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Operability and Location of Michigan's Timber Resource

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CONTENTS

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OPERABILITY AND LOCATION OF MICHIGAN'S TIMBER RESOURCE

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Michigan's 17.5 million acres of timberland in 1980 supported 19.1 billion cubic feet of growing stock (Raile and Smith 1983). Some of this material is unavailable to potential timber purchasers because landowners do not presently wish to sell their timber. Additional volume may be unavailable for harvesting or management due to operability. We define operability as the ease or difficulty of managing or harvesting timber because of physical conditions in the stand or on the site. Operability problems include small average tree size, fragile soils, poor drainage, inaccessibility, and small tract size, among others.

The purpose of this paper is to present the results of our analysis of the operability of Michigan's timberland. The methods we used to assess operability are similar to those used by Spencer *et al.* (1986) in Minnesota. Because the approaches are similar, users can compare data from these two States as well as Wisconsin, which is currently being analyzed using methods identical to those used here. A detailed description of these methods is presented by Spencer *et al.* (1986); therefore, we will give only a brief summary here.

Statewide inventory information was provided by Forest Inventory and Analysis (FIA) permanent sample plots. Although some subjectivity was involved in assigning values to operability components, the use of FIA data favors objectivity for calculating areas and volumes by operability classes. Users of this information can also mitigate some of this subjectivity by tailoring the results to more closely fit their own requirements. Up to three of the seven operability characteristics used to stratify areas into operability classes may be eliminated, and the remaining characteristics—those deemed important to the user—may be used alone to estimate operability class.

METHODS

Information used to define the operability class components was selected from tree and stand data collected during the 1980 State inventory.[1] Operability classes for Michigan's timberland were based on seven components—stand area, growing-stock volume per acre, sawtimber volume per acre, percent of cull trees in the stand, average diameter at breast height (d.b.h.) of growing-stock trees, merchantable height of growing-stock trees, and distance to a maintained[2] road from the stand (table 1). These seven major operability components were the factors identified by the public and private forestry sectors as most important in determining operability. Operability classifications I, II, or III (good, medium, or poor) also were defined for each component (table 1). The overall operability classification of any area is based on the poorest operability component.

The seven operability components were the same used by Spencer *et al.* (1986) in Minnesota. These components and associated values were selected after a great deal of correspondence with and review by professionals involved in both public and private sector

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[1] *Areas and volumes presented in this report do not exactly match those published in other resource reports published by North Central Forest Experiment Station. For example, Raile and Smith (1983) reported the area of timberland to be 17,489.5 thousand acres; here, we report a timberland area of 17,489.8 thousand acres. These minor differences are due to slight procedural changes in data processing used to compute operability information from those methods used in 1980.*

[2] *See Definitions of Terms in Appendix.*

Table 1.—*Operability component values for each operability class*

Operability component	Operability class		
	I (Good)	II (Medium)	III (Poor)
1. Stand area (in acres)	More than 60	10-60	Less than 10
2. Growing-stock volume per acre (in cubic feet)[1]	More than 1,000	400-1,000	Less than 400
3. Sawtimber volume per acre (in board feet, International 1/4-inch rule)[2]	More than 2,500	700-2,500	Less than 700
4. Percent of all live trees that are cull (in percent)	Less than 20	20-50	More than 50
5. Average diameter at breast height (d.b.h.) of growing-stock trees (in inches)[3]	More than 9	6-9	Less than 6
6 Average merchantable height of growing-stock trees (in feet)	More than 28	16-28	Less than 16
7. Distance to a maintained road (in miles)	Less than 1/4	1/4 - 3/4	More than 3/4

[1] Threshold values for growing stock volume per acre used in the Minnesota study (Spencer *et al.* 1986) were "more than 800," "300 to 800," and "less than 300" cubic feet per acre.

[2] Threshold values for sawtimber volume per acre used in the Minnesota study (Spencer *et al.* 1986) were "more than 3,000," "1,100 to 2,000," and "less than 1,100" board feet per acre.

[3] Threshold values for average d.b.h. of growing-stock trees used in the Minnesota study (Spencer *et al.* 1986) were "more than 10," "6-10," and "less than 6" inches.

forest management and timber acquisition in the Lake States region. After the Minnesota operability study was published, identical tables for Michigan were produced and reviewed by public and private forestry professionals. These reviewers saw a need to change some of the threshold levels (values used to define good, medium, or poor operability classes) from those used in Minnesota (changes are shown in the footnotes of table 1). The thresholds were changed to reflect as nearly as possible what those currently harvesting timber in Michigan consider are good, medium, or poor operability stands.

In order for an inventory plot to be rated class I (good), *all* of the values for the seven components on the plot had to be class I. A plot was rated class II (medium) if the values for the seven components on the plot were either class I or II. A plot was rated operability class III (poor) if *any* of the component values were class III (e.g., if the values for six components on a plot were class I and the value for the remaining component was class III, the plot was considered operability class III). All sapling-seedling and nonstocked plots were considered inoperable (class IV); we believe that most of this land would not be harvested in the near future and that including it in the study would only dilute the findings.

Some operability class components might not be considered important by some users. To permit these users to develop classes containing only those components of concern to them, we developed tables 8 and 9 (Appendix) showing area of timberland in operability classes II and III by limiting factor. We also developed similar tables for growing-stock volume (tables 16 and 17).

A limiting factor represents the operability class component or components that prevents the plot from being classed higher. The limiting factor tables for class II show the individual components that were rated class II and, therefore, caused the area or volume to be rated class II rather than class I. Limiting factor tables for class III show the same information. The limiting factor tables permit the reader to find the area or volume on plots called operability class II or III because of components they consider unimportant. These areas or plot volumes then can be added to those listed as operability class I or II to produce revised estimates.

We identified 15 current major wood-using centers in Michigan: Alpena, Brighton, Cadillac, Escanaba, Filer City, Gaylord-Grayling, Iron Mountain, L'Anse, Manistique, Midland, Muskegon, Newberry, Ontona-

gon, Otsego, and West Branch. The straight-line distance of each plot to these cities was recorded. The area and volume represented by each plot could be related to its distance from each city. These plot areas and volumes were summed and stratified by operability class to estimate the area of timberland (table 13) and volume of growing stock (table 21) by distance from each of the 15 wood-using centers.

RESULTS

Area

Using the method outlined above, 7.0 million acres (40 percent of the total) of timberland in Michigan are rated operability class III—poor (table 7). Another 5.8 million acres (33 percent) are rated class II—medium, and only 100,900 acres (less than 1 percent) are rated class I—good. Class IV forest, sapling-seedling stands and nonstocked areas, total 4.6 million acres (26 percent); this class will not be discussed further. Of the 14 forest types identified in Michigan, only 7 have any area in operability class I (table 7).

Adjustment by Limiting Factors

Using the method of limiting factors described earlier, forest areas can be shifted towards the good operability class (class I). For example, the 100.9 thousand acres originally rated operability class I can be increased to 519.7 thousand acres (100.9 + 418.8 thousand acres from tables 7 and 8) by waiving the stand area component (operability component 1). Alternatively, the total area in class I can be increased to 347.0 thousand acres (100.9 + 246.1 thousand acres) by removing the constraint on distance to road (operability component 7). By waiving both components, the new class I area becomes 1,316.8 thousand acres (100.9 + 418.8 + 246.1 + 551.0 thousand acres). Although the resulting 1,316.8 thousand acres is 13 times larger than the original class I area, it still represents only 10 percent of the State's total for classes I-III. This suggests, too, that the physical standards for some operability components may be too confining, or that the definitions of operability classes could be modified further to meet individual user needs. However, new standards should reflect actual conditions and should *not* be developed only to achieve a more equal distribution of the resource among operability classes.

Volume Per Acre

As expected, higher volumes per acre are associated with the better operability classes (table 2). All of the class I land, 79 percent of class II land, and 61 percent of class III land have more than 1,000 cubic feet of growing-stock volume per acre.

Table 2.—*Percent of timberland (excluding sapling-seedling stands and nonstocked areas) by growing-stock volume and operability class, Michigan, 1980*

(In percent)

Growing-stock volume per acre (cu.ft./acre)	Operability class		
	I	II	III
More than 1,000	100	79	61
400-1,000	—	21	34
Less than 400	—	—	5
Total	100	100	100

Ownership

The proportion of timberland in each operability class differs greatly among ownership classes (table 3). Farmers and other miscellaneous private owners, who together own more than half the timberland in Michigan, own the highest percentages of timberland in operability classes I and II. This timberland tends to be accessible by road in Michigan and to receive less forest management (especially harvesting) than timberland owned by the public or forest industry. Timberland owned by the public or forest industry is managed more intensely than private timberland and may be predisposed to higher operability ratings.

Distance from Wood-using Center

If sapling-seedling stands and nonstocked areas are ignored, 540 thousand acres of timberland are within 20 miles (straight-line distance) of L'Anse, Michigan. L'Anse had the largest concentration of operable timberland of the 15 major wood-using centers in the State. Newberry, Michigan, had 429 thousand acres and Gaylord-Grayling had 377 thousand acres within 20 miles. If the timbershed is extended to a radius of

Table 3.—*Percent of timberland (excluding sapling-seedling stands and nonstocked areas) by major ownership class and operability class, Michigan, 1980*

(In percent)

Ownership class	Operability class			
	All classes	I	II	III
Farmer	100	2	49	49
Misc. private	100	1	48	51
Forest industry	100	1	43	56
State	100	0	45	55
Co. and municipal	100	0	37	63
National Forest	100	0	33	67
All owners	100	1	45	54

50 miles, L'Anse is still first with 2,553 thousand acres, followed by Gaylord-Grayling (2,080 thousand) and Cadillac (1,905 thousand).

If, however, operability is factored into the consideration of distance from wood-using center, a different picture emerges. Brighton, Michigan, becomes the leader: it has 6,800 acres in operability class I timberland within 20 miles of town. However, because this is such a small area, as is the entire class I area, it makes more sense to expand the discussion to operability classes I and II.

If operability class I and II land within 20 miles of major wood-using centers is considered, L'Anse (305 thousand acres), Cadillac (193 thousand acres), and Gaylord-Grayling (189 thousand acres) lead the list. Analysts, then, can use table 13 to estimate the difficulty of managing or harvesting timber within 3 different radii from 15 different wood-using centers in the State.

Volume

Growing-stock volume on timberland in Michigan was stratified into operability classes, just as was the area of timberland. Because the same kind of tables were generated for volume that were discussed for area above, only the highlights are discussed.

Michigan's 1980 growing-stock inventory of 17.6 billion cubic feet is broken down into operability classes as follows:

Operability class	Growing-stock volume	
	Million cubic feet	*Percent*
I	182	1
II	8,724	50
III	8,702	49
All classes	17,608	100

The maple-birch type, which represents 43 percent of the combined volumes in classes I through III, includes 49 percent of the operability class I volume (table 15), reflecting the bias of the components towards larger, older trees.

Adjustment by Limiting Factors

Volumes can be adjusted to suit the needs of the user the same way area can be adjusted, as discussed earlier. Waiving the same two operability components as in the area discussion (stand area and distance to road) changes the volume in operability class I from 182 to 2,482 million cubic feet (tables 15 and 16). Likewise, the volume in operability class II shifts from 8,724 to 13,665 million cubic feet and that in class III declines from 8,702 to 1,460 million cubic feet (tables 15 and 17). Percentages in each class then become:

Operability class	Volume
	Percent
I	14
II	78
III	8
All classes	100

Volume Per Acre

Average volume per acre differed somewhat by operability class and volume per acre class, but it generally is highest in the best operability classes (table 4).

Ownership

The largest proportion of growing-stock volume—like area, discussed earlier—in operability classes I and II is on farmer and other miscellaneous privately owned timberland (table 5).

Distance from Wood-using Center

L'Anse is within 20 miles of 507 million cubic feet of operability class I and II growing stock—more than any other wood-using center in the State. Gaylord-Grayling and Cadillac follow with 294 and 292 million cubic feet, respectively (table 21). The same cities are in the same order if the radius is extended to 50 miles.

SUMMARY

The tables provided in this report permit timberland and growing-stock volume to be separated into operability classes by forest type, volume per acre class, stand-age class, ownership class, and distance from wood-using center. In addition, the tables permit up to three operability components to be discounted and operability class to be determined based on the remaining relevant components.

Table 4.—*Average growing-stock volume per acre on timberland by volume and operability class, Michigan, 1980*

(In cubic feet per acre)

Volume per acre class	Operability class			
	Average all classes	I	II	III
More than 1,000	1,658	1,804	1,708	1,602
400-1,000	754	—	802	730
Less than 400	291	—	—	291

Table 5.—*Percent of growing-stock volume*[1] *by ownership class and operability class, Michigan, 1980*
(In percent)

Ownership class	Operability class			
	All classes	I	II	III
Farmer	100	3	54	43
Misc. private	100	1	54	45
State	100	[2]	50	49
Forest industry	100	1	45	54
Co. and municipal	100	—	42	58
National Forest	100	—	36	64
All owners	100	1	50	49

[1] Excludes growing-stock volume in sapling-seedling stands and on nonstocked areas.
[2] Less than 0.5 percent.

LITERATURE CITED

Raile, Gerhard K.; Smith, W. Brad. 1983. Michigan forest statistics, 1980. Resour. Bull. NC-67. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 101 p.

Spencer, John S. Jr.; Hansen, Mark H.; Jakes, Pamela J. 1986. A method for estimating operability and location of the timber resource. Res. Pap. NC-273. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 52 p.

APPENDIX

PRINCIPAL TREE SPECIES GROUPS IN MICHIGAN[3]

Softwoods
- Eastern white pine ..... *Pinus strobus*
- Red pine ..... *Pinus resinosa*
- Jack pine ..... *Pinus banksiana*
- White spruce ..... *Picea glauca*
- Black spruce ..... *Picea mariana*
- Balsam fir ..... *Abies balsamea*
- Eastern hemlock ..... *Tsuga canadensis*
- Tamarack ..... *Larix laricina*
- Northern white-cedar ..... *Thuja occidentalis*
- Other softwoods
  - Eastern redcedar ..... *Juniperus virginiana*
  - Norway spruce ..... *Picea abies*
  - Engelmann spruce ..... *Picea engelmannii*
  - Austrian pine ..... *Pinus nigra*
  - Scotch pine ..... *Pinus sylvestris*

Hardwoods
- White oaks
  - White oak ..... *Quercus alba*
  - Swamp white oak ..... *Quercus bicolor*
  - Bur oak ..... *Quercus macrocarpa*
  - Chinkapin oak ..... *Quercus muehlenbergii*
  - Chestnut oak ..... *Quercus prinus*
- Select red oak
  - Northern red oak ..... *Quercus rubra*
- Other red oaks
  - Scarlet oak ..... *Quercus coccinea*
  - Northern pin oak ..... *Quercus ellipsoidalis*
  - Pin oak ..... *Quercus palustris*
  - Black oak ..... *Quercus velutina*
- Hickories
  - Bitternut hickory ..... *Carya cordiformis*
  - Pignut hickory ..... *Carya glabra*
  - Shellbark hickory ..... *Carya laciniosa*
  - Shagbark hickory ..... *Carya ovata*
  - Mockernut hickory ..... *Carya tomentosa*
- Yellow birch ..... *Betula alleghaniensis*
- Hard maples
  - Sugar maple ..... *Acer saccharum*
  - Black maple ..... *Acer nigrum*
- Soft maples
  - Red maple ..... *Acer rubrum*
  - Silver maple ..... *Acer saccharinum*
- American beech ..... *Fagus grandifolia*
- Ashes
  - White ash ..... *Fraxinus americana*
  - Black ash ..... *Fraxinus nigra*
  - Green ash ..... *Fraxinus pennsylvanica*
- Balsam poplar ..... *Populus balsamifera*
- Eastern cottonwood ..... *Populus deltoides*
- Aspens
  - Bigtooth aspen ..... *Populus grandidentata*
  - Quaking aspen ..... *Populus tremuloides*
- Basswood ..... *Tilia americana*
- Yellow-poplar ..... *Liriodendron tulipifera*
- Black walnut ..... *Juglans nigra*
- Black cherry ..... *Prunus serotina*
- Butternut ..... *Juglans cinerea*

[3] *The common and scientific names are based on: Little, Elbert D. 1979. Checklist of native and naturalized trees of the United States. Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service. 375 p.*

Elms
- American elm ..... *Ulmus americana*
- Slippery elm ..... *Ulmus rubra*
- Rock elm ..... *Ulmus thomasii*

Paper birch ..... *Betula papyrifera*

Other hardwoods
- Boxelder ..... *Acer negundo*
- Sweet birch ..... *Betula lenta*
- River birch ..... *Betula nigra*
- Black willow ..... *Salix nigra*
- Ohio buckeye ..... *Aesculus glabra*
- Flowering dogwood ..... *Cornus florida*
- Honeylocust ..... *Gleditsia triacanthos*
- Osage-orange ..... *Maclura pomifera*
- Black tupelo ..... *Nyssa sylvatica* var. *sylvatica*
- Sycamore ..... *Platanus occidentalis*
- Black locust ..... *Robinia pseudoacacia*
- Sassafras ..... *Sassafras albidum*
- Red mulberry ..... *Morus rubra*
- American chestnut ..... *Castanea dentata*

Metric Equivalents of Units Used in this Report

1 acre = 4,046.86 square meters or 0.405 hectare.
1,000 acres = 405 hectares.
1 cubic foot = 0.0283 cubic meter.
1 mile = 1.61 kilometers.
1 foot = 30.48 centimeters or 0.3048 meter.
1 inch = 25.4 millimeters, 2.54 centimeters, or 0.0254 meter.

Universal Transverse Mercator (UTM) Grid System

The UTM Grid system is designed for world use between 80° south latitude and 84° north latitude. The globe is divided into narrow zones of 6° of longitude in width, numbered 1 through 60. Each zone is bounded on the east and west by a meridian of longitude and with a central meridian passing through the center of the grid zone. In the northern hemisphere the intersection of the central meridian and the equator is given a value of 0 meters for northing coordinate, and the numbers increase towards the north pole. Because values increase from west to east, this same point of intersection is given a value of 500,000 meters for easting coordinate to avoid negative numbers at the west edge of the zone. A grid system of two sets of parallel lines intersecting at right angles and forming a series of squares is established within each grid zone. On the U.S. Geological Survey 7.5 minute topographic maps, the grid interval or length of each side of these squares is 1,000 meters. Each grid intersection can be uniquely identified by its easting and northing and the zone number. The first of these coordinates represents the distance in meters east of the central meridian of the grid zone and the second coordinate represents the distance in meters north of the equator. Any point on a topographic map can be referenced by using these coordinates and by dividing the sides of the grid square into 10 or multiples of 10 parts. The point coordinates, then, are read to a greater number of digits than the grid coordinates. Such a system permits a point to be located to the nearest 10 meters. If the UTM coordinates of any two points are known, it is a straightforward process to compute the distance between them, even if they are in different zones.

DEFINITION OF TERMS

Commercial forest land.—(See timberland.)

Commercial species.—Tree species presently or prospectively suitable for industrial wood products. (Note: Excludes species of typically small size, poor form, or inferior quality such as hophornbeam and hawthorn.)

County and municipal land.—Land owned by counties and local public agencies or municipalities, or land leased to these governmental units for 50 years or more.

Farm.—Any place from which $1,000 or more of agricultural products were produced and sold during the year.

Farmer-owned land.—Land owned by farm operators. (Note: Excludes land leased by farm operators from nonfarm owners, such as railroad companies and States.)

Forest land.—Land at least 16.7 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use. (Note: Stocking is measured by comparing specified standards with basal area and/or number of trees, age or size, and spacing.) The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, or other bodies of water or clearings in forest areas shall be classed as forest if less than 120 feet wide. Also see definition for timberland.

Forest industry land.—Land owned by companies or individuals operating primary wood-using plants.

Forest trees.—Woody plants having a well-developed stem and usually more than 12 feet tall at maturity.

Forest type.—A classification of forest land based upon the species forming a plurality of live tree stocking. Major forest types in Michigan are:

Jack pine.—Forests in which jack pine comprises

a plurality of the stocking. (Common associates include eastern white pine, red pine, aspen, birch, and maple.)

Red pine.—Forests in which red pine comprises a plurality of the stocking. (Common associates include eastern white pine, jack pine, aspen, birch, and maple.)

White pine.—Forests in which eastern white pine comprises a plurality of the stocking. (Common associates include red pine, jack pine, aspen, birch, and maple.)

Balsam fir.—Forests in which balsam fir and white spruce comprise a plurality of stocking with balsam fir the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)

White spruce.—Forests in which white spruce and balsam fir comprise a plurality of the stocking with white spruce the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)

Black spruce.—Forests in which swamp conifers comprise a plurality of the stocking with black spruce the most common. (Common associates include tamarack and northern white-cedar.)

Northern white-cedar.—Forests in which swamp conifers comprise a plurality of the stocking with northern white-cedar the most common. (Common associates include tamarack and black spruce.)

Tamarack.—Forests in which swamp conifers comprise a plurality of the stocking with tamarack the most common. (Common associates include black spruce and northern white-cedar.)

Oak-hickory.—Forests in which northern red oak, white oak, bur oak, or hickories, singly or in combination, comprise a plurality of the stocking. (Common associates include jack pine, beech, yellow-poplar, elm, and maple.)

Elm-ash-soft maple.—Forests in which lowland elm, ash, cottonwood, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include birches, spruce, and balsam fir.)

Maple-birch.—Forests in which sugar maple, basswood, yellow birch, upland American elm, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include white pine, elm, hemlock, and basswood.)

Aspen.—Forests in which quaking aspen or bigtooth aspen, singly or in combination, comprise a plurality of the stocking. (Common associates include balsam poplar, balsam fir, and paper birch.)

Paper birch.—Forests in which paper birch comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)

Exotic.—Forests in which species not native to Michigan comprise a plurality of the stocking. (Mostly scotch pine plantations.)

Growing-stock trees.—Live trees of commercial species qualifying as desirable and acceptable trees. (Note: Excludes rough and rotten trees.)

Growing-stock volume.—Net volume in cubic feet of growing-stock trees 5 inches d.b.h. and over, from a 1-foot stump to a minimum 4 inch top diameter outside bark of the central stem or to the point where the central stem breaks into limbs. Cubic feet can be converted to standard cords by dividing by 79. One standard cord is 128 cubic feet of stacked wood, including bark and air.

Hardwoods.—Dicotyledonous trees, usually broad-leaved and deciduous.

Indian land.—All land held in trust by the United States for individual Indians or tribes, or all lands, titles to which are held by individual Indians or tribes, subject to Federal restrictions against alienation.

Live trees.—Growing-stock, rough, and rotten trees 1 inch d.b.h. and larger.

Maintained road.—Any road, hard-topped or other surface, that is plowed or graded at least once a year. Includes rights-of-way that are cut or treated to limit herbaceous growth.

Miscellaneous Federal land.—Federal land other than National Forest and land administered by the Bureau of Land Management.

Miscellaneous private land.—Privately owned land other than forest-industry and farmer-owned land.

National Forest land.—Federal land that has been legally designated as National Forest or purchase units, and other land administered by the USDA Forest Service.

Net volume.—Gross volume less deductions for rot, sweep, or other defect affecting use for timber products.

Noncommercial species.—Tree species of typically small size, poor form, or inferior quality that normally do not develop into trees suitable for industrial wood products.

Nonstocked land.—Timberland less than 16.7 percent stocked with growing-stock trees.

Poletimber trees.—Growing-stock trees of commercial species at least 5 inches d.b.h. but smaller than sawtimber size.

Saplings.—Live trees 1 to 5 inches d.b.h.

Sapling-seedling stands.—(See stand-size class.)

Saw log.—A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight and with a minimum diameter outside bark (d.o.b.) for softwoods of 7 inches (9 inches for hardwoods) or other combinations of size and defect specified by regional standards.

Saw log portion.—That part of the bole of sawtimber trees between the stump and the saw log top.

Saw log top.—The point on the bole of sawtimber trees above which a saw log cannot be produced. The minimum saw log top is 7 inches d.o.b. for softwoods and 9 inches d.o.b. for hardwoods.

Sawtimber stands.—(See stand-size class.)

Sawtimber trees.—Growing-stock trees of commercial species containing at least a 12-foot saw log or two noncontiguous saw logs 8 feet or longer and meeting regional specifications for freedom from defect. Softwoods must be at least 9 inches d.b.h. Hardwoods must be at least 11 inches d.b.h.

Sawtimber volume.—Net volume of the saw log portion of live sawtimber in board feet, International ¼-inch rule, from stump to a minimum 7 inches top diameter outside bark (d.o.b.) for softwoods and a minimum 9 inches top d.o.b. for hardwoods.

Seedlings.—Live trees less than 1 inch d.b.h. that are expected to survive. Only softwood seedlings more than 6 inches tall and hardwood seedlings more than 1 foot tall are counted.

Softwoods.—Coniferous trees, usually evergreen, having needles or scale-like leaves.

Stand.—A growth of trees on a minimum of 1 acre of forest land that is stocked by forest trees of any size.

Stand-age class.—Age of the main stand. Main stand refers to trees of the dominant forest type and stand-size class.

Stand-size class.—A classification of forest land based on the size class of growing-stock trees on the area; that is, sawtimber, poletimber, or seedlings and saplings.

a. *Sawtimber stands.*—Stands at least 16.7 percent stocked with growing-stock trees, with half or more of total stocking in sawtimber or poletimber trees, and with sawtimber stocking at least equal to poletimber stocking.

b. *Poletimber stands.*—Stands at least 16.7 percent stocked with growing-stock trees of which half or more of this stocking is in poletimber and/or sawtimber trees, and with poletimber stocking exceeding that of sawtimber.

c. *Sapling-seedling stands.*—Stands at least 16.7 percent stocked with growing-stock trees of which more than half of the stocking is saplings and/or seedlings.

d. *Nonstocked areas.*—Timberland on which stocking of growing-stock trees is less than 16.7 percent.

State land.—Land owned either by States or leased to them for 50 years or more.

Timberland.—(Formerly called commercial forest land.) Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. (Note: Areas qualifying as timberland are capable of producing more than 20 cubic feet per acre per year of annual growth when managed. Currently inaccessible and inoperable areas are included except when the areas involved are small and unlikely to become suitable for producing industrial wood in the foreseeable future.)

