plains, clearing of phreatophyte cover for farm or grazing land has caused the greatest attrition. In many cases, the soils are admirably suited for these purposes even though they can be subject to flooding. This flooding may be alleviated by construction of dams upstream, which allows the farm activity to extend close to the channel. Alkalinity of much of the flood plain now covered by phreatophytes may be too high for farming, however. Where water is fairly close to the surface or can be obtained, grazing is often a desirable use for such lands if woody vegetation is removed.

Wildlife

Phreatophyte areas can provide shelter for game species. Of topmost interest are white-winged and mourning doves. The white-winged dove particularly nests in large numbers in phreatophyte areas in Arizona, and is a valuable hunting resource (Cottam and Trefethen 1968). Dense woody stands of saltcedar provide nesting sites, but the food — as for most wildlife — must be provided in large part from areas outside the flood plains. Large numbers of doves feed primarily on agricultural fields nearby. When these depredations become severe, the farmer, such as in the Gila River Valley around Buckeye, Arizona, often changes his type of crop. To maintain an optimum population of these doves, it may be necessary to provide food for them.

Historically, doves nested in the mesquite bosques which produced much more food than the extensive saltcedar thickets of today (Arnold 1943). Clearing of the mesquite depleted the dove numbers, which were not restored until saltcedar invaded the area.

Game departments have long been interested in using phreatophyte areas as wintering grounds for waterfowl, particularly on the Rio Grande and the Pecos River flood plains as well as along the Gila River in the Buckeye area. The Game and Fish Departments in both Arizona and New Mexico have cleared areas for the production of green forage. A compromise must be made between preserving cover for nesting of doves and removal of cover to produce food for waterfowl and possibly for doves.

Recently, the value of cottonwood and other phreatophytes for nongame birds has been stressed. This form of wildlife use has intangible values which are very hard to evaluate. The highest concentration of birds noted anywhere in the United States has been reported by Johnson (1970) from the cottonwood communities of the Verde Valley in central Arizona. The most birds and greatest diversity of species occurred in areas containing the densest riparian vegetation. Results of Johnson's study indicated that thinning cottonwood for water savings and flood control reduced nesting bird populations as follows:

	Pairs of nesting birds per 100 acres	
	1969	1970
Severely thinned (10.1 trees per acre)	583	524
Moderately thinned (26.0 trees per acre)	963	886
No treatment (46.6 trees per acre)	1,325	1,006

Rare or endangered bird species must be evaluated in any management plan, particularly in the cottonwood stands of southern Arizona.

Other Tangible Values

Other tangible values of the moist-site species include the use of saltcedar stands as a refuge for honey bees, especially during the season insecticides are being applied to the croplands. Management of saltcedar for honey production needs more research. Colonies apparently must be widely spaced because of the possibility of disease. Spreading the colonies would allow for intervening areas to be managed for other purposes. Mesquite also is valuable for apiaries. Tannin has been listed as a possible resource from saltcedar, but the recent tests would show that these values are comparatively limited and it would not be possible to maintain any sort of an industry using tannin obtained from saltcedar.

Production of fuelwood is probably not very important from saltcedar areas, but is very much so from mesquite bosques and the cottonwood areas. Riparian wood, as a source of fuel, has largely been replaced just as has the wood-burning stoves that originally burned this wood. And now, of the numerous streamside species, only cottonwood and mesquite occur in extensive enough stands to support a timber utilization industry. Cottonwood has been used for pulpwood, wood shavings, crating, boxes, and pallets. In northern Mexico, a small industry presently utilizes cottonwood for wooden bowls and small statues. In Arizona, cottonwood is estimated to occur on less than 8,000 acres; the major concentrations are in the Verde, Little Colorado, and Gila River drainages with present stands too scattered for most commercial concerns (Barger and Ffolliott 1971).

Flood Control

Saltcedar and other species tend to clog channels because the seedlings invade sandbanks and sandbars close to the stream. As they develop a barrier, sediment collects in the heavy stands. Floodflows are then diverted onto the surrounding lands. These diversions tend to spread the woody barriers more widely, which further increases the flooding. Deposition of debris above the delta of a reservoir may be beneficial, however, if it keeps the debris from entering the reservoir and reducing its storage capacity. Another factor that must be kept in mind, especially after clearing, is the possibility of channel cutting after the channel banks are cleared of vegetation. Wind erosion likewise can be serious after clearing.

Recreation

Heavy saltcedar stands are not particularly valuable for recreational purposes; campgrounds are not appropriate mainly because of hot and humid summer days and because of the unpleasant exudation of salt from saltcedar cover, especially on warm mornings. The shrubs are bare during the fall and winter and they are really attractive only for a relatively short period in spring when many are in full bloom. Saltcedar areas could, of course, be converted to other phreatophyte types; for instance, they could be selectively cleared and cottonwood or mesquite allowed to establish. The development of picnic and camping areas is an important recreation use in cottonwood areas. Cottonwoods are appealing and are definitely needed in areas close to roads or where recreational facilities can be established.

Preservation of Natural Conditions

Due to the changes in phreatophyte areas throughout the Southwest, the preservation of natural conditions is rarely a factor. There are mountain reaches in Arizona and New Mexico, however, where canyons have retained their natural ecological balance. The desirability of preserving these areas is very great.

CONTROL METHODS

To establish optimum multiple-use management in phreatophyte areas, some control or manipulation of portions of the vegetation will often be required.

Mechanical

At present, the rootplow seems one of the most successful mechanical methods for control of saltcedar and other small trees and shrubs. The rootplow undercuts the plants and raises them so they dry out rapidly and are killed. Plowing can be done most effectively when the soil is relatively dry (Horton 1960). Large areas have been rootplowed and then usually raked to get the material into windrows so it will not interfere with floodflows. Because rootplowing tends to kill a large percentage of any grass cover mixed with the saltcedar, it may lead to serious wind erosion. Other mechanical methods of removing the brush were described by Lowry (1966).

Where grass is a factor in the understory, a rotary-type mower can cut the shrubs several inches above the ground. This does not kill saltcedar, but grazing can further reduce or control cover. Although larger plants cannot be cut in this fashion, the method is appropriate if the water table is close to the surface and heavy grazing can be applied. Other trees, for example cottonwood and mesquite, can be selectively removed by sawing and applying systemic herbicides to the trunk.

Chemical

Much research has been done on the chemical control of saltcedar (Hughes 1966), but no really satisfactory method has been developed. Translocation is relatively slow, and the sprouting ability of the root crown is such that there is not a good or consistent response to chemical methods.

Antitranspirants

A great deal has been done with the use of chemicals to close the stomata and, therefore, decrease transpiration and water loss on agricultural crops. Most studies have also shown a corresponding decrease in the growth of the plant due to decreased photosynthesis. Brooks and Thorud (1971) evaluated various antitranspirants on saltcedar, and indicated the method has possibilities.

MANAGEMENT APPROACHES

The development of optimum management plans for the alluvial flood plains and riparian reaches of Arizona is complicated not only by the great variety of environmental situations but also by the many conflicting demands on the various resources. For management purposes, the flood plains can be identified and separated into four ground-water levels, which control the vegetation structure. Although soil texture and salinity are also important factors, the relationships of soil characteristics to vegetation cover of the flood plains are not precisely known; thus, optimum management, at present, must be determined primarily by the existing vegetation and knowledge of water-table depth. The riparian reaches in canyons can be separated by altitude and by species dominance for management purposes.

The four flood-plain zones are not precisely separated by water-table depth but there are specific differences between the zones which affect management practices. Due to the abundance of saltcedar, this species is used as a practical means of separating the zones.

Flood-Plain Zone 1
(Very shallow water table — 0-4 ft)

This zone can easily be recognized by the dwarfed and multistemmed saltcedar and the vigorous Bermudagrass or saltgrass cover. No specific water table depth can be given, but it is generally less than 3 or 4 ft. Along some streams this particular zone is not developed because the stream or delta banks are several feet above the water table.

Grazing and flood passageways would in most cases be the optimum use of the zone. Water savings would be small if the saltcedar were removed. Wildlife use would be minimal because the shrubs are not high enough for nesting purposes. The shrubs could be periodically cut with a rotary mower to maintain this zone. Grazing would tend to keep the plants under sufficient control to minimize maintenance costs.

In summary, zone 1 can usually be managed for grazing and flood control without expecting any appreciable water savings or revenues from other resources. If the water table is lowered by pumping or water diversion, the area should be reclassified to zones 2, 3, or 4.

Flood-Plain Zone 2
(Shallow water table — 4-8 ft)

The water table is shallow enough in this zone to be readily available to the roots of any grass, but not so shallow as to restrict growth of saltcedar. During summer rainy periods many grasses establish themselves in this zone. The water-table depth would be roughly between 4 and 8 ft, depending on soil characteristics.

There are many conflicting uses for this zone. The saltcedar stand is desirable for wildlife purposes or, in some areas, as a haven for bees. But saltcedar can also be removed and the water thus saved utilized either by pumping to irrigate on-site replacement vegetation or allowed to increase river flow an unknown amount for off-site use.

On-site use of the salvaged water could be directed to beneficial resources such as grazing areas or winter food for migratory waterfowl or summer-maturing grain for doves. The habit of the white-winged dove to nest in colonies, even in uniform cover, would it seems, allow clearing of a portion of the saltcedar without appreciably affecting the dove population. Moreover, the bird's dependence on agricultural crops for food seems to be a more determining factor in its numbers than nesting space.

It is probable that partial clearings of saltcedar in strips or patches would save enough water for production of wildlife food. Optimum management is the easiest in this zone with its relatively shallow water table, and both wildlife and better land utilization can be provided.

Fires threaten saltcedar areas. Breaking the heavy stands into blocks would make wildfires easier to control and reduce acreage of destroyed habitat.

Flood-Plain Zone 3
(Medium water table — 8-20 ft)

It is in this zone that the greatest water savings could be obtained by the removal of phreatophyte cover. Practically all of the water consumed by a heavy stand of saltcedar over a water table even as deep as 15 or 20 ft below the surface would be available for salvage if the stand were cleared. The clearing would either raise the water table to make more water available for pumping, or would increase ground-water flow. Many water salvage programs have been designed for this zone.

Unfortunately, this zone also presents serious problems if the saltcedar is removed for water savings. Inasmuch as the water table is too deep for the establishment of Bermudagrass or other species so often found in the shallower water-table areas, the vegetation must be a desert type able to survive on the annual rainfall. In some cases, precipitation is not sufficient to provide a suitable vegetation cover to protect the soil surface from wind erosion and from unesthetic appearance.

Considerable research on replacement cover is needed if the present tree, shrub, and herbaceous cover is removed for water salvage. Many desert species, such as Atriplex, would provide a cover for wildlife and reduce wind erosion if they could be established successfully.

Optimum management of this zone would leave strips or blocks of untouched saltcedar for wildlife between cleared areas for water savings or the establishment of vegetation to provide food for doves and waterfowl. Part of the water saved by the removal of saltcedar could be used for irrigation to establish and maintain a vegetation crop for wildlife food.

Much research is needed in this zone to develop optimum management practices. The value of the salvage water must be determined, and the values of saltcedar for wildlife as well as methods for growing food for doves and waterfowl must also be developed.

Flood-Plain Zone 4
(Deep water table — below 20 ft)

Though roots of mesquite and other desert trees may penetrate down to deeper layers than saltcedar, we have no information on the relative depths of root penetration or on the depths to which saltcedar will be able to extract water. Undoubtedly, there is no definite demarcation between this and the other zones; the 20-ft figure is only a rough approximation. Scattered individuals of saltcedar do grow in alluvial soils that do not receive any moisture other than the annual rainfall or floods. The shrubs are very widely spaced and become dormant during the drier periods but, when rejuvenated by rain or floods, will grow rapidly during the growing season.

Reducing the water table from a zone 3 to zone 4 will kill a large percentage of the saltcedar in a dense stand. Also, because saltcedar is easily killed if burned under drought stress, fires take an additional toll. Much of the Salt River through the Tempe and Phoenix area has been changed to this type of open tamarisk stand. It is far from esthetic and is not particularly used by nesting doves, though quail and other birds may occupy fringes.

Although pumped water could be used to develop a stand or groups of saltcedar, cottonwood and mesquite would be preferable for revegetating this zone if it is desired to provide picnicking and camping sites as well as nesting habit for song birds, such as mourning and white-winged doves.

Streams Below 3,500 Feet

At elevations below 3,500 ft, particularly on the wide flood plains of ephemeral streams and arroyos where deep alluvium occurs and ground water is generally less than about 20 ft, deep-rooted trees and shrubs depend on the subterranean water throughout the growing season. Depending on the porosity of the alluvium, annual recharge, size of the aquifer, and the density of vegetation, this reservoir of ground water will be depleted by evapotranspiration each growing season; streamflow from winter precipitation sometimes, but not always, replenishes the water lost to evapotranspiration. Obviously, removal of the trees and shrubs would eliminate the summer transpirational loss. Water-budget analysis in this zone on lower Sycamore Creek by Thomsen and Schumann (1968) indicated evapotranspiration losses of about 1.1 acre-ft from some 1,400 acres of mesquite and acacia. In this case, the estimated 1,500 acre-ft saved following removal of the deep-rooted trees and shrubs would flow directly into the Verde River without additional costs of pumping or transportation. On flood plains in remote mountain reaches, costs of pumping and transporting the water in a closed system to permanent rivers may be prohibitive; a management alternative is to remove the vegetation and allow the natural channel to transport the increased water yield. In a natural channel, however, expected increased surface water and soil evaporation losses might nearly equal prior losses by evapotranspiration.

Finally, present uses of this vegetated zone — by livestock, small birds and mammals, campers, picnickers, and small-game hunters — will have to be considered carefully before vegetation removal for water-yield increases are initiated.

In narrow canyons in this elevation zone, vegetation is sparse and management to increase water yields is not feasible. These zones could be managed to increase the number of miles of warm-water fish habitat. Also, construction of nature trails would create recreational areas which are currently not utilized by man. Construction of highway "viewpoints" near narrows would improve tourist conception of natural wonders.

Streams Between 3,500 and 7,000 Feet

On a number of flood plains in this elevation zone, selective thinning or removal of undergrowth could improve esthetic appearances and reduce flood hazards. Water savings, if any, from such thinning treatments are not known; in general, vegetation removal of at least 40 percent on watersheds has been necessary to show significant water-yield increases. Neither is the exact extent of losses to wildlife foods and habitats known as a result of selective thinning. Recreation use would increase if the area is accessible by nearby roads. In high-density recreational areas where flooding could cause loss of life or severe property damage, vegetation thinning for flood controls may be necessary. Such thinning should not be so severe as to force abandonment of other on-site uses of the streams, however. Total riparian vegetation eradication for water-yield increases is not recommended because of loss of fish and wildlife habitats and recreation uses.

In narrows, where the channel is mostly cut on bedrock, present uses of the channel are limited to fishermen, hikers and horsemen. Some trails should be relocated away from the streambank to prevent bank sloughing, and new trails should be constructed on ridges away from the stream where erosion is not as severe. Neither vegetation thinning nor complete removal is recommended for water-yield increases because of the generally sparse cover.