TABLE TITLES

Text tables

Appendix tables

Table 6.--Area of timberland by operability class component and forest type, Michigan, 1980

(In thousand acres)

Operability class component	Forest type								
	All types	Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
Stand area (acres)									
More than 60	3,658.4	151.1	79.3	26.0	93.7	21.9	96.1	387.1	27.3
10-60	6,529.8	269.5	270.4	80.2	171.7	31.5	80.8	322.9	22.1
Less than 10	7,301.6	415.8	306.8	107.9	370.2	46.5	343.0	463.7	65.4
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Growing-stock volume (cubic feet/acre)									
More than 1000	8,972.0	205.7	320.8	135.5	297.2	54.9	127.3	683.7	7.9
400-1000	5,224.4	408.8	194.6	49.1	231.8	27.8	226.1	348.7	43.7
Less than 400	3,293.4	221.9	141.1	29.5	106.6	17.2	166.5	141.3	63.2
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Sawtimber volume (board feet/acre)									
More than 2500	6,922.1	200.5	222.9	141.3	239.7	43.5	52.8	401.0	5.4
700-2500	5,750.5	347.3	169.4	49.9	234.6	26.3	198.7	450.7	40.4
Less than 700	4,817.2	288.6	264.2	22.9	161.3	30.1	268.4	322.0	69.0
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Percent cull trees (percent)									
Less than 20	13,768.9	700.9	531.9	172.9	515.0	83.1	446.4	909.3	92.4
20-50	2,534.7	82.7	46.3	34.5	110.9	9.8	42.5	222.5	9.7
More than 50	1,186.2	52.8	78.3	6.7	9.7	7.0	31.0	41.9	12.7
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Average d.b.h. of growing-stock trees (inches)									
More than 9	4,717.9	132.8	99.6	115.4	78.6	14.3	11.2	104.3	9.0
6-9	11,484.5	634.0	416.9	98.7	523.8	71.1	410.5	973.9	75.6
Less than 6	1,287.4	69.6	140.0	--	33.2	14.5	98.2	95.5	30.2
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Average merchantable height of growing-stock trees (feet)									
More than 28	11,519.0	318.6	280.7	164.4	306.0	53.0	146.7	149.3	29.2
16-28	5,113.3	480.3	300.1	49.7	313.3	39.9	335.2	959.9	76.2
Less than 16	857.5	37.5	75.7	--	16.3	7.0	38.0	64.5	9.4
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8
Distance to road (miles)									
Less than 1/4	6,818.6	365.0	291.8	95.1	192.4	42.2	89.6	306.2	38.9
1/4-3/4	8,171.6	347.3	317.3	76.6	299.8	42.6	221.5	604.9	43.6
More than 3/4	2,499.6	124.1	47.4	42.4	143.4	15.1	208.8	262.6	32.3
All classes	17,489.8	836.4	656.5	214.1	635.6	99.9	519.9	1,173.7	114.8

(Table 6 continued on next page)

(Table 6 continued)

Operability class component	Forest type						
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic	Non-stocked
Stand area (acres)							
More than 60	285.9	260.2	1,435.6	690.8	59.0	8.5	35.9
10-60	887.5	436.2	2,480.1	1,276.0	133.4	41.4	26.1
Less than 10	599.1	631.1	2,182.8	1,438.8	183.1	36.4	111.0
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Growing-stock volume (cubic feet/acre)							
More than 1000	929.4	545.2	4,091.8	1,329.7	231.9	11.0	--
400-1000	594.0	447.2	1,392.4	1,133.9	98.9	27.4	--
Less than 400	249.1	335.1	614.3	942.0	44.7	47.9	173.0
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Sawtimber volume (board feet/acre)							
More than 2500	791.2	453.6	3,450.6	841.5	73.2	4.9	--
700-2500	630.8	491.5	1,748.9	1,164.1	183.4	12.9	1.6
Less than 700	350.5	382.4	899.0	1,400.0	118.9	68.5	171.4
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Percent cull trees (percent)							
Less than 20	1,525.3	1,000.2	4,750.4	2,651.9	315.2	54.5	19.5
20-50	151.8	224.2	1,059.5	468.1	46.2	14.0	12.0
More than 50	95.4	103.1	288.6	285.6	14.1	17.8	141.5
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Average d.b.h. of growing-stock trees (inches)							
More than 9	775.8	413.4	2,187.5	727.9	31.3	8.3	8.5
6-9	944.1	831.0	3,751.9	2,363.2	326.8	36.3	26.7
Less than 6	52.6	83.1	159.1	314.5	17.4	41.7	137.8
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Average merchantable height of growing-stock trees (feet)							
More than 28	1,356.7	884.3	5,095.4	2,445.9	262.7	12.0	14.1
16-28	366.4	374.3	886.1	748.5	102.7	56.9	23.8
Less than 16	49.4	68.9	117.0	211.2	10.1	17.4	135.1
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0
Distance to road (miles)							
Less than 1/4	825.9	586.8	2,328.2	1,386.1	123.9	73.8	72.7
1/4-3/4	854.0	631.9	2,860.1	1,603.6	181.4	12.5	74.5
More than 3/4	92.6	108.8	910.2	415.9	70.2	--	25.8
All classes	1,772.5	1,327.5	6,098.5	3,405.6	375.5	86.3	173.0

Table 7.--Area of timberland by forest type and operability class, Michigan, 1980

(In thousand acres)

Forest type	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine	836.4	2.5	173.4	442.6	217.9
Red pine	656.5	1.2	168.1	300.1	187.1
White pine	214.1	2.5	74.2	111.3	26.1
Balsam fir	635.6	--	140.4	318.7	176.5
White spruce	99.9	--	23.6	49.4	26.9
Black spruce	519.9	--	28.4	246.1	245.4
Northern white-cedar	1,173.7	3.7	326.3	616.7	227.0
Tamarack	114.8	--	7.5	40.5	66.8
Oak-hickory	1,772.5	28.5	828.7	608.1	307.2
Elm-ash-soft maple	1,327.5	--	415.8	509.0	402.7
Maple-birch	6,098.5	48.7	2,545.4	2,453.9	1,050.5
Aspen	3,405.6	13.8	921.1	1,103.5	1,367.2
Paper birch	375.5	--	95.0	210.8	69.7
Exotic	86.3	--	6.0	34.1	46.2
Nonstocked	173.0	--	--	--	173.0
All types	17,489.8	100.9	5,753.9	7,044.8	4,590.2

Table 8.--Area of timberland in operability class II (medium) by limiting factor and forest type, Michigan, 1980

(In thousand acres)

Limiting factor	All types	Forest type							
		Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
1	418.8	3.2	--	21.7	--	--	1.6	6.1	--
2	6.2	--	--	--	--	--	--	--	--
3	3.0	--	--	--	--	--	--	--	--
4	14.6	--	--	--	--	1.5	--	--	--
5	161.8	7.5	4.1	1.5	--	1.5	--	1.5	--
6	--	--	--	--	--	--	--	--	--
7	246.1	--	3.5	1.5	--	--	--	1.4	--
1 & 2	38.5	4.6	2.6	--	--	--	--	--	--
1 & 3	8.0	--	--	--	--	--	--	--	--
1 & 4	75.8	1.5	2.0	--	--	--	--	--	--
1 & 5	426.5	20.9	19.7	9.0	16.3	--	--	1.6	--
1 & 6	1.5	--	--	--	--	--	--	1.5	--
1 & 7	551.0	1.7	4.9	12.0	4.9	1.7	--	2.9	--
2 & 3	11.7	1.4	--	--	--	--	--	--	--
2 & 4	2.3	--	2.3	--	--	--	--	--	--
2 & 5	3.8	--	--	--	--	--	--	--	--
2 & 6	1.4	--	--	--	--	--	--	--	--
2 & 7	33.6	--	4.7	--	--	--	--	1.8	--
3 & 4	--	--	--	--	--	--	--	--	--
3 & 5	114.1	2.6	--	--	--	--	--	--	1.6
3 & 6	--	--	--	--	--	--	--	--	--
3 & 7	8.3	--	--	--	--	--	--	--	--
4 & 5	9.2	--	--	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--	--	--	--
4 & 7	43.3	--	--	--	--	--	--	--	--
5 & 6	21.1	--	3.8	--	1.5	--	--	7.2	--
5 & 7	283.7	4.2	8.6	2.9	7.5	3.0	1.5	3.3	--
6 & 7	--	--	--	--	--	--	--	--	--
1 & 2 & 3	44.2	--	--	--	1.2	--	--	--	--
1 & 2 & 4	8.4	--	--	--	--	--	--	--	--
1 & 2 & 5	9.9	2.7	--	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--	--	--	--
1 & 2 & 7	46.7	--	--	--	--	--	--	--	--
1 & 3 & 4	--	--	--	--	--	--	--	--	--
1 & 3 & 5	218.4	1.1	3.0	1.7	4.7	1.7	--	--	--
1 & 3 & 6	--	--	--	--	--	--	--	--	--
1 & 3 & 7	8.3	--	--	--	--	--	--	--	--
1 & 4 & 5	25.2	--	--	--	--	--	--	2.0	--
1 & 4 & 6	1.6	--	--	--	--	--	--	1.6	--
1 & 4 & 7	109.4	--	--	--	--	--	--	2.0	--
1 & 5 & 6	26.3	--	3.7	--	1.6	--	--	13.6	--
1 & 5 & 7	588.2	10.5	32.3	5.8	23.8	5.8	1.6	7.1	--
1 & 6 & 7	3.1	--	--	--	--	--	--	3.1	--
2 & 3 & 4	1.4	--	--	--	--	--	--	--	--
2 & 3 & 5	37.3	1.4	--	--	--	--	--	--	--
2 & 3 & 6	--	--	--	--	--	--	--	--	--
2 & 3 & 7	44.6	--	--	1.8	--	--	--	--	--
2 & 4 & 5	3.2	--	--	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--	--	--	--
2 & 4 & 7	13.1	--	1.4	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--	--	--	--
2 & 5 & 7	6.2	1.4	2.3	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--	--	--	--
3 & 4 & 5	5.4	--	--	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--	--	--	--
3 & 4 & 7	2.5	--	--	--	--	--	--	--	--
3 & 5 & 6	22.9	--	--	--	--	--	--	4.7	--
3 & 5 & 7	187.6	1.5	--	--	4.8	--	--	1.5	--
3 & 6 & 7	--	--	--	--	--	--	--	--	--
4 & 5 & 6	10.4	--	--	--	--	--	--	7.4	--
4 & 5 & 7	43.7	--	--	--	--	1.4	--	2.0	--
4 & 6 & 7	--	--	--	--	--	--	--	--	--
5 & 6 & 7	48.5	1.8	--	1.4	3.8	1.5	--	28.5	--
4 or more	1,753.1	105.4	69.2	14.9	70.3	5.5	23.7	225.5	5.9
All factors	5,753.9	173.4	168.1	74.2	140.4	23.6	28.4	326.3	7.5

(Table 8 continued on next page)

(Table 8 continued)

Limiting factor	Forest type					
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic
1	76.5	28.9	229.2	46.7	--	4.9
2	--	3.3	2.9	--	--	--
3	--	--	1.5	1.5	--	--
4	--	--	11.5	1.6	--	--
5	8.7	5.9	93.5	35.2	2.4	--
6	--	--	--	--	--	--
7	54.3	16.0	141.2	26.7	1.5	--
1 & 2	16.6	3.2	9.2	2.3	--	--
1 & 3	4.1	2.3	--	1.6	--	--
1 & 4	13.2	10.0	46.9	2.2	--	--
1 & 5	57.0	23.0	185.3	87.1	6.6	--
1 & 6	--	--	--	--	--	--
1 & 7	92.8	44.7	279.6	98.4	7.4	--
2 & 3	--	2.9	5.1	2.3	--	--
2 & 4	--	--	--	--	--	--
2 & 5	--	--	--	3.8	--	--
2 & 6	--	--	1.4	--	--	--
2 & 7	4.2	2.5	15.1	5.3	--	--
3 & 4	--	--	--	--	--	--
3 & 5	15.8	8.2	59.3	26.6	--	--
3 & 6	--	--	--	--	--	--
3 & 7	4.2	--	4.1	--	--	--
4 & 5	--	--	7.7	1.5	--	--
4 & 6	--	--	--	--	--	--
4 & 7	2.5	8.0	29.0	3.8	--	--
5 & 6	2.9	--	4.2	1.5	--	--
5 & 7	24.5	19.4	160.4	41.4	7.0	--
6 & 7	--	--	--	--	--	--
1 & 2 & 3	14.7	5.8	9.4	10.8	2.3	--
1 & 2 & 4	--	--	4.6	3.8	--	--
1 & 2 & 5	3.9	--	3.3	--	--	--
1 & 2 & 6	--	--	--	--	--	--
1 & 2 & 7	27.4	12.3	4.8	2.2	--	--
1 & 3 & 4	--	--	--	--	--	--
1 & 3 & 5	30.7	10.0	100.9	52.8	11.8	--
1 & 3 & 6	--	--	--	--	--	--
1 & 3 & 7	5.1	--	1.5	1.7	--	--
1 & 4 & 5	--	4.8	13.0	5.4	--	--
1 & 4 & 6	--	--	--	--	--	--
1 & 4 & 7	7.2	8.5	86.4	5.3	--	--
1 & 5 & 6	2.6	--	4.8	--	--	--
1 & 5 & 7	58.6	29.3	310.8	88.2	14.4	--
1 & 6 & 7	--	--	--	--	--	--
2 & 3 & 4	--	--	1.4	--	--	--
2 & 3 & 5	13.4	3.3	10.8	8.4	--	--
2 & 3 & 6	--	--	--	--	--	--
2 & 3 & 7	4.2	9.7	8.2	20.7	--	--
2 & 4 & 5	--	--	3.2	--	--	--
2 & 4 & 6	--	--	--	--	--	--
2 & 4 & 7	5.5	--	3.4	2.8	--	--
2 & 5 & 6	--	--	--	--	--	--
2 & 5 & 7	--	2.5	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--
3 & 4 & 5	--	--	3.9	1.5	--	--
3 & 4 & 6	--	--	--	--	--	--
3 & 4 & 7	--	--	2.5	--	--	--
3 & 5 & 6	7.6	1.5	3.0	6.1	--	--
3 & 5 & 7	10.7	19.6	92.0	44.0	13.5	--
3 & 6 & 7	--	--	--	--	--	--
4 & 5 & 6	--	1.6	1.4	--	--	--
4 & 5 & 7	--	--	24.6	14.2	1.5	--
4 & 6 & 7	--	--	--	--	--	--
5 & 6 & 7	--	1.5	10.0	--	--	--
4 or more	259.8	127.1	554.4	263.7	26.6	1.1
All factors	828.7	415.8	2,545.4	921.1	95.0	6.0

Table 9.--Area of timberland in operability class III (poor) by limiting factor and forest type, Michigan, 1980

(In thousand acres)

Limiting factor	All types	Forest type: Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
1	3,540.7	216.8	148.5	60.8	194.2	23.6	107.4	269.0	12.7
2	23.4	4.9	--	1.5	--	--	--	--	--
3	672.8	41.5	45.0	5.2	9.3	7.9	10.8	67.1	3.5
4	56.5	--	--	--	--	--	--	1.0	--
5	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--
7	1,160.3	59.1	15.2	13.8	46.4	10.6	16.3	141.3	4.8
1 & 2	67.1	16.4	2.6	5.1	--	--	--	2.3	1.0
1 & 3	439.6	26.0	28.5	--	20.4	1.7	17.9	39.7	1.7
1 & 4	17.5	2.6	--	--	--	--	--	2.6	--
1 & 5	2.0	--	2.0	--	--	--	--	--	--
1 & 6	--	--	--	--	--	--	--	--	--
1 & 7	499.2	12.0	14.1	20.2	32.0	1.5	56.5	50.7	4.3
2 & 3	52.8	7.4	--	--	--	--	--	1.6	--
2 & 4	22.7	2.2	--	--	--	--	--	--	--
2 & 5	--	--	--	--	--	--	--	--	--
2 & 6	--	--	--	--	--	--	--	--	--
2 & 7	4.1	2.2	1.9	--	--	--	--	--	--
3 & 4	1.6	--	--	--	--	--	--	--	--
3 & 5	68.2	2.6	29.3	--	1.5	--	7.8	12.6	1.6
3 & 6	--	--	--	--	--	--	--	--	--
3 & 7	96.9	6.4	--	--	4.9	--	11.6	8.4	3.0
4 & 5	--	--	--	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--	--	--	--
4 & 7	12.7	--	--	--	1.5	--	--	--	--
5 & 6	--	--	--	--	--	--	--	--	--
5 & 7	--	--	--	--	--	--	--	--	--
6 & 7	--	--	--	--	--	--	--	--	--
1 & 2 & 3	111.0	20.7	2.6	3.3	5.2	--	1.6	--	2.7
1 & 2 & 4	16.9	--	--	--	--	--	--	2.3	1.9
1 & 2 & 5	--	--	--	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--	--	--	--
1 & 2 & 7	6.8	2.2	--	1.4	--	1.5	--	1.7	--
1 & 3 & 4	13.6	--	--	--	--	--	--	2.2	--
1 & 3 & 5	24.9	--	8.0	--	--	2.6	2.1	5.0	--
1 & 3 & 6	--	--	--	--	--	--	--	--	--
1 & 3 & 7	49.7	12.2	--	--	1.6	--	6.6	1.5	1.7
1 & 4 & 5	--	--	--	--	--	--	--	--	--
1 & 4 & 6	--	--	--	--	--	--	--	--	--
1 & 4 & 7	2.9	--	--	--	--	--	--	1.3	--
1 & 5 & 6	--	--	--	--	--	--	--	--	--
1 & 5 & 7	--	--	--	--	--	--	--	--	--
1 & 6 & 7	--	--	--	--	--	--	--	--	--
2 & 3 & 4	15.9	--	--	--	--	--	--	1.5	1.6
2 & 3 & 5	5.8	1.4	2.4	--	--	--	--	--	--
2 & 3 & 6	--	--	--	--	--	--	--	--	--
2 & 3 & 7	7.3	1.5	--	--	--	--	--	--	--
2 & 4 & 5	--	--	--	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--	--	--	--
2 & 4 & 7	--	--	--	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--	--	--	--
2 & 5 & 7	--	--	--	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--	--	--	--
3 & 4 & 5	--	--	--	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--	--	--	--
3 & 4 & 7	--	--	--	--	--	--	--	--	--
3 & 5 & 6	0.2	--	--	--	--	--	--	0.2	--
3 & 5 & 7	6.3	1.6	--	--	--	--	4.7	--	--
3 & 6 & 7	--	--	--	--	--	--	--	--	--
4 & 5 & 6	--	--	--	--	--	--	--	--	--
4 & 5 & 7	--	--	--	--	--	--	--	--	--
4 & 6 & 7	--	--	--	--	--	--	--	--	--
5 & 6 & 7	--	--	--	--	--	--	--	--	--
4 or more	45.4	2.9	--	--	1.7	--	2.8	4.7	--
All factors	7,044.8	442.6	300.1	111.3	318.7	49.4	246.1	616.7	40.5

(Table 9 continued on next page)

(Table 9 continued)

Limiting factor	Forest type					
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic
1	315.8	289.4	1,308.0	496.2	92.3	6.0
2	--	3.4	10.0	3.6	--	--
3	82.1	28.5	154.2	182.7	29.1	5.9
4	21.5	4.5	23.6	5.9	--	--
5	--	--	--	--	--	--
6	--	--	--	--	--	--
7	43.3	51.8	593.4	127.0	37.3	--
1 & 2	12.4	14.2	8.9	4.2	--	--
1 & 3	48.8	23.4	95.6	99.1	24.5	12.3
1 & 4	3.7	2.3	4.9	1.4	--	--
1 & 5	--	--	--	--	--	--
1 & 6	--	--	--	--	--	--
1 & 7	21.2	23.5	162.8	83.8	16.6	--
2 & 3	8.8	12.1	9.7	13.2	--	--
2 & 4	4.9	6.0	7.0	2.6	--	--
2 & 5	--	--	--	--	--	--
2 & 6	--	--	--	--	--	--
2 & 7	--	--	--	--	--	--
3 & 4	--	--	1.6	--	--	--
3 & 5	--	--	2.2	4.1	--	6.5
3 & 6	--	--	--	--	--	--
3 & 7	12.4	5.2	16.5	23.6	4.9	--
4 & 5	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--
4 & 7	--	--	11.2	--	--	--
5 & 6	--	--	--	--	--	--
5 & 7	--	--	--	--	--	--
6 & 7	--	--	--	--	--	--
1 & 2 & 3	12.0	22.7	12.9	23.9	--	3.4
1 & 2 & 4	10.5	--	2.2	--	--	--
1 & 2 & 5	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--
1 & 2 & 7	--	--	--	--	--	--
1 & 3 & 4	--	--	11.4	--	--	--
1 & 3 & 5	--	5.7	1.5	--	--	--
1 & 3 & 6	--	--	--	--	--	--
1 & 3 & 7	2.2	--	--	21.6	2.3	--
1 & 4 & 5	--	--	--	--	--	--
1 & 4 & 6	--	--	--	--	--	--
1 & 4 & 7	--	--	1.6	--	--	--
1 & 5 & 6	--	--	--	--	--	--
1 & 5 & 7	--	--	--	--	--	--
1 & 6 & 7	--	--	--	--	--	--
2 & 3 & 4	--	6.3	4.2	--	2.3	--
2 & 3 & 5	--	--	2.0	--	--	--
2 & 3 & 6	--	--	--	--	--	--
2 & 3 & 7	--	--	1.9	3.9	--	--
2 & 4 & 5	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--
2 & 4 & 7	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--
2 & 5 & 7	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--
3 & 4 & 5	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--
3 & 4 & 7	--	--	--	--	--	--
3 & 5 & 6	--	--	--	--	--	--
3 & 5 & 7	--	--	--	--	--	--
3 & 6 & 7	--	--	--	--	--	--
4 & 5 & 6	--	--	--	--	--	--
4 & 5 & 7	--	--	--	--	--	--
4 & 6 & 7	--	--	--	--	--	--
5 & 6 & 7	--	--	--	--	--	--
4 or more	8.5	10.0	6.6	6.7	1.5	--
All factors	608.1	509.0	2,453.9	1,103.5	210.8	34.1

Table 10.--Area of timberland by forest type, average growing-stock volume and operability class, Michigan, 1980

(In thousand acres)

Forest type and average growing-stock volume per acre (cu.ft. per acre)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine					
More than 1000	205.7	2.5	86.1	117.1	--
400-1000	408.8	--	87.3	263.7	57.8
Less than 400	221.9	--	--	61.8	160.1
All classes	836.4	2.5	173.4	442.6	217.9
Red pine					
More than 1000	320.8	1.2	126.0	184.8	8.8
400-1000	194.6	--	42.1	105.8	46.7
Less than 400	141.1	--	--	9.5	131.6
All classes	656.5	1.2	168.1	300.1	187.1
White pine					
More than 1000	135.5	2.5	63.4	69.6	--
400-1000	49.1	--	10.8	30.4	7.9
Less than 400	29.5	--	--	11.3	18.2
All classes	214.1	2.5	74.2	111.3	26.1
Balsam fir					
More than 1000	297.2	--	98.0	198.0	1.2
400-1000	231.8	--	42.4	113.8	75.6
Less than 400	106.6	--	--	6.9	99.7
All classes	635.6	--	140.4	318.7	176.5
White spruce					
More than 1000	54.9	--	23.6	31.3	--
400-1000	27.8	--	--	16.6	11.2
Less than 400	17.2	--	--	1.5	15.7
All classes	99.9	--	23.6	49.4	26.9
Black spruce					
More than 1000	127.3	--	14.8	112.5	--
400-1000	226.1	--	13.6	130.5	82.0
Less than 400	166.5	--	--	3.1	163.4
All classes	519.9	--	28.4	246.1	245.4
Northern white-cedar					
More than 1000	683.7	3.7	254.6	422.7	2.7
400-1000	348.7	--	71.7	181.6	95.4
Less than 400	141.3	--	--	12.4	128.9
All classes	1,173.7	3.7	326.3	616.7	227.0
Tamarack					
More than 1000	7.9	--	1.6	6.3	--
400-1000	43.7	--	5.9	27.0	10.8
Less than 400	63.2	--	--	7.2	56.0
All classes	114.8	--	7.5	40.5	66.8

(Table 10 continued on next page)

(Table 10 continued)

Forest type and average growing-stock volume per acre (cu.ft. per acre)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Oak-hickory					
More than 1000	929.4	28.5	539.7	355.6	5.6
400-1000	594.0	--	289.0	195.4	109.6
Less than 400	249.1	--	--	57.1	192.0
All classes	1,772.5	28.5	828.7	608.1	307.2
Elm-ash-soft maple					
More than 1000	545.2	--	295.1	247.0	3.1
400-1000	447.2	--	120.7	187.3	139.2
Less than 400	335.1	--	--	74.7	260.4
All classes	1,327.5	--	415.8	509.0	402.7
Maple-birch					
More than 1000	4,091.8	48.7	2,191.5	1,819.9	31.7
400-1000	1,392.4	--	353.9	568.6	469.9
Less than 400	614.3	--	--	65.4	548.9
All classes	6,098.5	48.7	2,545.4	2,453.9	1,050.5
Aspen					
More than 1000	1,329.7	13.8	747.0	556.2	12.7
400-1000	1,133.9	--	174.1	489.2	470.6
Less than 400	942.0	--	--	58.1	883.9
All classes	3,405.6	13.8	921.1	1,103.5	1,367.2
Paper birch					
More than 1000	231.9	--	87.4	144.5	--
400-1000	98.9	--	7.6	62.5	28.8
Less than 400	44.7	--	--	3.8	40.9
All classes	375.5	--	95.0	210.8	69.7
Exotic					
More than 1000	11.0	--	4.9	6.1	--
400-1000	27.4	--	1.1	24.6	1.7
Less than 400	47.9	--	--	3.4	44.5
All classes	86.3	--	6.0	34.1	46.2
Nonstocked					
More than 1000	--	--	--	--	--
400-1000	--	--	--	--	--
Less than 400	173.0	--	--	--	173.0
All classes	173.0	--	--	--	173.0
All types					
More than 1000	8,972.0	100.9	4,533.7	4,271.6	65.8
400-1000	5,224.4	--	1,220.2	2,397.0	1,607.2
Less than 400	3,293.4	--	--	376.2	2,917.2
All classes	17,489.8	100.9	5,753.9	7,044.8	4,590.2

Table 11.--Area of timberland by forest type, stand-age class and operability class, Michigan, 1980

(In thousand acres)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine					
less than 21	185.0	--	--	16.4	168.6
21-40	230.3	--	41.9	139.1	49.3
41-60	306.2	--	90.5	215.7	--
61-80	91.2	2.5	38.7	50.0	--
81-100	18.9	--	--	18.9	--
101-120	2.3	--	2.3	--	--
More than 120	2.5	--	--	2.5	--
All ages	836.4	2.5	173.4	442.6	217.9
Red pine					
less than 21	192.0	--	2.4	15.7	173.9
21-40	299.1	--	96.0	189.9	13.2
41-60	82.5	1.2	39.6	41.7	--
61-80	41.1	--	12.7	28.4	--
81-100	23.8	--	13.7	10.1	--
101-120	16.5	--	3.7	12.8	--
More than 120	1.5	--	--	1.5	--
All ages	656.5	1.2	168.1	300.1	187.1
White pine					
less than 21	19.5	--	--	--	19.5
21-40	22.9	--	1.7	14.6	6.6
41-60	34.1	--	19.7	14.4	--
61-80	60.3	2.5	32.9	24.9	--
81-100	46.8	--	13.5	33.3	--
101-120	13.0	--	--	13.0	--
More than 120	17.5	--	6.4	11.1	--
All ages	214.1	2.5	74.2	111.3	26.1
Balsam fir					
less than 21	125.6	--	--	--	125.6
21-40	122.5	--	17.9	53.7	50.9
41-60	211.6	--	57.1	154.5	--
61-80	99.5	--	37.9	61.6	--
81-100	37.0	--	12.8	24.2	--
101-120	23.5	--	6.3	17.2	--
More than 120	15.9	--	8.4	7.5	--
All ages	635.6	--	140.4	318.7	176.5
White spruce					
less than 21	25.7	--	--	--	25.7
21-40	21.0	--	1.6	18.2	1.2
41-60	25.6	--	11.2	14.4	--
61-80	8.0	--	1.5	6.5	--
81-100	7.9	--	2.5	5.4	--
101-120	9.5	--	4.6	4.9	--
More than 120	2.2	--	2.2	--	--
All ages	99.9	--	23.6	49.4	26.9

(Table 11 continued on next page)

(Table 11 continued)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Black spruce					
less than 21	126.0	--	--	2.9	123.1
21-40	201.7	--	--	91.7	110.0
41-60	102.3	--	16.3	77.3	8.7
61-80	52.8	--	6.1	43.1	3.6
81-100	10.7	--	--	10.7	--
101-120	13.3	--	4.4	8.9	--
More than 120	13.1	--	1.6	11.5	--
All ages	519.9	--	28.4	246.1	245.4
Northern white-cedar					
less than 21	81.4	--	1.5	2.3	77.6
21-40	161.5	--	9.9	21.0	130.6
41-60	176.5	--	63.1	94.6	18.8
61-80	268.4	--	83.7	184.7	--
81-100	221.7	--	86.3	135.4	--
101-120	139.4	2.2	35.4	101.8	--
More than 120	124.8	1.5	46.4	76.9	--
All ages	1,173.7	3.7	326.3	616.7	227.0
Tamarack					
less than 21	35.6	--	2.3	--	33.3
21-40	27.4	--	--	--	27.4
41-60	24.2	--	2.0	16.1	6.1
61-80	15.7	--	1.6	14.1	--
81-100	5.9	--	1.6	4.3	--
101-120	3.7	--	--	3.7	--
More than 120	2.3	--	--	2.3	--
All ages	114.8	--	7.5	40.5	66.8
Oak-hickory					
less than 21	297.1	--	2.6	--	294.5
21-40	122.0	--	53.0	56.3	12.7
41-60	485.4	4.2	251.9	229.3	--
61-80	394.7	8.4	219.1	167.2	--
81-100	250.5	9.1	155.3	86.1	--
101-120	167.0	6.8	116.9	43.3	--
More than 120	55.8	--	29.9	25.9	--
All ages	1,772.5	28.5	828.7	608.1	307.2
Elm-ash-soft maple					
less than 21	336.8	--	--	--	336.8
21-40	214.9	--	42.6	108.7	63.6
41-60	264.1	--	123.0	138.8	2.3
61-80	206.9	--	89.4	117.5	--
81-100	140.8	--	86.4	54.4	--
101-120	102.1	--	48.4	53.7	--
More than 120	61.9	--	26.0	35.9	--
All ages	1,327.5	--	415.8	509.0	402.7

(Table 11 continued on next page)

(Table 11 continued)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Maple-birch					
less than 21	929.8	--	--	--	929.8
21-40	567.9	--	195.2	253.2	119.5
41-60	1,792.3	5.9	909.1	876.1	1.2
61-80	917.0	3.9	478.9	434.2	--
81-100	916.5	21.1	478.7	416.7	--
101-120	618.6	14.5	317.5	286.6	--
More than 120	356.4	3.3	166.0	187.1	--
All ages	6,098.5	48.7	2,545.4	2,453.9	1,050.5
Aspen					
less than 21	1,293.0	--	--	13.6	1,279.4
21-40	506.4	--	135.4	286.4	84.6
41-60	990.1	4.6	455.5	526.8	3.2
61-80	395.8	4.0	206.1	185.7	--
81-100	161.6	5.2	90.4	66.0	--
101-120	50.1	--	33.7	16.4	--
More than 120	8.6	--	--	8.6	--
All ages	3,405.6	13.8	921.1	1,103.5	1,367.2
Paper birch					
less than 21	63.9	--	--	6.6	57.3
21-40	37.1	--	5.6	19.1	12.4
41-60	137.8	--	40.9	96.9	--
61-80	106.7	--	32.4	74.3	--
81-100	20.4	--	11.4	9.0	--
101-120	3.1	--	1.5	1.6	--
More than 120	6.5	--	3.2	3.3	--
All ages	375.5	--	95.0	210.8	69.7
Exotic					
less than 21	38.5	--	--	--	38.5
21-40	38.3	--	1.1	29.5	7.7
41-60	9.5	--	4.9	4.6	--
61-80	--	--	--	--	--
81-100	--	--	--	--	--
101-120	--	--	--	--	--
More than 120	--	--	--	--	--
All ages	86.3	--	6.0	34.1	46.2
Nonstocked					
less than 21	139.7	--	--	--	139.7
21-40	18.8	--	--	--	18.8
41-60	10.9	--	--	--	10.9
61-80	--	--	--	--	--
81-100	3.6	--	--	--	3.6
101-120	--	--	--	--	--
More than 120	--	--	--	--	--
All ages	173.0	--	--	--	173.0
All types					
less than 21	3,889.6	--	8.8	57.5	3,823.3
21-40	2,591.8	--	601.9	1,281.4	708.5
41-60	4,653.1	15.9	2,084.8	2,501.2	51.2
61-80	2,658.1	21.3	1,241.0	1,392.2	3.6
81-100	1,866.1	35.4	952.6	874.5	3.6
101-120	1,162.1	23.5	574.7	563.9	--
More than 120	669.0	4.8	290.1	374.1	--
All ages	17,489.8	100.9	5,753.9	7,044.8	4,590.2

Table 12.--Area of timberland by forest type, ownership class and operability class, Michigan, 1980

(In thousand acres)