Vegetation treatment on small tributaries of major channels offers a distinct opportunity to increase water yields sufficiently to fill small ponds for on-site recreation and wildlife use. Such ponds would improve land utilization, particularly in the chaparral zone, without destroying esthetic values. Development of water for on-site uses should probably become an important management practice.

Streams Above 7,000 Feet

Little, if any, foreseeable change in present management practices is indicated on the high-elevation mountain streams in the Southwest. Neither erosion nor evapotranspiration losses are severe on streams above 7,000 ft Recreation and wildlife use are presently not severely in direct conflict. Erosion control and improvement of fish habitats should have high priority. In general, extensive management should prevail in these zones without change in present management objectives.

Cottonwood Management

Cottonwood, common in the phreatophyte and riparian zones of the upper desert and chaparral areas, once dominated most of the streams and flood plains of the Southwest, even along the rivers where saltcedar now thrives. It is probable, however, that it did not develop readily on the flood plains except in zones 1 and 2, described above. Zone 3 might have had cottonwood if it originally developed under more favorable moisture conditions. It is found at present most commonly along alluvial reaches in the foothill or mountain areas.

Except for limited reach studies, information on water losses from cottonwood areas is lacking but the indications are that losses would probably equal or exceed those from tamarisk.

At the elevations where cottonwood now flourishes, indications are that complete removal of the trees would save 1.5 to 2.0 ft of water. No information is available on the amount saved if stands are only thinned or after other natural growth invades the streams.

A particularly negative feature of cottonwood stands adjacent to farmlands is the clogging of the river channel and diversion of floodflows onto farmlands or other developments. Some undergrowth cutting along a central channel may be necessary to reduce flood hazard. These clearings might be used for recreational areas or to increase grazing.

In spite of these disadvantages, cottonwood stands have important intangible esthetic values, such as the bird life that thrives and develops in these groves. These values of cottonwood must be taken into consideration in the optimum management of our streams.

Thinning cottonwood stands probably would not save much water. It is probable that at least 50 percent or more of the cover would have to be removed before there would be any appreciable savings. Thus, in most cases, management of cottonwood would be determined not by the desire to increase water but by the need for flood control, or the suitability of the area for recreation or grazing use. Any of these resources could be developed without destruction of esthetic values if sufficient trees are left. However, bird life seems to be reduced in proportion to the amount of thinning.

In both southern New Mexico and southern Arizona, some efforts are being made to improve riparian habitats where peripheral bird habitats lap into the United States from Sonoro, Mexico. Livestock are being excluded in some areas to allow germination and/or resprouting of riparian species in an effort to improve wildlife habitats and to encourage bird reproduction in the area.

Because cottonwood trees grow rapidly, it is relatively easy to establish them wherever there is sufficient water for esthetic or wildlife purposes.

CONCLUSIONS

Optimum management of moist-site areas, whether dominated by saltcedar, cottonwood, or other riparian species, requires careful consideration of both environmental factors and the economic needs of the area. Seldom are areas best managed by devoting the land to a single use, as compromise management will usually return the greatest economic value (Horton 1972).

Only rarely in the Southwest are there phreatophyte areas that would be best managed by complete preservation. Examples are areas of cottonwood and other native species in the southern portion of Arizona, which should definitely be set aside as natural areas.

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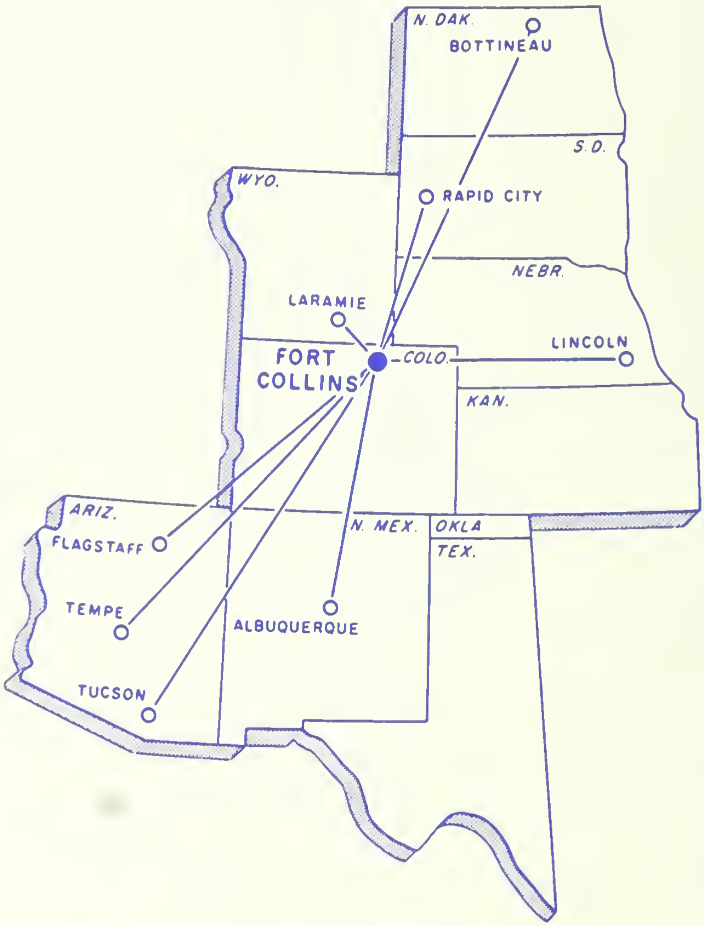
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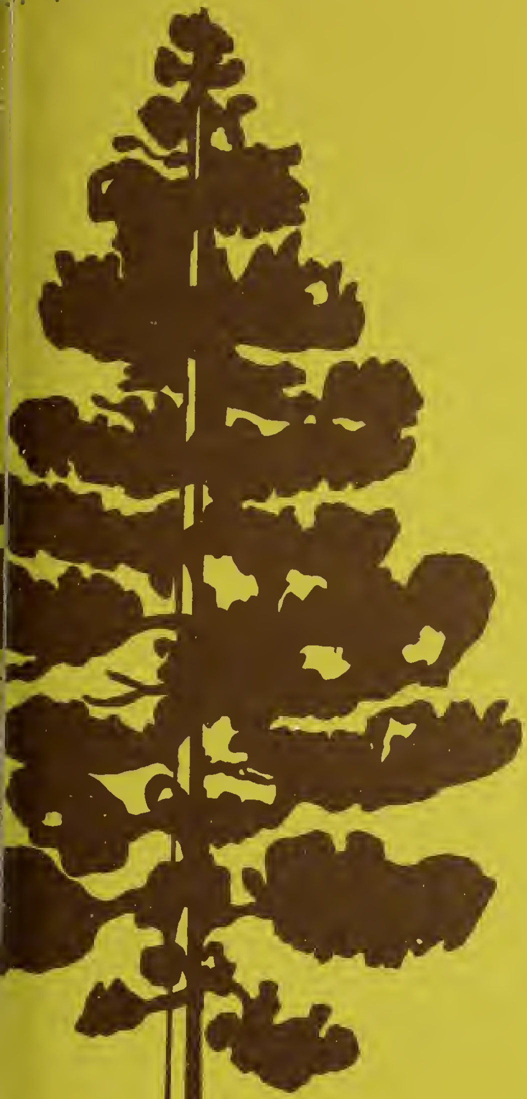

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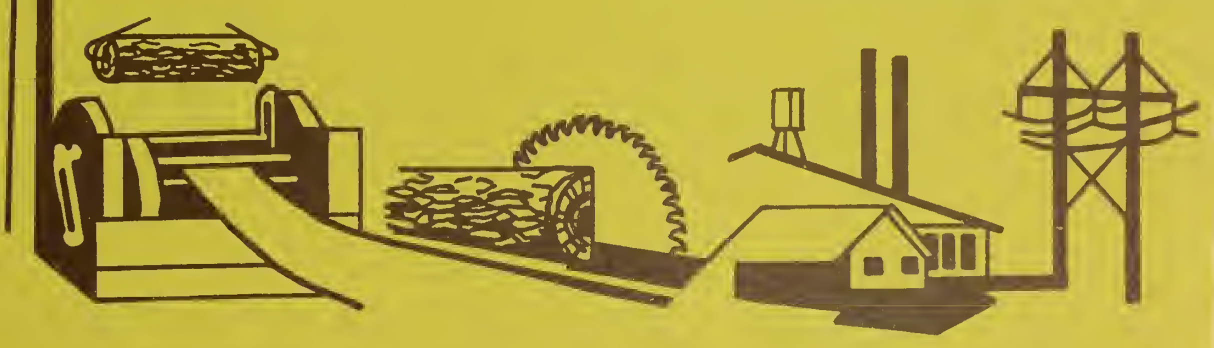
BLACK HILLS PONDEROSA PINE TIMBER:
Poles, Saw Logs, Veneer Logs, Stud Logs, or Pulp?



by Vern P. Yerkes

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Fort Collins, Colorado

Abstract

A multiproduct analysis indicates that public lands contain gross volumes per acre of 4,944 board feet (fbm) of saw logs, 4,680 fbm of veneer logs, or 3,052 fbm of stud logs if inventoried for these products individually. If inventoried simultaneously for highest multiproduct potentials, however, they contained gross allocated volumes of 881, 3,165, and 143 fbm per acre for each product, respectively. These analyses demonstrate the usefulness of multiproduct evaluation techniques in evaluating utilization alternatives.

Oxford: 228:831.4:832.10,20:861.0. **Keywords:** Poles, saw logs, veneer logs, stud logs, pulp, *Pinus ponderosa*.

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BLACK HILLS PONDEROSA PINE TIMBER:

Poles, Saw Logs, Veneer Logs, Stud Logs, or Pulp?

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BLACK HILLS PONDEROSA PINE TIMBER:
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Vern P. Yerkes

Introduction

Describing a timber stand in terms of board-foot or cubic-foot volume alone does not adequately describe its potential as raw material for multiproduct industry. Total cubic volume estimates may be useful to pulpwood producers without much additional information, but would be of little value to plywood producers without some definition of log size and quality. Likewise, the number of board feet in a stand would be useful information to an experienced local sawmiller, but would have considerably less value to a producer of utility poles.

A multiproduct inventory system devised by Barger and Ffolliott (1970) permits evaluation of a timber stand for several products from one set of field inventory data. Their system can be coupled with a computer program (MULTI), developed by Heidt et al. (1971), to evaluate the stand for virtually any primary product for which a set of grading specifications can be defined.

In this Paper, two segments of the Black Hills ponderosa pine resource were evaluated by these combined multiproduct field inventory and data processing systems. The analyses apply the following currently accepted grading systems for poles and saw logs, and preliminary grading systems for veneer logs and stud logs. The output of the computer program described the two forest areas in terms of average volumes per acre suitable for each product and product grade. Analysis of a forest resource for potential alternative uses will permit timber managers and processors to identify the most profitable products or product mixes, and will help them make management adjustments to achieve maximum benefits from the resource.

Product Specifications

Commercial Poles

The specifications and dimensions used in this study are a conversion of American Standard pole specifications (American Standards Association 1963) to outside-bark diameter dimensions for ponderosa pine poles. The converted table of dimensions was developed by Bert Jennings, Forester, Southwest Forest Industries, for use in identifying and selecting ponderosa pine poles in the field. Specifications and dimensions follow:

1. All trees 9.0 through 20.9 inches d.b.h. **with acceptable pole form**, will be considered potential pole material.
2. Defects that are inadmissible in commercial poles include
   —sweep (deviation greater than ⅓ d.b.h.),
   —major crook (deviation greater than ½ pole diameter at crook),
   —knots larger than 4 inches in diameter dead or green),
   —knot whorls or clusters aggregating more than 8 inches of knot diameter within 1 linear foot,
   —fork,
   —heart rot,
   —lightning scar,
   —fire scar.
3. For trees meeting minimum merchantable specifications, stem length to the first limiting defect will be recorded (such as length to first inadmissible knot, and so forth). Such defects as fork, crook, and fire scar, if located near the butt or top of the stem, may not eliminate the pole but require a reduction of acceptable pole length.

Table 1.--Pole specifications for ponderosa pine, minimum diameter, inside and outside bark

Pole length, (ft)	Pole class 1	2	3	4	5	6	7
	d.b.h., o.b., inches						
16					9.9	9.4	9.0
18			11.6	11.0	10.3	9.7	9.4
20			12.1	11.3	10.7	10.0	
25			13.2	12.4	11.8		
30		14.8	14.0	13.2	12.7		
35		15.6	14.8	13.8	13.4		
40		16.5	15.6	14.7	14.2		
45		17.2	16.3	15.3	14.8		
50	18.3	17.8	16.9	16.1			
55	19.5	18.5	17.7				
60	20.0	19.0	18.2				
	Top, inches						
d.i.b.	10.0	9.4	8.8	8.3	7.8	7.0	6.0
d.o.b.	12.0	11.3	10.6	10.0	9.4	8.4	7.2

The range of merchantable diameters and heights of commercial poles to be expected from ponderosa pine in the Black Hills can be approximated from table 1.

Saw Logs

The grading specifications used for saw logs (Gaines 1962) were:

1. Logs 6.0 inches and larger in scaling diameter are considered potential saw logs. All trees 9.0 inches and larger in d.b.h. are considered sawtimber trees.
   All grading specifications are written for 16-foot log lengths. The same specifications apply to shorter logs in proportion to their length.
2. All logs meeting the minimum merchantability standards are graded according to the Improved Ponderosa Pine — Sugar Pine Log Grades (Gaines 1962). Grades criteria include:

   Panel — log surface area one-fourth the circumference and 4 feet long.
   Primary defect — log knots, including limbs, limb stubs, overgrown knots, etc.
   Secondary defect — scars, burls, forks, crooks, cankers, etc.

   Grading specifications for four of the five grades are abbreviated below. (Grade 4 logs, as described by Gaines, rarely occur in Black Hills ponderosa pine. Grade 4 was therefore omitted in this analysis.)

Defects Permitted

Grade	Primary	Secondary
1	One log knot not over ½ inch in diameter	Confined to three panels or less
2	Confined to four panels or less	Secondary plus primary confined to six panels
3	Six panels free of all grading defects	
4	All other logs with net scale of ⅓ or more of gross scale	

Veneer Logs

Preliminary specifications used for grading veneer logs (Yerkes and Woodfin 1972) were:

1. Logs 8.0 inches and larger in scaling diameter are considered potential veneer logs (8-foot block lengths are required).
2. Logs will be graded by the following specifications:

   Grade 1 — blocks believed capable of yielding a preponderance of C and better grades of veneer:
   (1) Dead knots must be equal to or less than 2 inches in horizontal diameter.
   (2) Live knots must be less than 2 inches in horizontal diameter.

   Grade 2 — blocks believed capable of yielding a preponderance of D grade veneer:
   (1) Dead knots greater than 2 and less than 4 inches in horizontal diameter.
   (2) Live knots — no limit.

   Unacceptable — if logs include:
   (1) Dead knots greater than 4 inches horizontal diameter.
   (2) Crook greater than ⅓ top diameter of the 8-foot block.
   (3) Fork or distorted grain associated with fork.
   (4) Fire scar.
   (5) Lightning scar.
   (6) Decayed wood where lathe chucks strike block.