Forest type and ownership class	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack Pine					
National Forest	268.1	--	46.8	159.4	61.9
Other federal	8.9	--	1.4	5.7	1.8
Indian	--	--	--	--	--
State	360.5	--	87.2	169.3	104.0
County and municipal	17.3	--	1.6	7.5	8.2
Forest industry	11.9	--	3.0	7.6	1.3
Farmer	25.4	--	8.6	6.3	10.5
Miscellaneous private	144.3	2.5	24.8	86.8	30.2
All owners	836.4	2.5	173.4	442.6	217.9
Red pine					
National Forest	319.4	--	84.4	110.4	124.6
Other federal	1.9	--	--	1.9	--
Indian	--	--	--	--	--
State	161.4	1.2	48.2	81.1	30.9
County and municipal	9.8	--	3.4	4.7	1.7
Forest industry	4.8	--	1.4	3.4	--
Farmer	58.9	--	9.1	42.3	7.5
Miscellaneous private	100.3	--	21.6	56.3	22.4
All owners	656.5	1.2	168.1	300.1	187.1
White pine					
National Forest	22.3	--	11.0	11.3	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	68.2	--	23.2	27.7	17.3
County and municipal	--	--	--	--	--
Forest industry	18.7	--	4.7	14.0	--
Farmer	27.5	2.5	9.7	11.4	3.9
Miscellaneous private	77.4	--	25.6	46.9	4.9
All owners	214.1	2.5	74.2	111.3	26.1
Balsam fir					
National Forest	115.8	--	5.5	90.0	20.3
Other federal	3.1	--	1.6	1.5	--
Indian	--	--	--	--	--
State	118.3	--	35.4	47.5	35.4
County and municipal	3.3	--	1.7	--	1.6
Forest industry	135.6	--	23.9	59.6	52.1
Farmer	47.2	--	15.2	18.8	13.2
Miscellaneous private	212.3	--	57.1	101.3	53.9
All owners	635.6	--	140.4	318.7	176.5
White spruce					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	22.5	--	4.6	8.1	9.8
County and municipal	2.5	--	--	--	2.5
Forest industry	21.0	--	4.8	13.3	2.9
Farmer	10.2	--	4.7	3.1	2.4
Miscellaneous private	43.7	--	9.5	24.9	9.3
All owners	99.9	--	23.6	49.4	26.9

(Table 12 continued on next page)

(Table 12 continued)

Forest type and ownership class	All classes	Overability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Black spruce					
National Forest	161.7	--	5.6	124.0	32.1
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	149.3	--	10.6	50.1	88.6
County and municipal	3.2	--	--	1.7	1.5
Forest industry	70.3	--	4.5	22.1	43.7
Farmer	20.2	--	3.1	4.5	12.6
Miscellaneous private	115.2	--	4.6	43.7	66.9
All owners	519.9	--	28.4	246.1	245.4
Northern white-cedar					
National Forest	68.3	--	8.9	54.1	5.3
Other federal	--	--	--	--	--
Indian	1.6	--	--	--	1.6
State	323.8	2.2	103.0	165.9	52.7
County and municipal	11.0	--	--	8.1	2.9
Forest industry	205.3	--	42.9	131.1	31.3
Farmer	212.4	--	60.4	90.8	61.2
Miscellaneous private	351.3	1.5	111.1	166.7	72.0
All owners	1,173.7	3.7	326.3	616.7	227.0
Tamarack					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	44.6	--	3.2	14.0	27.4
County and municipal	--	--	--	--	--
Forest industry	20.0	--	--	9.7	10.3
Farmer	11.4	--	2.0	3.4	6.0
Miscellaneous private	38.8	--	2.3	13.4	23.1
All owners	114.8	--	7.5	40.5	66.8
Oak-hickory					
National Forest	245.9	--	130.6	78.5	36.8
Other federal	10.8	--	--	--	10.8
Indian	--	--	--	--	--
State	341.9	2.6	142.9	124.3	72.1
County and municipal	19.0	--	2.3	10.9	5.8
Forest industry	13.0	--	3.9	9.1	--
Farmer	364.3	13.4	155.4	150.6	44.9
Miscellaneous private	777.6	12.5	393.6	234.7	136.8
All owners	1,772.5	28.5	828.7	608.1	307.2
Elm-ash-soft maple					
National Forest	40.6	--	14.9	25.7	--
Other federal	4.3	--	--	4.3	--
Indian	1.5	--	--	1.5	--
State	185.6	--	62.7	62.3	60.6
County and municipal	23.4	--	10.2	6.3	6.9
Forest industry	101.2	--	32.0	44.6	24.6
Farmer	440.7	--	156.2	148.4	136.1
Miscellaneous private	530.2	--	139.8	215.9	174.5
All owners	1,327.5	--	415.8	509.0	402.7

(Table 12 continued on next page)

(Table 12 continued)

Forest type and ownership class	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Maple-birch					
National Forest	687.2	--	230.1	442.5	14.6
Other federal	4.9	--	1.6	--	3.3
Indian	12.6	--	9.4	3.2	--
State	846.6	3.4	319.9	344.1	179.2
County and municipal	62.4	--	24.8	31.0	6.6
Forest industry	1,105.5	10.6	506.3	482.8	105.8
Farmer	1,212.1	24.8	484.7	386.8	315.8
Miscellaneous private	2,167.2	9.9	968.6	763.5	425.2
All owners	6,098.5	48.7	2,545.4	2,453.9	1,050.5
Aspen					
National Forest	452.6	--	113.3	171.1	168.2
Other federal	7.9	--	--	6.4	1.5
Indian	6.7	--	5.1	--	1.6
State	832.9	--	202.0	200.0	430.9
County and municipal	29.3	--	5.4	14.6	9.3
Forest industry	210.2	--	42.8	70.3	97.1
Farmer	555.3	6.9	179.2	197.3	171.9
Miscellaneous private	1,310.7	6.9	373.3	443.8	486.7
All owners	3,405.6	13.8	921.1	1,103.5	1,367.2
Paper birch					
National Forest	41.2	--	0.9	40.3	--
Other federal	1.5	--	--	1.5	--
Indian	--	--	--	--	--
State	73.2	--	32.9	36.0	4.3
County and municipal	5.3	--	--	--	5.3
Forest industry	61.0	--	11.3	38.0	11.7
Farmer	56.6	--	9.4	31.4	15.8
Miscellaneous private	136.7	--	40.5	63.6	32.6
All owners	375.5	--	95.0	210.8	69.7
Exotic					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	--	--	--	--	--
County and municipal	--	--	--	--	--
Forest industry	1.0	--	--	--	1.0
Farmer	17.8	--	--	13.3	4.5
Miscellaneous private	67.5	--	6.0	20.8	40.7
All owners	86.3	--	6.0	34.1	46.2
Nonstocked					
National Forest	16.0	--	--	--	16.0
Other federal	1.7	--	--	--	1.7
Indian	--	--	--	--	--
State	44.7	--	--	--	44.7
County and municipal	--	--	--	--	--
Forest industry	2.5	--	--	--	2.5
Farmer	38.6	--	--	--	38.6
Miscellaneous private	69.5	--	--	--	69.5
All owners	173.0	--	--	--	173.0
All types					
National Forest	2,439.1	--	652.0	1,307.3	479.8
Other federal	45.0	--	4.6	21.3	19.1
Indian	22.4	--	14.5	4.7	3.2
State	3,573.5	9.4	1,075.8	1,330.4	1,157.9
County and municipal	186.5	--	49.4	84.8	52.3
Forest industry	1,982.0	10.6	681.5	905.6	384.3
Farmer	3,098.6	47.6	1,097.7	1,108.4	844.9
Miscellaneous private	6,142.7	33.3	2,178.4	2,282.3	1,648.7
All owners	17,489.8	100.9	5,753.9	7,044.8	4,590.2

Table 13.--Area of timberland by distance from major wood-using center and operability class, Michigan, 1980

(In thousand acres)

Wood-using center and distance (miles)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Alpena					
Less than 20	263.3	--	66.8	94.9	101.6
20-50	1,277.4	2.4	314.0	543.3	417.7
More than 50	15,949.1	98.5	5,373.1	6,406.6	4,070.9
Brighton					
Less than 20	142.3	6.8	59.4	46.8	29.3
20-50	509.8	6.8	208.8	141.8	152.4
More than 50	16,837.7	87.3	5,485.7	6,856.2	4,408.5
Cadillac					
Less than 20	475.4	2.3	190.4	165.6	117.1
20-50	2,277.6	14.2	777.6	754.6	731.2
More than 50	14,736.8	84.4	4,785.9	6,124.6	3,741.9
Escanaba					
Less than 20	328.2	1.4	87.3	144.4	95.1
20-50	1,795.4	10.6	442.7	902.7	439.4
More than 50	15,366.2	88.9	5,223.9	5,997.7	4,055.7
Filer City					
Less than 20	287.1	--	99.8	103.9	83.4
20-50	1,252.9	6.8	464.8	441.4	339.9
More than 50	15,949.8	94.1	5,189.3	6,499.5	4,166.9
Gaylord-Grayling					
Less than 20	558.2	2.4	186.9	188.0	180.9
20-50	2,446.1	9.8	812.7	880.5	743.1
More than 50	14,485.5	88.7	4,754.3	5,976.3	3,666.2
Iron Mountain					
Less than 20	269.8	1.5	95.8	94.5	78.0
20-50	1,902.2	8.8	510.9	831.8	550.7
More than 50	15,317.8	90.6	5,147.2	6,118.5	3,961.5
L'Anse					
Less than 20	615.6	--	305.3	234.5	75.8
20-50	2,394.4	1.6	900.6	1,111.3	380.9
More than 50	14,479.8	99.3	4,548.0	5,699.0	4,133.5
Manistique					
Less than 20	345.9	1.7	71.7	199.8	72.7
20-50	1,621.8	6.7	428.6	801.7	384.8
More than 50	15,522.1	92.5	5,253.6	6,043.3	4,132.7
Midland					
Less than 20	217.5	--	61.1	79.2	77.2
20-50	1,095.0	15.2	384.5	339.3	356.0
More than 50	16,177.3	85.7	5,308.3	6,626.3	4,157.0
Muskegon					
Less than 20	223.4	--	93.0	61.0	69.4
20-50	832.7	8.4	315.3	260.8	248.2
More than 50	16,433.7	92.5	5,345.6	6,723.0	4,272.6
Newberry					
Less than 20	623.7	3.0	129.4	296.2	195.1
20-50	1,494.0	6.8	279.8	862.8	344.6
More than 50	15,372.1	91.1	5,344.7	5,885.8	4,050.5
Ontonagon					
Less than 20	364.3	--	177.6	144.0	42.7
20-50	1,717.8	4.8	660.1	792.6	260.3
More than 50	15,407.7	96.1	4,916.2	6,108.2	4,287.2
Otsego					
Less than 20	223.8	--	109.8	52.1	61.9
20-50	600.3	7.6	205.8	182.8	204.1
More than 50	16,665.7	93.3	5,438.3	6,809.9	4,324.2
West Branch					
Less than 20	503.8	2.3	150.2	181.9	169.4
20-50	2,098.4	12.1	597.3	792.7	696.3
More than 50	14,887.6	86.5	5,006.4	6,070.2	3,724.5
Closest wood-using center					
Less than 20	5,442.3	21.4	1,884.5	2,086.8	1,449.6
20-50	10,688.1	69.2	3,378.6	4,480.5	2,759.8
More than 50	1,359.4	10.3	490.8	477.5	380.8

Table 14.--Growing-stock volume on timberland by operability class component and forest type, Michigan, 1980

(In thousand cubic feet)

Operability class component	All types	Forest type: Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
Stand area (acres)									
More than 60	4,259,224	115,265	76,614	30,446	99,233	37,291	58,644	433,816	15,900
10-60	8,076,397	227,065	333,827	141,458	200,068	37,290	52,799	409,311	10,973
Less than 10	6,768,201	273,069	278,924	128,495	355,759	40,886	231,166	556,658	27,183
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Growing-stock volume (cubic feet/acre)									
More than 1000	14,845,051	280,191	542,975	259,176	463,741	94,921	168,132	1,120,404	9,835
400-1000	3,706,755	289,833	135,547	33,678	168,618	17,893	147,937	250,796	30,647
Less than 400	552,016	45,375	10,843	7,545	22,701	2,653	26,540	28,585	13,574
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Sawtimber volume (board feet/acre)									
More than 2500	11,575,470	233,706	354,301	261,890	381,911	74,392	74,696	715,464	6,209
700-2500	5,470,850	263,231	170,868	32,003	208,374	22,785	170,156	493,783	26,823
Less than 700	2,057,502	118,462	164,196	6,506	64,775	18,290	97,757	190,538	21,024
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Percent cull trees (percent)									
Less than 20	16,701,643	569,796	664,408	267,137	563,812	107,033	309,649	1,177,261	46,880
20-50	2,252,166	39,943	23,623	32,558	89,569	8,434	32,645	215,564	4,927
More than 50	150,013	5,660	1,334	704	1,679	--	315	6,960	2,249
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Average d.b.h. of growing-stock trees (inches)									
More than 9	6,241,488	93,697	113,039	191,898	98,949	15,711	10,024	158,300	3,884
6-9	12,645,219	506,342	517,494	108,501	549,525	96,450	308,023	1,208,415	44,218
Less than 6	217,115	15,360	58,832	--	6,586	3,306	24,562	33,070	5,954
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Average merchantable height of growing-stock trees (feet)									
More than 28	15,044,742	289,703	384,431	264,704	401,591	78,542	115,510	250,438	20,176
16-28	4,034,691	325,262	303,073	35,695	253,039	36,925	226,180	1,136,487	32,706
Less than 16	24,389	434	1,861	--	430	--	919	12,860	1,174
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056
Distance to road (miles)									
Less than 1/4	6,974,766	267,253	285,270	145,083	180,572	40,746	57,080	353,579	18,184
1/4-3/4	9,262,494	255,150	352,740	102,599	332,091	50,223	151,897	725,378	19,126
More than 3/4	2,866,562	92,996	51,355	52,712	142,397	24,498	133,632	320,828	16,746
All classes	19,103,822	615,399	689,365	300,399	655,060	115,467	342,609	1,399,785	54,056

(Table 14 continued on next page)

(Table 14 continued)

Operability class component	Forest type						
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic	Non-stocked
Stand area (acres)							
More than 60	376,219	275,628	1,954,942	699,518	81,419	3,030	1,259
10-60	1,040,962	476,669	3,586,408	1,354,252	184,949	20,323	43
Less than 10	596,937	505,530	2,513,536	1,058,101	177,151	22,108	2,698
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Growing-stock volume (cubic feet/acre)							
More than 1000	1,513,594	894,785	6,926,413	2,185,089	366,876	18,919	--
400-1000	447,092	299,365	1,017,627	778,371	69,070	20,281	--
Less than 400	53,432	63,677	110,846	148,411	7,573	6,261	4,000
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Sawtimber volume (board feet/acre)							
More than 2500	1,257,159	743,214	5,896,801	1,432,233	134,797	8,697	--
700-2500	578,342	395,331	1,742,277	1,132,913	224,650	8,946	368
Less than 700	178,617	119,282	415,808	546,725	84,072	27,818	3,632
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Percent cull trees (percent)							
Less than 20	1,866,655	1,065,442	6,817,528	2,797,123	409,118	37,863	1,938
20-50	117,050	180,029	1,170,654	296,366	33,612	6,133	1,059
More than 50	30,413	12,356	66,704	18,382	789	1,465	1,003
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Average d.b.h. of growing-stock trees (inches)							
More than 9	987,742	475,330	3,298,265	749,809	34,582	9,235	1,023
6-9	1,022,378	774,620	4,742,749	2,327,831	407,485	28,565	2,623
Less than 6	3,998	7,877	13,872	34,231	1,452	7,661	354
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Average merchantable height of growing-stock trees (feet)							
More than 28	1,755,945	1,007,385	7,396,463	2,699,532	364,890	13,588	1,844
16-28	256,566	249,179	657,565	409,972	78,629	31,360	2,053
Less than 16	1,607	1,263	858	2,367	--	513	103
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000
Distance to road (miles)							
Less than 1/4	929,393	478,667	2,856,451	1,195,899	125,531	39,803	1,250
1/4-3/4	976,764	650,829	3,915,660	1,502,125	220,651	5,658	1,603
More than 3/4	107,961	128,331	1,282,775	413,847	97,337	--	1,147
All classes	2,014,118	1,257,827	8,054,886	3,111,871	443,519	45,461	4,000

Table 15.--Growing-stock volume on timberland by forest type and operability class, Michigan, 1980

(In thousand cubic feet)

est type	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine	615,399	3,341	197,059	354,922	60,077
Red pine	689,365	1,779	258,663	385,630	43,293
White pine	300,399	3,133	140,572	147,709	8,985
Balsam fir	655,060	--	195,373	393,447	66,240
White spruce	115,467	--	39,710	66,566	9,191
Black spruce	342,609	--	33,015	237,764	71,830
Northern white-cedar	1,399,785	8,912	475,214	830,187	85,472
Tamarack	54,056	--	7,267	29,033	17,756
Oak-hickory	2,014,118	48,959	1,146,032	710,111	109,016
Elm-ash-soft maple	1,257,827	--	580,539	549,515	127,773
Maple-birch	8,054,886	89,254	4,070,461	3,466,173	428,998
Aspen	3,111,871	26,678	1,409,006	1,243,615	432,572
Paper birch	443,519	--	161,071	258,064	24,384
Exotic	45,461	--	9,758	29,181	6,522
Nonstocked	4,000	--	--	--	4,000
All types	19,103,822	182,056	8,723,740	8,701,917	1,496,109

Table 16.--Growing-stock volume on timberland in operability class II (medium) by limiting factor and forest type, Michigan, 1980

(In thousand cubic feet)

Limiting factor	All types	Forest type							
		Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
1	791,368	4,704	--	58,379	--	--	3,375	13,306	--
2	5,349	--	--	--	--	--	--	--	--
3	3,489	--	--	--	--	--	--	--	--
4	20,719	--	--	--	--	3,294	--	--	--
5	294,381	9,878	7,364	2,465	--	1,874	--	2,415	--
6	--	--	--	--	--	--	--	--	--
7	465,664	--	6,508	2,648	--	--	--	4,074	--
1 & 2	31,558	3,709	1,773	--	--	--	--	--	--
1 & 3	9,503	--	--	--	--	--	--	--	--
1 & 4	122,567	2,387	2,339	--	--	--	--	--	--
1 & 5	781,814	34,099	29,651	22,458	26,876	--	--	3,771	--
1 & 6	3,759	--	--	--	--	--	--	3,759	--
1 & 7	1,043,337	2,665	7,853	19,499	8,475	1,950	--	6,367	--
2 & 3	9,172	744	--	--	--	--	--	--	--
2 & 4	1,747	--	1,747	--	--	--	--	--	--
2 & 5	3,627	--	--	--	--	--	--	--	--
2 & 6	1,354	--	--	--	--	--	--	--	--
2 & 7	29,128	--	3,695	--	--	--	--	1,372	--
3 & 4	--	--	--	--	--	--	--	--	--
3 & 5	165,515	2,984	--	--	--	--	--	--	1,720
3 & 6	--	--	--	--	--	--	--	--	--
3 & 7	10,996	--	--	--	--	--	--	--	--
4 & 5	11,793	--	--	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--	--	--	--
4 & 7	77,180	--	--	--	--	--	--	--	--
5 & 6	32,524	--	7,195	--	2,379	--	--	11,097	--
5 & 7	529,819	5,457	14,724	3,864	11,742	7,868	1,555	6,047	--
6 & 7	--	--	--	--	--	--	--	--	--
1 & 2 & 3	31,950	--	--	--	536	--	--	--	--
1 & 2 & 4	7,189	--	--	--	--	--	--	--	--
1 & 2 & 5	9,266	2,636	--	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--	--	--	--
1 & 2 & 7	40,362	--	--	--	--	--	--	--	--
1 & 3 & 4	--	--	--	--	--	--	--	--	--
1 & 3 & 5	322,815	1,308	4,402	1,734	5,927	2,010	--	--	--
1 & 3 & 6	--	--	--	--	--	--	--	--	--
1 & 3 & 7	8,887	--	--	--	--	--	--	--	--
1 & 4 & 5	34,929	--	--	--	--	--	--	3,976	--
1 & 4 & 6	2,419	--	--	--	--	--	--	2,419	--
1 & 4 & 7	167,920	--	--	--	--	--	--	5,691	--
1 & 5 & 6	46,910	--	8,862	--	3,717	--	--	25,764	--
1 & 5 & 7	1,089,365	16,146	75,175	12,971	47,056	9,242	3,272	12,581	--
1 & 6 & 7	4,234	--	--	--	--	--	--	4,234	--
2 & 3 & 4	828	--	--	--	--	--	--	--	--
2 & 3 & 5	28,860	1,181	--	--	--	--	--	--	--
2 & 3 & 6	--	--	--	--	--	--	--	--	--
2 & 3 & 7	30,307	--	--	804	--	--	--	--	--
2 & 4 & 5	2,709	--	--	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--	--	--	--
2 & 4 & 7	11,152	--	1,074	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--	--	--	--
2 & 5 & 7	5,080	1,045	1,670	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--	--	--	--
3 & 4 & 5	6,130	--	--	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--	--	--	--
3 & 4 & 7	3,460	--	--	--	--	--	--	--	--
3 & 5 & 6	29,743	--	--	--	--	--	--	5,928	--
3 & 5 & 7	287,357	2,157	--	--	8,644	--	--	1,832	--
3 & 6 & 7	--	--	--	--	--	--	--	--	--
4 & 5 & 6	19,520	--	--	--	--	--	--	16,083	--
4 & 5 & 7	65,521	--	--	--	--	2,590	--	3,651	--
4 & 6 & 7	--	--	--	--	--	--	--	--	--
5 & 6 & 7	78,117	2,283	--	2,335	5,205	2,279	--	49,393	--
4 or more	1,942,347	103,676	84,631	13,415	74,816	8,603	24,813	291,454	5,547
All factors	8,723,740	197,059	258,663	140,572	195,373	39,710	33,015	475,214	7,267

(Table 16 continued on next page)

(Table 16 continued)

Limiting factor	Forest type					
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic
1	129,588	55,741	436,616	80,962	--	8,697
2	--	3,128	2,221	--	--	--
3	--	--	1,550	1,939	--	--
4	--	--	15,162	2,263	--	--
5	20,098	10,753	170,850	62,541	6,143	--
6	--	--	--	--	--	--
7	100,276	30,651	263,314	55,227	2,966	--
1 & 2	13,795	1,780	8,209	2,292	--	--
1 & 3	4,833	2,734	--	1,936	--	--
1 & 4	20,698	14,015	79,127	4,001	--	--
1 & 5	105,769	48,125	339,538	160,609	10,918	--
1 & 6	--	--	--	--	--	--
1 & 7	170,607	81,525	552,256	176,517	15,623	--
2 & 3	--	1,479	4,677	2,272	--	--
2 & 4	--	--	--	--	--	--
2 & 5	--	--	--	3,627	--	--
2 & 6	--	--	1,354	--	--	--
2 & 7	4,023	2,336	13,164	4,538	--	--
3 & 4	--	--	--	--	--	--
3 & 5	21,299	9,283	86,045	44,184	--	--
3 & 6	--	--	--	--	--	--
3 & 7	5,626	--	5,370	--	--	--
4 & 5	--	--	9,775	2,018	--	--
4 & 6	--	--	--	--	--	--
4 & 7	5,870	15,729	50,440	5,141	--	--
5 & 6	2,984	--	5,975	2,894	--	--
5 & 7	46,897	37,964	293,702	85,708	14,291	--
6 & 7	--	--	--	--	--	--
1 & 2 & 3	9,905	3,796	7,986	7,748	1,979	--
1 & 2 & 4	--	--	3,769	3,420	--	--
1 & 2 & 5	3,496	--	3,134	--	--	--
1 & 2 & 6	--	--	--	--	--	--
1 & 2 & 7	24,104	9,782	4,404	2,072	--	--
1 & 3 & 4	--	--	--	--	--	--
1 & 3 & 5	50,521	10,928	144,359	80,735	20,891	--
1 & 3 & 6	--	--	--	--	--	--
1 & 3 & 7	5,423	--	1,611	1,853	--	--
1 & 4 & 5	--	6,740	17,017	7,196	--	--
1 & 4 & 6	--	--	--	--	--	--
1 & 4 & 7	10,496	11,644	130,552	9,537	--	--
1 & 5 & 6	2,751	--	5,816	--	--	--
1 & 5 & 7	93,719	53,829	569,660	170,508	25,206	--
1 & 6 & 7	--	--	--	--	--	--
2 & 3 & 4	--	--	828	--	--	--
2 & 3 & 5	9,611	2,846	9,106	6,116	--	--
2 & 3 & 6	--	--	--	--	--	--
2 & 3 & 7	2,285	6,605	6,078	14,535	--	--
2 & 4 & 5	--	--	2,709	--	--	--
2 & 4 & 6	--	--	--	--	--	--
2 & 4 & 7	4,600	--	3,235	2,243	--	--
2 & 5 & 6	--	--	--	--	--	--
2 & 5 & 7	--	2,365	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--
3 & 4 & 5	--	--	4,514	1,616	--	--
3 & 4 & 6	--	--	--	--	--	--
3 & 4 & 7	--	--	3,460	--	--	--
3 & 5 & 6	8,410	1,512	3,889	10,004	--	--
3 & 5 & 7	17,265	24,484	141,903	68,941	22,131	--
3 & 6 & 7	--	--	--	--	--	--
4 & 5 & 6	--	1,961	1,476	--	--	--
4 & 5 & 7	--	--	37,721	18,735	2,824	--
4 & 6 & 7	--	--	--	--	--	--
5 & 6 & 7	--	2,023	14,599	--	--	--
4 or more	251,083	126,781	613,290	305,078	38,099	1,061
All factors	1,146,032	580,539	4,070,461	1,409,006	161,071	9,758

Table 17.--Growing-stock volume on timberland in operability class III (poor) by limiting factor and forest type, Michigan, 1980

(In thousand cubic feet)

Limiting factor	All types	Forest type							
		Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar	Tamarack
1	4,757,598	194,114	192,062	91,963	248,530	28,001	101,782	404,737	10,662
2	7,418	1,750	--	590	--	--	--	--	--
3	641,477	33,223	55,617	3,349	7,234	11,708	8,580	67,247	2,166
4	48,352	--	--	--	--	--	--	527	--
5	--	--	--	--	--	--	--	--	--
6	--	--	--	--	--	--	--	--	--
7	1,781,433	57,878	31,396	20,622	65,703	21,458	21,963	215,896	4,913
1 & 2	21,834	4,811	891	1,946	--	--	--	782	273
1 & 3	394,769	18,142	39,353	--	14,871	1,219	14,880	36,428	1,302
1 & 4	11,191	1,365	--	--	--	--	--	1,697	--
1 & 5	1,483	--	1,483	--	--	--	--	--	--
1 & 6	--	--	--	--	--	--	--	--	--
1 & 7	703,108	11,551	17,781	28,243	45,255	2,289	63,183	71,002	3,498
2 & 3	15,331	2,023	--	--	--	--	--	430	--
2 & 4	6,185	810	--	--	--	--	--	--	--
2 & 5	--	--	--	--	--	--	--	--	--
2 & 6	--	--	--	--	--	--	--	--	--
2 & 7	1,238	820	418	--	--	--	--	--	--
3 & 4	805	--	--	--	--	--	--	--	--
3 & 5	68,561	2,380	39,099	--	941	--	7,086	10,043	1,103
3 & 6	--	--	--	--	--	--	--	--	--
3 & 7	101,048	6,785	--	--	6,004	--	9,844	8,511	2,392
4 & 5	--	--	--	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--	--	--	--
4 & 7	7,981	--	--	--	876	--	--	--	--
5 & 6	--	--	--	--	--	--	--	--	--
5 & 7	--	--	--	--	--	--	--	--	--
6 & 7	--	--	--	--	--	--	--	--	--
1 & 2 & 3	32,084	6,101	675	502	1,738	--	397	--	840
1 & 2 & 4	6,069	--	--	--	--	--	--	833	556
1 & 2 & 5	--	--	--	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--	--	--	--
1 & 2 & 7	2,182	587	--	494	--	559	--	542	--
1 & 3 & 4	7,999	--	--	--	--	--	--	1,274	--
1 & 3 & 5	19,212	--	6,049	--	--	1,332	2,086	5,434	--
1 & 3 & 6	--	--	--	--	--	--	--	--	--
1 & 3 & 7	38,995	9,689	--	--	1,645	--	4,444	1,222	910
1 & 4 & 5	--	--	--	--	--	--	--	--	--
1 & 4 & 6	--	--	--	--	--	--	--	--	--
1 & 4 & 7	2,143	--	--	--	--	--	--	952	--
1 & 5 & 6	--	--	--	--	--	--	--	--	--
1 & 5 & 7	--	--	--	--	--	--	--	--	--
1 & 6 & 7	--	--	--	--	--	--	--	--	--
2 & 3 & 4	4,958	--	--	--	--	--	--	457	418
2 & 3 & 5	1,836	553	806	--	--	--	--	--	--
2 & 3 & 6	--	--	--	--	--	--	--	--	--
2 & 3 & 7	1,355	559	--	--	--	--	--	--	--
2 & 4 & 5	--	--	--	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--	--	--	--
2 & 4 & 7	--	--	--	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--	--	--	--
2 & 5 & 7	--	--	--	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--	--	--	--
3 & 4 & 5	--	--	--	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--	--	--	--
3 & 4 & 7	--	--	--	--	--	--	--	--	--
3 & 5 & 6	164	--	--	--	--	--	--	164	--
3 & 5 & 7	4,288	1,459	--	--	--	--	2,829	--	--
3 & 6 & 7	--	--	--	--	--	--	--	--	--
4 & 5 & 6	--	--	--	--	--	--	--	--	--
4 & 5 & 7	--	--	--	--	--	--	--	--	--
4 & 6 & 7	--	--	--	--	--	--	--	--	--
5 & 6 & 7	--	--	--	--	--	--	--	--	--
4 or more	10,820	322	--	--	650	--	690	2,009	--
All factors	8,701,917	354,922	385,630	147,709	393,447	66,566	237,764	830,187	29,033

(Table 17 continued on next page)

(Table 17 continued)