Stud Logs

Preliminary specifications used for grading stud logs (Barger and Ffolliott 1970) were:

1. Logs 6.0 through 16.9 inches in scaling diameter will be considered potential stud logs. All specifications are to be applied to 8-foot log lengths.
2. Logs that meet the basic size and quality requirements for stud logs will be graded by the following specifications:

   Grade 1 — attempts to identify stud logs from which a high proportion of SELECT and CONSTRUCTION grade studs can be recovered:
   (1) Dead knots allowed to 1 inch in diameter.
   (2) Green knots allowed to 2 inches in diameter.
   (3) Total number of knots cannot exceed 16.

   Grade 2 — attempts to identify stud logs from which a high proportion of STANDARD grade studs can be recovered:
   (1) Dead knots allowed to 2 inches in diameter.
   (2) Green knots allowed to 2 inches in diameter.
   (3) Total number of knots cannot exceed 32.

Grade 3 — attempts to identify stud logs from which a high proportion of UTILITY and ECONOMY grade studs can be recovered:
(1) Dead knots allowed to 2 inches in diameter.
(2) Green knots allowed to 3 inches in diameter.
(3) Total number of knots unlimited.

Unacceptable — if logs include:
(1) Dead knots greater than 2 inches in diameter.
(2) Green knots greater than 3 inches in diameter.
(3) Sweep (deviation greater than one-third scaling diameter).
(4) Crook.
(5) Fork or distorted grain resulting from fork.
(6) Massed pitch.
(7) Fire or lightning scar.
(8) Heart rot.

Data Collection and Analysis

Field data were collected from trees 5.0 inches d.b.h. and larger from permanent sample plots established in pole and sawtimber stands. The basic system described by Barger and Ffolliott (1970) was used, although some modifications were necessary to provide data in a form useful for a plywood feasibility study. Data are from two sources:

1. **General Ownership Lands** — a 1968 resurvey of the fixed-plot permanent sample plots in the Black Hills National Forest (USDA,FS), Custer State Park (State of South Dakota),[2] and the Bureau of Land Management (USDI) Exemption Area around Lead and Deadwood, South Dakota.
2. **Custer State Park Lands** — an intensive timber survey in 1969 by the South Dakota State Forester's Office, based on a variable-plot permanent sampling system for the Park that used plot establishment and measurement techniques outlined by the USDA Forest Service Survey Project at Intermountain Forest and Range Experiment Station, Ogden, Utah.

[2]The General Ownership survey included only eight 1/5-acre plots on the Custer State Park. The effect of these plots in the General Ownership survey is considered minimal. The more intensive survey made by the South Dakota State Forester's Office is therefore used to characterize the Park stands.

Both surveys used the same multiproduct evaluation system, but because sampling systems were different, data cannot be combined. The computer program MULTI (Heidt et al. 1971) was adjusted to accept the data in the format as collected.

Stem Characteristics

Stem characteristics included in field inventory data for multiproduct evaluation of Black Hills ponderosa pine were:

Sweep — gradual bend in the merchantable tree tree stem.
- Class 1 — deviation of the stem centerline from a straight line is less than the d.b.h. of the tree.
- Class 2 — deviation of the stem centerline from a straight line is greater than the d.b.h. of the tree.

Crook[3] — an abrupt bend in the merchantable stem.
- Class 1 — deviation of the centerline of the stem is less than one-third of the small-end diameter of the 8-foot section containing the crook.
- Class 2 — deviation of the centerline of the stem is between one-third and one-half of the small-end diameter of the 8-foot section containing the crook.
- Class 3 — deviation of the centerline of the stem is greater than one-half the small-end diameter of the 8-foot section containing the crook.
- Location — location of crook by half-log position.

Fork — point where merchantable stem divides into two or more stems of nearly equal size.
- Location — location of fork by half-log position.

Fire or basal scar — distortion of the lower portion of the merchantable stem by callous growth and/or exposed wood resulting from fire or mechanical damage.
- Class 1 — distortion or exposed wood extends less than one-fourth the circumference of the tree.
- Class 2 — distortion or exposed wood extends over more than one-fourth the circumference of the tree.

Rot[3] — decayed wood visible behind or in fire or basal scars. Only visible decay is recorded.

[3]Indicates a deviation from the basic inventory method described by Barger and Ffolliott (1970). Lean was not considered a defect and was not recorded.

Lightning Scar — vertical or spiraled strip of exposed wood and/or callous growth resulting from a lightning strike.

Class 1 — damage to the merchantable stem is limited to one one-quarter face of the merchantable stem.

Class 2 — damage to the merchantable stem extends into more than one one-quarter face of the stem.

Knots — side branch extending from the merchantable stem.

Live — branch with tight bark, live needles on twigs.

Dead — branch stub with no live needles.

Product and Grade Combinations

Eleven separate combinations of product and grade were evaluated, both as independent products and on a product priority basis.

Independent product evaluations were made by evaluating all tree stems in the stand for only one product at a time. Estimated total resource volume per acre is reported alternatively as that suitable for each individual product.

Product priority evaluations were made by evaluating each tree or stem section for its suitability for each product, beginning with the highest valued product and progressing to the lowest. Each stem or stem section was allocated to the highest valued product for which it qualified. The total resource volume per acre is reported collectively as the proportion of stand volume allocated to each product considered.

Product-grade combinations were ranked in the following order of decreasing value:

1 — Poles
2 — Grade 1 saw logs
3 — Grade 2 saw logs
4 — Grade 3 saw logs
5 — Grade 1 veneer logs
6 — Grade 2 veneer logs
7 — Grade 1 stud logs
8 — Grade 2 stud logs
9 — Grade 3 stud logs
10 — Grade 5 saw logs
11 — Pulpwood

Volumes for trees and logs were calculated from Black Hills ponderosa pine volume tables (Myers 1964), with merchantable heights calculated from total heights (Van Deusen 1967), and volumes distributed by log position through the use of taper tables (Woodfin 1960). Both gross product volume and volume adjusted for visual scaling defects (reduced volume) were determined. Defects that affect usable volume, and average scale deductions for each class of defect, were calculated as shown in table 2.

Grading specifications used for poles were adapted from Association specifications for

Table 2.--Percent scale reduction applied to product volume for defects

Defect type and degree	Poles[1]	Saw log[2] 16 ft	Saw log[2] 8 ft	Veneer log[2]	Stud log[3]	Pul
SWEEP:						
Class 1	100	0	0	0	0	0
Class 2	100	20	20	0	0	0
CROOK:						
Class 1	0	25	50	50	50	0
Class 2	0	25	50	100	100	0
Class 3	([4])	25	50	100	100	0
FORK	([4])	25	50	100	100	0
FIRE OR BASAL SCAR:						
Class 1	([4])	0	0	([5])	0	([6])
Class 2	([4])	13	0	([5])	25	([6])
KNOTS(Inches)						
Live >4.0	100	0	0	0	100	0
Dead ≥4.0	100	0	0	0	0	0
Dead ≥4.0	100	0	0	100	0	0
Dead ≥3.0	([7])	0	0	0	100	0
ROT	100	0	0	([5])	([8])	0
LIGHTNING SCAR:						
Class 1	100	25	25	100	25	0
Class 2	100	50	50	100	50	0

[1]9.0 to 20.9 inches, d.b.h.
[2]9.0+ inches, d.b.h.; 8-ft veneer log length.
[3]5.0 to 22.9 inches, d.b.h.; 8-ft log length.
[4]5-ft reduction in pole height if in first or last 8-ft section; 100 percent if in center 8-ft section.
[5]100 percent if rot is in conjunction with fire scar; 25 percent of degree 2 fire scar and no rot.
[6]50 percent of butt section.
[7]Not applicable.
[8]100 percent if rot is in the butt section.

wood poles (American Standard Association 1963) and visually applied to the trees during data collection. Grading specifications used for saw log grades were those developed by Gaines (1962) and included in the basic MULTI program. Veneer blocks were evaluated according to knot size and defect specifications outlined by Yerkes and Woodfin (1972). The basic MULTI program was adjusted to include changes in veneer log quality criteria. Stud logs were evaluated according to knot size and defect specifications outlined by Barger and Ffolliott (1970), and included in the program.

Standard errors were calculated for the General Ownership lands by means of cluster analysis techniques with unequal number of subplots, developed by J. L. Kovner, Rocky Mountain Station biometrician. Standard errors for Custer State Park lands were calculated with individual plot data considered as random sample observations.

Results and Discussion

Pole and sawtimber stands sampled in the 1968 survey of the General Ownership lands contained an average volume of 4,900 fbm gross Scribner scale per acre[4] in trees 9.0 inches d.b.h. and larger (fig. 1, table 3). When evaluated for products other than lumber, these stands contained gross volumes of about 4,700 fbm of veneer logs or 3,100 fbm of stud logs per acre. Volume deductions for visible defects were 9, 4, and 9 percent, respectively, for the three products.

If, on the other hand, each log or block were to be evaluated for its highest valued product, the same stands (fig. 2, table 3) would contain 10 commercial poles,[5] 4,190 fbm of logs — 21 percent saw logs, 76 percent veneer logs, and 3 percent stud logs — and 147 ft^3 of pulpwood per acre. Board-foot volume differences in table 3 are the result of shifting potential saw log material between alternative products.

Timber stand data of the same type were collected for Custer State Park by the South Dakota State Forester's Office during the initiation of a permanent sampling system for the Park. These data show that Custer State Park stands differ considerably from stands sampled on General Ownership lands. They contain smaller gross volumes per acre (fig. 1, table 3) in all single-product classes — 3,500 fbm of saw logs, 3,300 fbm of veneer logs, or 1,800 fbm of stud logs, which probably reflects the fact that Custer State Park includes some of the eastern "fringe" timber of the Black Hills ponderosa pine type with more open stands. The overall quality of the Custer State Park timber stand is higher, however (table 3), as indicated by higher proportions of saw log grades 1, 2, and 3, and veneer log grades 1 and 2. This higher quality may reflect past management practices in the Park, which limited cutting largely to sanitation salvage operations, thereby leaving the stand with a greater proportion of old-growth "high-quality" stems.

Estimated total cubic volume (pulpwood) in sawtimber and pole timber stands on General

[4]All board-foot (fbm) volume figures in this report are Scribner scale. Product volumes that have been reduced for visual scaling defects (table 2) are identified as "Reduced scale."

[5]Some of the stems classed as poles in the field survey may not be marketable as poles. Height/diameter ratio and red rot were not considered limitations in classifying stems as poles, due to the difficulty of evaluating these characteristics in standing trees.

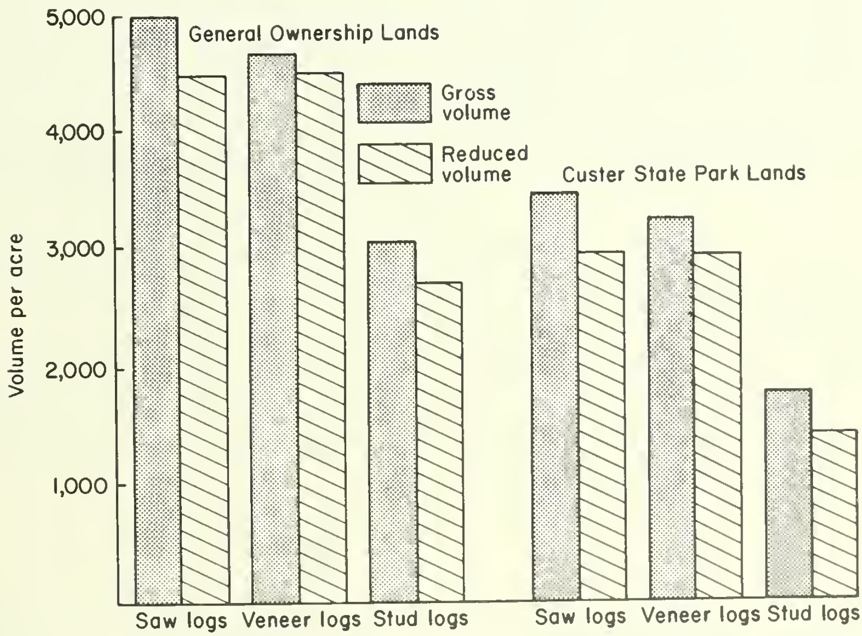

Figure 1. — Comparison of total volume per acre (gross and reduced, fbm, Scribner Scale) suitable for independent products.

Table 3.--Estimated volume per acre (board feet, Scribner scale), by independent product basis and on product priority basis

Tree d.b.h. class	INDEPENDENT PRODUCT BASIS						PRODUCT PRIORITY BASIS							
	Saw logs		Veneer logs[1]		Stud logs[2]		Saw logs		Veneer logs		Stud logs		Total	
(Inches)	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced
	- - - - Board feet - - - -						- - - - Board feet - - - -							
GENERAL OWNERSHIP LANDS														
10	496.52	433.94	536.03	501.35	554.44	479.65	44.97	34.43	367.45	340.47	34.34	1.01	446.76	375.91
12	908.21	813.26	856.02	814.53	788.18	702.00	88.76	72.42	569.54	541.98	34.54	1.23	692.84	615.63
14	1,020.34	919.94	955.70	916.24	748.73	670.26	119.82	98.43	678.61	648.33	36.88	2.89	835.31	749.65
16	867.14	791.22	804.09	788.16	531.92	493.48	143.12	126.16	546.72	535.54	29.69	8.83	719.53	670.53
18	650.31	587.00	603.38	583.46	325.93	290.30	172.89	141.05	383.85	373.09	5.43	0.0	562.17	514.14
20	387.39	365.94	364.10	355.09	90.07	87.57	109.11	101.89	227.60	223.79	2.44	1.22	339.15	326.90
22	253.77	234.83	225.40	224.14	13.03	13.03	98.08	86.87	151.61	150.60	0.0	0.0	249.69	237.47
24	153.57	139.07	141.92	139.35	--	--	44.60	39.42	104.12	101.93	--	--	148.72	141.35
26	107.30	99.60	101.88	101.12	--	--	35.84	32.38	68.19	68.19	--	--	104.03	100.57
28	55.99	54.18	51.51	51.03	--	--	8.31	8.31	43.30	42.82	--	--	51.61	51.13
30	13.61	13.61	13.61	13.61	--	--	4.90	4.90	8.71	8.71	--	--	13.61	13.61
32	30.34	26.19	26.09	21.54	--	--	10.92	6.77	15.17	15.17	--	--	26.09	21.94
Total	4,944.49	4,478.78	4,679.73	4,509.62	3,052.30	2,736.29	881.32	753.03	3,164.87	3,050.62	143.32	15.18	4,189.51	3,818.83
							- - - - Percent - - - -							
							21	20	76	80	3	<.5	100	100
CUSTER STATE PARK LANDS														
							- - - - Board feet - - - -							
10	274.05	224.41	333.71	272.82	330.28	238.65	47.82	35.36	261.33	209.68	26.29	0.0	335.44	245.04
12	563.66	459.29	550.19	472.67	379.28	302.06	156.17	124.71	370.04	317.22	11.57	0.0	537.78	441.93
14	679.10	583.81	635.52	579.60	409.89	341.52	218.20	182.06	345.16	310.71	12.53	0.0	575.89	492.77
16	648.72	548.40	567.05	535.20	354.16	283.83	272.53	213.50	309.33	294.14	20.84	7.04	602.70	514.68
18	490.57	422.43	442.45	421.45	232.31	195.67	233.89	196.44	211.59	206.47	7.46	0.0	452.94	402.91
20	437.83	383.00	388.11	370.36	77.05	69.28	166.88	134.16	222.81	217.16	2.70	0.0	392.39	351.32
22	232.15	210.61	194.07	190.68	11.87	11.57	93.30	78.15	125.97	124.91	0.0	0.0	219.27	203.06
24	97.32	89.96	92.32	87.51	--	--	52.89	47.00	44.43	43.73	--	--	97.32	90.73
26	48.54	45.22	41.00	37.52	--	--	22.66	19.88	22.19	21.59	--	--	44.85	41.47
28	0.0	0.0	0.0	0.0	--	--	0.0	0.0	0.0	0.0	--	--	0.0	0.0
30	7.58	7.58	5.69	5.69	--	--	3.64	3.64	4.02	4.02	--	--	7.66	7.66
Total	3,479.52	2,974.71	3,250.11	2,973.50	1,794.84	1,442.58	1,267.98	1,034.90	1,916.87	1,749.63	81.39	7.04	3,266.24	2,791.57
							- - - - Percent - - - -							
							39	37	59	63	2	<.5	100	100

[1]Includes grades 1 and 2 veneer logs

[2]Includes only grades 1, 2, and 3 stud logs

Ownership lands was 1,257 ft^3 per acre for 9.0-inch and larger trees, but only 147 ft^3 were left as a residual after the higher valued products were deducted. Similar estimates for Custer State Park lands were 933 ft^3, of which only 126 ft^3 remained after higher valued products were deducted.

Because poles were considered the highest valued potential product, the pole count per acre was the same whether the stands were analyzed for the yield of either a single product or for multiple products under a product priority system (table 4). To more precisely estimate pole values, table 5 (appendix) indicates the number of poles per acre in each d.b.h. class by pole length and estimated top diameter for General Ownership lands.

Detailed data describing volumes per acre by grades for the other products considered are similarly presented in tables 5 through 8 (appendix).

As an example of the kinds of comparisons that can be drawn from these analyses, note that the independent product analyses for General Ownership stands indicate about equal volumes of timber suitable for saw logs and veneer logs (table 3). However, if the product priorities based on potential value are applied, the timber volume allocated to veneer logs is about 3½ times that allocated to saw logs (table 3). These proportions will change any time different product priorities or specifications are used. The usefulness of such information in deciding what products to manufacture or what timber management objectives to establish is apparent.

Conclusions

A multiproduct analysis of the type described here provides the resource manager with qualitative and quantitative information on the timber stand that allows him to realistically evaluate alternative management objectives. Treatments that would emphasize an individual product can be compared against treatments to produce a mix of products, with specific products given priority according to their value.

This type of analysis in the Black Hills indicates that ponderosa pine stands on public (General Ownership) lands contain gross volumes per acre of 4,944 fbm of saw logs, 4,680 fbm of veneer logs, or 3,052 fbm of stud logs if inventoried for these products individually. However, if inventoried simultaneously for highest multiproduct potentials, the same stands would contain gross allocated volumes of 881, 3,165, and 143 fbm per acre for each product, respectively.

By comparison, Custer State Park lands contain smaller gross volumes per acre, but of higher quality. If inventoried for a single product, the stands would contain gross volumes of 3,480 fbm of saw logs, 3,250 fbm of veneer logs, or 1,795 fbm of stud logs. However, if inventoried for multiproduct potential, these stands would contain 1,268 fbm of saw logs, 1,917 fbm of veneer logs, and 81 fbm of stud logs per acre.

These analyses demonstrate the usefulness of multiproduct evaluation techniques in evaluating utilization alternatives. Successful application of the multiproduct inventory and analysis system to Black Hills ponderosa pine

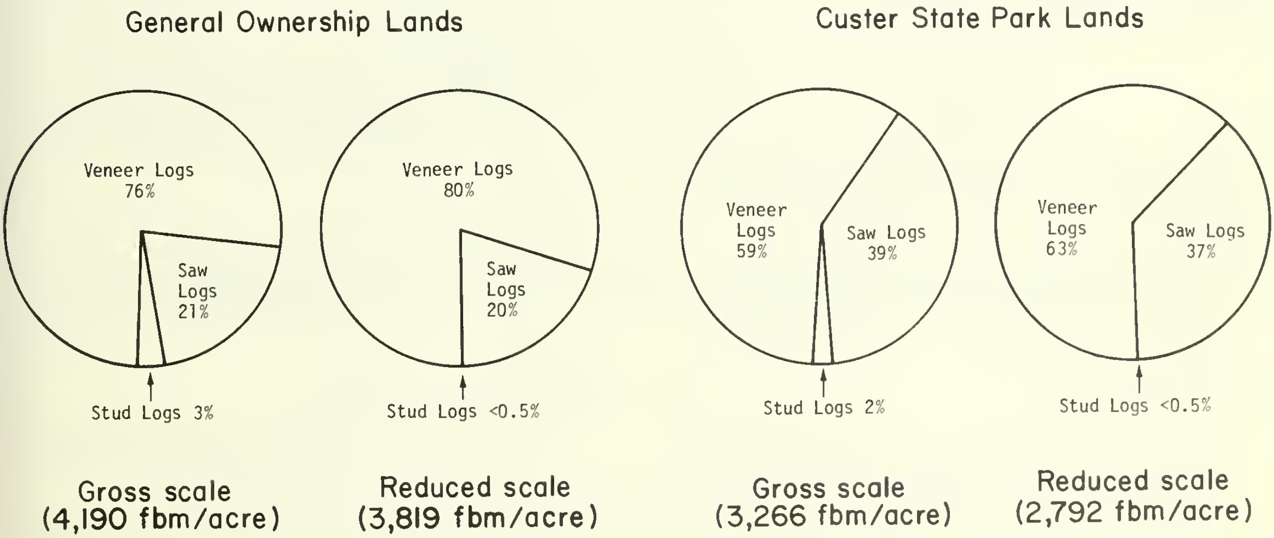

Figure 2. — Comparison of the proportion of Black Hills timber stands suitable for the highest valued individual products.

Table 4.--Estimated number of poles per acre by pole height

Tree d.b.h. class (Inches)	Pole height (ft)									
	15	20	25	30	35	40	45	50	55	60	Total
					GENERAL OWNERSHIP LANDS[1]						
10	0.06	1.85	1.24	0.78	0.10	--	0.01	--	--	--	4.04
12	.06	1.21	.86	.83	.37	0.04	--	--	--	--	3.37
14	.01	.47	.47	.24	.27	.11	--	0.01	--	--	1.58
16	.02	.16	.13	.20	.16	.07	.02	.01	--	--	.77
18	--	.12	.06	.06	.01	--	.03	.01	--	--	.29
20	--	.03	.01	.01	.03	--	--	--	--	0.01	.09
Total	.15	3.84	2.77	2.12	.94	.22	.06	.03	--	.01	10.14
					CUSTER STATE PARK LANDS[1]						
10	--	.37	.81	--	--	--	--				1.18
12	--	.10	.18	.16	--	--	--				.44
14	--	.23	.23	.14	.08	.04	--				.72
16	.03	.06	.09	--	.03	--	--				.21
18	--	.04	.03	--	.02	--	.02				.11
20	.02	.02	.02	.02	.02	.02	--				.12
Total	.05	.82	1.36	.32	.15	.06	.02				2.78

[1] Some of the stems classed as poles in the field survey may not be marketable as poles. Height/diameter ratio and red rot were not considered limitations in classifying stems as poles, due to the difficulty of evaluating these characteristics in standing trees.

stands suggests that any timber resource can be similarly analyzed, using appropriate product specifications and priorities.

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Appendix

Detailed Product Volumes Per Acre — Independent Product and Product Priority Bases

Table 5.--Estimated number of poles per acre by d.b.h. classes, General Ownership lands[1]

Pole height (feet)	Pole top diameter outside bark (inches)														
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total
	10-inch d.b.h. class (273 trees)														
15	--	0.040	0.013	0.010	--										0.063
20	0.040	.581	.857	.329	0.044										1.851
25	.084	.541	.487	.111	--										1.223
30	.111	.430	.202	.020	.020										.783
35	.040	.010	.044	.010	--										.104
40	--	--	--	--	--										--
45	--	.010	--	--	--										.010
Total	.275	1.612	1.603	.480	.064										4.034
	12-inch d.b.h. class (224 trees)														
15	--	.010	--	.020	.024	0.010	--								.064
20	.040	.013	.222	.501	.222	.198	0.010								1.206
25	--	.158	.215	.215	.218	.044	--								.850
30	.020	.192	.289	.245	.084	--	--								.830
35	.010	.091	.104	.151	.010	--	--								.366
40	.010	--	--	.030	--	--	--								.040
Total	.080	.464	.830	1.162	.558	.252	.010								3.356
	14-inch d.b.h. class (116 trees)														
15	--	--	--	--	--	.010	--	--	--						.010
20	--	--	--	.067	.111	.124	.087	0.081	--						.470
25	--	--	.020	.030	.094	.195	.081	.034	0.020						.474
30	--	.020	.040	.074	.050	.044	.010	--	--						.238
35	--	.034	.064	.050	.044	.054	.020	--	--						.266
40	.010	--	.050	.030	.010	.010	--	--	--						.110
45	--	--	--	--	--	--	--	--	--						--
50	--	--	--	--	--	.010	--	--	--						.010
Total	.010	.054	.174	.251	.309	.447	.198	.115	.020						1.578
	16-inch d.b.h. class (58 trees)														
15		--	--	--	--	--	--	.020	--	--					.020
20		--	--	--	--	.071	.020	.030	.020	0.020					.161
25		--	--	.024	--	.010	.050	.020	.030	--					.134
30		--	--	--	.040	.044	.030	.054	.030	--					.198
35		.010	.024	.034	.013	.020	.030	.020	.013	--					.164
40		.010	--	.010	.024	.013	.013	--	--	--					.070
45		--	.010	.010	--	--	--	--	--	--					.020
50		--	--	--	--	.010	--	--	--	--					.010
Total		.020	.034	.078	.077	.168	.143	.144	.093	.020					.777
	18-inch d.b.h. class (21 trees)														
20						--	--	.050	.010	.020	--	0.040			.120
25						--	.010	.020	.010	.020	--	--			.060
30						--	.030	--	.010	--	0.010	.010			.060
35						--	--	.013	--	--	--	--			.013
40						--	--	--	--	--	--	--			--
45						.020	.010	--	--	--	--	--			.030
50						.013	--	--	--	--	--	--			.013
Total						.033	.050	.083	.030	.040	.010	.050			.296
	20-inch d.b.h. class (9 trees)														
20									--	--	--	--	0.020	0.010	.030
25									--	.010	--	--	--	--	.010
30									.010	--	--	--	--	--	.010
35									--	.013	.010	.010	--	--	.033
40									--	--	--	--	--	--	--
45									--	--	--	--	--	--	--
50									--	--	--	--	--	--	--
55									--	--	--	--	--	--	--
60									--	.010	--	--	--	--	.010
Total									.010	.033	.010	.010	.020	.010	.093

[1]Some of the stems classed as poles in the field survey may not be marketable as poles. Height/diameter ratio and red rot were not considered limitations in classifying stems as poles, due to the difficulty of evaluating these characteristics in standing trees.

Table 6.--Estimated saw-log volume per acre (board feet, Scribner scale), by independent product basis and on product priority basis

Tree d.b.h. class (Inches)	Grade 1		Grade 2		Grade 3		Grade 5		Total	
	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced
GENERAL OWNERSHIP LANDS										
INDEPENDENT PRODUCT BASIS										
10	0.83	0.65	4.41	3.63	44.07	33.51	447.21	396.15	496.52	433.94
12	4.46	3.51	12.64	9.54	87.31	72.57	803.80	727.64	908.21	813.26
14	8.62	6.62	30.60	22.25	106.40	94.00	874.72	797.07	1,020.34	919.94
16	19.17	18.31	24.03	20.62	122.19	111.78	701.75	640.51	867.14	791.22
18	27.24	24.52	40.30	33.15	117.51	98.06	465.26	431.27	650.31	587.00
20	17.58	14.18	32.31	29.96	62.33	60.74	275.17	261.06	387.39	365.94
22	34.67	28.50	21.32	20.91	35.34	33.41	162.44	152.01	253.77	234.83
24	10.72	8.22	2.98	2.60	27.84	27.30	112.03	100.95	153.57	139.07
26	8.03	7.19	3.32	3.32	24.49	21.87	71.46	67.22	107.30	99.60
28	4.28	4.28	0.0	0.0	4.03	4.03	47.68	45.87	55.99	54.18
30	0.0	0.0	0.0	0.0	4.90	4.90	8.71	8.71	13.61	13.61
32	10.92	6.77	0.0	0.0	0.0	0.0	19.42	19.42	30.34	26.19
Total	146.52	122.75	171.91	145.98	636.41	562.17	3,989.65	3,647.88	4,944.49	4,478.78
Standard error	18.28	15.65	16.14	14.06	49.40	44.28	156.44	147.81		
PRODUCT PRIORITY BASIS										
10	.83	.65	3.81	3.11	40.16	29.76	.17	.91	44.97	34.43
12	3.90	2.95	11.50	8.39	71.76	58.00	1.60	3.08	88.76	72.42
14	7.98	5.98	28.96	20.80	80.21	69.41	2.67	2.24	119.82	98.43
16	17.19	16.33	20.58	17.17	98.00	88.08	7.35	4.58	143.12	126.16
18	27.24	24.52	35.73	28.58	101.92	83.20	8.00	4.75	172.89	141.05
20	15.76	12.82	32.31	29.96	60.44	58.85	.60	.26	109.11	101.89
22	34.67	28.50	21.32	20.91	35.34	33.41	6.75	4.05	98.08	86.87
24	10.72	8.22	2.98	2.60	27.84	27.30	3.06	1.30	44.60	39.42
26	8.03	7.19	3.32	3.32	24.49	21.87	0.0	0.0	35.84	32.38
28	4.28	4.28	0.0	0.0	4.03	4.03	0.0	0.0	8.31	8.31
30	0.0	0.0	0.0	0.0	4.90	4.90	0.0	0.0	4.90	4.90
32	10.92	6.77	0.0	0.0	0.0	0.0	0.0	0.0	10.92	6.77
Total	141.52	118.21	160.51	134.84	549.09	478.81	30.20	21.17	881.32	753.03
Standard error	17.99	15.42	15.65	13.57	43.28	38.13	4.90	2.83		
CUSTER STATE PARK LANDS										
INDEPENDENT PRODUCT BASIS										
10	4.85	4.43	0.0	0.0	45.03	32.16	224.17	187.82	274.05	224.41
12	12.56	10.44	26.29	19.62	117.55	92.09	407.26	337.14	563.66	459.29
14	26.93	20.71	59.98	50.70	149.14	128.41	443.05	383.99	679.10	583.81
16	30.89	22.39	59.66	44.45	188.21	157.18	369.96	324.38	648.72	548.40
18	20.30	15.91	47.06	40.14	170.56	144.53	252.65	221.85	490.57	422.43
20	18.91	13.52	20.72	17.50	129.10	113.00	269.10	238.98	437.83	383.00
22	26.27	22.02	19.17	16.37	41.62	37.28	145.09	134.94	232.15	210.61
24	15.24	12.40	11.05	8.87	23.67	23.10	47.36	45.59	97.32	89.96
26	6.11	4.28	10.16	9.21	6.39	6.39	25.88	25.34	48.54	45.22
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	3.64	3.64	0.0	0.0	3.94	3.94	7.58	7.58
Total	162.06	126.10	257.73	210.50	871.27	734.14	2,188.46	1,903.97	3,479.52	2,974.71
Standard error	30.79	24.89	40.30	33.80	102.86	88.10	192.43	168.36		
PRODUCT PRIORITY BASIS										
10	4.85	4.43	0.0	0.0	42.97	30.61	0.0	0.32	47.82	35.36
12	12.56	10.44	26.29	19.62	114.81	90.04	2.51	4.61	156.17	124.71
14	26.93	20.71	56.70	47.84	132.07	111.34	2.50	2.17	218.20	182.06
16	30.89	22.39	59.66	44.45	173.26	142.66	8.72	4.00	272.53	213.50
18	20.30	15.91	43.54	36.62	165.17	139.14	4.88	4.77	233.89	196.44
20	15.81	10.82	20.72	17.50	110.69	95.09	19.66	10.75	166.88	134.16
22	26.27	22.02	19.17	16.37	41.62	37.28	6.24	2.48	93.30	78.15
24	15.24	12.40	11.05	8.87	23.67	23.10	2.93	2.63	52.89	47.00
26	6.11	4.28	10.16	9.21	6.39	6.39	0.0	0.0	22.66	19.88
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	3.64	3.64	0.0	0.0	0.0	0.0	3.64	3.64
Total	158.96	123.40	250.93	204.12	810.65	675.65	47.44	31.73	1,267.98	1,034.90
Standard error	30.79	24.88	39.11	32.57	95.58	80.54	14.66	8.99		