Limiting factor	Forest type					
	Oak-hickory	Elm-ash-soft maple	Maple-birch	Aspen	Paper birch	Exotic
1	454,056	367,024	1,948,764	606,167	104,037	5,699
2	--	1,063	2,709	1,306	--	--
3	74,637	22,878	151,286	169,072	29,705	4,775
4	19,340	3,380	21,380	3,725	--	--
5	--	--	--	--	--	--
6	--	--	--	--	--	--
7	58,593	77,220	939,558	204,926	61,307	--
1 & 2	4,117	4,613	2,993	1,408	--	--
1 & 3	40,565	15,750	89,513	79,047	30,007	13,692
1 & 4	2,394	1,310	3,620	805	--	--
1 & 5	--	--	--	--	--	--
1 & 6	--	--	--	--	--	--
1 & 7	24,900	32,710	254,495	124,389	23,812	--
2 & 3	2,727	3,818	2,651	3,682	--	--
2 & 4	898	1,898	2,014	565	--	--
2 & 5	--	--	--	--	--	--
2 & 6	--	--	--	--	--	--
2 & 7	--	--	--	--	--	--
3 & 4	--	--	805	--	--	--
3 & 5	--	--	1,404	2,028	--	4,477
3 & 6	--	--	--	--	--	--
3 & 7	16,535	4,519	20,141	21,499	4,818	--
4 & 5	--	--	--	--	--	--
4 & 6	--	--	--	--	--	--
4 & 7	--	--	7,105	--	--	--
5 & 6	--	--	--	--	--	--
5 & 7	--	--	--	--	--	--
6 & 7	--	--	--	--	--	--
1 & 2 & 3	4,233	6,067	4,196	6,797	--	538
1 & 2 & 4	3,817	--	863	--	--	--
1 & 2 & 5	--	--	--	--	--	--
1 & 2 & 6	--	--	--	--	--	--
1 & 2 & 7	--	--	--	--	--	--
1 & 3 & 4	--	--	6,725	--	--	--
1 & 3 & 5	--	3,675	636	--	--	--
1 & 3 & 6	--	--	--	--	--	--
1 & 3 & 7	1,603	--	--	16,342	3,140	--
1 & 4 & 5	--	--	--	--	--	--
1 & 4 & 6	--	--	--	--	--	--
1 & 4 & 7	--	--	1,191	--	--	--
1 & 5 & 6	--	--	--	--	--	--
1 & 5 & 7	--	--	--	--	--	--
1 & 6 & 7	--	--	--	--	--	--
2 & 3 & 4	--	2,099	1,294	--	690	--
2 & 3 & 5	--	--	477	--	--	--
2 & 3 & 6	--	--	--	--	--	--
2 & 3 & 7	--	--	310	486	--	--
2 & 4 & 5	--	--	--	--	--	--
2 & 4 & 6	--	--	--	--	--	--
2 & 4 & 7	--	--	--	--	--	--
2 & 5 & 6	--	--	--	--	--	--
2 & 5 & 7	--	--	--	--	--	--
2 & 6 & 7	--	--	--	--	--	--
3 & 4 & 5	--	--	--	--	--	--
3 & 4 & 6	--	--	--	--	--	--
3 & 4 & 7	--	--	--	--	--	--
3 & 5 & 6	--	--	--	--	--	--
3 & 5 & 7	--	--	--	--	--	--
3 & 6 & 7	--	--	--	--	--	--
4 & 5 & 6	--	--	--	--	--	--
4 & 5 & 7	--	--	--	--	--	--
4 & 6 & 7	--	--	--	--	--	--
5 & 6 & 7	--	--	--	--	--	--
4 or more	1,696	1,491	2,043	1,371	548	--
All factors	710,111	549,515	3,466,173	1,243,615	258,064	29,181

Table 18.--Growing-stock volume on timberland by forest type, average growing-stock volume and operability class, Michigan, 1980

(In thousand cubic feet)

Forest type and average growing-stock volume per acre (cu.ft. per acre)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine					
More than 1000	280,191	3,341	124,141	152,709	--
400-1000	289,833	--	72,918	183,877	33,038
Less than 400	45,375	--	--	18,336	27,039
All classes	615,399	3,341	197,059	354,922	60,077
Red pine					
More than 1000	542,975	1,779	229,359	302,390	9,447
400-1000	135,547	--	29,304	80,450	25,793
Less than 400	10,843	--	--	2,790	8,053
All classes	689,365	1,779	258,663	385,630	43,293
White pine					
More than 1000	259,176	3,133	132,845	123,198	--
400-1000	33,678	--	7,727	20,979	4,972
Less than 400	7,545	--	--	3,532	4,013
All classes	300,399	3,133	140,572	147,709	8,985
Balsam fir					
More than 1000	463,741	--	158,606	303,928	1,207
400-1000	168,618	--	36,767	87,131	44,720
Less than 400	22,701	--	--	2,388	20,313
All classes	655,060	--	195,373	393,447	66,240
White spruce					
More than 1000	94,921	--	39,710	55,211	--
400-1000	17,893	--	--	10,796	7,097
Less than 400	2,653	--	--	559	2,094
All classes	115,467	--	39,710	66,566	9,191
Black spruce					
More than 1000	168,132	--	21,825	146,307	--
400-1000	147,937	--	11,190	90,911	45,836
Less than 400	26,540	--	--	546	25,994
All classes	342,609	--	33,015	237,764	71,830
Northern white-cedar					
More than 1000	1,120,404	8,912	419,761	688,690	3,041
400-1000	250,796	--	55,453	137,667	57,676
Less than 400	28,585	--	--	3,830	24,755
All classes	1,399,785	8,912	475,214	830,187	85,472
Tamarack					
More than 1000	9,835	--	1,720	8,115	--
400-1000	30,647	--	5,547	18,831	6,269
Less than 400	13,574	--	--	2,087	11,487
All classes	54,056	--	7,267	29,033	17,756

(Table 18 continued on next page)

(Table 18 continued)

Forest type and average growing-stock volume per acre (cu.ft. per acre)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Oak-hickory					
More than 1000	1,513,594	48,959	909,063	549,680	5,892
400-1000	447,092	--	236,969	142,943	67,180
Less than 400	53,432	--	--	17,488	35,944
All classes	2,014,118	48,959	1,146,032	710,111	109,016
Elm-ash-soft maple					
More than 1000	894,785	--	492,196	399,382	3,207
400-1000	299,365	--	88,343	129,084	81,938
Less than 400	63,677	--	--	21,049	42,628
All classes	1,257,827	--	580,539	549,515	127,773
Maple-birch					
More than 1000	6,926,413	89,254	3,782,339	3,015,618	39,202
400-1000	1,017,627	--	288,122	431,005	298,500
Less than 400	110,846	--	--	19,550	91,296
All classes	8,054,886	89,254	4,070,461	3,466,173	428,998
Aspen					
More than 1000	2,185,089	26,678	1,269,298	875,999	13,114
400-1000	778,371	--	139,708	352,001	286,662
Less than 400	148,411	--	--	15,615	132,796
All classes	3,111,871	26,678	1,409,006	1,243,615	432,572
Paper birch					
More than 1000	366,876	--	155,137	211,739	--
400-1000	69,070	--	5,934	45,087	18,049
Less than 400	7,573	--	--	1,238	6,335
All classes	443,519	--	161,071	258,064	24,384
Exotic					
More than 1000	18,919	--	8,697	10,222	--
400-1000	20,281	--	1,061	18,421	799
Less than 400	6,261	--	--	538	5,723
All classes	45,461	--	9,758	29,181	6,522
Nonstocked					
More than 1000	--	--	--	--	--
400-1000	--	--	--	--	--
Less than 400	4,000	--	--	--	4,000
All classes	4,000	--	--	--	4,000
All types					
More than 1000	14,845,051	182,056	7,744,697	6,843,188	75,110
400-1000	3,706,755	--	979,043	1,749,183	978,529
Less than 400	552,016	--	--	109,546	442,470
All classes	19,103,822	182,056	8,723,740	8,701,917	1,496,109

Table 19.--Growing-stock volume on timberland by forest type, stand-age class and operability class, Michigan, 1980

(In thousand cubic feet)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack pine					
less than 21	49,121	--	--	5,790	43,331
21-40	159,612	--	42,341	100,525	16,746
41-60	300,594	--	109,321	191,273	--
61-80	88,203	3,341	43,905	40,957	--
81-100	15,544	--	--	15,544	--
101-120	1,492	--	1,492	--	--
More than 120	833	--	--	833	--
All ages	615,399	3,341	197,059	354,922	60,077
Red pine					
less than 21	50,244	--	2,569	10,508	37,167
21-40	415,825	--	169,749	239,950	6,126
41-60	99,384	1,779	46,935	50,670	--
61-80	54,031	--	13,110	40,921	--
81-100	42,582	--	20,974	21,608	--
101-120	25,749	--	5,326	20,423	--
More than 120	1,550	--	--	1,550	--
All ages	689,365	1,779	258,663	385,630	43,293
White pine					
less than 21	7,559	--	--	--	7,559
21-40	12,616	--	1,374	9,816	1,426
41-60	37,543	--	27,492	10,051	--
61-80	107,813	3,133	72,201	32,479	--
81-100	79,455	--	25,545	53,910	--
101-120	21,236	--	--	21,236	--
More than 120	34,177	--	13,960	20,217	--
All ages	300,399	3,133	140,572	147,709	8,985
Balsam fir					
less than 21	48,241	--	--	--	48,241
21-40	87,345	--	21,359	47,987	17,999
41-60	270,635	--	75,396	195,239	--
61-80	132,163	--	55,732	76,431	--
81-100	60,547	--	19,961	40,586	--
101-120	34,691	--	9,076	25,615	--
More than 120	21,438	--	13,849	7,589	--
All ages	655,060	--	195,373	393,447	66,240
White spruce					
less than 21	8,554	--	--	--	8,554
21-40	21,503	--	2,181	18,685	637
41-60	31,775	--	15,804	15,971	--
61-80	16,929	--	5,880	11,049	--
81-100	15,318	--	4,045	11,273	--
101-120	17,484	--	7,896	9,588	--
More than 120	3,904	--	3,904	--	--
All ages	115,467	--	39,710	66,566	9,191

(Table 19 continued on next page)

(Table 19 continued)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Black spruce					
less than 21	41,729	--	--	5,081	36,648
21-40	115,261	--	--	82,705	32,556
41-60	84,946	--	15,819	66,876	2,251
61-80	54,637	--	5,447	48,815	375
81-100	11,643	--	--	11,643	--
101-120	17,627	--	8,374	9,253	--
More than 120	16,766	--	3,375	13,391	--
All ages	342,609	--	33,015	237,764	71,830
Northern white-cedar					
less than 21	28,487	--	788	1,110	26,589
21-40	80,697	--	9,466	21,477	49,754
41-60	204,354	--	83,551	111,674	9,129
61-80	356,952	--	117,790	239,162	--
81-100	330,488	--	134,344	196,144	--
101-120	201,947	3,645	61,113	137,189	--
More than 120	196,860	5,267	68,162	123,431	--
All ages	1,399,785	8,912	475,214	830,187	85,472
Tamarack					
less than 21	10,207	--	1,986	--	8,221
21-40	7,756	--	--	--	7,756
41-60	15,163	--	1,988	11,396	1,779
61-80	11,387	--	1,720	9,667	--
81-100	5,727	--	1,573	4,154	--
101-120	2,074	--	--	2,074	--
More than 120	1,742	--	--	1,742	--
All ages	54,056	--	7,267	29,033	17,756
Oak-hickory					
less than 21	104,612	--	1,551	--	103,061
21-40	115,010	--	62,108	46,947	5,955
41-60	590,410	12,070	343,682	234,658	--
61-80	531,250	13,277	289,295	228,678	--
81-100	331,055	13,694	206,424	110,937	--
101-120	269,969	9,918	198,652	61,399	--
More than 120	71,812	--	44,320	27,492	--
All ages	2,014,118	48,959	1,146,032	710,111	109,016
Elm-ash-soft maple					
less than 21	103,151	--	--	--	103,151
21-40	165,187	--	54,552	87,661	22,974
41-60	268,289	--	150,333	116,308	1,648
61-80	250,948	--	127,106	123,842	--
81-100	230,330	--	145,273	85,057	--
101-120	148,734	--	66,129	82,605	--
More than 120	91,188	--	37,146	54,042	--
All ages	1,257,827	--	580,539	549,515	127,773

(Table 19 continued on next page)

(Table 19 continued)

Forest type and stand-age class (years)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Maple-birch					
less than 21	365,842	--	--	--	365,842
21-40	613,448	--	260,134	290,750	62,564
41-60	2,537,651	8,532	1,380,192	1,148,335	592
61-80	1,378,530	7,050	745,877	625,603	--
81-100	1,488,227	38,004	814,677	635,546	--
101-120	1,045,344	28,878	575,977	440,489	--
More than 120	625,844	6,790	293,604	325,450	
All ages	8,054,886	89,254	4,070,461	3,466,173	428,998
Aspen					
less than 21	399,191	--	--	6,553	392,638
21-40	492,072	--	175,521	279,316	37,235
41-60	1,265,178	11,485	676,813	574,181	2,699
61-80	629,367	7,356	366,873	255,138	--
81-100	223,996	7,837	127,906	88,253	--
101-120	88,025	--	61,893	26,132	--
More than 120	14,042	--	--	14,042	--
All ages	3,111,871	26,678	1,409,006	1,243,615	432,572
Paper birch					
less than 21	23,284	--	--	4,567	18,717
21-40	34,878	--	7,523	21,688	5,667
41-60	200,530	--	76,273	124,257	--
61-80	137,939	--	52,381	85,558	--
81-100	31,230	--	17,397	13,833	--
101-120	5,407	--	2,966	2,441	--
More than 120	10,251	--	4,531	5,720	--
All ages	443,519	--	161,071	258,064	24,384
Exotic					
less than 21	4,665	--	--	--	4,665
21-40	28,651	--	1,061	25,733	1,857
41-60	12,145	--	8,697	3,448	--
61-80	--	--	--	--	--
81-100	--	--	--	--	--
101-120	--	--	--	--	--
More than 120	--	--	--	--	--
All ages	45,461	--	9,758	29,181	6,522
Nonstocked					
less than 21	1,353	--	--	--	1,353
21-40	657	--	--	--	657
41-60	1,540	--	--	--	1,540
61-80	--	--	--	--	--
81-100	450	--	--	--	450
101-120	--	--	--	--	--
More than 120	--	--	--	--	--
All ages	4,000	--	--	--	4,000
All types					
less than 21	1,246,240	--	6,894	33,609	1,205,737
21-40	2,350,518	--	807,369	1,273,240	269,909
41-60	5,920,137	33,866	3,012,296	2,854,337	19,638
61-80	3,750,149	34,157	1,897,317	1,818,300	375
81-100	2,866,592	59,535	1,518,119	1,288,488	450
101-120	1,879,779	42,441	998,894	838,444	--
More than 120	1,090,407	12,057	482,851	595,499	--
All ages	19,103,822	182,056	8,723,740	8,701,917	1,496,109

Table 20.--Growing-stock volume on timberland by forest type, ownership class and operability class, Michigan, 1980

(In thousand cubic feet)

Forest type and ownership class	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Jack Pine					
National Forest	202,335	--	59,900	122,841	19,594
Other federal	5,824	--	1,045	3,852	927
Indian	--	--	--	--	--
State	252,569	--	91,220	138,920	22,429
County and municipal	14,346	--	1,850	8,820	3,676
Forest industry	11,779	--	4,094	7,685	--
Farmer	18,948	--	9,322	6,756	2,870
Miscellaneous private	109,598	3,341	29,628	66,048	10,581
All owners	615,399	3,341	197,059	354,922	60,077
Red pine					
National Forest	350,707	--	157,710	161,527	31,470
Other federal	418	--	--	418	--
Indian	--	--	--	--	--
State	164,744	1,779	58,719	100,052	4,194
County and municipal	13,147	--	5,507	7,434	206
Forest industry	6,114	--	845	5,269	--
Farmer	54,696	--	6,306	47,003	1,387
Miscellaneous private	99,539	--	29,576	63,927	6,036
All owners	689,365	1,779	258,663	385,630	43,293
White pine					
National Forest	49,596	--	30,812	18,784	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	76,491	--	33,615	36,079	6,797
County and municipal	--	--	--	--	--
Forest industry	34,345	--	7,339	27,006	--
Farmer	33,273	3,133	18,028	10,506	1,606
Miscellaneous private	106,694	--	50,778	55,334	582
All owners	300,399	3,133	140,572	147,709	8,985
Balsam fir					
National Forest	141,126	--	9,959	126,672	4,495
Other federal	4,331	--	2,589	1,742	--
Indian	--	--	--	--	--
State	126,275	--	50,369	62,534	13,372
County and municipal	2,821	--	1,652	--	1,169
Forest industry	126,324	--	35,509	69,850	20,965
Farmer	40,598	--	16,009	19,197	5,392
Miscellaneous private	213,585	--	79,286	113,452	20,847
All owners	655,060	--	195,373	393,447	66,240
White spruce					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	24,736	--	10,939	10,358	3,439
County and municipal	2,264	--	--	--	2,264
Forest industry	22,254	--	6,065	15,552	637
Farmer	12,056	--	7,949	4,107	--
Miscellaneous private	54,157	--	14,757	36,549	2,851
All owners	115,467	--	39,710	66,566	9,191

(Table 20 continued on next page)

(Table 20 continued)

Forest type and ownership class	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Black spruce					
National Forest	143,389	--	8,570	127,539	7,280
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	85,832	--	12,587	44,692	28,553
County and municipal	1,670	--	--	1,228	442
Forest industry	40,246	--	4,830	22,531	12,885
Farmer	12,807	--	3,206	4,456	5,145
Miscellaneous private	58,665	--	3,822	37,318	17,525
All owners	342,609	--	33,015	237,764	71,830
Northern white-cedar					
National Forest	87,431	--	13,447	70,764	3,220
Other federal	--	--	--	--	--
Indian	694	--	--	--	694
State	390,409	3,645	148,010	215,433	23,321
County and municipal	10,594	--	--	9,817	777
Forest industry	243,875	--	60,608	172,336	10,931
Farmer	222,507	--	83,477	118,897	20,133
Miscellaneous private	444,275	5,267	169,672	242,940	26,396
All owners	1,399,785	8,912	475,214	830,187	85,472
Tamarack					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	19,673	--	3,293	10,161	6,219
County and municipal	--	--	--	--	--
Forest industry	10,721	--	--	6,522	4,199
Farmer	4,976	--	1,988	2,300	688
Miscellaneous private	18,686	--	1,986	10,050	6,650
All owners	54,056	--	7,267	29,033	17,756
Oak-hickory					
National Forest	202,972	--	133,281	61,158	8,533
Other federal	719	--	--	--	719
Indian	--	--	--	--	--
State	371,821	4,197	203,388	136,800	27,436
County and municipal	15,631	--	4,145	9,508	1,978
Forest industry	16,012	--	6,048	9,964	--
Farmer	463,046	23,618	229,411	191,433	18,584
Miscellaneous private	943,917	21,144	569,759	301,248	51,766
All owners	2,014,118	48,959	1,146,032	710,111	109,016
Elm-ash-soft maple					
National Forest	53,635	--	21,794	31,841	--
Other federal	656	--	--	656	--
Indian	1,205	--	--	1,205	--
State	196,038	--	96,107	77,083	22,848
County and municipal	20,285	--	15,621	2,813	1,851
Forest industry	117,587	--	51,326	56,432	9,829
Farmer	374,883	--	199,957	137,361	37,565
Miscellaneous private	493,538	--	195,734	242,124	55,680
All owners	1,257,827	--	580,539	549,515	127,773

(Table 20 continued on next page)

(Table 20 continued)

Forest type and ownership class	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Maple-birch					
National Forest	1,082,052	--	354,232	720,035	7,785
Other federal	2,106	--	1,938	--	168
Indian	24,990	--	18,805	6,185	--
State	1,048,521	5,013	528,028	440,942	74,538
County and municipal	75,867	--	32,645	41,604	1,618
Forest industry	1,567,794	19,175	774,070	714,849	59,700
Farmer	1,473,057	46,063	787,368	511,140	128,486
Miscellaneous private	2,780,499	19,003	1,573,375	1,031,418	156,703
All owners	8,054,886	89,254	4,070,461	3,466,173	428,998
Aspen					
National Forest	421,622	--	169,154	197,725	54,743
Other federal	4,123	--	--	4,123	--
Indian	10,049	--	9,950	--	99
State	666,536	--	311,444	240,174	114,918
County and municipal	27,358	--	9,126	14,321	3,911
Forest industry	170,273	--	65,361	75,396	29,516
Farmer	521,312	12,182	257,141	202,256	49,733
Miscellaneous private	1,290,598	14,496	586,830	509,620	179,652
All owners	3,111,871	26,678	1,409,006	1,243,615	432,572
Paper birch					
National Forest	52,358	--	1,432	50,926	--
Other federal	2,003	--	--	2,003	--
Indian	--	--	--	--	--
State	112,035	--	60,176	49,256	2,603
County and municipal	1,912	--	--	--	1,912
Forest industry	71,798	--	20,372	47,278	4,148
Farmer	52,547	--	15,337	31,687	5,523
Miscellaneous private	150,866	--	63,754	76,914	10,198
All owners	443,519	--	161,071	258,064	24,384
Exotic					
National Forest	--	--	--	--	--
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	--	--	--	--	--
County and municipal	--	--	--	--	--
Forest industry	--	--	--	--	--
Farmer	14,759	--	--	14,487	272
Miscellaneous private	30,702	--	9,758	14,694	6,250
All owners	45,461	--	9,758	29,181	6,522
Nonstocked					
National Forest	127	--	--	--	127
Other federal	--	--	--	--	--
Indian	--	--	--	--	--
State	1,825	--	--	--	1,825
County and municipal	--	--	--	--	--
Forest industry	119	--	--	--	119
Farmer	--	--	--	--	--
Miscellaneous private	1,929	--	--	--	1,929
All owners	4,000	--	--	--	4,000
All types					
National Forest	2,787,350	--	960,291	1,689,812	137,247
Other federal	20,180	--	5,572	12,794	1,814
Indian	36,938	--	28,755	7,390	793
State	3,537,505	14,634	1,607,895	1,562,484	352,492
County and municipal	185,895	--	70,546	95,545	19,804
Forest industry	2,439,241	19,175	1,036,467	1,230,670	152,929
Farmer	3,299,465	84,996	1,635,499	1,301,586	277,384
Miscellaneous private	6,797,248	63,251	3,378,715	2,801,636	553,646
All owners	19,103,822	182,056	8,723,740	8,701,917	1,496,109

Table 21.--Growing-stock volume on timberland by distance from major wood-using center and operability class, Michigan, 1980

(In thousand cubic feet)

Wood-using center and distance (miles)	All classes	Operability class			
		I - Good	II - Medium	III - Poor	IV - Sapling-seedling and nonstocked
Alpena					
Less than 20	263,338	--	116,485	107,311	39,542
20-50	1,179,547	2,839	433,623	605,551	137,534
More than 50	17,660,937	179,217	8,173,632	7,989,055	1,319,033
Brighton					
Less than 20	156,398	9,918	76,413	62,132	7,935
20-50	509,098	10,822	282,131	168,582	47,563
More than 50	18,438,326	161,316	8,365,196	8,471,203	1,440,611
Cadillac					
Less than 20	542,012	3,510	288,805	207,608	42,089
20-50	2,270,991	23,531	1,123,356	905,910	218,194
More than 50	16,290,819	155,015	7,311,579	7,588,399	1,235,826
Escanaba					
Less than 20	336,282	1,430	122,410	183,075	29,367
20-50	1,951,115	22,094	652,882	1,130,884	145,255
More than 50	16,816,425	158,532	7,948,448	7,387,958	1,321,487
Filer City					
Less than 20	286,396	--	130,948	139,798	15,650
20-50	1,370,899	10,701	721,111	533,280	105,807
More than 50	17,446,527	171,355	7,871,681	8,028,839	1,374,652
Gaylord-Grayling					
Less than 20	535,373	2,839	291,323	188,991	52,220
20-50	2,458,513	15,475	1,209,706	1,015,056	218,276
More than 50	16,109,936	163,742	7,222,711	7,497,870	1,225,613
Iron Mountain					
Less than 20	290,921	2,791	145,933	115,440	26,757
20-50	1,975,448	18,557	762,074	1,002,233	192,584
More than 50	16,837,453	160,708	7,815,733	7,584,244	1,276,768
L'Anse					
Less than 20	880,863	--	506,903	342,452	31,508
20-50	3,105,368	2,256	1,490,762	1,466,362	145,988
More than 50	15,117,591	179,800	6,726,075	6,893,103	1,318,613
Manistique					
Less than 20	343,351	2,176	106,004	213,525	21,646
20-50	1,836,338	10,114	605,941	1,102,430	117,853
More than 50	16,924,133	169,766	8,011,795	7,385,962	1,356,610
Midland					
Less than 20	189,476	--	82,012	80,674	26,790
20-50	1,087,231	30,613	531,671	392,105	132,842
More than 50	17,827,115	151,443	8,110,057	8,229,138	1,336,477
Muskegon					
Less than 20	237,465	--	142,997	69,227	25,241
20-50	852,770	18,966	475,802	285,860	72,142
More than 50	18,013,587	163,090	8,104,941	8,346,830	1,398,726
Newberry					
Less than 20	651,759	5,621	179,001	393,154	73,983
20-50	1,529,971	9,915	395,574	1,028,521	95,961
More than 50	16,922,092	166,520	8,149,165	7,280,242	1,326,165
Ontonagon					
Less than 20	507,389	--	300,015	186,701	20,673
20-50	2,253,904	9,774	1,057,121	1,098,607	88,402
More than 50	16,342,529	172,282	7,366,604	7,416,609	1,387,034
Otsego					
Less than 20	261,964	--	185,970	51,844	24,150
20-50	648,973	17,897	345,850	217,095	68,131
More than 50	18,192,885	164,159	8,191,920	8,432,978	1,403,828
West Branch					
Less than 20	508,088	7,308	222,235	223,959	54,586
20-50	1,978,183	18,013	848,960	874,459	236,751
More than 50	16,617,551	156,735	7,652,545	7,603,499	1,204,772
Closest wood-using center					
Less than 20	5,991,075	35,593	2,897,454	2,565,891	492,137
20-50	11,687,390	125,738	5,085,450	5,589,322	886,880
More than 50	1,425,357	20,725	740,836	546,704	117,092

Hansen, Mark H.; Hahn, Jerold T.
1987. Operability and location of Michigan's timber resource. Gen. Tech. Rep. NC-116. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 41 p.

Operability is the ease or difficulty of managing or harvesting timber because of physical conditions in the stand or on the site. Data collected during the 1980 Michigan Statewide forest inventory were used to examine operability of the timber resource based on seven operability components.

KEY WORDS: Management opportunities, forest inventory, prime forest land, harvesting, accessibility.

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Computer Program for Calculating and Plotting Fire Direction and Rate of Spread

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COMPUTER PROGRAM FOR CALCULATING AND PLOTTING FIRE DIRECTION AND RATE OF SPREAD

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An algorithm has been developed for calculating the direction and rate of spread of a fire across a triangular plot (Simard *et al.* 1984). Data required are the times of arrival of the fire at any three points (which form the three corners of a triangle), the length of the two sides adjacent to the fire's first arrival point, and the included angle. A program has been written to perform the calculations on a TI-59[1] hand-held calculator (Eenigenburg 1983). In this paper, we extend the computational procedures to allow plots with more than three time measurement points. By comparing the rates and directions derived from each triangle formed from four or more points taken three at a time, we can evaluate the uniformity of fire spread across the plot.

FIELD PROCEDURES

If time and accessibility permit, a systematic network of triangular grid points can be precisely deployed, following a pattern similar to that shown by Simard *et al.* (1984). The pattern can be modified to suit specific needs. Alternatively, an approximate pattern can be paced out quickly, with precise post-fire measurements made to determine distances and bearings. The information needed can even be obtained without pre-established measuring points.

Several methods can be used to obtain time data. We can follow the advancing front of low intensity fires and drop numbered tags on the ground at specific time intervals. Post-fire measurements can then be made in the same way as with the approximately located pre-established points. Or, we can observe the fire as it arrives at points pre-marked with a stake. In addition small, self-contained electronic timers can be used for obtaining fire arrival times in higher intensity fires (Blank and Simard 1983).

[1] *Use of trade names does not constitute official endorsement of the product by the USDA Forest Service.*

Using the algorithm presented here can eliminate the tedious job of measuring two side lengths and included angles for all possible triangles in the field. Instead, the location of each point in a plot is defined by the distance and bearing from a common point. Given this information, the program calculates the necessary lengths and angles for every possible triangle in the plot.[2] An important feature is that the common point from which the bearings and distances are obtained need not be contained within the plot. Thus, we can establish one common point for the entire fire and obtain all measurements from it. This is useful when missing or erroneous data or highly variable fire behavior requires unplanned plot combinations. Also, using a single common point for a fire with n fire arrival times requires a minimal n-1 distance and bearing observations.

PROGRAM SPREAD

SPREAD is written in ANSI-standard FORTRAN 77 and has been tested on a CDC Cyber 170-750[1] computer. Compile time was 2.423 seconds. The example in Appendices 3 and 4 incorporates 19 separate plots with an average of four time measurements per plot. Execution including optional graphics output required 19,072 words of memory and 0.702 seconds. Without graphics, the program executed in 0.250 seconds, using 17,664 words of memory.

The program (Appendix 1) contains a MAIN and 19 subprograms. There are 1,287 lines of code including 434 lines of comment. The program's 182 variables are listed and defined in Appendix 2. The program is internally documented; user instructions will not be repeated here. The user will find enough information

[2] *Due to the error inherent in field measurements, the program ignores triangles with an angle less than 0.2 radians (about 11.5 degrees). The user can easily adjust this limit by following instructions included in the BLOCK DATA subprogram.*

in MAIN to run the program. BLOCK DATA also discusses restrictions on some variables that the user might wish to modify. For those who want an in-depth understanding of the program, comments have been included in every subprogram and in the variable list.

AN EXAMPLE

We tested Program SPREAD using data obtained from a prescribed fire conducted by the Canadian Forestry Service, Great Lakes Forest Research Centre, in the Province of Ontario.[3] The purpose of the fire was to study pre-steady state fire behavior during the acceleration period. Thus, a single point source was used for ignition.

Before the fire, a grid of 18 electronic timers was located downwind from the fire's origin. This grid began approximately 20 meters from the origin to allow the fire time to stabilize into a quasi-steady spread condition. Data were obtained from 15 of the 18 timers (points A through O, fig. 1). The grid was divided into six plots, each containing four or five timers (most timers were used in more than one plot). Distance and bearing information for each plot was calculated relative to one point within the plot.

Also before ignition, three lines of metal stakes were placed at 5-meter intervals fanning out from the origin (point Z). In this area, times were manually recorded as the fire advanced (points P through X, fig. 1). Distances and bearings for these points were measured relative to the origin (the origin itself was included as a point in only one of the five plots, numbered 7 to 11, formed in this area). Four additional plots (numbered 12 to 15) were established connecting this area to the original grid.

The variability of fire behavior along line IK was disclosed in the first run of the program, so three 3-point plots (numbered 16 to 18) and a 5-point plot (number 19) were added to obtain information for different permutations of triangles that crossed the boundaries of the original plots. The input file for the example is shown in Appendix 3.

The output file for the example (Appendix 4) shows the area for each plot and the rate and direction of spread for each accepted triangle in the plot.

This is followed by a summary table where the vector average is presented (calculated by weighting each individual vector by its triangles area). Conceptually, the spread vector measures the rate at which the fire advances from one point to another along the direction of spread and is, therefore, appropriate for fire growth calculations.