Table 7.--Estimated veneer-log volume per acre (board feet, Scribner scale), by independent product basis and on product priority basis

Tree d.b.h. class	INDEPENDENT PRODUCT BASIS								PRODUCT PRIORITY BASIS					
	Grade 1		Grade 2		Total		Unacceptable		Grade 1		Grade 2		Total	
(Inches)	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced
							GENERAL OWNERSHIP LANDS							
10	493.84	462.18	42.19	39.17	536.03	501.35	48.39	.41	331.62	307.49	35.83	32.98	367.45	340.47
12	685.97	650.63	170.05	163.90	856.02	814.53	70.38	2.04	438.40	416.15	131.14	125.83	569.54	541.98
14	617.55	587.92	338.15	328.32	955.70	916.24	71.88	1.66	397.38	376.02	281.23	272.31	678.61	648.33
16	433.88	422.99	370.21	365.17	804.09	788.16	66.68	4.55	233.21	226.98	313.51	308.56	546.72	535.54
18	274.01	260.58	329.37	322.88	603.38	583.46	46.93	6.54	115.40	110.99	268.45	262.10	383.85	373.09
20	156.58	149.29	207.52	205.80	364.10	355.09	23.29	2.99	51.24	48.81	176.36	174.98	227.60	223.79
22	90.24	89.99	135.16	134.15	225.40	224.14	28.36	4.72	28.69	28.69	122.92	121.91	151.61	150.60
24	47.91	47.52	94.01	91.83	141.98	139.35	11.66	0.0	14.62	14.62	89.50	87.31	104.12	101.93
26	46.75	45.99	55.13	55.13	101.88	101.12	5.41	1.19	16.60	16.60	51.59	51.59	68.19	68.19
28	10.41	10.41	41.10	40.62	51.51	51.03	4.48	3.19	4.02	4.02	39.28	38.80	43.30	42.82
30	2.72	2.72	10.89	10.89	13.61	13.61	0.0	0.0	0.0	0.0	8.71	8.71	8.71	8.71
32	10.92	6.37	15.17	15.17	26.09	21.54	4.25	4.25	0.0	0.0	15.17	15.17	15.17	15.17
Total	2,870.78	2,736.59	1,808.95	1,773.03	4,679.73	4,508.62	381.71	31.54	1,631.18	1,550.37	1,533.69	1,500.25	3,164.87	3,050.62
Standard error	111.24	107.36	78.15	77.60			21.90	4.87	72.16	69.73	67.62	66.91		
							CUSTER STATE PARK LANDS							
10	265.80	216.93	67.91	55.89	333.21	272.82	46.04	1.10	201.23	160.95	60.10	48.73	261.33	209.68
12	325.27	272.52	224.92	200.15	550.19	472.67	53.76	8.72	173.74	143.32	196.30	173.90	370.04	317.22
14	334.78	296.04	300.74	283.56	635.52	579.60	49.81	8.71	118.68	100.08	226.48	210.63	345.16	310.71
16	278.30	254.59	288.75	280.61	567.05	535.20	93.91	11.48	91.24	81.95	218.09	212.19	309.33	294.14
18	203.06	185.72	239.39	235.73	442.45	421.45	50.14	11.42	41.99	39.14	169.60	167.33	211.59	206.47
20	143.27	130.35	244.84	240.01	388.11	370.36	50.72	12.92	35.17	33.48	187.64	183.68	222.81	217.16
22	66.59	63.81	127.48	126.87	194.07	190.68	39.08	12.90	17.53	16.47	108.44	108.44	125.97	124.91
24	39.77	34.96	52.55	52.55	92.32	87.51	4.99	4.66	2.96	2.26	41.47	41.47	44.43	43.73
26	15.07	12.52	25.93	25.00	41.00	37.52	7.54	7.54	3.19	3.19	19.00	18.40	22.19	21.59
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	1.67	1.67	4.02	4.02	5.69	5.69	1.89	1.89	0.0	0.0	4.02	4.02	4.02	4.02
Total	1,673.58	1,469.11	1,576.53	1,504.39	3,250.11	2,973.50	397.88	81.34	685.73	580.84	1,231.14	1,168.79	1,916.87	1,749.63
Standard error	151.87	138.45	134.74	131.93			42.00	18.41	81.53	70.56	109.46	106.08		

Table 8.--Estimated stud-log volume per acre (board feet, Scribner scale), by independent product basis and on product priority basis

Tree d.b.h. class (Inches)	Grade 1		Grade 2		Grade 3		Total		Unacceptable	
	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced	Gross	Reduced
					GENERAL OWNERSHIP LANDS					
INDEPENDENT PRODUCT BASIS										
10	194.91	166.94	323.10	281.93	36.43	30.78	554.44	479.65	18.06	12.35
12	270.62	233.81	445.78	403.79	71.78	64.40	805.39	702.00	71.74	54.53
14	296.37	251.17	360.88	334.32	91.48	84.77	748.73	670.26	133.18	115.13
16	248.54	226.75	210.98	200.49	72.40	66.24	531.92	493.48	159.22	145.01
18	187.89	162.29	111.00	102.63	27.04	25.38	325.93	290.30	146.29	135.08
20	44.15	43.19	33.04	32.12	12.88	12.26	90.07	87.57	66.28	61.84
22	4.82	4.82	5.76	5.76	2.45	2.45	13.03	13.03	30.39	28.40
Total	1,247.30	1,088.97	1,490.55	1,361.04	314.45	286.28	3,052.30	2,736.29	625.16	552.34
Standard error	61.91	54.80	76.40	71.86	15.52	15.26			28.00	25.09
PRODUCT PRIORITY BASIS										
10	12.46	.46	18.92	.48	2.96	.07	34.34	1.01		
12	9.20	.74	21.32	.49	4.02	0.0	34.54	1.23		
14	21.39	1.37	12.81	1.52	2.68	0.0	36.88	2.89		
16	13.44	3.96	10.66	4.20	5.59	.67	29.69	8.83		
18	2.81	0.0	2.62	0.0	0.0	0.0	5.43	0.0		
20	0.0	0.0	1.19	.60	1.25	.62	2.44	1.22		
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total	59.30	6.53	67.52	7.29	16.50	1.36	143.32	15.18		
Standard error	7.65	1.81	5.95	1.73	1.74	.38				
					CUSTER STATE PARK LANDS					
INDEPENDENT PRODUCT BASIS										
10	111.14	71.07	189.19	143.49	29.95	24.09	330.28	238.65	42.15	27.96
12	184.83	139.48	160.06	133.04	34.39	29.54	379.28	302.06	172.07	128.82
14	204.15	166.39	155.85	129.66	49.89	45.47	409.89	341.52	162.55	135.20
16	205.38	156.16	122.86	106.29	25.92	21.38	354.16	283.83	165.60	147.16
18	152.22	128.99	70.77	57.36	9.32	9.32	232.21	195.67	125.19	113.20
20	34.43	28.66	29.69	27.69	12.93	12.93	77.05	69.28	101.14	94.80
22	5.08	4.78	6.79	6.79	0.0	0.0	11.33	11.57	28.95	26.42
Total	897.23	695.53	735.21	604.32	162.40	142.73	1,794.84	1,442.58	797.65	673.56
Standard error	96.62	78.69	82.86	70.50	16.22	15.46			70.93	60.77
PRODUCT PRIORITY BASIS										
10	8.37	0.0	17.18	0.0	.74	0.0	26.29	0.0		
12	5.42	0.0	3.42	0.0	2.73	0.0	11.57	0.0		
14	0.0	0.0	10.80	0.0	1.73	0.0	12.53	0.0		
16	9.58	2.14	9.18	4.16	2.08	.74	20.84	7.04		
18	1.50	0.0	5.96	0.0	0.0	0.0	7.46	0.0		
20	1.39	0.0	1.31	0.0	0.0	0.0	2.70	0.0		
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Total	26.26	2.14	47.84	4.16	7.29	.74	81.39	7.04		
Standard error	5.99	1.54	8.99	2.30	2.56	.53				

Agriculture—CSU, Ft. Collins

Yerkes, Vern P.
1974. Black Hills ponderosa pine timber: Poles, saw logs, veneer logs, stud logs, or pulp? USDA For. Serv. Res. Pap. RM-118, 12p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

A multiproduct analysis indicates that public lands contain gross volumes per acre of 4,944 board feet (fbm) of saw logs, 4,680 fbm of veneer logs, or 3,052 fbm of stud logs if inventoried for these products individually. If inventoried simultaneously for highest multiproduct potentials, however, they contained gross allocated volumes of 881, 3,165, and 143 fbm per acre for each product, respectively. These analyses demonstrate the usefulness of multiproduct evaluation techniques in evaluating utilization alternatives.

Oxford: 228:831.4:832.10,20:861.0. **Keywords:** Poles, saw logs, veneer logs, stud logs, pulp, *Pinus ponderosa.*

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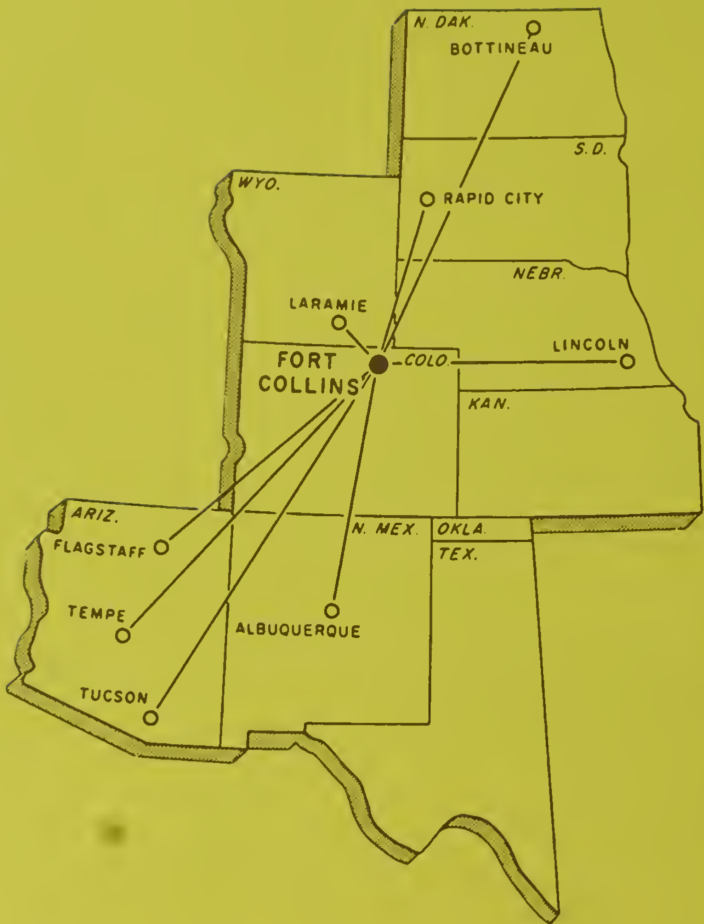

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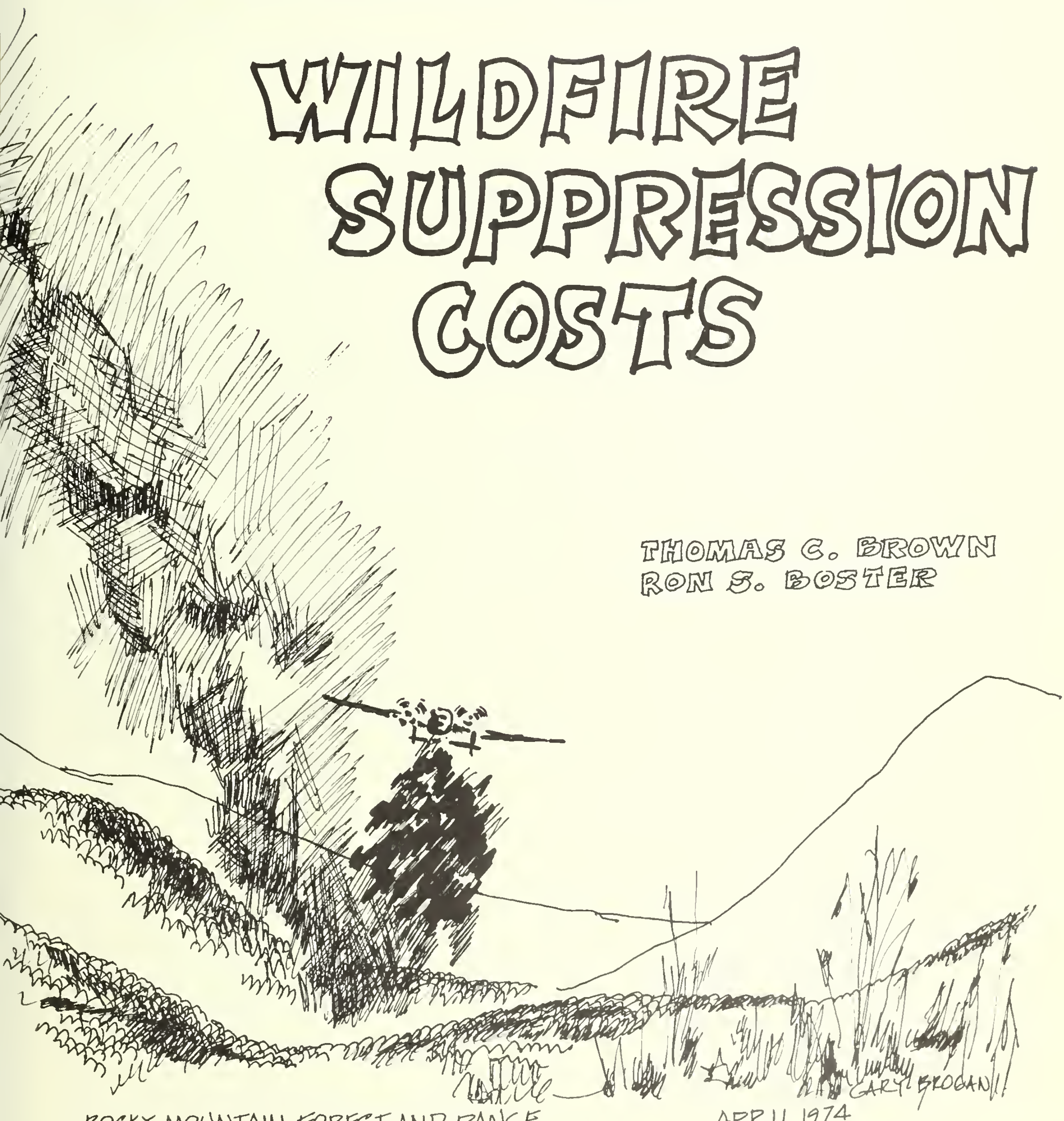
EFFECTS OF CHAPARRAL -TO- GRASS CONVERSION ON