The summary table also includes arithmetic means of the rate and direction, again weighted by area. Conceptually, the arithmetic mean measures the rate at which the fire passes a point, and is therefore appropriate for fire intensity calculations.

After analyzing each of the individual plots, the program produces an OVERALL STATISTICS summary table where each plot is entered, weighted by its area. Note that adding the extra plots (numbered 16 to 19) means that the area defined by HKNIGH is included twice in this summary, as is the thin sliver of area defined by triangle XUIX where plots 11 and 14 overlap plot 15.

In the OVERALL STATISTICS, the 'TOTAL AREA' is calculated as follows. Starting at the northernmost point, the program sweeps clockwise until a plot point is reached. Continuing from that point, another clockwise sweep is made until the next point is found. This continues until the first point is again reached, and the area of the convex polygon just described is calculated. In the example, the points were located in the following order: ACFONZWXA.

Note that this area may include sections that are not included in the summary table. In the example, plot number 12, QNZQ, did not contain a triangle with a large enough angle and was dropped from the analysis. Another area, ADXA, was never included in the original data set. Nevertheless, both areas are included in the 'TOTAL AREA' calculation (neither is included in the 'SUM OF ALL PLOT AREAS' calculation).

The graphics part of this program has been designed for use on the CALCOMP[1] plotter. If the user lacks such a plotter, the output file QRATE can still be obtained by setting the variable GRAPH to .FALSE. in the BLOCK DATA subprogram. To help users modify the program for different plotters, the seven CALCOMP commands used are described in Appendix 5.

The CALCOMP plotter produced the drawing shown in figure 1. The plotter identifies timer locations and plot boundaries, and it plots one scaled rate of spread vector for each triangle analyzed. From this plot and the output file, we can see that spread direction and rate are highly variable within the area bounded by KMLIK. Starting at 10 minutes after ignition, a finger of fire advanced through the above region to the far side of the plot in just 6 minutes. The fire then spread as a backing fire to the NNW and a head fire to the SSE.

[3] *Douglas J. McRae, Forest Fire Research Officer, Great Lakes Forest Research Centre, personal communication.*

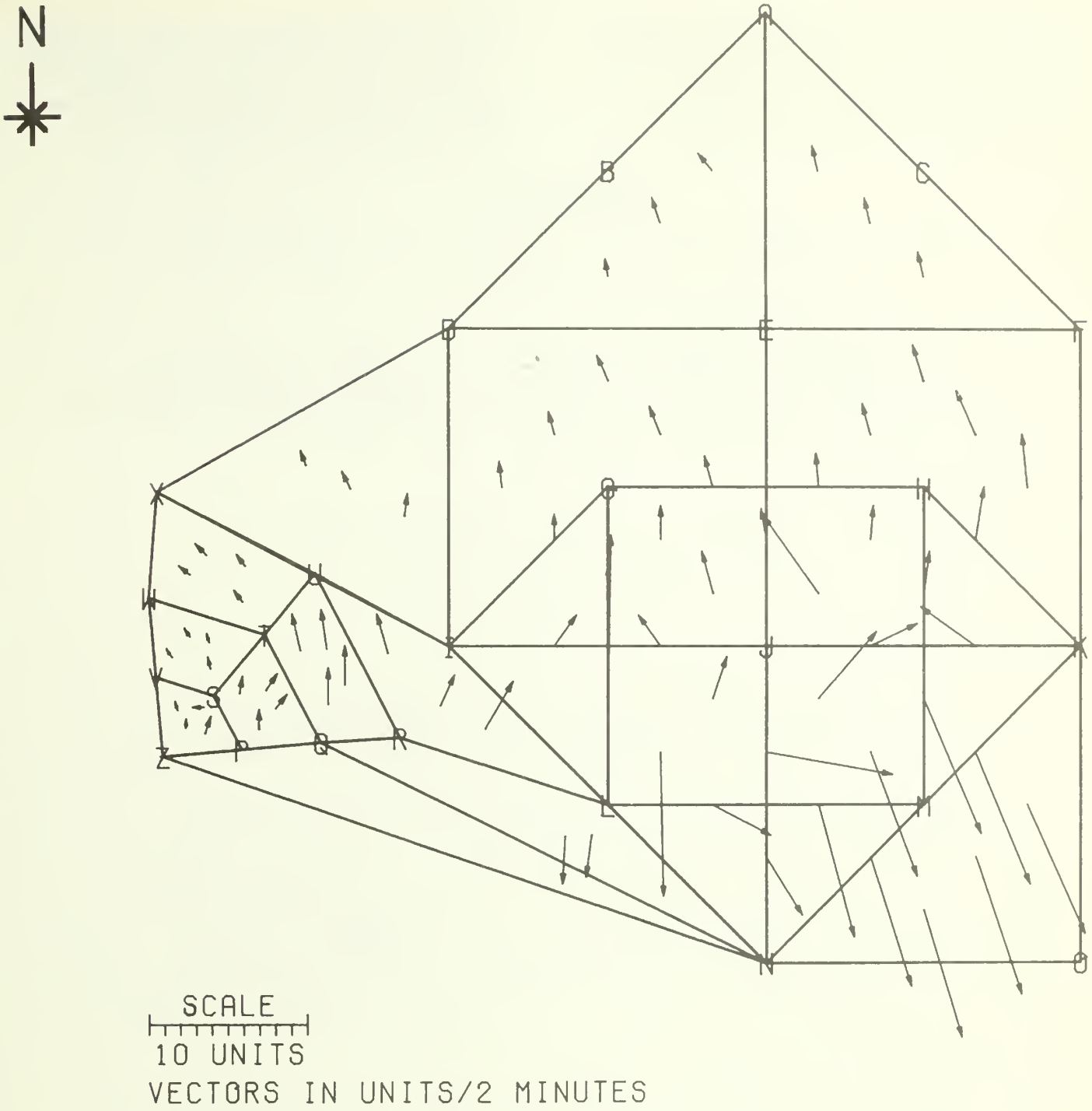

Figure 1.—*CALCOMP plotter output for the prescribed burn example. The plot program selects a spread vector scale so that the third largest vector is less than 1.5 inches.*

The procedure described in this paper documented a fairly complex spread pattern. It is reasonable to conclude that rate of spread can be estimated reliably for most prescribed burns and wildfires using this approach.

REFERENCES

Blank, Richard W.; Simard, Albert J. 1983. An electronic timer for measuring spread rates of wildland fires. Res. Note NC-304. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 4 p.

Eenigenburg, James E. 1983. User's guide to calculating rate of fire spread. Gen. Tech. Rep. NC-89. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 17 p.

Simard, Albert J.; Eenigenburg, James E.; Adams, Kenneth B.; Nissen, Roger L., Jr.; Deacon, Arthur G. 1984. A general procedure for sampling and analyzing wildland fire spread. Forest Science. 30(1): 51-64.

APPENDIX 1

```
      PROGRAM SPREAD
C
C     PROGRAMMED IN ANSI-STANDARD  FORTRAN 77  BY JAMES E. EENIGENBURG.
C     DOCUMENTATION, VARIABLE LIST, AND  SAMPLE RUN ARE PROVIDED IN THE
C     NC GENERAL TECHNICAL REPORT 'COMPUTER PROGRAM FOR CALCULATING AND
C     PLOTTING FIRE DIRECTION AND RATE OF SPREAD', 1987, BY
C
C                          JAMES E. EENIGENBURG
C               U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE
C                   NORTH CENTRAL FOREST EXPERIMENT STATION
C                            1407 S. HARRISON ROAD
C                          EAST LANSING, MI  48823
C                              (517) 355-7740
C
C     ------------------------------------------------------------------
C
C     THE PROGRAM IS PROVIDED 'AS IS' WITHOUT WARRANTY OF ANY KIND, EI-
C     THER EXPRESSED OR  IMPLIED, INCLUDING BUT  NOT LIMITED TO IMPLIED
C     WARRANTIES OF FITNESS FOR A  PARTICULAR PURPOSE.  THE ENTIRE RISK
C     AS TO THE QUALITY AND PERFORMANCE  OF THE PROGRAM IS WITH THE US-
C     ER.  SHOULD THE PROGRAM PROVE DEFECTIVE, THE USER ASSUMES THE EN-
C     TIRE COST OF ALL NECESSARY SERVICING, REPAIR, OR CORRECTION.
C
C     IN NO EVENT WILL THE USDA FOREST  SERVICE OR THE AUTHOR BE LIABLE
C     FOR ANY DAMAGES,  INCLUDING BUT NOT LIMITED  TO ANY LOST PROFITS,
C     LOST SAVINGS, OR OTHER INCIDENTAL  OR CONSEQUENTIAL DAMAGES ARIS-
C     ING OUT OF THE USE OR INABILITY TO USE THIS PROGRAM.
C
C     THE USER MAY NOT ASSERT ANY PROPRIETARY RIGHTS THERETO NOR REPRE-
C     SENT THE PROGRAM  TO ANYONE AS  OTHER THAN A  GOVERNMENT-PRODUCED
C     COMPUTER PROGRAM.
C
C     ------------------------------------------------------------------
C
C     PROGRAM SPREAD CALCULATES  THE DIRECTION AND  RATE OF SPREAD OF A
C     FIRE ACROSS A PLOT  WHERE THE TIME OF FIRE  ARRIVAL AT EACH OF AT
C     LEAST THREE AND AS MANY AS 'NVL' POINTS HAS BEEN RECORDED.  A BA-
C     SIC DESIGN IS ILLUSTRATED  AT RIGHT WHERE THE LET-
C     TERS A TO E INDICATE TIMER  POSITIONS (ANY CHARAC-   D        C
C     TER OTHER  THAN '#'  MAY BE  USED AS LONG  AS EACH
C     TIMER HAS A UNIQUE  IDENTIFIER).  THE PROGRAM DOES        E
C     NOT REQUIRE  THE  TIMERS TO BE  PLACED  EXACTLY IN
C     SUCH A SQUARE-LIKE PATTERN, AND WILL WORK WITH AR-   A        B
C     BITRARILY PLACED TIMERS.  CHOOSE ANY POINT (A TIM-
C     ER POINT, OR  ANY OTHER  POINT INSIDE  OR OUTSIDE THE  PLOT) AS A
C     MARKER FROM WHICH TO  MEASURE THE DISTANCE  AND COMPASS DIRECTION
C     OF EACH OF THE TIMERS.
```

```
C
C     IN THE ABOVE DIAGRAM,  LET POINT E BE CHOSEN  AS THE MARKER.  IN-
C     PUTS TO  THE PROGRAM  ARE:   1) THE  TIME THE  FIRE  REACHED EACH
C     POINT; 2) THE DISTANCE OF EACH  POINT TO POINT E; AND 3) THE COM-
C     PASS DIRECTION OF EACH POINT FROM POINT E.
C
C     THE PROGRAM EXPECTS  INPUTS ON A FILE NAMED  'QDATA'.  THE FORMAT
C     FOR EACH INPUT RECORD IS AS FOLLOWS:  (A1, 2I3, F7.2, I4)
C        A1     THE LETTER IDENTIFYING THE POINT.
C       2I3     THE TIME WHEN THE FIRE REACHED THE POINT (MINSEC).
C        F7.2   THE DISTANCE OF THE POINT TO THE MARKER.
C        I4     COMPASS DIRECTION OF THE POINT FROM THE MARKER ( DEG).
C     EACH INPUT RECORD MUST  CONTAIN ONE AND  ONLY ONE POINT.   POINTS
C     WHERE TIMERS DID NOT  WORK MAY EITHER BE  SKIPPED, OR THE MINUTES
C     ENTERED WITH  (999).   IF THE  MARKER POINT  IS ONE OF  THE TIMER
C     POINTS, ITS INPUT FIELDS  FOR DISTANCE AND  COMPASS DIRECTION MAY
C     EITHER BE LEFT BLANK OR FILLED WITH ZEROS.
C
C     FOR EACH PLOT, THE PROGRAM CONSIDERS THE TRIANGLE FORMED BY EVERY
C     POSSIBLE COMBINATION OF THREE  POINTS AND CALCULATES THE RATE AND
C     DIRECTION OF SPREAD  ACROSS EACH.  ON OUTPUT  FILE 'QRATE', RATES
C     ARE WRITTEN IN  UNITS PER MINUTE  (UNITS OF THE  SAME TYPE AS THE
C     INPUT DISTANCES)  AND DIRECTIONS  ARE WRITTEN IN  COMPASS DEGREES
C     (FROM 0 DEGREES NORTH CLOCKWISE THROUGH 360 DEGREES).
C
C     REPRESENTING THE RATE  AND DIRECTION OF SPREAD  FOR EACH TRIANGLE
C     AS A VECTOR, AND WEIGHTING EACH  VECTOR BY ITS TRIANGLE'S AREA, A
C     VECTOR AVERAGE FOR THE PLOT IS DETERMINED.
C
C     WEIGHTING THE RATE OF  SPREAD FOR EACH TRIANGLE  BY ITS AREA, THE
C     WEIGHTED ARITHMETIC  MEAN OF THE RATE IS THEN  CALCULATED.  SIMI-
C     LARLY, THE WEIGHTED ARITHMETIC MEAN OF THE DIRECTION OF SPREAD IS
C     FOUND, AS WELL AS STANDARD DEVIATIONS FOR EACH.
C
C     COMPARING THE VECTOR  AVERAGE WITH A NEW  VECTOR REPRESENTING THE
C     ARITHMETIC  MEANS OF THE  RATE AND  DIRECTION, THE  RATE AT WHICH
C     THESE TWO VECTORS ARE DIVERGING (LABLED 'V/A DIVERGENCE') IS ALSO
C     WRITTEN TO FILE 'QRATE'.
C
C     FINALLY, THE VARIABILITY  OF THE RATE AND THE  VARIABILITY OF THE
C     DIRECTION ARE CONSIDERED  SEPARATELY, AND  EACH IS GIVEN A VERBAL
C     DESCRIPTION:  LOW, MODERATE, OR  HIGH.  (SIMARD, ALBERT J.; EENI-
C     GENBURG, JAMES E.; ADAMS, KENNETH B.; NISSEN, ROGER L., JR.; DEA-
C     CON, ARTHUR G. 1984. A GENERAL PROCEDURE FOR SAMPLING AND ANALYZ-
C     ING WILDLAND FIRE SPREAD. FOREST SCIENCE 30(1): 51-64.)
C
C     UP TO 'NSL' PLOTS MAY  BE INVESTIGATED WITH  ONE EXECUTION OF THE
C     PROGRAM.  SIMPLY SEPARATE EACH PLOT ON FILE 'QDATA' WITH A SINGLE
C     RECORD CONTAINING THE  SINGLE CHARACTER '#'  IN THE FIRST COLUMN.
C     ALTHOUGH ALL  POINTS  IN ANY ONE  PLOT MUST  USE THE  SAME MARKER
C     POINT, EACH PLOT MAY HAVE ITS OWN UNIQUE MARKER.
```

```
C
C     AFTER ALL PLOTS ARE ANALYZED INDIVIDUALLY, EACH PLOT (WEIGHTED BY
C     ITS AREA) IS TAKEN AS A SINGLE ENTRY IN A GROUP AVERAGE, AND SUM-
C     MARY STATISTICS FOR THE AGGREGATION ARE WRITTEN TO FILE 'QRATE'.
C
C     LIMITS 'NVL' AND 'NSL',  MENTIONED ABOVE, MAY  BE SET BY THE USER
C     WITH THE  PARAMETER  STATEMENTS  AT THE  BEGINNING OF  SUBPROGRAM
C     QUEUE.  LIMIT 'NGL', THE TOTAL  NUMBER OF TIMERS POSSIBLE, IS SET
C     BY A PARAMETER STATEMENT AT THE BEGINNING OF SUBPROGRAM ORIGIN.
C
C     ALL OTHER USER ADJUSTABLE  VARIABLES ARE  GROUPED TOGETHER IN THE
C     BLOCK DATA SUBPROGRAM (E.G., IF ONE HAS ACCESS TO A CALCOMP PLOT-
C     TER, A MAP OF  THE FIRE  WITH SPREAD  VECTORS CAN BE  OBTAINED BY
C     SETTING THE LOGICAL 'GRAPH' TO .TRUE.).
C
C     ------------------------------------------------------------------

      CALL QUEUE
      END



      SUBROUTINE QUEUE
C
C     PROGRAM HANDLES UP TO 'NVL' POINTS  PER PLOT,  IGNORING ANY ADDI-
C     TIONAL POINTS FOR THE PLOT ENTERED ON FILE 'QDATA'.
      PARAMETER (NVL=5)
C
C     PROGRAM HANDLES UP TO 'NSL' PLOTS,  IGNORING ANY ADDITIONAL PLOTS
C     ENTERED ON FILE 'QDATA'.
      PARAMETER (NSL=20)
C
C     ------------------------------------------------------------------

      COMMON /LIMIT/ NV, NVLIM,  NS, NSLIM,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /CNTRL/ PWT, GRAPH, AMIN
      COMMON /PLOTS/ NP,PWGT, PRSUM,PRSUM2, PDSUM,PDSUM2, PXSUM,PYSUM
C
      CHARACTER VPT*(NVL), VPP*(NVL+1)
      DIMENSION VPX (NVL), VPY (NVL),  TIME(NVL), VDIR(NVL), NPP(NVL)
      CHARACTER SPT(NSL)*(NVL), SPP(NSL)*(NVL+1)
      DIMENSION SPX(NVL,NSL),   SPY(NVL,NSL),     MPT(NSL)
      REAL      MIN
      LOGICAL   GRAPH, MORE
      CHARACTER PT*1,  RECORD*18, TH(4)*2
      CHARACTER FMT1*39, FMT2*33, FMT3*39, FMT4(2)*28
C
      DATA MORE /.TRUE./, TH /'ST','ND','RD','TH'/, RAD /57.2957795131/
      DATA FMT1 /'('' STATISTICS FOR PLOT #'', I1, ''--'', A)'/
      DATA FMT2 /'('' AREA:  '', I1, '' SQUARE UNITS'')'/
      DATA FMT3 /'('' PLOT AREAS:  '', I1, '' SQUARE UNITS'')'/
      DATA FMT4 /'('' PROBLEM IN THE '', I1, ''TH',
     +           ' RECORD OF PLOT #'', I1, '':'')'/
C     ------------------------------------------------------------------
```

```
C
C     CONVERT PARAMETER LIMITS TO VARIABLES.
      NVLIM = NVL
      NSLIM = NSL
C
C     OPEN INPUT, OUTPUT, AND SCRATCH FILES.
      OPEN   (INPT, FILE='QDATA', STATUS='OLD', ERR=100, BLANK='ZERO')
      REWIND (INPT)
      OPEN   (IOUT, FILE='QRATE', STATUS='NEW', ERR=110)
      REWIND (IOUT)
      IF (GRAPH) THEN
         OPEN   (IVEC, STATUS='SCRATCH')
         REWIND (IVEC)
      END IF
C
C     WRITE OUTPUT HEADING IDENTIFYING PROGRAM.
      LINE = LINES
      LINE = LINED (1) + 3
      WRITE (IOUT, '('' USDA FOREST SERVICE SPREAD RATE PROGRAM''/)')
      WRITE (IOUT, '(''          RATES IN UNITS/MINUTE'')')
      WRITE (IOUT, '(''      DIRECTIONS IN DEGREES AZIMUTH'')')
C
C     READ INPUT DATA ONE PLOT AT A TIME.
   10 NV = 0
      NS = NS + 1
      IF (NS .LE. NSL) THEN
   11    READ (INPT, '(A,  2F3.0,  F7.2, F4.0)', ERR=120, END=30)
     +                PT, MIN,SEC, DIST, COMP
         IF (PT .EQ. '#') GO TO 40
         IF (NV .LT. NVL .AND. MIN .LT. 999.0) THEN
C
C           CHECK FOR UNIQUENESS OF POINT.
            IF (NV .GE. 1) THEN
               DO 20 I=1,NV
   20          IF (PT .EQ. VPT(I:I)) GO TO 11
            END IF
C
C           ENTER NEW POINT INTO ARRAYS.
            NV         = NV + 1
            VPT (NV:) = PT
            TIME(NV)  = MIN + SEC/60.0
            COMP       = COMP/RAD
            VPX (NV)  = DIST*COS(COMP)
            VPY (NV)  = DIST*SIN(COMP)
            IF (GRAPH) THEN
               SPT(NS)(NV:) = PT
               SPX(NV,NS)   = VPX(NV)
               SPY(NV,NS)   = VPY(NV)
            END IF
         END IF
         GO TO 11
      END IF
   30 CLOSE (INPT, STATUS='KEEP')
      MORE = .FALSE.
```

```
C
C     PROCESS PLOT.
   40 IF (NV .GE. 3) THEN
         PWT  = AREA (NV, VPT, VPX, VPY, VPP, VDIR, NPP)
         NPWT = NINT(PWT)
         IF (NPWT .GT. 0) THEN
            IF (GRAPH) SPP(NS) = VPP
            LINE = LINED (NV) + 3
            WRITE (FMT1(29:29), '(I1)') INT(ALOG10(REAL(NS))) + 1
            WRITE (IOUT, FMT1) NS, VPP
            IF (NPWT .LT. 1.0E9) THEN
               WRITE (FMT2(15:15), '(I1)') INT(ALOG10(REAL(NPWT))) + 1
               WRITE (IOUT, FMT2) NPWT
            END IF
            WRITE (IOUT, '(23X, ''RATE  DIRECTION'')')
            WRITE (IOUT, '('' INDIVIDUAL TRIANGLES'')')
            CALL CHRONO (VPT, VPX, VPY, TIME)
         ELSE
            CALL NOPLOT (VPT)
         END IF
      ELSE IF (NV .GE. 1) THEN
         CALL NOPLOT (VPT)
      ELSE
         NS = NS - 1
      END IF
      IF (MORE) GO TO 10
C     ------------------------------------------------------------------
C
C     OUTPUT SUMMARY HEADING.
      IF (NP .GE. 2) THEN
         WRITE (IOUT, '(/)')
         IF (GRAPH) THEN
            LINE = LINED (6)
         ELSE
            LINE = LINED (5)
         END IF
         WRITE (IOUT, '('' OVERALL STATISTICS'')')
      END IF
C
C     IF GRAPHICS, DRAW PLOTS AND OUTPUT AREA CALCULATIONS.
      IF (GRAPH) THEN
         ENDFILE (IVEC)
         CALL CALCOM (SPT, SPX, SPY, SPP, MPT)
         CLOSE   (IVEC)
C
C     IF NO GRAPHICS, OUTPUT THE AREA OF THE SUM OF THE PLOTS.
      ELSE IF (NP .GE. 2) THEN
         NPWGT = NINT(PWGT)
         IF (NPWGT .LT. 1.0E9) THEN
            WRITE (FMT3(21:21), '(I1)') INT(ALOG10(REAL(NPWGT))) + 1
            WRITE (IOUT, '('' SUM OF ALL'')')
            WRITE (IOUT, FMT3) NPWGT
            CALL NOTE1
         ELSE
            CALL NOTE2
         END IF
      END IF
```

```
C
C     OUTPUT SUMMARY STATISTICS.
      IF (NP .GE. 2 .AND. (PXSUM .NE. 0.0 .OR. PYSUM .NE. 0.0)) THEN
         WRITE (IOUT, '(/ 23X, ''RATE  DIRECTION'')')
         CALL STATS (NP,PWGT, PRSUM,PRSUM2, PDSUM,PDSUM2, PXSUM,PYSUM)
      END IF
      WRITE (IOUT, '(''1'')')
      CLOSE (IOUT, STATUS='KEEP')
      STOP
C     ------------------------------------------------------------------
C
C     ERROR OPENING FILE 'QDATA'.
  100 STOP 'FILE QDATA COULD NOT BE FOUND.'
C
C     ERROR OPENING FILE 'QRATE'.
  110 CLOSE (INPT, STATUS='KEEP')
      STOP 'FILE QRATE ALREADY EXISTS.'
C
C     ERROR READING RECORD FROM FILE 'QDATA'.
  120 BACKSPACE (INPT)
      READ  (INPT, '(A)') RECORD
      CLOSE (INPT, STATUS='KEEP')
      LINE = LINED (2)
      WRITE (IOUT, '('' ''''READ'''' ERROR DETECTED ON FILE QDATA''/)')
      NV = NV + 1
      WRITE (FMT4(1)(23:23), '(I1)') INT(ALOG10(REAL(NV))) + 1
      WRITE (FMT4(1)(27:28), '(A2)') TH(MIN0(NV, 4))
      WRITE (FMT4(2)(22:22), '(I1)') INT(ALOG10(REAL(NS))) + 1
      WRITE (IOUT, FMT4) NV, NS
      WRITE (IOUT, '(A19)') RECORD
      WRITE (IOUT, '('' PMINSECDDDD.DDCCCC   IS THE CORRECT FORMAT'')')
      WRITE (IOUT, '(''    WHERE--                                  '')')
      WRITE (IOUT, '(''       P = THE LETTER IDENTIFYING THE POINT'')')
      WRITE (IOUT, '('' MINSEC = THE TIME FIRE REACHED THE POINT '')')
      WRITE (IOUT, '('' DDDD.DD = DISTANCE OF POINT FROM MARKER   '')')
      WRITE (IOUT, '(''    CCCC = DIRECTION OF POINT FROM MARKER  '')')
      WRITE (IOUT, '(/ '' PLEASE AMEND RECORD AND RESUBMIT FILE.  '')')
      WRITE (IOUT, '(''1'')')
      CLOSE (IOUT, STATUS='KEEP')
      STOP 'READ ERROR ON FILE QDATA.'
      END



      FUNCTION AREA (N, PT, PX, PY, PP, DIR, NPP)
C
C     CALCULATES THE AREA OF A CONVEX POLYGON.
C
      CHARACTER *(*) PT, PP
      DIMENSION PX(N), PY(N), DIR(N), NPP(N)
C
C     DEGREES PER RADIAN.
      DATA RAD /57.2957795131/
```

```
C
C     FUNCTIONS TO CALCULATE DISTANCES BETWEEN TWO POINTS.
      XCORD (I, J) = PX(J) - PX(I)
      YCORD (I, J) = PY(J) - PY(I)
      SIDE  (I, J) = SQRT(XCORD(I,J)**2 + YCORD(I,J)**2)
C     ------------------------------------------------------------------
C
C     FIND INDEX 'NX' OF NORTHERNMOST POINT 'PP(1:1)' IN PLOT.
      NX = 1
      DO 10 I=2,N
   10 IF (PX(I) .GT. PX(NX)) NX = I
      K       = 1
      PP (1:) = PT(NX:NX)
      NPP(1)  = NX
C
C     FIND COMPASS DIRECTION OF ALL OTHER POINTS FROM 'NX'.
      DO 20 J=1,N
      IF (J .NE. NX) THEN
         IF (PX(J) .NE. PX(NX) .OR. PY(J) .NE. PY(NX)) THEN
            DIR(J) = CIRCLE(RAD*ATAN2(YCORD(NX,J), XCORD(NX,J)), 180.0)
         ELSE
            DIR(J) = 999.0
         END IF
      END IF
   20 CONTINUE
      DIR(NX) = 360.0
C
C     FIND INDEX 'MX' OF NEXT CLOCKWISE PERIMETER POINT IN PLOT.
   30 MX = 1
      DO 31 I=2,N
      IF (DIR(I) .LT. DIR(MX)) THEN
         MX = I
      ELSE IF (DIR(I) .EQ. DIR(MX)) THEN
         IF (SIDE(NPP(K),I) .GT. SIDE(NPP(K),MX)) MX = I
      END IF
   31 CONTINUE
C
C     FIND COMPASS DIRECTION OF REMAINING POINTS FROM 'MX'.
      IF (MX .NE. NX) THEN
         K       = K + 1
         PP (K:) = PT(MX:MX)
         NPP(K)  = MX
         DO 40 J=1,N
         IF (J .NE. MX .AND. DIR(J) .LE. 450.0) THEN
            IF (PX(J) .NE. PX(MX) .OR. PY(J) .NE. PY(MX)) THEN
               DIR(J) = CIRCLE (RAD*ATAN2(YCORD(MX,J), XCORD(MX,J)),
     +                          DIR(MX) + 180.0)
            ELSE
               DIR(J) = 999.0
            END IF
         END IF
   40    CONTINUE
         DIR(MX) = 999.0
         GO TO 30
      END IF
      PP(K+1:) = PP(1:1)
```

```
C
C     USING 'NX' WITH  EACH SET OF TWO  ADJACENT PERIMETER  POINTS, SUM
C     THE AREAS OF THE TRIANGLES FORMED TO FIND THE PLOT'S AREA.
      AREA = 0.0
      AX   = SIDE (NPP(2), NX)
      DO 50 I=3,K
      BX   = AX
      AX   = SIDE (NPP(I), NX)
      AB   = SIDE (NPP(I), NPP(I-1))
      S    = 0.5*(AX + BX + AB)
      ABX  = SQRT(AMAX1(0.0, S*(S - AX)*(S - BX)*(S - AB)))
   50 AREA = AREA + ABX
      RETURN
      END



      SUBROUTINE CHRONO (VPT, VPX, VPY, TIME)
C
C     SELECTS TRIANGLES BY ORDERING THE PLOT'S POINTS CHRONOLOGICALLY.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /CNTRL/ PWT, GRAPH, AMIN
      COMMON /TRIAN/ NT,TWGT, TRSUM,TRSUM2, TDSUM,TDSUM2, TXSUM,TYSUM
      COMMON /PLOTS/ NP,PWGT, PRSUM,PRSUM2, PDSUM,PDSUM2, PXSUM,PYSUM
      COMMON /MEANS/ RMEAN, DMEAN, XMEAN, YMEAN, RLOW, RMOD, DLOW, DMOD
C
      CHARACTER VPT*(*)
      DIMENSION VPX(NVL), VPY(NVL), TIME(NVL)
C     ------------------------------------------------------------------
C
C     INITIALIZE COUNTERS FOR SUBSEQUENT MEAN AND VECTOR CALCULATIONS.
      NT     = 0
      TWGT   = 0.0
      TRSUM  = 0.0
      TRSUM2 = 0.0
      TDSUM  = 0.0
      TDSUM2 = 0.0
      TXSUM  = 0.0
      TYSUM  = 0.0
C
C     DISTINGUISH EACH TRIANGLE ORDERING POINTS CHRONOLOGICALLY.
      DO 10 I=  1,NV-2
      DO 10 J=I+1,NV-1
      DO 10 K=J+1,NV
      IF (TIME(I) .LE. TIME(J) .AND. TIME(I) .LE. TIME(K)) THEN
         IF (TIME(J) .LE. TIME(K)) THEN
            CALL TRIGON (I,J,K, VPT,VPX,VPY,TIME)
         ELSE
            CALL TRIGON (I,K,J, VPT,VPX,VPY,TIME)
         END IF
```

```
      ELSE IF (TIME(J) .LE. TIME(I) .AND. TIME(J) .LE. TIME(K)) THEN
         IF (TIME(I) .LE. TIME(K)) THEN
            CALL TRIGON (J,I,K, VPT,VPX,VPY,TIME)
         ELSE
            CALL TRIGON (J,K,I, VPT,VPX,VPY,TIME)
         END IF
      ELSE
         IF (TIME(I) .LE. TIME(J)) THEN
            CALL TRIGON (K,I,J, VPT,VPX,VPY,TIME)
         ELSE
            CALL TRIGON (K,J,I, VPT,VPX,VPY,TIME)
         END IF
      END IF
   10 CONTINUE
C
C     IF THERE ARE NO TRIANGLES (OR NO RESULTANT VECTOR), RETURN.
      IF (NT .EQ. 0 .OR. (TXSUM .EQ. 0.0 .AND. TYSUM .EQ. 0.0)) THEN
         LINE = LINE + 2
         WRITE (IOUT, '('' THIS PLOT HAS INSUFFICIENT DATA.  IT IS''/
     +                 '' NOT INCLUDED IN THE OVERALL STATISTICS.'')')
         RETURN
      END IF

C     CALCULATE VECTOR AVERAGE, ARITHMETIC MEAN, AND STD. DEVIATION.
      IF (NT .GT. 1 .AND. LINE + 6 .GT. LINES) CALL SPLIT
      CALL STATS (NT,TWGT, TRSUM,TRSUM2, TDSUM,TDSUM2, TXSUM,TYSUM)
C
C     ADD THIS PLOT TO OVERALL FIGURES.
      IF (NP .GE. 1) DMEAN = CIRCLE (DMEAN, PDSUM/PWGT)
      NP     = NP     + 1
      PWGT   = PWGT   + PWT
      PRSUM  = PRSUM  + PWT*RMEAN
      PRSUM2 = PRSUM2 + PWT*RMEAN*RMEAN
      PDSUM  = PDSUM  + PWT*DMEAN
      PDSUM2 = PDSUM2 + PWT*DMEAN*DMEAN
      PXSUM  = PXSUM  + PWT*XMEAN
      PYSUM  = PYSUM  + PWT*YMEAN
      RETURN
      END



      SUBROUTINE TRIGON (I,J,K, VPT,VPX,VPY,TIME)
C
C     GIVEN ANY TRIANGLE, LET VERTEX  'A' BE THE POINT THE FIRE REACHED
C     FIRST AT TIME(I), VERTEX 'B' BE THE POINT THE FIRE REACHED SECOND
C     AT TIME(J), AND VERTEX 'C' BE THE  POINT THE FIRE REACHED LAST AT
C     TIME(K).  THE  RATE AND DIRECTION  OF SPREAD ARE  CALCULATED WITH
C     RESPECT TO TRIANGLE 'ABC', AND  THEN REORIENTATED WITH RESPECT TO
C     NORTH AS VIEWED FROM 'A'.
C
```

```
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /CNTRL/ PWT, GRAPH, AMIN
      COMMON /TRIAN/ NT,TWGT, TRSUM,TRSUM2, TDSUM,TDSUM2, TXSUM,TYSUM
C
      CHARACTER VPT*(*),  TRI*3
      DIMENSION VPX(NVL), VPY(NVL), TIME(NVL)
      LOGICAL   GRAPH
C
C     DEGREES PER RADIAN.
      DATA RAD /57.2957795131/
C
C     FUNCTIONS TO CALCULATE DISTANCES BETWEEN TWO POINTS.
      XCORD (I, J) = VPX(J) - VPX(I)
      YCORD (I, J) = VPY(J) - VPY(I)
      SIDE  (I, J) = SQRT(XCORD(I,J)**2 + YCORD(I,J)**2)
C
C     FUNCTION:  THE LAW OF COSINES.
      ANGLE (R,S,T) = ACOS(AMIN1(ABS((R*R + S*S - T*T)/(2.*R*S)), 1.0))
C     ------------------------------------------------------------------
C
C     FIND ALL SIDES (REJECT THOSE EQUAL TO ZERO) OF TRIANGLE 'ABC'.
      AB = SIDE (I, J)
      IF (AB .LE. 0.0) RETURN
      AC = SIDE (I, K)
      IF (AC .LE. 0.0) RETURN
      BC = SIDE (K, J)
      IF (BC .LE. 0.0) RETURN
C
C     FIND ALL ANGLES (REJECT PARTICULARLY NARROW ONES) OF 'ABC'.
      A = ANGLE (AB, AC, BC)
      IF (A .LT. AMIN) RETURN
      B = ANGLE (AB, BC, AC)
      IF (B .LT. AMIN) RETURN
      C = ANGLE (AC, BC, AB)
      IF (C .LT. AMIN) RETURN
C
C     FIND THE AREA OF TRIANGLE 'ABC'.
      ACSINA = AC*SIN(A)
      TWT    = 0.5*AB*ACSINA
C
C     CALCULATE DIRECTION AND RATE OF SPREAD RELATIVE TO SIDE 'AB'.
      IF (TIME(I) .NE. TIME(J)) THEN
         TIMJI = TIME(J) - TIME(I)
         TIMKI = TIME(K) - TIME(I)
         THETA = ATAN(TIMKI*AB/(TIMJI*ACSINA) - 1.0/TAN(A))
         RATE  = AB*COS(THETA)/TIMJI
         THETA = RAD*THETA
      ELSE
         RATE  = ACSINA/(TIME(K) - TIME(I))
         THETA = 90.0
      END IF
```

```
C
C     RELATE THETA TO COMPASS NORTH, AS VIEWED FROM POINT A.
      BAN = RAD*ATAN2(YCORD(I,J), XCORD(I,J))
      CAN = RAD*ATAN2(YCORD(I,K), XCORD(I,K))
      CAN = CIRCLE (CAN, BAN)
      IF (BAN .LE. CAN) THEN
         THETA = BAN + THETA
      ELSE
         THETA = BAN - THETA
      END IF
      THETA = CIRCLE (THETA, 180.0)
C
C     OUTPUT RATE AND DIRECTION FOR THIS TRIANGLE.
      TRI = VPT(I:I)//VPT(J:J)//VPT(K:K)
      IF (LINE .EQ. LINES) CALL SPLIT
      LINE = LINE + 1
      WRITE (IOUT, '(A19, F8.1, I8)') TRI, RATE, NINT(THETA)
C
C     ADD LATEST THETA TO SUMMATION VARIABLES.
      IF (NT .GE. 1) THETA = CIRCLE (THETA, TDSUM/TWGT)
      NT     = NT     + 1
      TWGT   = TWGT   + TWT
      TRSUM  = TRSUM  + TWT*RATE
      TRSUM2 = TRSUM2 + TWT*RATE*RATE
      TDSUM  = TDSUM  + TWT*THETA
      TDSUM2 = TDSUM2 + TWT*THETA*THETA
      THETA  = THETA/RAD
      RCOS   = RATE*COS(THETA)
      RSIN   = RATE*SIN(THETA)
      TXSUM  = TXSUM  + TWT*RCOS
      TYSUM  = TYSUM  + TWT*RSIN
C
C     IF REQUESTED, ADD VECTOR TO SCRATCH FILE.
      IF (GRAPH) WRITE (IVEC, '(A, 3F9.2)') TRI, RATE, RCOS, RSIN
      RETURN
      END



      SUBROUTINE STATS (N,WGT, RSUM,RSUM2, DSUM,DSUM2, XSUM,YSUM)
C
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /MEANS/ RMEAN, DMEAN, XMEAN, YMEAN, RLOW, RMOD, DLOW, DMOD
C
      CHARACTER *8 RVAR, DVAR
C
C     DEGREES PER RADIAN.
      DATA RAD /57.2957795131/
C
C     FUNCTION FOR CALCULATING WEIGHTED STANDARD DEVIATIONS.
      STDDEV (S, S2) = SQRT(AMAX1(0., FN/WGT*(S2 - S*S/WGT)/(FN - 1.)))
C     ------------------------------------------------------------------
```

```
C
C     CALCULATE VECTOR AVERAGE.
      XMEAN = XSUM/WGT
      YMEAN = YSUM/WGT
      VRATE = SQRT(XMEAN*XMEAN + YMEAN*YMEAN)
      VDIR  = CIRCLE (RAD*ATAN2(YMEAN, XMEAN), 180.0)
      IVDIR = NINT(VDIR)
C
C     CALCULATE ARITHMETIC MEANS.
      RMEAN = RSUM/WGT
      DMEAN = CIRCLE (DSUM/WGT, 180.0)
      IF (N .EQ. 1) RETURN
      IDMEAN = NINT(DMEAN)
C
C     CALCULATE ARITHMETIC STANDARD DEVIATIONS.
      FN    = N
      RSTD  = STDDEV (RSUM, RSUM2)
      DSTD  = STDDEV (DSUM, DSUM2)
      IDSTD = NINT(DSTD)
C
C     FIND RATE AT WHICH VECTOR AND ARITHMETIC AVERAGES ARE DIVERGING.
      VADIV = SQRT(AMAX1(0.0, VRATE*VRATE + RMEAN*RMEAN -
     +        2.0*VRATE*RMEAN*COS((VDIR - DMEAN)/RAD)))
C
C     CLASSIFY ARITHMETIC AVERAGES INTO CLASSES.
      COVAR = RSTD/RMEAN
      IF (COVAR .LE. RLOW) THEN
         RVAR = '     LOW'
      ELSE IF (COVAR .LT. RMOD) THEN
         RVAR = '    MOD.'
      ELSE
         RVAR = '    HIGH'
      END IF
      IF (DSTD .LE. DLOW) THEN
         DVAR = '     LOW'
      ELSE IF (DSTD .LT. DMOD) THEN
         DVAR = '    MOD.'
      ELSE
         DVAR = '    HIGH'
      END IF
C
C     OUTPUT RESULTS OF THIS PLOT.
      LINE = LINE + 6
      WRITE (IOUT, '('' SUMMARY TABLE'')')
      WRITE (IOUT, '(''    VECTOR AVERAGE '', F8.1, I8)') VRATE, IVDIR
      WRITE (IOUT, '(''    V/A DIVERGENCE '', F8.1)')     VADIV
      WRITE (IOUT, '(''    ARITHMETIC MEAN'', F8.1, I8)') RMEAN, IDMEAN
      WRITE (IOUT, '(''          STD. DEV.'', F8.1, I8)') RSTD,  IDSTD
      WRITE (IOUT, '(''          VARIANT  '', 2A)')       RVAR,  DVAR
      RETURN
      END
```

```
      FUNCTION CIRCLE (ANGA, ANGB)
C
C     THIS FUNCTION IS USED WHEN COMPARING  TWO ANGLES (CONSIDERING THE
C     CYCLIC NATURE OF A COMPASS).  IF 'ANGA' IS NOT WITHIN PLUS OR MI-
C     NUS 180 DEGREES OF 'ANGB', THEN 360 DEGREES IS SUBTRACTED OR ADD-
C     ED TO 'ANGA' TO PUT IT IN THAT RANGE.
C
C     ------------------------------------------------------------------
C
      IF (ANGA .GE. ANGB + 180.0) THEN
         CIRCLE = ANGA - 360.0
      ELSE IF (ANGA .LT. ANGB - 180.0) THEN
         CIRCLE = ANGA + 360.0
      ELSE
         CIRCLE = ANGA
      END IF
      RETURN
      END



      FUNCTION LINED (NV)
C
C     THIS FUNCTION PREVENTS THE OUTPUT  OF A PLOT FROM BEING SPLIT BE-
C     TWEEN TWO PAGES WHENEVER FEASIBLE.
C
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C
      DIMENSION MLINE(8)
C
      DATA MLINE /4, 15, 8, 17, 23, 33, 48, 69/
C     ------------------------------------------------------------------
C
C     DETERMINE MAXIMUM POSSIBLE NUMBER OF LINES FOR THIS PLOT.
      IF (NV .LE. 8) THEN
         L = MLINE(NV)
      ELSE
         L = LINES
      END IF
C
C     ADD TO EXISTING PAGE IF POSSIBLE, OR BEGIN NEW PAGE.
      IF (LINE + L .LE. LINES) THEN
         LINED = LINE + 4
         WRITE (IOUT, '(//)')
      ELSE
         LINED = 1
         WRITE (IOUT, '(''1'')')
      END IF
      RETURN
      END
```

```
      SUBROUTINE SPLIT
C
C     HEADS NEW OUTPUT PAGE WHENEVER A PLOT IS SPLIT BETWEEN TWO PAGES.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C
      CHARACTER FMT*33
C
      DATA FMT /'('' CONTINUATION OF PLOT #'', I1)'/
C     ------------------------------------------------------------------
C
      LINE = 3
      WRITE (IOUT, '(''1'')')
      WRITE (FMT(30:30), '(I1)') INT(ALOG10(REAL(NS))) + 1
      WRITE (IOUT, FMT) NS
      WRITE (IOUT, '(23X, ''RATE  DIRECTION'')')
      RETURN
      END



      SUBROUTINE NOPLOT (VPT)
C
C     CALLED WHEN A PLOT HAS TOO FEW POINTS AND/OR NEGLIGIBLE AREA.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C
      CHARACTER VPT*(*), FMT*45
C
      DATA FMT /'('' INSUFFICIENT DATA IN PLOT #'', I1, ''--'', A)'/
C     ------------------------------------------------------------------
C
      LINE = LINED (1)
      WRITE (FMT(35:35), '(I1)') INT(ALOG10(REAL(NS))) + 1
      WRITE (IOUT, FMT) NS, VPT
      RETURN
      END
```

```
      SUBROUTINE CALCOM (SPT, SPX, SPY, SPP, MPT)
C
C     INITIALIZES THE CALCOMP PLOTTER AND PLOTS THE NORTH POINTER.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XLIM,YLIM
C
      CHARACTER *(*) SPT(NSL), SPP(NSL)
      DIMENSION SPX(NVL,NSL), SPY(NVL,NSL), MPT(NSL)
C     ------------------------------------------------------------------
C
C     INITIALIZE PLOTTER QUEUE.
      IF (ITYPE .EQ. 0 .OR. ITYPE .EQ. 5 .OR. ITYPE .EQ. 10) THEN
         XAXIS = 10.0
      ELSE IF (ITYPE .EQ. 1 .OR. ITYPE .EQ. 6) THEN
         XAXIS = 30.0
      ELSE
         STOP 'ERROR IN PLOTTER QUEUE TYPE'
      END IF
      CALL PLOTS (IBUF, 257, ITYPE)
C
C     PLOT COMPASS NORTH SYMBOL.
      CALL NEWPEN (1)
      CALL SYMBOL (-0.09, XAXIS - 0.32, 0.28, 'N',  0.0,  1)
      CALL SYMBOL (-0.07, XAXIS - 0.32, 0.28, 'N',  0.0,  1)
      CALL SYMBOL (-0.01, XAXIS - 0.59, 0.28,  13,  0.0, -1)
      CALL SYMBOL ( 0.01, XAXIS - 0.59, 0.28,  13,  0.0, -1)
      CALL SYMBOL (-0.01, XAXIS - 0.83, 0.28,  11, 45.0, -1)
      CALL SYMBOL ( 0.01, XAXIS - 0.83, 0.28,  11, 45.0, -1)
      CALL SYMBOL (-0.01, XAXIS - 0.85, 0.28,  11, 45.0, -1)
      CALL SYMBOL ( 0.01, XAXIS - 0.85, 0.28,  11, 45.0, -1)
      CALL NEWPEN (2)
      CALL SYMBOL (-0.08, XAXIS - 0.32, 0.28, 'N',  0.0,  1)
      CALL SYMBOL ( 0.00, XAXIS - 0.58, 0.28,  13,  0.0, -1)
      CALL SYMBOL ( 0.00, XAXIS - 0.84, 0.28,  11, 45.0, -1)
C
C     LAY OUT THE PLOTS.
      CALL ORIGIN (SPT, SPX, SPY, SPP, MPT)
C
C     CLOSE PLOTTER QUEUE.
      CALL PLOT (BORDL, 0.0, 999)
      RETURN
      END
```

```
      SUBROUTINE ORIGIN (SPT, SPX, SPY, SPP, MPT)
C
C     ORIENTS ALL POINTS FROM A COMMON ORIGIN.
C
C     PROGRAM HANDLES UP TO 'NGL' TIMERS, A MACHINE LIMITATION EQUAL TO
C     ITS TOTAL NUMBER OF INDIVIDUAL ALPHANUMERIC CHARACTERS OTHER THAN
C     THE '#' (RESERVED FOR SEPARATING PLOTS ON FILE 'QDATA').
      PARAMETER (NGL=61)
C     ------------------------------------------------------------------
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGLIM
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /PLOTS/ NP,PWGT, PRSUM,PRSUM2, PDSUM,PDSUM2, PXSUM,PYSUM
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XLIM,YLIM
C
      CHARACTER *(*) SPT(NSL), SPP(NSL), GPT*(NGL), GPP*(NGL+1)
      DIMENSION SPX(NVL,NSL), SPY(NVL,NSL), MPT(NSL)
      DIMENSION GPX(NGL), GPY(NGL), GDIR(NGL), NPP(NGL)
      CHARACTER TOTAL*7, FMT1*39, FMT2*38, FMT3*38
C
      DATA TOTAL /' TOTAL '/, IDIGIT /0/, TAREA /0.0/
      DATA FMT1  /'(A, ''AREA: '', I1, '' SQUARE UNITS--'', A)'/
      DATA FMT2  /'('' TOTAL AREA: '', I1, '' SQUARE UNITS'')'/
      DATA FMT3  /'('' PLOT AREAS: '', I1, '' SQUARE UNITS'')'/
C     ------------------------------------------------------------------
C
C     CONVERT PARAMETER LIMIT TO VARIABLE.
      NGLIM = NGL
C
C     DETERMINE NUMBER OF DIGITS IN AREA CALCULATION OUTPUT.
      NPWGT = NINT(PWGT)
      IF (NPWGT .GT. 0 .AND. NPWGT .LT. 1.0E9)
     +   IDIGIT = MIN1(ALOG10(REAL(NPWGT)), 7.0) + 2
C
C     INITIALIZE PLOT SELECTION MATRIX.
      MPS = NS
      DO 10 J=1,MPS
   10 MPT(J) = J
C
C     ENTER FIRST PLOT INTO GRAPHIC MATRIX.
   20 XLIM = SPX(1,MPT(1))
      YLIM = SPY(1,MPT(1))
      DO 21 I=1,NVL
      IF (SPT(MPT(1))(I:I) .EQ. ' ') GO TO 30
   21 CALL MATRIX (I,MPT(1),0.0,0.0, SPT,SPX,SPY, GPT,GPX,GPY)
C
C     REORIENT REMAINING PLOTS TO ORIGIN OF FIRST PLOT.
   30 DO 31 I=2,MPS
      J = I
   31 CALL ORIENT (J, SPT, SPX, SPY, MPT, GPT, GPX, GPY)
```

```
C
C     RERUN PLOTS THAT DIDN'T HAVE A MATCH ON THE FIRST PASS.
   40 IF (MP .GT. 0) THEN
         IF (MP .NE. MPS) THEN
            MPS = MP
            MP  = 0
            DO 41 I=1,MPS
            J   = I
   41       CALL ORIENT (J, SPT, SPX, SPY, MPT, GPT, GPX, GPY)
            GO TO 40
         ELSE
            TOTAL = ' '
         END IF
      END IF
C
C     MOVE ALL POINTS TO THE FIRST QUADRANT.
      GPX(1) = GPX(1) - XLIM
      GPY(1) = GPY(1) - YLIM
      XMAX   = GPX(1)
      YMAX   = GPY(1)
      DO 50 K=2,NG
      GPX(K) = GPX(K) - XLIM
      GPY(K) = GPY(K) - YLIM
      XMAX   = AMAX1(GPX(K), XMAX)
   50 YMAX   = AMAX1(GPY(K), YMAX)
      XLIM   = XMAX
      YLIM   = YMAX
C
C     CALCULATE THE AREA AND GRAPH THE CONVEX POLYGON JUST FORMED.
      IF (NP .GE. 2) THEN
         AREAS = AREA (NG, GPT, GPX, GPY, GPP, GDIR, NPP)
         NAREA = NINT(AREAS)
         IF (NAREA .GT. 0 .AND. NAREA .LT. 1.0E9) THEN
            IDIGIT = MAX0(IDIGIT, INT(ALOG10(REAL(NAREA))) + 1)
            WRITE (FMT1(16:16), '(I1)') IDIGIT
            WRITE (IOUT, FMT1) TOTAL, NAREA, GPP
         END IF
         TAREA = TAREA + AREAS
      END IF
      CALL GRAFIC (SPP, GPT, GPX, GPY)
C
C     REPEAT THE ABOVE FOR ANY DISJOINT PLOTS.
      IF (MP .GT. 0) THEN
         MP = 0
         NG = 0
         GO TO 20
      END IF
```

```
C
C     IF DISJOINT PLOTS, WRITE THE TOTAL AREA TO THE OUTPUT FILE.
      IF (NP .GE. 2) THEN
         IF (TOTAL .EQ. ' ') THEN
            NAREA = NINT(TAREA)
            IF (NAREA .LT. 1.0E9) THEN
               IDIGIT = MAX0(IDIGIT, INT(ALOG10(REAL(NAREA))) + 1)
               WRITE (FMT2(20:20), '(I1)') IDIGIT
               WRITE (IOUT, FMT2) NAREA
            END IF
         END IF
C
C        OUTPUT THE SUM OF THE INDIVIDUAL PLOT AREAS.
         IF (NPWGT .LT. 1.0E9) THEN
            WRITE (FMT3(20:20), '(I1)') IDIGIT
            WRITE (IOUT, '('' SUM OF ALL'')')
            WRITE (IOUT, FMT3) NPWGT
         END IF
C
C        IF BOTH AREA CALCULATIONS WERE OUTPUT, NOTE DISCREPANCIES.
         IF (NAREA .LT. 1.0E9 .AND. NPWGT .LT. 1.0E9) THEN
            IF (TAREA .GE. 1.01*PWGT) THEN
               WRITE (IOUT, '(/
     +         '' NOTE:  A PORTION OF THE ''''TOTAL AREA'''' IS''/
     +         '' NOT CONTAINED WITHIN ANY PLOT,  AND NOT''/
     +         '' INCLUDED IN THE FOLLOWING STATISTICS.  '')')
               CALL NOTE1
            ELSE IF (TAREA .LE. 0.99*PWGT) THEN
               WRITE (IOUT, '(/
     +         '' NOTE:  THE INPUT  FILE  INCLUDED  PLOTS''/
     +         '' THAT OVERLAPPED  EACH OTHER.   BOTH THE''/
     +         '' ''''SUM OF ALL PLOT AREAS'''' AND THE FOLLOW-''/
     +         '' ING STATISTICS,  WHICH ARE  WEIGHTED BY''/
     +         '' AREA,  REFLECT  ADDED  EMPHASIS  IN THE''/
     +         '' OVERLAPPED AREAS.                      '')')
               CALL NOTE3
            ELSE IF (NAREA .NE. NPWGT) THEN
               WRITE (IOUT, '(/
     +         '' NOTE:  THE  ''''TOTAL AREA''''  DIFFERS  FROM''/
     +         '' THE ''''SUM  OF ALL  PLOT  AREAS''''  BY LESS''/
     +         '' THAN 1 PERCENT.  THIS SMALL DISCREPANCY''/
     +         '' MAY BE DUE  TO A PORTION  OF THE ''''TOTAL''/
     +         '' AREA'''' NOT  CONTAINED  WITHIN  ANY PLOT,''/
     +         '' OVERLAPPING  PLOTS,  OR  POSSIBLY  BOTH''/
     +         '' REASONS.                               '')')
            END IF
```

```
C
C        BOTH AREA CALCULATIONS WERE NOT OUTPUT.
         ELSE
            IF (NPWGT .LT. 1.0E9) THEN
               CALL NOTE1
            ELSE
               IF (NAREA .LT. 1.0E9) CALL NOTE3
               CALL NOTE2
            END IF
         END IF
      END IF
      RETURN
      END



      SUBROUTINE ORIENT (J, SPT, SPX, SPY, MPT, GPT, GPX, GPY)
C
C     REORIENTS THE JTH PLOT TO THE ORIGIN OF FIRST PLOT.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XLIM,YLIM
C
      CHARACTER *(*) SPT(NSL), GPT
      DIMENSION SPX(NVL,NSL),SPY(NVL,NSL),MPT(NSL), GPX(NGL),GPY(NGL)
      LOGICAL   MISS
C     ------------------------------------------------------------------
C
C     FIND MATCH BETWEEN POINT IN JTH PLOT AND POINT ALREADY IN MATRIX.
      MISS = .TRUE.
      J    = MPT(J)
      DO 13 I=1,NVL
      IF (SPT(J)(I:I) .EQ. ' ') GO TO 20
      DO 13 K=1,NG
      IF (SPT(J)(I:I) .EQ. GPT(K:K)) THEN
         MISS = .FALSE.
C
C        FIND COORDINATE DIFFERENCE BETWEEN MATCHED POINTS.
         X = GPX(K) - SPX(I,J)
         Y = GPY(K) - SPY(I,J)
C
C        ADD UNMATCHED POINTS TO GRAPHIC MATRIX.
         DO 10 II=1,I-1
   10    CALL MATRIX (II,J,X,Y, SPT,SPX,SPY, GPT,GPX,GPY)
         DO 12 II=I+1,NVL
         IF (SPT(J)(II:II) .EQ. ' ') RETURN
         DO 11 KK=1,NG
   11    IF (SPT(J)(II:II) .EQ. GPT(KK:KK)) GO TO 12
         CALL MATRIX (II,J,X,Y, SPT,SPX,SPY, GPT,GPX,GPY)
   12    CONTINUE
         RETURN
      END IF
   13 CONTINUE
```

```
C
C     MATCH NOT FOUND.
   20 IF (MISS) THEN
         MP = MP + 1
         MPT(MP) = J
      END IF
      RETURN
      END




      SUBROUTINE MATRIX (I,J,X,Y, SPT,SPX,SPY, GPT,GPX,GPY)
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XMIN,YMIN
C
      CHARACTER *(*) SPT(NSL), GPT
      DIMENSION SPX(NVL,NSL), SPY(NVL,NSL), GPX(NGL), GPY(NGL)
C     ------------------------------------------------------------------
C
C     ADD THE SELECTED POINT TO THE GRAPHIC MATRIX.
      NG       = NG + 1
      GPT(NG:) = SPT(J)(I:I)
      GPX(NG)  = SPX(I,J) + X
      GPY(NG)  = SPY(I,J) + Y
      XMIN     = AMIN1(XMIN, GPX(NG))
      YMIN     = AMIN1(YMIN, GPY(NG))
      RETURN
      END




      SUBROUTINE GRAFIC (SPP, GPT, GPX, GPY)
C
C     PLOTS THE FIRE USING CALCOMP COMMANDS.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XMAX,YMAX
C
      CHARACTER *(*) SPP(NSL), GPT, PN*1, PI*1
      DIMENSION GPX(NGL), GPY(NGL)
C     ------------------------------------------------------------------
```

```
C
C     DETERMINE SCALING FACTOR AND LENGTH OF Y-AXIS.
      FCT   = XAXIS/XMAX
      YAXIS = YMAX*FCT
      BORDR = BORDL + YAXIS + 1.0
      IF (BORDR .GT. 29.0) CALL PLIMIT (BORDR + 1.0)
C
C     SCALE THE FIRE TO THE PLOTTER COORDINATES.
      DO 10 K=1,NG
      GPX(K) = GPX(K)*FCT
   10 GPY(K) = GPY(K)*FCT + BORDL
C
C     DETERMINE NUMBER OF INCREMENTS FOR PLOT SCALE.
      CALL NEWPEN (1)
      PS    = 10.0
      SCALE = 10.0*FCT + BORDL
      IF (SCALE .GT. BORDR) THEN
         DO 20 PS=5.0,1.0,-1.0
         SCALE = PS*FCT + BORDL
   20    IF (SCALE .LE. BORDR) GO TO 30
         GO TO 40
      END IF
C
C     PLACE THE SCALE ALONG THE EDGE OF THE DRAWING.
   30 CENTER = 0.5*PS*FCT + BORDL
      CALL SYMBOL (CENTER - 0.32, -0.37, 0.14, 'SCALE', 0.0, 5)
      Y = BORDL
      CALL PLOT (Y, -0.37, 3)
      CALL PLOT (Y, -0.51, 2)
      DO 31 SI=1.0,PS
      CALL PLOT (Y, -0.44, 3)
      Y = Y + FCT
      CALL PLOT (Y, -0.44, 2)
   31 CALL PLOT (Y, -0.51, 2)
      CALL PLOT (Y, -0.37, 2)
C
C     LABEL THE SCALE.
      IF (PS .GE. 10.0) THEN
         CALL SYMBOL (CENTER - 0.53, -0.72, 0.14, '10 UNITS', 0.0, 8)
      ELSE IF (PS .GT. 1.0) THEN
         CALL NUMBER (CENTER - 0.46, -0.72, 0.14,     PS,     0.0,-1)
         CALL SYMBOL (CENTER - 0.32, -0.72, 0.14,  ' UNITS',  0.0, 6)
      ELSE
         CALL SYMBOL (CENTER - 0.39, -0.72, 0.14,  '1 UNIT',  0.0, 6)
      END IF
```

```
C
C     MOVE PEN TO THE NORTHERNMOST POINT OF EACH PLOT.
   40 DO 53 J=1,NS
      PN = SPP(J)(1:1)
      DO 41 K=1,NG
      IF (PN .EQ. GPT(K:K)) THEN
         XPN = GPX(K)
         YPN = GPY(K)
         CALL PLOT (YPN, XPN, 3)
         GO TO 50
      END IF
   41 CONTINUE
C
C     CONNECT THE PLOT'S PERIMETER POINTS.
   50 DO 52 I=2,NVL+1
      PI = SPP(J)(I:I)
      IF (PI .NE. PN) THEN
         DO 51 K=1,NG
         IF (PI .EQ. GPT(K:K)) THEN
            CALL PLOT (GPY(K), GPX(K), 2)
            GO TO 52
         END IF
   51    CONTINUE
         GO TO 53
      ELSE
         CALL PLOT (YPN, XPN, 2)
         GO TO 53
      END IF
   52 CONTINUE
   53 CONTINUE
C
C     PLOT THE TIMER POINTS.
      CALL NEWPEN (3)
      DO 60 K=1,NG
      X = GPX(K) - 0.08
      Y = GPY(K) - 0.04
   60 CALL SYMBOL (Y, X, 0.14, GPT(K:K), 0.0, 1)
C
C     PLOT THE SPREAD VECTORS.
      CALL NEWPEN (2)
      CALL VECTOR (GPT, GPX, GPY)
C
C     DETERMINE LENGTH OF GRAPH PAPER USED.
      BORDL = BORDR + 1.0
      RETURN
      END
```

```
      SUBROUTINE VECTOR (GPT, GPX, GPY)
C
C     PLOTS THE SPREAD VECTORS USING CALCOMP COMMANDS.
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XLIM,YLIM
C
      CHARACTER GPT*(*),  TRI(3)*1
      DIMENSION GPX(NGL), GPY(NGL)
C
C     DEGREES PER RADIAN.
      DATA RAD /57.2957795131/
C     ------------------------------------------------------------------
C
C     REWIND THE VECTOR FILE AND OPEN A SCRATCH FILE.
      REWIND (IVEC)
      OPEN   (JVEC, STATUS='SCRATCH')
      REWIND (JVEC)
C
C     INITIALIZE THREE LONGEST VECTORS.
      VMAX1 = 0.0
      VMAX2 = 0.0
      VMAX3 = 0.0
C
C     READ A VECTOR AND DETERMINE STARTING COORDINATES.
   10 READ (IVEC, '(3A, 3F9.2)', END=20) TRI, RATE, RCOS, RSIN
      X1 = 0.0
      Y1 = 0.0
      DO 12 I=1,3
      DO 11 K=1,NG
      IF (TRI(I) .EQ. GPT(K:K)) THEN
         X1 = X1 + GPX(K)
         Y1 = Y1 + GPY(K)
         GO TO 12
      END IF
   11 CONTINUE
      GO TO 10
   12 CONTINUE
      X1 = X1/3.0
      Y1 = Y1/3.0
C
C     DETERMINE PER MINUTE CHANGE IN VECTOR.
      DX = RCOS*FCT
      DY = RSIN*FCT
      DV = RATE*FCT
      WRITE (JVEC, '(5F9.2)') X1, Y1, DX, DY, DV
```

```
C
C     DETERMINE LENGTH OF THREE LONGEST VECTORS.
      IF (DV .GT. VMAX3) THEN
         IF (DV .GT. VMAX2) THEN
            VMAX3 = VMAX2
            IF (DV .GT. VMAX1) THEN
               VMAX2 = VMAX1
               VMAX1 = DV
            ELSE
               VMAX2 = DV
            END IF
         ELSE
            VMAX3 = DV
         END IF
      END IF
      GO TO 10
C
C     DETERMINE BEST TIME FRAME FOR DRAWING VECTOR.
   20 ENDFILE (JVEC)
      CALL SYMBOL (BORDL, -1.0, 0.14, 'VECTORS IN UNITS/', 0.0, 17)
      FRAME = BORDL + 2.38
      IF (VMAX3 .LE. 0.0) VMAX3 = VMAX1
      M = 1.5/VMAX3
C
C     USE TIME INTERVALS OF LESS THAN A MINUTE.
      IF (M .EQ. 0) THEN
         DS = INT(VMAX3/1.5) + 1
         IF (DS .GE. 5.0) DS = 6.0
         DSEC = 60.0/DS
         DMIN =  1.0/DS
         CALL NUMBER (FRAME,        -1.0, 0.14,    DSEC,    0.0,-1)
         CALL SYMBOL (FRAME + 0.28, -1.0, 0.14, ' SECONDS', 0.0, 8)
C
C     USE TIME INTERVALS OF ONE MINUTE.
      ELSE IF (M .EQ. 1) THEN
         DMIN = 1.0
         CALL SYMBOL (FRAME,        -1.0, 0.14,  'MINUTE',  0.0, 6)
C
C     USE TIME INTERVALS OF GREATER THAN A MINUTE.
      ELSE IF (M .LE. 9) THEN
         DMIN = AMIN0(M, 6)
         CALL NUMBER (FRAME,        -1.0, 0.14,    DMIN,    0.0,-1)
         CALL SYMBOL (FRAME + 0.14, -1.0, 0.14, ' MINUTES', 0.0, 8)
      ELSE IF (M .LE. 39) THEN
         DMIN = 10*(M/10)
         CALL NUMBER (FRAME,        -1.0, 0.14,    DMIN,    0.0,-1)
         CALL SYMBOL (FRAME + 0.28, -1.0, 0.14, ' MINUTES', 0.0, 8)
      ELSE
         DMIN = 60.0
         CALL SYMBOL (FRAME,        -1.0, 0.14,   'HOUR',   0.0, 4)
      END IF
```

```
C
C     LOCATE PLOTTER NORTH AND EAST BOUNDARIES.
      XBND = XAXIS + 1.5
      YBND = BORDL + YAXIS + 1.5
C
C     DETERMINE ENDING COORDINATES AND PLOT VECTOR.
      REWIND (JVEC)
   30 READ   (JVEC, '(5F9.2)', END=40) X1, Y1, DX, DY, DV
      X2 = X1 + DX*DMIN
      Y2 = Y1 + DY*DMIN
      HEAD = AMIN1(0.07, 0.67*DV*DMIN)
C
C     MAKE SURE VECTOR HEAD IS WITHIN BOUNDS OF PLOTTER.
      IF (X2 .LT. -1.3 .OR. X2 .GT. XBND .OR.
     +    Y2 .LT. -0.5 .OR. Y2 .GT. YBND) THEN
         CALL PLOT (Y1, X1, 3)
C
C        PLOT VECTOR SHAFT AND SYMBOL INDICATING SHORTENED VECTOR.
         IF (Y2 .NE. Y1) THEN
            SLOPE = (X2 - X1)/(Y2 - Y1)
            X2    = AMAX1(-1.3, AMIN1(X2,                    XBND))
            Y2    = AMAX1(-0.5, AMIN1(Y1 + (X2 - X1)/SLOPE, YBND))
            X2    = X1 + (Y2 - Y1)*SLOPE
            S     = SIGN(1.0/SQRT(SLOPE*SLOPE + 1.0), Y2 - Y1)
            S1    = 1.085*S
            S2    = 1.000*S
            S3    = 0.915*S
            ANGLE = RAD*ATAN(SLOPE) + 45.0
            CALL PLOT   (Y2 - S1, X2 - S1*SLOPE, 2)
            CALL SYMBOL (Y2 - S2, X2 - S2*SLOPE, 0.12, 8, ANGLE, -1)
            Y1    = Y2 - S3
            X1    = X2 - S3*SLOPE
C
C        SPECIAL CASE:  VECTOR POINTS DIRECTLY NORTH OR SOUTH.
         ELSE
            X2 = AMAX1(-1.3, AMIN1(X2, XBND))
            S  = SIGN(1.0, X2)
            CALL PLOT   (Y2, X2 - 1.085*S, 2)
            CALL SYMBOL (Y2, X2 - 1.000*S, 0.12, 8, -45.0, -1)
            X1 = X2 - 0.915*S
         END IF
      END IF
C
C     PLOT VECTOR.
      CALL AROWHD (Y1, X1, Y2, X2, HEAD, 0.5*HEAD, 2, 2)
      GO TO 30
C
C     ALL VECTORS READ AND PLOTTED.
   40 CLOSE (JVEC)
      RETURN
      END
```

```
      SUBROUTINE NOTE1
C
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C     ------------------------------------------------------------------
C
      WRITE (IOUT, '(/
     +'' NOTE:  THE INPUT FILE MAY HAVE INCLUDED''/
     +'' PLOTS THAT  OVERLAPPED  EACH OTHER.  IF''/
     +'' SO, BOTH  THE ''''SUM  OF ALL  PLOT AREAS''''''/
     +'' AND THE FOLLOWING STATISTICS, WHICH ARE''/
     +'' WEIGHTED BY AREA,  REFLECT ADDED EMPHA-''/
     +'' SIS IN THE OVERLAPPED AREAS.          '')')
      RETURN
      END



      SUBROUTINE NOTE2
C
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C     ------------------------------------------------------------------
C
      WRITE (IOUT, '(/
     +'' NOTE:  IF THE  INPUT FILE  INCLUDED ANY''/
     +'' PLOTS THAT  OVERLAPPED  EACH OTHER, THE''/
     +'' FOLLOWING STATISTICS, WHICH ARE WEIGHT-''/
     +'' ED BY AREA,  REFLECT ADDED  EMPHASIS IN''/
     +'' THE OVERLAPPED AREAS.                 '')')
      RETURN
      END



      SUBROUTINE NOTE3
C
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
C     ------------------------------------------------------------------
C
      WRITE (IOUT, '(/
     +'' NOTE:  A PORTION  OF  THE  ''''TOTAL AREA''''''/
     +'' MAY NOT BE  CONTAINED WITHIN  ANY PLOT.''/
     +'' IF SO, THIS PORTION  IS NOT INCLUDED IN''/
     +'' THE FOLLOWING STATISTICS.             '')')
      RETURN
      END
```

```
      BLOCK DATA
C
      COMMON /LIMIT/ NV, NVL,  NS, NSL,  NG, NGL
      COMMON /FILES/ INPT, IOUT, IVEC, JVEC, LINE, LINES
      COMMON /CNTRL/ PWT, GRAPH, AMIN
      COMMON /PLOTS/ NP,PWGT, PRSUM,PRSUM2, PDSUM,PDSUM2, PXSUM,PYSUM
      COMMON /MEANS/ RMEAN, DMEAN, XMEAN, YMEAN, RLOW, RMOD, DLOW, DMOD
      COMMON /GRPHC/ IBUF(257),ITYPE,XAXIS,YAXIS,BORDL,FCT,MP,XLIM,YLIM
C
      LOGICAL GRAPH
C
C     ASSOCIATE INPUT, OUTPUT, & SCRATCH FILE NAMES WITH UNIT NUMBERS.
      DATA INPT, IOUT, IVEC, JVEC /6, 7, 8, 9/
C
C     MAXIMUM LINES OF OUTPUT ALLOWED PER PAGE.
      DATA LINES /60/
C
C     BECAUSE OF THE ERROR INHERENT IN  FIELD MEASUREMENTS, THE PROGRAM
C     OMITS FROM CONSIDERATION TRIANGLES  HAVING AN ANGLE LESS THAN 0.2
C     RADIANS (ABOUT 11.46 DEGREES).
      DATA AMIN /0.2/
C
C     MAXIMUM VALUES  ALLOWED FOR THE  LOW AND THE  MODERATE CLASSES OF
C     THE COEFFICIENT OF VARIATION OF THE RATE, AND THE STANDARD DEVIA-
C     TION OF THE DIRECTION.
      DATA RLOW /0.2/, RMOD /0.5/, DLOW /10.0/, DMOD /20.0/
C
C     INITIALIZE GRAPHICS CAPABILITY.
      DATA GRAPH /.TRUE./
C
C     INITIALIZE CALCOMP  PLOTTER QUEUE (IGNORE IF  GRAPH SET .FALSE.).
C     AN 'ITYPE' OF 0 OR 5 SELECTS 15" PAPER; 1 OR 6 SELECTS 35" PAPER.
C     AN 'ITYPE' OF 0 OR 1 SELECTS STANDARD BALLPOINT PENS; 5 OR 6 DOES
C     THE SAME  EXCEPT  BLACK  LIQUID  INK SIZE  4 FOR  PEN #1.   OTHER
C     CHOICES FOR 'ITYPE' ARE AVAILABLE (SEE CALCOMP MANUAL).
      DATA ITYPE /0/
C
C     INITIALIZE (THE USER SHOULD NOT ALTER THE FOLLOWING VARIABLES).
      DATA NS, NG, NP, MP /4*0/,       BORDL /1.0/
      DATA PWGT, PRSUM, PRSUM2, PDSUM, PDSUM2, PXSUM, PYSUM /7*0.0/
      END
```