WILDFIRE SUPPRESSION COSTS

THOMAS C. BROWN
RON S. BOSTER



ROCKY MOUNTAIN FOREST AND RANGE
EXPERIMENT STATION

APRIL 1974
RESEARCH PAPER

Abstract

Properly planned, carried out, and maintained, chaparral-to-grass conversions should reduce the occurrence of large, expensive wildfires. Dollar values of "fire benefits" were calculated for 141 convertible areas in Arizona's Salt-Verde Basin. Case histories of large chaparral fires are analyzed to illustrate principles of chaparral and grass fires in the Southwest. Historical fire data were used in a predictive model, but where data were absent or insufficient, parameters were varied within specified limits. The fire benefit, though not as high as water and forage benefits resulting from conversion, is an important addition to a benefit-cost analysis. The fire benefit varies significantly from area to area because of differences in man-caused and lightning risks, and also in accessibility. While transference of dollar values to other areas is tenuous, the methodology is transferable and can be a very useful planning tool.

Oxford: 436:651.7:432.16:268.44. **Keywords:** Fire use, economic evaluation, fire hazard reduction, chaparral conversion.

USDA Forest Service
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April 1974

Effects of Chaparral-to-Grass Conversion on Wildfire Suppression Costs*

by

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and

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**Paper presented at 16th Annual Meeting of the Western Regional Science Association, Long Beach, California, February 22, 1974.*

†Authors are located at Station's Research Work Unit at Tucson, in cooperation with the University of Arizona under Cooperative Agreement 16-344-CA; Station's central headquarters is maintained at Fort Collins, in cooperation with Colorado State University.

Contents

Effects of Chaparral-to-Grass Conversion on Wildfire Suppression Costs

Thomas C. Brown and Ron S. Boster

If properly planned, carried out, and maintained, chaparral-to-grass[1] conversions can favorably influence water yield (Hibbert and Ingebo 1971), forage (Pond 1967), sediment (Boster and Davis 1972), recreation (O'Connell 1972a),[2] and wildlife habitat (Reynolds 1972). Practical experience has reinforced research findings. Conversions are costly, however, and the increased productivity is less than certain. The relevant question, therefore, is: are the conversion benefits worth the costs?

A truly comprehensive economic analysis of chaparral-to-grass conversion requires a full accounting of all the relevant costs and benefits. The total benefit is the sum of the individual benefits attributable to specific resources or products. The costs of chaparral-to-grass conversions are reasonably well known, as are the benefits from the traditional watershed products — water, forage, and recreation (O'Connell 1972b). There is, however, one benefit resulting from conversion that never has been adequately identified. This "fire benefit" is illustrated by the following example.

For 7 days in May 1972, the Battle Fire raged on the Prescott National Forest, Arizona — the first Class E or larger (300 acres and above) fire on that Forest in 14 years. The fire started in an area that was a classic conversion site — gentle slopes, good access, and dense brush — and burned 14,000 acres of chaparral plus 13,500 acres of pine and mixed pine and chaparral. The suppression cost was $1.4 million. The intense heat of this wildfire destroyed more organic matter and left the soil more vulnerable to erosion than would a properly planned prescribed burn. Ironically, the Battle Flat area (where the fire started) was planned as a conversion project 6 years earlier, but funds never were made available. There is general agreement that, had the area been converted to and maintained as weeping lovegrass *(Eragrostis curvula)*, a fire starting under identical conditions would have been held to approximately 160 acres at a probable suppression cost of less than $12,000.

Only through hindsight could one argue that the Battle Flat conversion would have been economical. Battle Flat was not the only candidate for conversion, nor was it the only target for a fire. This example should be taken only as illustrative of how conversion of chaparral to grass can decrease the occurrence of large, expensive fires. Once this obvious, but elusive, benefit is quantified, it can be incorporated into a comprehensive management framework that considers all products and alternatives in relation to costs.

Conversion of a chaparral area to grass is generally thought to contribute two fire-related benefits: (1) a decrease in wildfire suppression costs, and (2) a reduction in resource damage. This study is restricted to consideration of the first category only.

There can be no argument that wildfire often does great harm. Watersheds are not, however, vulnerable to total "destruction" as often implied by reported damages. Land does not stay damaged forever, so that damages in excess of either the market or productive value of the land defy economic logic. Besides, resource damages should be balanced with ecologic and productive benefits which also often result from wildfires. Fire-caused land damages and benefits are complex topics deserving special treatment, and therefore are deferred to a future study.

Specifically, then, this Paper concentrates on the benefits associated with conversion of chaparral to grass attributable to the reduction of fire suppression costs. Because of esthetic, wildlife, recreation, and soil considerations, only a 60 percent conversion is assumed. Thus, either isolated patches of chaparral are left untreated within the conversion area, or such patches are allowed to return to a chaparral cover following initial brush treatment.

Study Area and Methods

The Salt-Verde Basin — an 8.4-million-acre watershed in Arizona defined by the drainage of

[1] *The Arizona chaparral type consists of broad sclerophyll shrub communities of mostly low-growing, moderate to deep-rooted species with thick evergreen leaves. Shrub live oak* (Quercus turbinella) *is the dominant species of most stands.*

[2] *More information is available in a larger in-Service report available upon request from the Rocky Mt. For. and Range Exp. Stn., Tucson, Arizona.*

the Salt and Verde Rivers above Granite Reef Dam (fig. 1) — was the study area for this investigation. The Basin is the most important water-producer in the State; cattle grazing and timber production are significant land uses, and the Basin also offers outstanding outdoor recreation opportunities.

The Salt-Verde Basin contains approximately 1 million acres of chaparral. Some of this chaparral acreage is convertible, and conversion would increase wildland productivity in many instances. Not surprisingly, considerable interest exists across a broad spectrum for comprehensive study of the economics of such conversions.

Briefly, the study method was as follows. Possible conversion areas within the study area were identified (Brown 1973), and the fire histories of these and adjacent chaparral and grass areas were documented. These data, along with supplemental information regarding fire behavior, occurrence, and suppression costs, were then examined within an economic framework to determine the fire-related benefits of chaparral-to-grass conversions.

Chaparral Wildfire

Considerable money is spent each year on the Tonto and Prescott National Forests fighting chaparral wildfires. From 1962 to 1972, 420 chaparral fires were reported on the Tonto; 137 on the Prescott. Each of these fires required some action by Forest Service personnel; per-fire suppression costs ranged from near zero to more than $1 million.

The probability of a fire start can be described as a function of fire hazard and risk (Deeming et al. 1972). Fire hazard is determined by weather and fuel conditions. The important weather variables are present and antecedent temperature, humidity, and rainfall. High temperatures and low humidity favor fire starts.

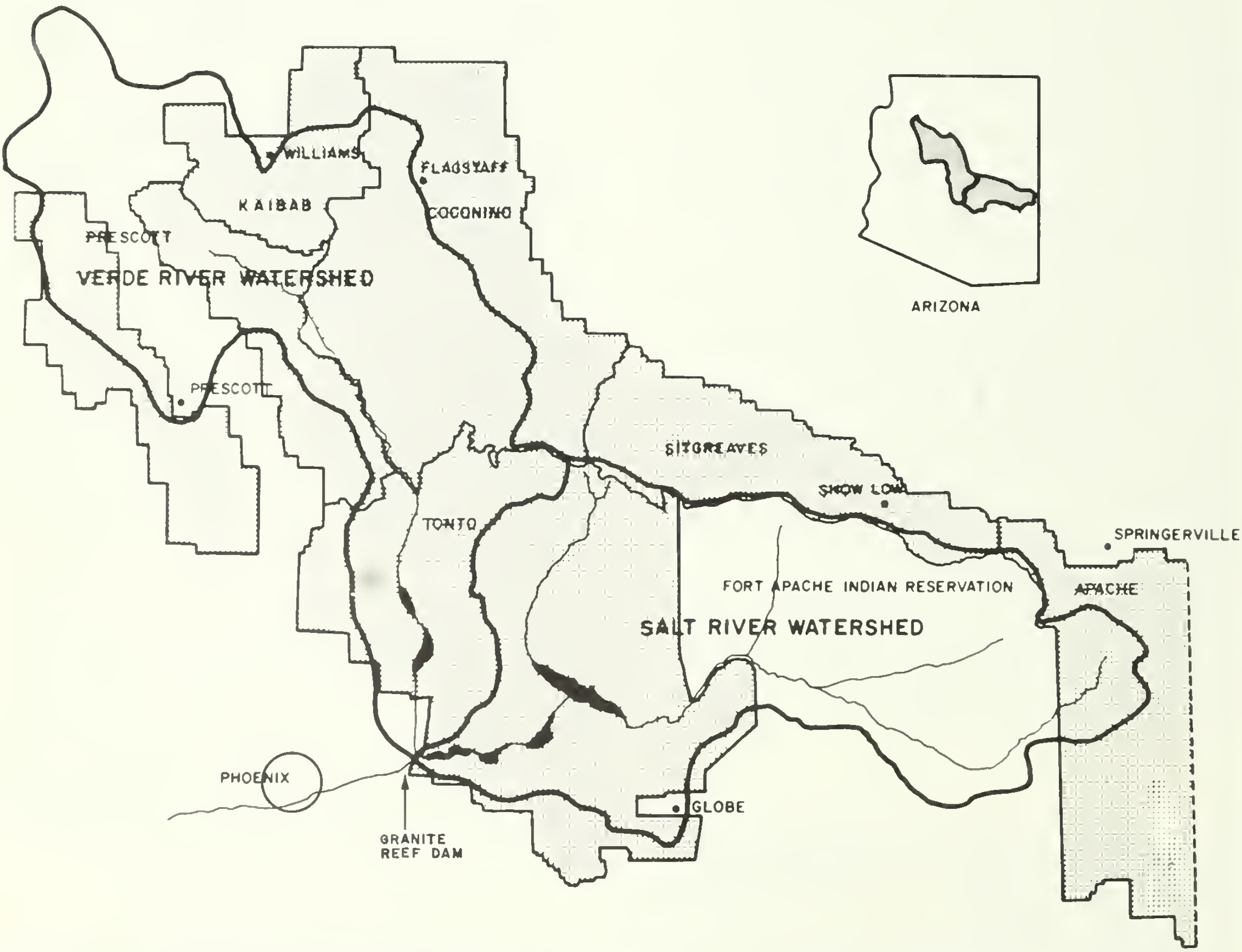

Figure 1. — Salt-Verde Basin, including the Prescott, Kaibab, Coconino, Tonto and Apache-Sitgreaves National Forests.

The longer these conditions persist in any particular season, the more likely fires become. Previous season's rainfall is important because rainfall favors growth of grasses and forbs, which are easily ignitable when cured.

The fuel situation in chaparral depends, in large part, on the amount of cured grass and dead, desiccated chaparral present in the stand. Sparse chaparral stands usually have grass and/or forbs between the bushes (unless the area has been overgrazed). In these areas, herbaceous growth is often as important as the chaparral in carrying a fire. In denser chaparral stands, which have less grass, fire starts are less frequent; fires, when they occur, are fierce and literally jump from one chaparral clump to another (Lindenmuth and Davis 1973). Several years are required for chaparral alone to produce sufficient fuel to carry a fire. Pond and Bohning (1971) estimate that at least 10 to 15 years are generally required for a shrub live oak stand to reburn. Baldwin[3] has estimated that, for Arizona, a dense chaparral stand normally will not burn for 15 to 20 years following a fire, and that about 35 years may be required for sufficient fuels to develop to support a conflagration.

Risk of wildfire (the probability of ignition) is a function of access, human use, and lightning incidence. The better the access to an area and the more human use it receives, the greater the chance of a man-caused fire start. Likewise, the more often lightning strikes an area, the greater the chance of a lightning fire start.

The size a fire will reach depends on a combination of natural and man-influenced variables. Weather is important, particularly wind, temperature, net radiation, humidity, and rainfall. Topography, too, is important, especially in conjunction with wind. Fuels must be dense and dry for a large fire to develop (Lindenmuth and Davis 1973). Also, man's firefighting efforts and capabilities must be considered. Finally, seasonal variations in the abovementioned factors are important.

Both detection and access help determine how soon a fire is attacked and controlled. While there is considerable variation in the ability to observe and reach the different chaparral areas in the Salt-Verde Basin, this variation has lessened considerably in recent years with technological advances. Air surveillance can locate fires far from lookouts, and helicopters and air tankers can move men and equipment and drop fire retardant on target within minutes. The well-planned and relatively well-funded fire suppression efforts of the Forest Service hold most fires to within a few acres. However, even with the current sophistication, occasionally a fire — such as the Battle Fire — escapes.

Effect of Conversion on Wildfire Suppression

A 60 percent conversion of dense chaparral stands to lovegrass has a definite effect on firefighting efforts in and near the conversion areas. The probability of a fire start is influenced by the changes in vegetative cover (hazard) and access (man-caused risk). Likewise, the ultimate size of a fire starting in or near the conversion area will be influenced by the change in fuels and available access.

For illustrative purposes, we divided post-conversion fires into two categories: fires starting in a converted area (onsite effects) and fires starting near an area (offsite, or fuelbreak effects). Two case studies are presented in each category.