APPENDIX 2

SPREAD RATE PROGRAM VARIABLE LIST

COMMON BLOCK VARIABLES
(Listed in the order in which they appear in each COMMON Statement)

COMMON /LIMIT/

NV Number of points in current plot.

NVL The upper limit to the number of points allowed per plot (also refered to as NVLIM). This limit can be adjusted by altering the PARAMETER statement in subprogram QUEUE.

NS Number of plots in current run of program.

NSL The upper limit to the number of plots allowed (also referred to as NSLIM). This limit can be adjusted by altering the PARAMETER statement in subprogram QUEUE.

NG Number of timers in current run of program.

NGL The upper limit to the number of timers allowed (also referred to as NGLIM). This is a machine limitation equal to its total number of individual alphanumeric characters other than the '#' (reserved for separating plots on the input file). This limit can be adjusted by altering the PARAMETER statement in subprogram ORIGIN.

COMMON /FILES/

INPT Unit number of input file QDATA.

IOUT Unit number of output file QRATE.

IVEC Unit number of a scratch file used for storing each vector for subsequent graphing.

JVEC Unit number of a scratch file used for grouping vectors (if plots are disjoint) and scaling them to the appropriate size for graphics.

LINE Current line number on the current output page.

LINES Maximum number of lines of output allowed per page. Can be adjusted by the user in subprogram BLOCK DATA.

COMMON /CNTRL/

PWT Area of current plot (square units).

GRAPH Logical variable set .TRUE. by the user in subprogram BLOCK DATA if graphics are available and desired.

AMIN Minimum size for each angle that a triangle must possess to be allowed entry into the analysis (radians). Can be adjusted by the user in subprogram BLOCK DATA.

COMMON /TRIAN/

NT Number of triangles in current plot.
TWGT Sum of the areas of the NT triangles in the current plot.
TRSUM Sum of the rates of spread, weighted by each triangle's area, over the NT triangles in the current plot.
TRSUM2 Sum of squares of the rates of spread, weighted by each triangle's area, over the NT triangles in the current plot.
TDSUM Sum of the directions of spread, weighted by each triangle's area, over the NT triangles in the current plot.
TDSUM2 Sum of squares of the directions of spread, weighted by each triangle's area, over the NT triangles in the current plot.
TXSUM Sum of the x-axis components of the rate of spread vectors, weighted by each triangle's area, over the NT triangles in the current plot.
TYSUM Sum of the y-axis components of the rate of spread vectors, weighted by each triangle's area, over the NT triangles in the current plot.

COMMON /PLOTS/

NP Number of plots with at least one acceptable triangle.
PWGT Sum of the areas of the NP plots.
PRSUM Sum of the rates of spread, weighted by each plot's area, over the NP plots.
PRSUM2 Sum of squares of the rates of spread, weighted by each plot's area, over the NP plots.
PDSUM Sum of the directions of spread, weighted by each plot's area, over the NP plots.
PDSUM2 Sum of squares of the directions of spread, weighted by each plot's area, over the NP plots.
PXSUM Sum of the x-axis components of the rate of spread vectors, weighted by each plot's area, over the NP plots.
PYSUM Sum of the y-axis components of the rate of spread vectors, weighted by each plot's area, over the NP plots.

COMMON /MEANS/

RMEAN Mean of the rates of spread of the NT triangles in the current plot or of the NP plots in current run (units/minute).
DMEAN Mean of the directions of spread of the NT triangles in the current plot or of the NP plots in current run (degrees azimuth).
XMEAN Mean of the x-axis components of the rate of spread vectors of the NT triangles in the current plot or of the NP plots in current run (units/minute).
YMEAN Mean of the y-axis components of the rate of spread vectors of the NT triangles in the current plot or of the NP plots in current run (units/minute).
RLOW Maximum value of the low variability class of the coefficient of variation of the rate of spread.

RMOD Maximum value of the moderate variability class of the coefficient of variation of the rate of spread.

DLOW Maximum value of the low variability class of the standard deviation of the direction of spread.

DMOD Maximum value of the moderate variability class of the standard deviation of the direction of spread.

COMMON /GRPHC/

IBUF The name of a storage area required by the CALCOMP plotter for accumulating plotter commands and buffering output.

ITYPE The type of CALCOMP plotter queue--choices include type and size of pens and type and size of paper. Can be selected by the user in subprogram BLOCK DATA.

XAXIS Maximum length of x-axis (North-South line) available on the plotter based on width of paper selected by ITYPE (inches).

YAXIS Length of the y-axis (East-West line) on the plotter necessary to produce a drawing proportional with the XAXIS (inches).

BORDL The location of the left border of the current graphic from the plotter origin (inches).

FCT Scaling factor relating distance units to plotter inches.

MP In the case of disjoint plots, the number of points remaining disconnected from current plotter diagram (to be plotted as separate diagram(s) further to the right).

XLIM The maximum or minimum value of the x-coordinates of the points to be plotted, depending on what is needed at various stages of the process (referred to as XMAX or XMIN in subprograms where XLIM is strictly one or the other).

YLIM The maximum or minimum value of the y-coordinates of the points to be plotted, depending on what is needed at various stages of the process (referred to as YMAX or YMIN in subprograms where YLIM is strictly one or the other).

GLOBAL ARRAYS PASSED AS PARAMETERS
(Allows adjustable dimensions--Listed alphabetically)

GDIR(NGL) Passed as a parameter solely to maintain adjustable dimension (see DIR under FUNCTION AREA).

GPP Character*(NGL+1) array where the (at most) NG+1 perimeter points (beginning with northernmost point and proceeding clockwise around area back to starting point) of the current area being plotted are stored.

GPT Character*(NGL) array where the NG points of the current area being plotted are stored.

GPX(NGL) Array for storing all the x-coordinates of the NG points of the current area being plotted.

GPY(NGL) Array for storing all the y-coordinates of the NG points of the current area being plotted.

MPT(NSL) Array for storing the plot numbers of those plots that are disjoint from current (and previous) area being plotted.

NPP(NVL) Passed as a parameter solely to maintain adjustable dimension (see NPP under FUNCTION AREA).

NPP(NGL) Passed as a parameter solely to maintain adjustable dimension (see NPP under FUNCTION AREA).

SPP(NSL) Character*(NVL+1) array where the (at most) NV+1 perimeter points (beginning with northernmost point and proceeding clockwise around area back to starting point) of the NS plots are stored for subsequent graphics.

SPT(NSL) Character*(NVL) array where the NV plot points of each of the NS plots are stored for subsequent graphics.

SPX(NVL,NSL) Array for storing all the x-coordinates of the NV plot points of each of the NS plots for subsequent graphics.

SPY(NVL,NSL) Array for storing all the y-coordinates of the NV plot points of each of the NS plots for subsequent graphics.

TIME(NVL) The time fire reached each of the NV points in the current plot (minutes).

VDIR(NVL) Passed as a parameter solely to maintain adjustable dimension (see DIR under FUNCTION AREA).

VPP Character*(NVL+1) array where the (at most) NV+1 perimeter points (beginning with northernmost point and proceeding clockwise around area back to starting point) of the current plot are stored.

VPT Character*(NVL) array where the NV plot points of the current plot are stored.

VPX(NVL) Array for storing all the x-coordinates of the NV plot points of the current plot.

VPY(NVL) Array for storing all the y-coordinates of the NV plot points of the current plot.

LOCAL VARIABLES
(Listed alphabetically by subroutine)

SUBROUTINE QUEUE

COMP Compass direction of each point in current plot as viewed from the plot's marker point (input in degrees, immediately converted to radians).

DIST Distance of each point in current plot from the plot's marker point (units of the user's choice).

MIN Number of whole minutes on timer for current point.

MORE Logical variable indicating whether or not there are any more plots in the input file (true/false).

NPWGT Integer representation of PWGT (square units).

NPWT Integer representation of PWT (square units).

PT Alphanumeric character identifying each point in current plot.

RAD Degrees per radian.

SEC Number of seconds beyond MIN on timer for current point.

FUNCTION AREA

AB	Side of generic triangle ABX (units).
ABX	Each set of two consecutive perimeter points AB in conjunction with the northernmost point X of an area form a series of triangles labeled generically ABX. The sum of the areas of these triangles provides the total area figure.
AX	Side of generic triangle ABX (units).
BX	Side of generic triangle ABX (units).
DIR	An adjustable scratch array for storing compass directions of all points of an area relative to each successive perimeter point as the routine proceeds clockwise around the area.
MX	The index of each successive perimeter point.
N	Generic for the number of points in area (NV or NG).
NPP	An adjustable scratch array for storing the indexes of the perimeter points of an area beginning with the northernmost point and proceeding clockwise.
NX	The index of the northernmost perimeter point.
PP	Generic for the perimeter point array (VPP or GPP).
PT	Generic for the array of all points in the area (VPT or GPT).
PX	Generic for the x-coordinate array (VPX or GPX).
PY	Generic for the y-coordinate array (VPY or GPY).
RAD	Degrees per radian.
S	Intermediate variable used in the area of ABX calculation.

SUBROUTINE TRIGON

A	Vertex of current triangle that the fire reached first (radians).
AB	Length of current triangle's side between A and B (units).
AC	Length of current triangle's side between A and C (units).
ACSINA	Intermediate variable--side AC multiplied by sin(A).
B	Vertex of current triangle that the fire reached second (radians).
BAN	Compass direction of B as viewed from A (degrees azimuth).
BC	Length of current triangle's side between B and C (units).
C	Vertex of current triangle that the fire reached last (radians).
CAN	Compass direction of C as viewed from A (degrees azimuth).
RAD	Degrees per radian.
RATE	Rate of spread across current triangle (units/minute).
RCOS	The x-axis component of the rate of spread vector across the current triangle (units/minute).
RSIN	The y-axis component of the rate of spread vector across the current triangle (units/minute).
THETA	Angle of spread--first used relative to the current triangle, later added to or subtracted from BAN making it relative to north (degrees).
TIMJI	Intermediate variable--time at B minus time at A (minutes).
TIMKI	Intermediate variable--time at C minus time at A (minutes).

TRI	Three letter designation for current triangle listing its vertices in chronological order.
TWT	The area of the current triangle (square units).

SUBROUTINE STATS

COVAR	Coefficient of variation of the rate of spread.
DSTD	Standard deviation of the direction of spread.
DSUM	Generic for the sum of the directions of spread (TDSUM or PDSUM).
DSUM2	Generic for the sum of squares of the directions of spread (TDSUM2 or PDSUM2).
DVAR	Character variable identifying variability class of the direction of spread (low/moderate/high).
FN	Floating point generic for the number of areas (NT or NP).
IDMEAN	Integer representation of DMEAN (degrees azimuth).
IDSTD	Integer representation of DSTD.
IVDIR	Integer representation of VDIR (degrees azimuth).
N	Generic number of areas in analysis (NT or NP).
RAD	Degrees per radian.
RSTD	Standard deviation of the rate of spread.
RSUM	Generic for the sum of the rates of spread (TRSUM or PRSUM).
RSUM2	Generic for sum of squares of the rates of spread (TRSUM2 or PRSUM2).
RVAR	Character variable identifying variability class of the rate of spread (low/moderate/high).
VADIV	Rate at which the heads of the vector average and a vector representing the arithmetic average are spreading (units/minute).
VDIR	Vector direction of spread (degrees azimuth).
VRATE	Vector rate of spread (units/minute).
WGT	Generic for the sum of the areas involved (TWGT or PWGT).
XSUM	Generic for the sum of the x-axis components of the rate of spread vectors (TXSUM or PXSUM).
YSUM	Generic for the sum of the y-axis components of the rate of spread vectors (TYSUM or PYSUM).

FUNCTION LINED

L	Maximum number of output lines needed to process current plot.
MLINE	Array containing maximum output line counts for various plot configurations dependent on number of possible triangles that may be processed.

SUBROUTINE ORIGIN

AREAS The area of the current polygon under consideration.
IDIGIT The number of digits in the area figure. Used in formatting.
MPS The number of points still to be considered.
NAREA Integer representation of TAREA (square units).
NPWGT Integer representation of PWGT (square units).
TAREA Total convex polygonal area covering all individual plots (square units).
XMAX The maximum value in the GPX array.
YMAX The maximum value in the GPY array.

SUBROUTINE ORIENT

MISS Logical set .FALSE. when at least one point of current plot matches a point already stored in the GPT array.
X The difference between the x-coordinates of a point in the current plot and the identical point already stored in the GPT array.
Y The difference between the y-coordinates of a point in the current plot and the identical point already stored in the GPT array.

SUBROUTINE GRAFIC

BORDR The location of the right border of the current graphic from the plotter origin (inches).
CENTER The width of paper from the plotter origin up to the center of the scale (inches).
PI A perimeter point of the current individual plot.
PN The northernmost point of the current individual plot.
PS The number of increments in the scale.
SCALE The width of paper from the plotter origin up to the right side of the scale (inches).
X The x-coordinate of where to set the pen down in order to graph each timer's alphanumeric (inches).
XPN The x-coordinate of PN (inches).
Y The y-coordinate of where to set the pen down in order to graph each timer's alphanumeric (inches).
YPN The y-coordinate of PN (inches).

ANGLE	Amount of rotation given to symbol indicating truncated vector.
DMIN	The vectors are normally drawn in units/DMIN minutes (see DSEC).
DS	The number of divisions of a minute that the vectors are drawn in if units/minute results in too long a vector.
DSEC	If units/DMIN minutes results in vectors that are too long, then they are drawn in units/DSEC seconds.
DV	Plotter inches/minute change in vector length.
DX	Plotter inches/minute change in the x-axis component of the vector.
DY	Plotter inches/minute change in the y-axis component of the vector.
FRAME	The width of paper from the plotter origin up to the right side of the legend 'VECTORS IN UNITS/'.
HEAD	The length of the arrowhead on the spread vector.
M	Factor used to scale third longest vector to a size less than an inch and a half.
RAD	Degrees per radian.
RATE	Units/minute change in vector length.
RCOS	Units/minute change in the x-axis component of the vector.
RSIN	Units/minute change in the y-axis component of the vector.
S	Intermediate variable used in locating truncated vector symbol.
SLOPE	The slope of the vector.
S1	Intermediate variable (see S).
S2	Intermediate variable (see S).
S3	Intermediate variable (see S).
TRI(3)	Character array containing the 3 points in current triangle.
VMAX1	Length of longest vector (inches).
VMAX2	Length of second longest vector (inches).
VMAX3	Length of third longest vector (inches).
XBND	The location of plotter boundary in the North direction (inches).
X1	The x-coordinate of the tail of the vector (inches).
X2	The x-coordinate of the head of the vector (inches).
YBND	The location of plotter boundary in the East direction (inches).
Y1	The y-coordinate of the tail of the vector (inches).
Y2	The y-coordinate of the head of the vector (inches).

APPENDIX 3

FILE QDATA

Input File of the Example

```
A 57 21  14.14  45
B 54 41
D 41 14  14.14 225
E 33 20  14.14 135
#
A 57 21  14.14 315
C 43 05
E 33 20  14.14 225
F 28 12  14.14 135
#
D 41 14  14.14 315
E 33 20  14.14  45
G 26 37
I 14 29  14.14 225
J 14 32  14.14 135
#
E 33 20  14.14 315
F 28 12  14.14  45
H 22 45
J 14 32  14.14 225
K 16 13  14.14 135
#
I 14 29  14.14 315
J 14 32  14.14  45
L 12 33
N 18 58  14.14 135
#
J 14 32  14.14 315
K 16 13  14.14  45
M 17 22
N 18 58  14.14 225
O 20 20  14.14 135
#
Z  0 00
P  3 58   5.00  85
S  9 16   5.00  40
V 19 04   5.00 355
#
P  3 58   5.00  85
Q 10 29  10.00  85
S  9 16   5.00  40
T 16 55  10.00  40
#
Q 10 29  10.00  85
R 10 49  15.00  85
T 16 55  10.00  40
U 19 31  15.00  40
#
```

Input File Continued

```
S  9 16   5.00  40
T 16 55  10.00  40
V 19 04   5.00 355
W 33 57  10.00 355
#
T 16 55  10.00  40
U 19 31  15.00  40
W 33 57  10.00 355
X 41 30  15.00 355
#
Z  0 00
N 18 58  40.16 109
P  3 58   5.00  85
Q 10 29  10.00  85
#
L 12 33  28.16  96
N 18 58  40.16 109
Q 10 29  10.00  85
R 10 49  15.00  85
#
I 14 29  19.31  69
L 12 33  28.16  96
R 10 49  15.00  85
U 19 31  15.00  40
#
D 41 14  30.45  34
I 14 29  19.31  69
U 19 31  15.00  40
X 41 30  15.00 355
#
G 26 37  14.14  45
I 14 29
L 12 33  14.14 135
#
L 12 33  14.14 315
M 17 22  14.14  45
N 18 58
#
H 22 45  14.14 315
K 16 13
M 17 22  14.14 225
#
G 26 37  14.14 315
H 22 45  14.14  45
J 14 32
L 12 33  14.14 225
M 17 22  14.14 135
```

APPENDIX 4

FILE QRATE
Output File of the Example

USDA FOREST SERVICE SPREAD RATE PROGRAM

RATES IN UNITS/MINUTE
DIRECTIONS IN DEGREES AZIMUTH

STATISTICS FOR PLOT #1--AEDBA
AREA: 200 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
EBA	.7	322
EDA	.8	342
EDB	.6	347
SUMMARY TABLE		
VECTOR AVERAGE	.7	338
V/A DIVERGENCE	.0	
ARITHMETIC MEAN	.7	338
STD. DEV.	.1	12
VARIANT	LOW	MOD.

STATISTICS FOR PLOT #2--ACFEA
AREA: 200 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
ECA	.8	349
FEA	.8	348
FEC	.8	348
SUMMARY TABLE		
VECTOR AVERAGE	.8	348
V/A DIVERGENCE	.0	
ARITHMETIC MEAN	.8	348
STD. DEV.	.0	1
VARIANT	LOW	LOW

STATISTICS FOR PLOT #3--EJIDE
AREA: 400 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
GED	.9	340
IED	.7	344
JED	1.0	337
IGD	.7	355
IJD	.7	0
JGE	1.0	344
IJE	1.1	0
IJG	.8	0
SUMMARY TABLE		
VECTOR AVERAGE	.9	350
V/A DIVERGENCE	.0	
ARITHMETIC MEAN	.9	350
STD. DEV.	.1	10
VARIANT	LOW	MOD.