Onsite Effects of Conversion

The use of either weeping lovegrass or Lehmann lovegrass (*E. lehmanniana)* is assumed as the conversion species. Although easier to establish and more palatable to cattle, Lehmann lovegrass is subject to winterkill at higher elevations. Under normal moisture conditions in the chaparral country of central Arizona, these exotic (originally from Africa) perennial grasses are green from April to October.[4]

The likelihood of a fire start and the subsequent fire size depend, in part, upon the amount, proportion, and distribution of cured grass. Cattle grazing and prescribed burning help to control accumulations. However, because proper grazing management utilizes approximately 50 percent of a season's grass growth (Leithead 1963, USDA-Forest Service 1965), and because maintenance burns should be spaced 3 to 4 years apart, some cured grass will be held over most years. The probability of a fire start is very low immediately following either an initial (conversion) burn or a maintenance burn because of the lack of cured grass. The probability that a start will develop into a large fire is also significantly reduced during the same period.

The likelihood of a fire start increases as cured grass accumulates (especially in dry years immediately following a season of high herbage

[3]*Personal communication with Joy J. Baldwin Staff Officer, Tonto National Forest, USDA Forest Service, Phoenix, Arizona. 1972.*

[4]*More detailed botanical information about these grasses may be found in Crider (1945) and Humphrey (1960,1964).*

production). However, grass fires are generally easier to control than dense chaparral fires for several reasons: (1) grass fuels are finer than chaparral, making slurry much more effective and backfiring more feasible; (2) access is easier; (3) green lovegrass, present most years during the fire season, reduces the rate of spread, fire intensity, and flashiness; and (4) during a dry or low forage production year, grazing use will be above normal, which will reduce fuel concentration. Two examples of large chaparral fires which started in possible conversion areas illustrate these points.[5]

The **Boulder Fire** (fig. 2) burned 21,700 acres of brush and grass on the Tonto National Forest from June 13 to 25, 1959, and cost $567,408 to suppress. During the first 3 days the fire spread entirely within a chaparral area with

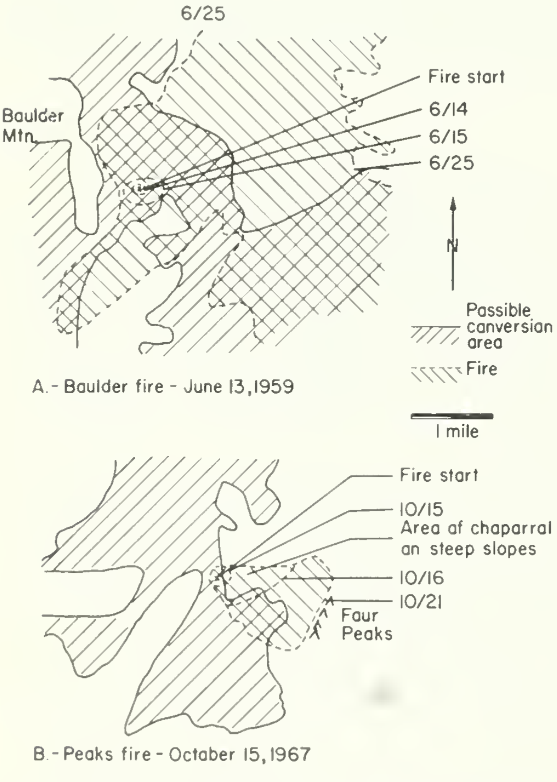

Figure 2. — Two fires used as examples for onsite effects of conversion: A, Boulder Fire, June 13, 1959; B, Peaks Fire, October 15, 1967.

[5] *The two fires described as case studies here and the two fires used as case studies in the following subsection were the only Class E or larger fires (300 acres and above) in or near possible conversion areas in the Salt-Verde Basin for which detailed fire reports were available. The Battle Fire occurred outside the Basin.*

possibilities for conversion to lovegrass. The fire did not spread far those first 3 days because about 0.5 inch of rain fell on the area the day the fire started. Reasons given for not controlling the fire were (1) very poor access due to lack of roads and dense brush, (2) too little fire retardant, and (3) the "extreme weather conditions" (high temperatures and strong, gusty, variable winds) which developed on June 16 (USDA-Forest Service 1959).

The spring and summer of 1958 saw a bumper grass crop in most parts of the State which would have resulted in a high carryover of grass herbage unless a maintenance burn followed in early 1959. Precipitation for the winter of 1958-59 was below average so that, by mid-June there may not have been much green lovegrass had the area been converted.

However, given the same attack methods and weather conditions, it is the consensus of experts that, with conversion, the fire would not have developed as it did. If the grass were sufficiently green, the rainfall and resultant humidity might have prevented or at least constrained the fire in its early stages; if not, the two slurry drops on June 14 probably would have been adequate to permit control. Even if they had failed, the men who reached the fire on the 14th could have used the grass for backfiring. Furthermore, foot access would have been improved because of the conversion.

The case of another large chaparral fire which started in a possible conversion area is quite different. The **Peaks Fire** (fig. 2) started October 15, 1967, and was controlled 6 days later at a cost of approximately $30,000. A total of 680 acres, mainly of dense brush, burned near Four Peaks. The fire burned within a possible conversion area during the first day, but moved into an area of chaparral too steep for conversion by the second day. The possible effect that conversion to lovegrass might have had on the fire depends in large part on how green the grass would have been that October 15.

In fact, 1967 was a dry year; January-September rainfall was 37 percent below normal, and no rain was recorded in October (average October precipitation is 1.59 inches). It is therefore reasonable to expect that any grass would have been cured by the middle of October. If grazing use had been light, the accumulated cured grass would have allowed the fire to spread faster than it actually did in the dense chaparral. If grazing had been normal, however, the light herbage production resulting from the low precipitation would probably have been largely consumed, so that fire spread would have been impeded. Regardless, the three men who arrived the first day might have been able to use the grass to backfire. In any case, no firm conclusion is possible.

The Fuelbreak Effect of Conversion

Conversion could have two beneficial effects on fires starting near converted areas. First of all, access to the area may be improved because of roads installed for the conversion or because of the removal of heavy brush in the area. More important, however, is the fuelbreak provided by the conversion area. If the fire moved in the direction of the converted area, it would stop at the conversion area if the grass were mostly green and/or closely grazed. If the grass were largely cured, a sufficiently rapid attack would permit it to be used for backfiring or slurry deposition. The presence of a converted area in the vicinity of a fire start could therefore permit firefighting efforts to be concentrated elsewhere.

The **Soldier Fire**[6] (fig. 3) which started about 150 yards from a possible chaparral conversion area, burned 4,700 acres west of Four Peaks from July 3 to July 7, 1970, and cost $375,000 to suppress. The fire moved mainly to the west and south, in the direction of the possible conversion area. Because of below-average January-to-June rainfall, a lovegrass stand would probably have contained a large proportion of cured grass unless it had recently burned. If recently burned it would have held the fire in its southerly and westerly spread; if cured, it could have been used for backfiring. Regardless, there should not have been much trouble in holding the fire in either direction. More effort could then have been centered on keeping the fire from spreading to the north and east.

A total of about 150,000 gallons of slurry, dropped by 11 planes, was used to fight the fire. The actual drop times are unavailable, but a conservative estimate is that if eight planes had each made three drops the morning of July 4 to suppress northerly and easterly spread (a total application of about 43,000 gallons of slurry), the fire would have been controlled by noon on July 4 and held to less than 500 acres.

The **Buckhorn Fire,** northwest of Roosevelt Lake, provides another example of the fuelbreak effect (fig. 3). The fire started June 14, 1966, and was controlled 6 days later, at a cost of $122,269, after having burned about 8,000 acres of brush and native grass. The fire started in mixed brush and grass on steep slopes between two possible conversion areas. Typical of fires which rely on desert grass for fuel, the fire quieted down early in the morning, June 15, and did not pick up again until midmorning. During this time 50 men arrived at the fire, which was then about 200 acres. Even with the aid of slurry, however, they were unable to control the fire.

Had the areas to the east, south, and north-northwest been converted to lovegrass, their firefighting efforts would likely have been more effective. The fire would have been held at the conversion areas if maintenance burns had preceded the wildfire that year. Otherwise, the lovegrass might have been green enough to hold the fire (this is not certain because of below-average rainfall in 1966); if not, the firefighting crews could have backfired from the grass. In either case, men and slurry could have concentrated on fighting the fire spread in directions not protected by conversion. During the time the fire quieted down, the 50 men more easily could have controlled the spread to the northeast by merely closing off the gap between the two possible conversion areas. Even if the fire had burned to its ultimate boundary to the southwest, the fire would still have been held to roughly 2,400 acres.

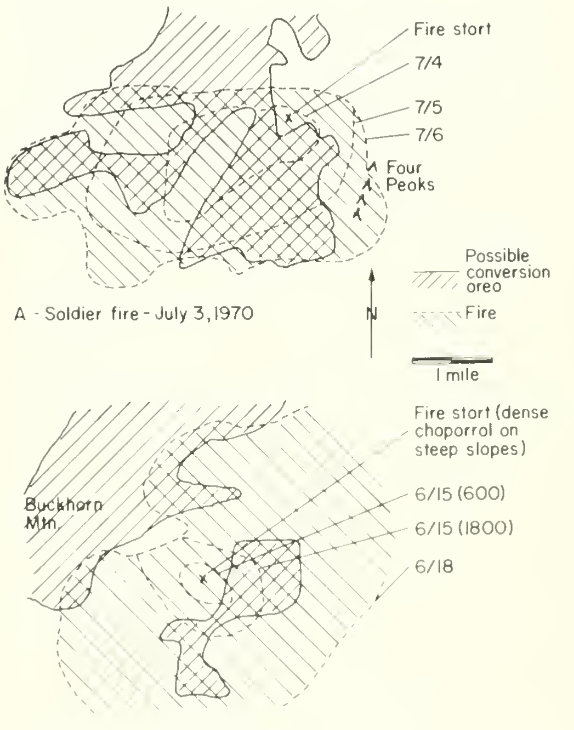

Figure 3. — Two fires used as examples for the fuelbreak effect of conversion: A, Soldier Fire, July 3, 1970; B, Buckhorn Fire, June 14, 1966.

[6] *From figure 2, it appears the Soldier Fire burned the same area in 1970 that the Peaks Fire burned in 1967. Although the fire report for the Soldier Fire only delineated the outside fire boundaries, that Fire actually burned around the Peaks burn, and only entered the perimeter of the earlier, cooler burn where stringers of unburned brush remained.*

Analysis Framework

Water and forage benefits arise from increased productivity, and are properly classified as "profit" maximization benefits. The fire benefit, so-called, is clearly a cost minimization benefit; the greater the reduction in firefighting costs, the greater the benefit. All benefits arising from conversion of chaparral to grass do, however, have one main commonality — they vary from year to year depending upon weather, management, and conversion maintenance. The problem is to estimate the yearly values.

Of the 1 million acres of chaparral within the Salt-Verde Basin, about 85 percent is on National Forest lands. Only part of this National Forest chaparral land, however, is suitable for conversion. Brown (1973) delineated 141 areas within the Basin, encompassing 354,000 acres of National Forest chaparral, for future conversion consideration based on three criteria: (1) chaparral crown cover greater than 30 percent, (2) slopes less than 60 percent, and (3) chaparral not in a wilderness or primitive area. The sizes of these areas range from 88 to 12,160 acres; the average size is 2,443 acres. The analysis that follows is based on the fire histories of these 141 areas.

We used the "with and without" procedure (U. S. Senate 1962). Estimated fire suppression costs with conversion were compared with estimated costs without conversion; the difference between them was the fire benefit. Present Forest Service wildfire suppression policy and practices were assumed. The basic items of information required were: (1) fire suppression costs by fire size class, (2) average annual number of fires per area, and (3) distribution of fires by size class.

Average annual fire suppression costs (C) for area i may be expressed as:

$$C_i = \sum_k N_{ik} c_k \qquad [1]$$

where,

N_{ik} = average number of class k fires in area i

c_k = average suppression costs of a class k fire.

Written another way,

$$C_i = N_i \sum_k p_{ik} c_k \qquad [2]$$

where,

N_i = average annual number of fires in area i

p_{ik} = proportion of class k fires in area i

Equation 2 contains the three basic parameters (above) as factors. Each parameter can be expected to differ for the two conditions — with conversion and without.

National Forest fire records provided the necessary data. Individual fire reports were useful data sources. Unfortunately, a generally observed Forest Service policy directs that these reports be destroyed after 10 years. Because much relevant fire data was thereby eliminated, an iteration approach was taken; where there was uncertainty over a parameter value, the parameter in question was varied over a range deemed inclusive of the true value. Table 1 summarizes these parameter variations — resulting in 252 alternatives — for the "with" and "without" conditions.

Table 1.--Summary of parameter variations, Salt-Verde Basin, Arizona

Parameter	Without conversion	With conversion
Fire occurrence	Computed from historical record	Factors 0.5-1.0 by 0.1 increments applied to the preconversion historical record (6 cases)
Fire size class distributions	Computed from historical record two ways: (1) Basinwide data: and (2) Ranger District data (2 cases)	Three postulated: (1) eliminate Class E and larger fires (2) eliminate one-half of Class E and larger fires (3) same as without conversion (3 cases)
Fire suppression costs	Classes A, B, and C computed from recent record for chaparral fires in Salt-Verde Basin; D and E+ fires cost from $15 to $75 per acre by $10 increments (7 cases)	Classes A, B, and C computed from recent record for grass fires in Salt-Verde Basin; D and E+ fires --same iterations as for preconversion (1 case)

The annual fire benefit (B) for each area (i) and for each alternative considered (j) is simply the difference between the with (C′) and without (C″) conversion wildfire suppression costs,

$$B_{ij} = C''_{ij} - C'_{ij} \quad [3]$$

Fire Occurrence

Fire occurrence maps, which pinpoint fire locations, were used to develop average fire occurrence rates (N_i in equation 2) for each of the 141 areas. The number of fires per area divided by the years of record gives an estimate of the average number of fires per year in an area. These averages ranged from zero to 3.0, with an average of 0.31.

Some might argue that because the length of record (24 years for most areas) is close to the minimum length of the chaparral fire cycle, individual area fire occurrence rates are only crude approximations of the true rates. This would be true were it not for the fact that natural fire cycles have for many years been interrupted by the Forest Service's wildfire suppression efforts. The many chaparral fires which have occurred have covered a rather small acreage, the result of the vast majority of wildfires being held to below 10 acres. Consequently, most areas under consideration here tend to be at or nearly at the end of their fire cycles, so that a 24-year record is probably adequate to obtain representative fire occurrence rates. Two points follow from this reasoning: (1) because most areas are at or nearly at the end of their fire cycles, fire occurrence rates will tend to be higher than they would be without the suppression program, and (2) large differences in fire occurrence rates between areas, which were not uncommon, very likely stem from intrinsic differences between the areas rather than from differences in position within the fire cycle.

Neither research nor management experience permits accurate estimates of postconversion fire occurrence. With inadequate maintenance, postconversion fire start rates may actually increase. However, with proper grazing management and an adequate maintenance commitment, fire start rates should vary from very low immediately following a maintenance burn to near-preconversion levels at the end of each maintenance cycle (3 to 4 years). Between these extremes is a fuel condition representative of an area's average postconversion fire hazard and associated with this condition is a fire start rate useful for long-range analysis. To account for our inability to justify any single value, a range of values, based on a canvass of chaparral fire experts, was used (table 1).

Fire Size Class Distribution

The Forest Service classification scheme was used for this parameter, though Class E and larger fires were aggregated into one category — "E+" — because of the relative infrequency of large chaparral fires in the Basin (table 2). Two average fire size class distributions were computed for the Basin, one from all chaparral fires and one from fires only occurring in the 141 areas (table 2). The two distributions are obviously similar; we used the latter because it was derived directly from fires in the 141 areas.

Size class distributions for these areas by each Ranger District (table 2, lines 3-12)[7] were also used (see table 1). Basin Ranger Districts obviously experienced varying degrees of chaparral fire suppression success; differences in weather, topography, fuels, and distance from suppression-related facilities (for example, airports, lookouts, and crew locations) are probably the main reasons. Because three Districts — Cave Creek, Chino Valley, and Verde — had few fires (table 2), their distributions are subject to considerable error; thus, the more aggregative Basinwide distribution (table 2, line 2) provided a useful check.

We reported the Battle Fire and the four Basin fires (which, as noted above, were not selectively chosen) to help describe the effect of conversion on wildfire suppression efforts. In all but one case, fire experts agreed that prior conversion, with maintenance, would have allowed firefighters to hold the fires to smaller size. We believe that conversion on other areas would have similar effects.

Probably, the most optimistic change in the postconversion fire size class distributions would be the elimination of all E+ fires in the vicinity of conversion sites. Although conversion will probably be quite effective in eliminating the very costly, large E+ fires, all E+ fires will not likely be eliminated. A more conservative and realistic expectation would be the elimination of half of all E+ fires. The lowest estimate is no change at all in the size class distribution following conversion (see table 1).

Fire Suppression Costs

Firefighting costs have skyrocketed during the past 2 decades. Updating suppression costs

[7] *Another fire occurrence distribution, derived from all chaparral fires by Ranger District, is statistically similar to the distribution based on chaparral fires only in delineated feasible conversion areas by Ranger District. The computed one-tail associated probability was 0.34, using the Wilcoxon Matched-Pairs Signed-Ranks Test (Siegel 1956, p. 75-88), indicating acceptance of the null hypothesis of "no difference."*

to current values would be difficult because of the unknown contribution from noninflationary causes such as the increased use of aircraft. Suppression costs for smaller fires have been reported only since 1970, but their high frequency of occurrence provided adequate cost estimates for classes A, B, and C chaparral and grass fires (table 3).

The scarcity of Class D and larger fires suggested the iterative approach described in table 1. The low value ($15 per acre) was reported by Suhr (1967, p. 24) as average for a project-size (Class E and above) chaparral fire in the Brushy Basin area of the Salt-Verde Basin. The high value ($75 per acre) is slightly above the per-acre cost of the 1972 Battle Fire, a high-cost fire.[8] These per-acre costs were then multiplied by the average size of D and E+ fires — 200 and 7,500 acres, respectively[9] — to obtain the average-suppression costs for Class D and E+ fires.

Table 3.--Average suppression costs for Classes A, B, and C chaparral and grass fires, Salt-Verde Basin, Arizona (data for 1970, 1971, 1972)

Class	Chaparral Number	Chaparral Average cost	Grass Number	Grass Average cost
A	132	$ 239	62	$ 204
B	37	1,632	42	485
C	15	2,994	19	1,646

Table 2.--Fire size class distributions (percent), Salt-Verde Basin, Arizona

Basis	Fire size class distributions: A (0-1/4 acres)	B (1/4-10 acres)	C (10-100 acres)	D (100-300 acres)	E+ (300+ acres)	Total	Number of fires
Basinwide data:							
1. All Basinwide chaparral fires	70	21	6	2	1	100	643
2. Fires in 141 chaparral areas	74	20	4	1	1	100	536
Ranger District data for 141 chaparral areas:							
Tonto National Forest--							
3. Cave Creek	37.5	37.5	12.5	--	12.5	100	8
4. Globe	47	39	11	3	--	100	74
5. Mesa	43	41	8	4	4	100	49
6. Payson	91	9	--	--	--	100	116
7. Pleasant Valley	84	15	1	--	--	100	102
8. Roosevelt	57	30	9	--	4	100	95
Prescott National Forest--							
9. Chino Valley	63	25	12	--	--	100	8
10. Thumb Butte	81	17	--	--	2	100	42
11. Verde	62	30.5	--	--	7.5	100	13
12. Walnut Creek	96	3	1	--	--	100	71

[8]Personal communication with Frank O. Carroll, Division of Fire and Air Management, Southwestern Region, USDA Forest Service, Albuquerque, New Mexico. 1972.

[9]The average size of a Class D fire may be assumed to be 200 acres (a Class D fire is defined as from 100 to 300 acres). The average for the 17 recorded Basin Class E+ fires from 1955-72 was 7,401 acres ($S_{\bar{x}}$ = 2,146).

Results

For all alternatives (see table 1) and for each of the 141 chaparral areas, the expected fire suppression costs both with and without conversion were calculated and the differences (B_{ij}) taken. The per-acre fire benefit associated with each alternative is the weighted average (by area size) of the 141 B_i's for that alternative.[10] We believe these simulated fire benefits, which range from $0.03 to $1.13 per acre per year, include all reasonable possibilities of the average cost savings from conversion of dense chaparral in the Salt-Verde Basin.

What happens to the fire benefit if parameter values are fixed? In the following analysis, the two fire size distributions (Basinwide and Ranger District) are retained, but we substitute the following values for the previously varied parameters: a $45 per-acre suppression cost for D and E+ chaparral and grass fires (approximately the average uncompounded suppression cost of the nine E+ fires recorded in the Basin for which cost records exist), and a 20 percent reduction in fire starts following conversion (a reasonable assumption provided conversions are maintained every 3 or 4 years).

These assumptions were coupled with the three postulated postconversion wildfire distributions to yield three sets of fire benefits (table 4). What we would call the maximum arguable benefit is associated with a postconversion distribution with no E+ fires in or near conversion areas. The annual per-acre benefit for this alternative is $0.48 or $0.67 (table 4, line 1),[11] depending on which fire size class distribution is used.

A more conservative estimate — and one more appropriate for benefit-cost analysis — derives from the assumption that half of the proximate E+ fires are eliminated as a result of conversion. The annual per-acre fire benefits for this alternative are $0.31 and $0.43 (table 4, line 2).

A still more conservative assumption is that conversion will cause no change in the postconversion fire occurrence distribution. For this alternative, the benefit estimates are lowest — $0.13 and $0.18 per acre per year (table 4, line 3) — reflecting only the 20 percent reduction in fire starts and reduced costs of suppressing small (Class A, B, and C) grass fires rather than small chaparral fires.

How do these values compare with other wildland values (for example, water and forage benefits) which also may result from conversion of chaparral to grass? As with fire benefits, water and grazing increases (if any) will vary considerably across areas. Based on an exhaustive analysis of feasible conversion areas in the Salt-Verde Basin, Brown, O'Connell, and Hibbert[12] place the average annual forage benefit at over $1 per acre and the water benefit at about double the forage benefit. It is readily seen (table 4) that even for the maximum arguable fire benefit ("eliminate E and larger fires"), the annual forage benefit is twice and the water benefit more than four times as great.

From a management perspective, present values are generally more useful than annual values. As distinguished from annual value (reported above), present value is the current worth of the stream of yearly benefits over time. Derivation of present values requires discounting annual values over a specified planning horizon.[13] The midpoints of the three sets of annual fire benefits (table 4) were chosen as the annual values for discounting purposes: for "no change" the midpoint between 13 and 18 cents is 15.5 cents; for "eliminate one-half of E+ fires" the value is 37.0 cents; and for "eliminate E+ fires" the value is 57.5 cents. These per-acre values were discounted at two rates over a 50-year planning horizon — 6-7/8 percent as recommended by the Water Resources Council (1973, p. 86) and also at 10 percent, which some have argued is more appropriate (Cicchetti et al. 1973). At 6-7/8 percent the present values for these three alternatives, in order, are $2.17, $5.19, and $8.06 per acre; at the 10 percent rate the values are $1.54, $3.67, and $5.70 per acre (table 4).

[10] *The weighted average annual per-acre fire benefits for each alternative j may be computed from:*

$$\frac{\sum_i B_{ij}}{\sum_i A_i}$$

where,

B_{ij} = *fire benefit for area i and alternative j*

A_i = *size of area i in acres*

[11] *The additional elimination of Class D fires increases the benefit little because of the low incidence of D fires: the annual per-acre benefit range is from $0.49 to $0.68.*

[12] *Brown, Thomas C., Paul F. O'Connell, and Alden R. Hibbert. Chaparral conversion potential in Arizona. Part II: an economic analysis. (in preparation for publication, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado).*

[13] *If A_t represents the annual value in year t, then for a planning horizon of n years, the present value is expressed as:*

$$\sum_{t=1}^{n} [A_t / (1+i)^t]$$

where i is the interest or discount rate.

The cost savings (fire benefits) reported herein are averages and, as such, should not be applied to any particular area. The model did, however, provide fire benefit estimates for individual areas (not listed in this report). For all alternatives considered (see table 1), individual area savings (B_i) were less than the mean for approximately three-fourths of the 141 areas. Differences in fire occurrence rates were the major source of variation. With special scrutiny (for example, onsite inspection), these individual area estimates can be validated or modified to provide useful planning information.

Summary and Conclusions

Our primary objective was to evaluate how chaparral-to-grass conversion would affect wildfire suppression costs on 141 chaparral areas in the 8.4-million-acre Salt-Verde Basin of central Arizona. The quantification of this potential cost savings is a necessary input into any comprehensive economic analysis of chaparral conversion for the Basin. An important assumption was that current Forest Service wildfire policies remain essentially unchanged. Another assumption was that, as a result of proper site selection and properly managed conversions, adequate grass stands are established and maintained.

Conversion of chaparral to perennial lovegrass tends to cut firefighting costs. Initial conversion and subsequent maintenance will keep dry fuels at lower levels, thereby reducing the average number of fires per year. If fires do start in the converted areas, they are more easily controlled because of fuel reduction and improved access. Whether a fire starts in or near a converted area, the lovegrass can be used as a fuelbreak if green, or for backfiring if cured.

Over a wide array of simulated alternatives, the average annual per-acre cost savings (fire benefit) ranged from $0.03 to $1.13 across the 141 areas. Focusing on the more plausible parameter values and three postconversion fire size class distributions narrows this range considerably. If all Class E and larger fires are eliminated as a result of conversion — an optimistic, but not incredible, assumption — fire benefits are highest, the estimates being $0.48 and $0.67 per acre per year. These are the maximum arguable economic values. If only half the E+ fires are eliminated — a more reasonable expectation — the values are $0.31 and $0.43. And, if the postconversion fire size class distributions remains unchanged, the fire benefits are lowest, $0.13 and $0.18.

The wide variation in fire benefits among individual areas, coupled with the fact that three-fourths of the areas had per-acre benefits below the mean benefit, requires this caveat: these average fire benefits should not be applied to individual areas without special scrutiny. However, individual area fire benefits (from which the averages were calculated) may, with supplemental knowledge, provide useful planning information.

This study concentrated on a specific area — Arizona's Salt-Verde Basin — and the calculated fire benefits may not be transferable to other areas. The methodology, however, is transferable. The crux of the method is the widely accepted "with and without" procedure. The degree of iteration-simulation will depend upon data availability. But no matter how much

Table 4.--Estimated average annual per-acre dollar savings and present values from conversion of chaparral to lovegrass, Salt-Verde Basin, Arizona[1]

Postconversion change in fire class distribution	Range of mean annual per-acre savings[2]	Present values at:[3] 6-7/8%	10%
1. Eliminate E and larger fires	$0.48 - 0.67	$8.06	5.70
2. Eliminate one-half of E and larger fires	.31 - .43	5.19	3.67
3. No change	.13 - .18	2.17	1.54

[1]Assumes a $45 per-acre suppression cost for Class D and larger chaparral and grass fires, and a 20 percent reduction in fire starts following conversion.

[2]The left values were derived using Basinwide data; the right values were derived using individual Ranger District data.

[3]A 50-year planning horizon was postulated. The present values were computed from the midpoint value of the mean annual per-acre savings for each row.

or how good the data, there is no substitute for concomitant input from those with firsthand knowledge of the areas.

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Properly planned, carried out, and maintained, chaparral-to-grass conversions should reduce the occurrence of large, expensive wildfires. Dollar values of "fire benefits" were calculated for 141 convertible areas in Arizona's Salt-Verde Basin. Case histories of large chaparral fires are analyzed to illustrate principles of chaparral and grass fires in the Southwest. Historical fire data were used in a predictive model, but where data were absent or insufficient, parameters were varied within specified limits. The fire benefit, though not as high as water and forage benefits resulting from conversion, is an important addition to a benefit-cost analysis. The fire benefit varies significantly from area to area because of differences in man-caused and lightning risks, and also in accessibility. While transference of dollar values to other areas is tenuous, the methodology is transferable and can be a very useful planning tool.

Oxford: 436:651.7:432.16:268.44. **Keywords:** Fire use, economic evaluation, fire hazard reduction, chaparral conversion.

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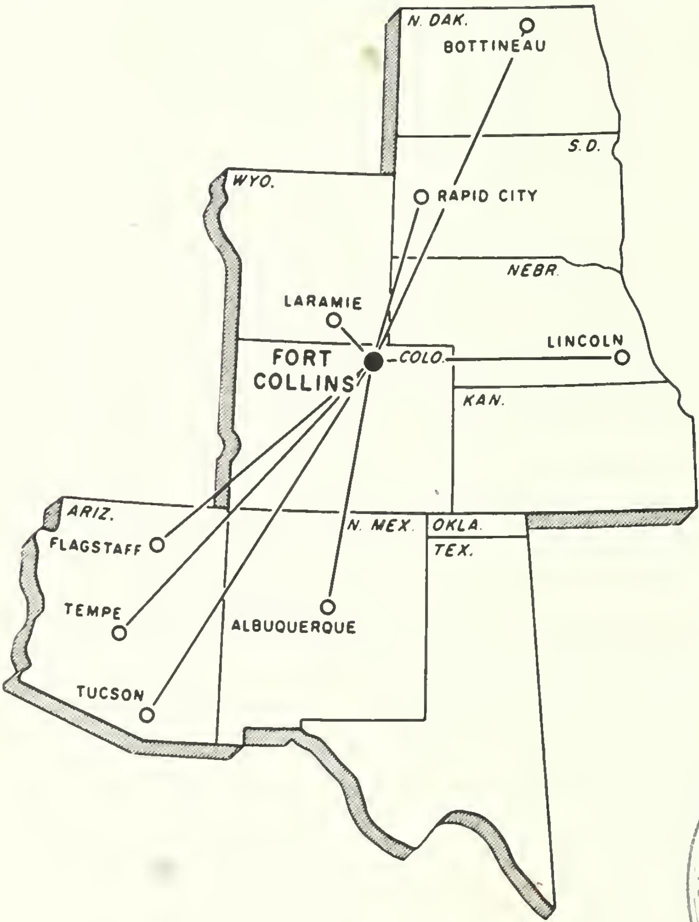

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