STATISTICS FOR PLOT #4--FKJEF
AREA: 400 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
HFE	1.2	342
JFE	1.0	345
KFE	1.5	337
JHE	1.1	353
JKE	1.1	5
KHF	1.7	355
JKF	1.7	8
JKH	1.3	7
SUMMARY TABLE		
VECTOR AVERAGE	1.3	354
V/A DIVERGENCE	.0	
ARITHMETIC MEAN	1.3	354
STD. DEV.	.3	13
VARIANT	MOD.	MOD.

STATISTICS FOR PLOT #5--JNIJ
AREA: 200 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	LIJ	5.1	1
	IJN	4.5	179
	LJN	2.1	118
SUMMARY TABLE			
VECTOR AVERAGE		1.3	157
V/A DIVERGENCE		3.1	
ARITHMETIC MEAN		4.1	119
STD. DEV.		1.4	89
VARIANT		MOD.	HIGH

STATISTICS FOR PLOT #6--KONJK
AREA: 400 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	JKM	4.6	157
	JKN	4.2	159
	JKO	4.5	158
	JMN	4.3	164
	JNO	4.3	163
	KMO	4.4	156
	KNO	4.6	162
	MNO	4.2	163
SUMMARY TABLE			
VECTOR AVERAGE		4.4	160
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		4.4	160
STD. DEV.		.2	3
VARIANT		LOW	LOW

STATISTICS FOR PLOT #7--VSPZV
AREA: 18 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	ZPS	.5	18
	ZPV	.3	7
	ZSV	.3	338
	PSV	.4	274
SUMMARY TABLE			
VECTOR AVERAGE		.3	354
V/A DIVERGENCE		.1	
ARITHMETIC MEAN		.3	349
STD. DEV.		.1	40
VARIANT		MOD.	HIGH

STATISTICS FOR PLOT #8--TQPST
AREA: 27 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	PSQ	.6	4
	PQT	.5	37
	PST	.6	11
	SQT	.6	30
SUMMARY TABLE			
VECTOR AVERAGE		.6	24
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		.6	25
STD. DEV.		.1	15
VARIANT		LOW	MOD.

STATISTICS FOR PLOT #9--URQTU
AREA: 44 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	QRT	1.1	359
	QRU	1.2	359
	QTU	1.2	347
	RTU	1.3	351
SUMMARY TABLE			
VECTOR AVERAGE		1.2	354
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		1.2	354
STD. DEV.		.1	6
VARIANT		LOW	LOW

STATISTICS FOR PLOT #10--WTSVW
AREA: 27 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	STV	.4	346
	STW	.3	337
	SVW	.3	328
	TVW	.3	333
SUMMARY TABLE			
VECTOR AVERAGE		.3	336
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		.3	336
STD. DEV.		.0	6
VARIANT		LOW	LOW

STATISTICS FOR PLOT #11--XUTWX
AREA: 44 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	TUW	.4	323
	TUX	.4	323
	TWX	.4	305
	UWX	.5	311
SUMMARY TABLE			
VECTOR AVERAGE		.4	316
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		.4	316
STD. DEV.		.0	9
VARIANT		LOW	LOW

STATISTICS FOR PLOT #12--QNZQ
AREA: 82 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		

THIS PLOT HAS INSUFFICIENT DATA. IT IS NOT INCLUDED IN THE OVERALL STATISTICS.

STATISTICS FOR PLOT #13--RLNQR
AREA: 86 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	QLN	1.5	182
	RLN	1.3	188
SUMMARY TABLE			
VECTOR AVERAGE		1.4	184
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		1.5	184
STD. DEV.		.1	4
VARIANT		LOW	LOW

STATISTICS FOR PLOT #14--UILRU
AREA: 74 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	RLI	1.7	31
	RIU	1.3	346
	RLU	1.0	26
SUMMARY TABLE			
VECTOR AVERAGE		1.3	19
V/A DIVERGENCE		.1	
ARITHMETIC MEAN		1.3	18
STD. DEV.		.4	22
VARIANT		MOD.	HIGH

STATISTICS FOR PLOT #15--DIXD
AREA: 173 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	IUD	.7	8
	IDX	.6	330
	UDX	.5	338
SUMMARY TABLE			
VECTOR AVERAGE		.6	341
V/A DIVERGENCE		.0	
ARITHMETIC MEAN		.6	341
STD. DEV.		.1	18
VARIANT		LOW	MOD.

STATISTICS FOR PLOT #16--GLIG
AREA: 100 SQUARE UNITS

		RATE	DIRECTION
INDIVIDUAL TRIANGLES			
	LIG	1.2	36

STATISTICS FOR PLOT #17--MNLM
AREA: 100 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
LMN	2.1	149

STATISTICS FOR PLOT #18--HKMH
AREA: 100 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
KMH	2.1	305

STATISTICS FOR PLOT #19--HMLGH
AREA: 400 SQUARE UNITS

	RATE	DIRECTION
INDIVIDUAL TRIANGLES		
JHG	1.0	349
LHG	1.4	345
MHG	3.0	324
LJG	1.2	324
LMG	1.3	19
JMH	1.6	64
LMH	2.8	42
LJM	4.1	100
SUMMARY TABLE		
VECTOR AVERAGE	1.4	17
V/A DIVERGENCE	.7	
ARITHMETIC MEAN	2.1	11
STD. DEV.	1.0	45
VARIANT	MOD.	HIGH

OVERALL STATISTICS
TOTAL AREA: 2468 SQUARE UNITS--ACFONZWXA
SUM OF ALL
PLOT AREAS: 2991 SQUARE UNITS

NOTE: THE INPUT FILE INCLUDED PLOTS THAT OVERLAPPED EACH OTHER. BOTH THE 'SUM OF ALL PLOT AREAS' AND THE FOLLOWING STATISTICS, WHICH ARE WEIGHTED BY AREA, REFLECT ADDED EMPHASIS IN THE OVERLAPPED AREAS.

NOTE: A PORTION OF THE 'TOTAL AREA' MAY NOT BE CONTAINED WITHIN ANY PLOT. IF SO, THIS PORTION IS NOT INCLUDED IN THE FOLLOWING STATISTICS.

	RATE	DIRECTION
SUMMARY TABLE		
VECTOR AVERAGE	.2	94
V/A DIVERGENCE	1.8	
ARITHMETIC MEAN	1.9	35
STD. DEV.	1.4	74
VARIANT	HIGH	HIGH

APPENDIX 5

CALCOMP PLOTTER COMMANDS

The program makes 49 calls to the CALCOMP plotter using the seven commands listed below. All calls originate from three subprograms: CALCOM, GRAFIC, and VECTOR.

Note that the coordinate system used by the program is based on the compass--North is on the positive x-axis and East is on the positive y-axis. Because the CALCOMP plotter is based on the standard Cartesian coordinate system, the two axes are reversed. In other words, if a plotter call normally expects arguments (X, Y), the user should use (Y, X) instead.

CALL PLOTS (IBUF, 257, ITYPE)

The first call to the plotter is made from subprogram CALCOM. Its purpose is to set aside an area of computer memory to accumulate plotter commands and to buffer output. The first argument, IBUF, is the name of the buffer; the second argument, 257, is its size. ITYPE, the third argument, selects the paper and pens (see BLOCK DATA). Note that IBUF and ITYPE are both carried by COMMON /GRPHC/.

CALL PLIMIT (BORDR + 1.0)

The single call to PLIMIT is made near the beginning of subprogram GRAFIC. Its purpose is to indicate the length of paper required. CALL PLOTS fixes the length of the x-axis (argument ITYPE determines, among other things, the width of the paper). This, in turn, determines BORDR--the total length of y-axis necessary for a proportional drawing. The argument, BORDR + 1.0, includes an extra inch for a border.

NEWPEN (n)

The call to NEWPEN is made five times--twice from subprogram CALCOM and three times from subprogram GRAFIC. The call enables the program to select a different pen from among the choices available where n is the number of the choice.

CALL PLOT (Y, X, n)

The call to PLOT is made 13 times--9 calls within subprogram GRAFIC, 3 calls from subprogram VECTOR, and 1 final call from subprogram CALCOM. The first two arguments (Y, X) are the coordinates of the position to which the pen is to be moved. When the third argument, n, is equal to 2, the pen is down during the move. If n = 3, the pen is up during the move and no line is drawn. In the final call from subprogram CALCOM, n is equal to 999, indicating all plotting calls have been made and the plot file can be closed.

CALL SYMBOL (Y, X, height, text, angle, n)

The call to SYMBOL is made 24 times--11 calls from subprogram CALCOM plotting the North directional symbol, 5 calls from subprogram GRAFIC plotting the scale and each of the timer points, and 8 more calls from subprogram VECTOR noting the time frame the vectors use (e.g., UNITS/MINUTE, UNITS/30 SECONDS, etc.) and plotting the truncated vector symbol (should a vector extend beyond the plotter limits).

Text can be entered on the plotter in a number of ways, three of which are used by the program. The first method is used in subprograms CALCOM and VECTOR and is identified by argument n = -1. The fourth argument, for this method, is an index into a special CALCOM symbol character set--text = 11 for an asterisk, text = 13 for a vertical line, and text = 8 for the character 'Z'. The third argument, height, is the vertical height (inches) for the symbol, and the fifth argument, angle, is the amount of counterclockwise rotation required (degrees).

In subprogram CALCOM, the asterisk is rotated 45° and topped off with the unrotated vertical bar pointing to North. In subprogram VECTOR, if a vector would extend beyond the limits of the plotter, a 'Z' is embedded on its shaft to indicate shortening. The (Y, X) coordinates, for this method, locate the center of the symbol.

In both of the other two methods that the program uses for plotting text, the (Y, X) coordinates locate the lower left-hand corner of the first character to be produced. The last argument n for both methods refers to the number of characters in the text. Arguments height and angle are as before (the angles are all 0.0 meaning no rotation). The two methods differ in the way the fourth argument is presented. In one case the argument is a variable name, GPT(K:K), and the text plotted is the content of that variable--the alphanumeric identifier of a timer. All other calls to SYMBOL use the argument text as a literal expression, signified by embedding the text within single quotes.

CALL NUMBER (Y, X, height, variable, angle, -1)

The four calls to NUMBER (one from subprogram GRAFIC and three from subprogram VECTOR) all use the same form of the command. The (Y, X) coordinates locate the lower left-hand corner of the first digit of the number. The arguments height and angle are as in SYMBOL. The fourth argument is the name of the variable that contains the number to be plotted. The last argument, -1, indicates that only the integer portion (after rounding) is to be plotted.

CALL AROWHD (Y1, X1, Y2, X2, HEAD, 0.5*HEAD, 2, 2)

The call to AROWHD appears only once (subprogram VECTOR) and plots each vector. The coordinates (Y1, X1) locate the start (tail) and (Y2, X2) locate the end (tip of the arrowhead) of the vector to be plotted. The arguments HEAD and 0.5*HEAD are the length and width, respectively, of the arrowhead. The seventh argument, 2, indicates that the pen is to be down for the shaft of the arrow (i.e., the line segment from (Y1, X1) to (Y2, X2) is to be drawn). The last argument, also a 2, selects the second type of arrowhead from a list of available styles.

Eenigenburg, James E.
1987. Computer program for calculating and plotting fire direction and rate of spread. Gen. Tech. Rep. NC-117. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 46 p.

Presents an analytical procedure that uses a FORTRAN 77 program to estimate fire direction and rate of spread. The program also calculates the variability of these parameters, both for subsections of the fire and for the fire as a whole. An option in the program allows users with a CALCOMP plotter to obtain a map of the fire with spread vectors.

KEY WORDS: FORTRAN program, CALCOMP plotter, vector, prescribed burn, wildland fire.

United States Department of Agriculture

Forest Service

North Central Forest Experiment Station

General Technical Report **NC-118**

Minnesota's Forest Statistics, 1987: An Inventory Update

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FOREWORD

Forest Inventory and Analysis (FIA) is a continuing endeavor as mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974, which was preceded by the McSweeney-McNary Forest Research Act of 1928. The objective of FIA is to periodically inventory the Nation's forest land to determine its extent, condition, and volume of timber, growth, and depletions. Up-to-date resource information is essential for framing intelligent forest policies and programs. USDA Forest Service regional experiment stations are responsible for conducting these inventories and publishing summary reports for individual States. The North Central Forest Experiment Station is responsible for Forest Inventory and Analysis work in Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, South Dakota, and Wisconsin.

We were aided in making area estimates by the Minnesota Department of Natural Resources, Minnesota forest industry, and Region 9 of the Forest Service.

CONTENTS

MINNESOTA'S FOREST STATISTICS, 1987: AN INVENTORY UPDATE

Jerold T. Hahn, *Principal Mensurationist, and* **W. Brad Smith,** *Research Forester*

UPDATE HIGHLIGHTS

Timberland

- Timberland area declined from 13.7 million acres in 1977 to 13.5 million acres in 1987, a loss of less than 1 percent.
- Aspen is still the dominant forest type with 5.3 million acres or 39 percent of Minnesota's 1987 timberland area.
- The area of maple-birch forest type climbed 1.2 percent to 1.3 million acres as Minnesota's second-growth forests continue to mature.
- Red pine is still the most popular plantation species as shown by the 70,000-acre gain in the red pine forest type since 1977. This estimate is based on information received from Minnesota Department of Natural Resources and forest industry experts.

Timber Volume

- Growing-stock volume in 1987 was 13.7 billion cubic feet, 14 percent higher than the 12.0 billion cubic feet reported in 1977. Average growing-stock volume per acre in 1987 was 1,013 cubic feet, compared with 881 cubic feet in 1977.
- Sawtimber volume totaled 30.9 billion board feet in 1987, up 30 percent from the 1977 figure adjusted to conform to changed volume equations.

Net Growth

- Annual net growth increased from 26 cubic feet per acre per year in 1976 to 36 cubic feet in 1986. The 1976 figure was adjusted to conform to changed volume equations.
- Mortality declined from 0.8 percent of inventory in 1976 to 0.6 percent in 1986. Much of the decline is attributed to increased management activity reflected by the update.
- The growth processor used in this study does not accommodate catastrophic mortality. Therefore the estimate of balsam fir volume should be 60 to 70 million cubic feet lower because of loss from spruce budworm attacks primarily in St. Louis, Lake, and Cook Counties in the Aspen-Birch Unit. This would represent a reduction of about 10 percent in the reported balsam fir volume in the Unit. The impact on forest area would be a shift of acres from the older age classes balsam fir (50 to 70 years) to the youngest age class.
- Additional loss may have also occurred in elm because of the increase in dutch elm disease in the State. As much as 10 to 15 percent of the reported volume may be affected.

Removals

- Annual growing-stock removals climbed sharply from 194 million cubic feet in 1976 to 251 million cubic feet in 1986. Major industrial expansion in the waferboard and pulp industry in northern Minnesota is primarily responsible for the increase.

Biomass

- Tree biomass totaled 797 million green tons in 1987. Of this volume, 73 percent was in growing-stock trees, 14 percent was in cull trees, and 13 percent was in trees less than 5 inches d.b.h.
- The average green weight per cubic foot (including bark) for softwood species was 45 pounds; the average for hardwoods was 53 pounds.

BACKGROUND

Current facts about the Nation's forest resources such as area, timber volume, biomass, and prospective supply and demand are essential for forming sound management practices and policies. The Forest and Rangeland Renewable Resources Planning Act of 1974

(RPA) requires the Forest Service to make and keep current a comprehensive inventory and analysis of renewable forest and rangeland resources.

The most recent field inventory data available for Minnesota are dated 1977; however, tree growth models developed at the North Central Forest Experiment Station have made it possible for the Forest Inventory and Analysis (FIA) work unit to update inventory data to estimate the current resource. The purpose of this report is to present updated statistics for Minnesota that will be used for the 1990 RPA assessment. The tables provide data by Forest Survey Unit (fig. 1) and represent the timberland base as of January 1, 1987.

The term "update", as it is used here, is an estimate of current forest statistics derived by modeling the dynamic change in a forest from a known time in the past. The major components of this change are land change, growth, mortality, regeneration, and removals.

METHODOLOGY

Land Base Change

The basic sample design used by FIA in the North Central Region is a two-phase sample consisting of (1) a photo sample to estimate forest-nonforest area and

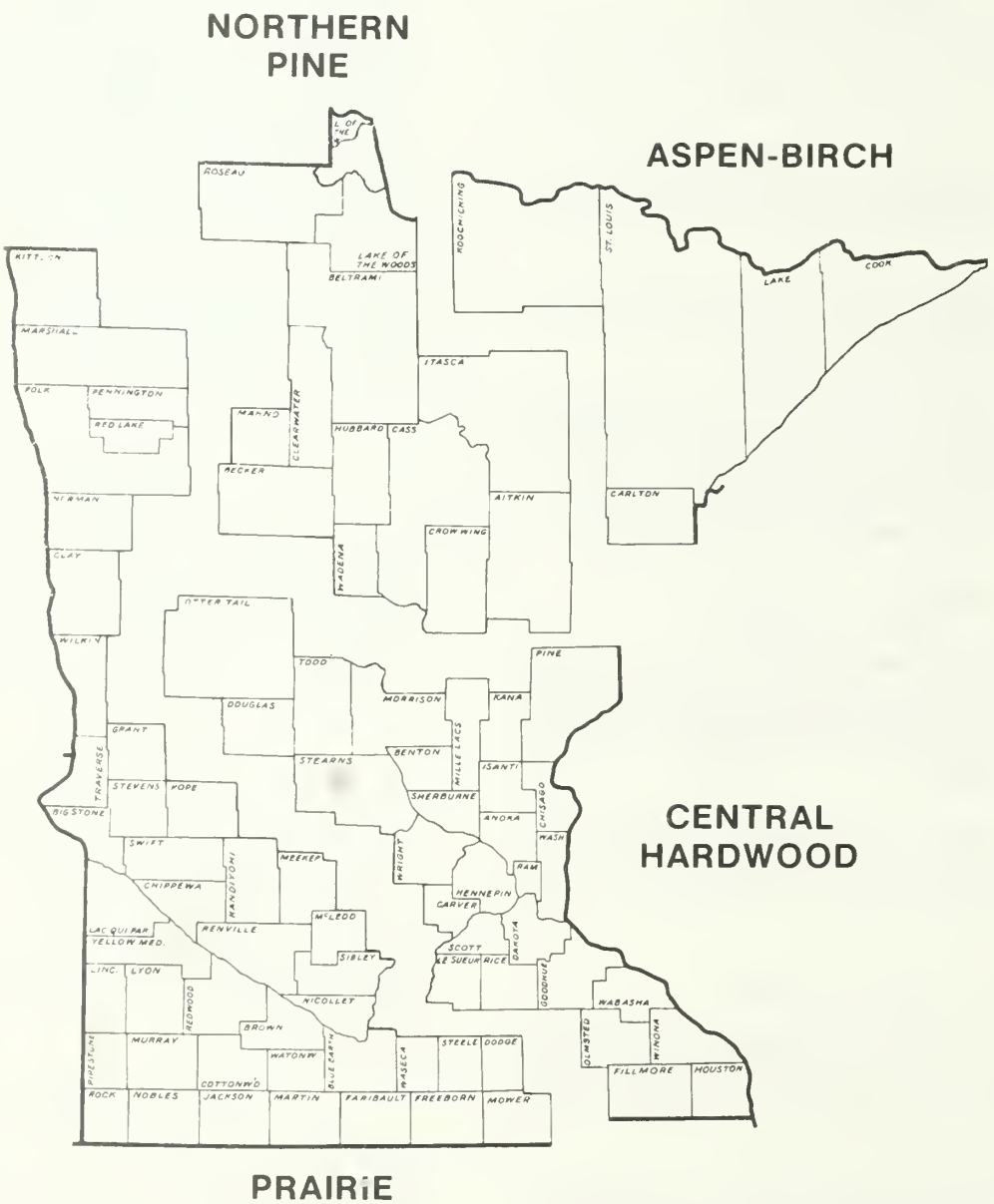

Figure 1.—*Minnesota's four Forest Survey Units.*

(2) a ground phase, which is a subsample of the photo sample, to provide information about the volume and condition of the forest.

New photo work for an update of the entire region would be too costly and time consuming with current technology. However, we've found that for update periods of 10 years or less, area change at the State level can be estimated using trend analysis and gathering information from local resource managers. These data then provide the first-phase area factors to be applied to the updated plots.

We assumed the timberland area for public and industry ownerships was stable during the update period. For all other ownerships, a modest annual decline of about 0.1 percent was assumed, which reflects the resource managers' view that urbanization and agricultural expansion have not seriously eroded the timberland base of the region.

The timberland area figures presented here represent the most recent data available at the time the update was processed. The reader is cautioned to contact the appropriate public agency to verify or update area figures for any analysis that may be sensitive to local changes in the timberland base, such as recently designated reserved or deferred forest lands. Area and volume figures would have to be adjusted accordingly for any ownerships affected by significant changes in the timberland base.

Public agencies are able to provide detailed information about management plans that outline the policies and programs designed to ensure a viable forest resource into the future. Additional information is available about non-industrial private owners and their objectives in the North Central Station report, "The Private Forest Landowners of Minnesota" (Carpenter *et al.* 1985).

Growth and Mortality

(We used the Stand and Tree Evaluation and Modeling System (STEMS) (Belcher 1981) to update to the year 1987 8,547 forest inventory plots established during the 1977 field survey.) STEMS is a distance-independent, individual tree growth model designed to simulate tree growth and mortality for a diverse range of forest conditions.

Growth and mortality functions were calibrated and validated with data from throughout the Lake States (Buchman 1983, Holdaway and Brand 1983, 1985). Test projections over a range of forest conditions produced reliable results when compared with remeasurement data from the Lake States. Adjustment factors derived from recent remeasurement data in the Lake States were used to fine tune the model and improve precision (Holdaway 1985).

Regeneration

Although STEMS regeneration routines for the Lake States had not been fully developed at the time of the update, the outcome was not significantly affected. Most trees that became established on harvested land or in seedling stands at the beginning of the update would not have grown to merchantable size by the end of the 9-year period.

Removals

Removals data were derived by trend analysis using periodic pulpwood (Blyth and Smith 1985), saw log (Blyth *et al.* 1981), and veneer (Blyth and Smith 1984) reports and base year data for all removals provided in the 1977 Minnesota report (Jakes 1980). Removals attributed to loss of timberland were made by adjusting plot expansion factors to arrive at a specified set of current area figures by forest type. Estimates of timber removals in the Lake States may be reviewed in more detail in a recent article, "Tracking Timber Demand in the Lake States" (Smith and Blyth 1986).

The Lake States version of STEMS was modified to simulate actual removals. Computerized management guides (Brand 1981) were used to select a subset of inventory plots that were eligible for silvicultural treatment during the update period. These guides were used in lieu of detailed information on Minnesota management strategies. A special removals algorithm scanned each selected plot to determine if it would be cut. The volume from cut plots was accumulated until the estimated volume of growing-stock removals by species was reached. Volume estimates were produced using volume equations developed for the Lake States (Hahn 1984, Smith 1985).

All area and volume figures for the update were reviewed by personnel from the Minnesota Department of Natural Resources, the National Forest System, industry resource managers, and other private individuals to assure reasonableness and consistency. A more detailed description of the methodology will be presented later in a publication on inventory updating procedures in the North Central Region.

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APPENDIX

METRIC EQUIVALENT OF UNITS USED IN THIS REPORT

1 acre = 4,046.86 square meters or 0.405 hectare.

1,000 acres = 405 hectares.

1 cubic foot = 0.0283 cubic meter.

1 foot = 30.48 centimeters or 0.3048 meter.

1 inch = 25.4 millimeters, 2.54 centimeters, or 0.0254 meter.

TREE SPECIES GROUPS IN MINNESOTA[1]

SOFTWOODS
- Eastern white pine ..... *Pinus strobus*
- Red pine ..... *Pinus resinosa*
- Jack pine ..... *Pinus banksiana*
- White spruce ..... *Picea glauca*
- Black spruce ..... *Picea mariana*
- Balsam fir ..... *Abies balsamea*
- Tamarack ..... *Larix laricina*
- Northern white-cedar ..... *Thuja occidentalis*
- Other softwoods
  - Eastern redcedar ..... *Juniperus virginiana*
  - Scotch pine ..... *Pinus sylvestris*

HARDWOODS
- White oak
  - White oak ..... *Quercus alba*
  - Swamp white oak ..... *Quercus bicolor*
  - Bur oak ..... *Quercus macrocarpa*
- Select red oak
  - Northern red oak ..... *Quercus rubra*
- Other red oak
  - Northern pin oak ..... *Quercus ellipsoidalis*
  - Black oak ..... *Quercus velutina*
- Hickory
  - Bitternut hickory ..... *Carya cordiformis*
  - Shagbark hickory ..... *Carya ovata*
- Hard maple
  - Sugar maple ..... *Acer saccharum*
  - Black maple ..... *Acer nigrum*
- Soft maple
  - Red maple ..... *Acer rubrum*
  - Silver maple ..... *Acer saccharinum*
- Ash
  - White ash ..... *Fraxinus americana*
  - Black ash ..... *Fraxinus nigra*
  - Green ash ..... *Fraxinus pennsylvanica*
- Balsam poplar ..... *Populus balsamifera*
- Eastern cottonwood ..... *Populus deltoides*
- Bigtooth aspen ..... *Populus grandidentata*
- Quaking aspen ..... *Populus tremuloides*
- Basswood ..... *Tilia americana*
- Black walnut ..... *Juglans nigra*
- Black cherry ..... *Prunus serotina*
- Butternut ..... *Juglans cinerea*
- Elm
  - American elm ..... *Ulmus americana*
  - Slippery elm ..... *Ulmus rubra*
  - Rock elm ..... *Ulmus thomasii*
- Paper birch ..... *Betula papyrifera*
- Other hardwoods
  - Boxelder ..... *Acer negundo*
  - River birch ..... *Betula nigra*
  - Black willow ..... *Salix nigra*
  - Hackberry ..... *Celtis occidentalis*
  - Kentucky coffeetree ..... *Gymnocladus dioicus*

[1] *The common and scientific names are based on: Little, Elbert L., Jr. 1976. Checklist of United States trees (native and naturalized). Agric. Handb. 541. Washington, DC: U.S. Department of Agriculture, Forest Service. 375 p.*

DEFINITIONS

Acceptable trees.—Growing-stock trees of commercial species that meet specified standards of size and quality.

Basal area.—The area in square feet of the cross section at breast height of a single tree. When the basal area of all trees in a stand are summed, the result is usually expressed as square feet of basal area per acre.

Biomass.—The total above-ground weight, excluding foliage, of all live trees reported in green tons. Biomass is made up of 5 components:

Growing-stock bole and stump.—Biomass of a growing-stock tree from ground level to a 4-inch top.

Growing-stock top and limbs.—Biomass of a growing-stock tree above a 4-inch top and all limbs below the 4-inch top.

Cull bole and stump.—Biomass of a cull tree from ground level to a 4-inch top.

Cull top and limbs.—Biomass of a cull tree above a 4-inch top and all limbs below the 4-inch top.

1- to 5-inch trees.—Above ground biomass of all live trees 1- to 5-inches in diameter at breast height.

Commercial species.—Tree species presently or prospectively suitable for industrial wood products. (Note: Excludes species of typically small size, poor

form, or inferior quality such as hophornbeam and hawthorn.)

County and municipal land.—Land owned by counties and local public agencies or municipalities, or land leased to these governmental units for 50 years or more.

Cropland.—Land under cultivation within the past 24 months; including cropland harvested, crop failures, cultivated summer fallow, idle cropland used only for pasture, orchards, and land in soil improvement crops, but excluding land cultivated in developing improved pasture.

Cull.—Portions of a tree that are unusable for industrial wood products because of rot, form, or other defect.

Diameter classes.—A classification of trees based on diameter outside bark, measured at breast height (4.5 feet above the ground). (Note: D.b.h. is the common abbreviation for diameter at breast height. Two-inch diameter classes are commonly used in Forest Survey, with the even inch the approximate midpoint for a class. For example, the 6-inch class includes trees 5.0 through 6.9 inches d.b.h.)

Farm.—Any place from which $1,000 or more of agricultural products were produced and sold during the year.

Farmer-owned land.—Land owned by farm operators. (Note: Excludes land leased by farm operators from nonfarm owners, such as railroad companies and States.)

Forest industry land.—Land owned by companies or individuals operating primary wood-using plants.

Forest land.—Land at least 16.7 percent stocked by forest trees of any size, or formerly having had such tree cover, and not currently developed for nonforest use. (Note: Stocking is measured by comparison of basal area and/or number of trees, by age or size and spacing with specified standards.) The minimum area for classification of forest land is 1 acre. Roadside, streamside, and shelterbelt strips of timber must have a crown width of at least 120 feet to qualify as forest land. Unimproved roads and trails, streams, or other bodies of water or clearings in forest areas shall be classed as forest if less than 120 feet wide. Also see definitions for land area, timberland, nontimberland, reserved forest land, stocking, woodland, and water.

Forest industry land.—Land owned by companies or individuals operating primary wood-using plants. Excludes land owned by small sawmill firms sawing less than 100,000 board feet annually.

Forest trees.—Woody plants having a well-developed stem and usually more than 12 feet tall at maturity.

Forest type.—A classification of forest land based on the species forming a plurality of live tree stocking. Major forest types are:

Jack pine.—Forests in which jack pine comprises a plurality of the stocking. (Common associates include eastern white pine, red pine, aspen, birch, and maple.)

Red pine.—Forests in which red pine comprises a plurality of the stocking. (Common associates include eastern white pine, jack pine, aspen, birch, and maple.)

White pine.—Forests in which eastern white pine comprises a plurality of the stocking. (Common associates include red pine, jack pine, aspen, birch, and maple.)

Balsam fir.—Forests in which balsam fir and white spruce comprise a plurality of stocking with balsam fir the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)

White spruce.—Forests in which white spruce and balsam fir comprise a plurality of the stocking with white spruce the most common. (Common associates include aspen, maple, birch, northern white-cedar, and tamarack.)

Black spruce.—Forests in which swamp conifers comprise a plurality of the stocking with black spruce the most common. (Common associates include tamarack and northern white-cedar.)

Northern white-cedar.—Forests in which swamp conifers comprise a plurality of the stocking with northern white-cedar the most common. (Common associates include tamarack and black spruce.)

Tamarack.—Forests in which swamp conifers comprise a plurality of the stocking with tamarack the most common. (Common associates include black spruce and northern white-cedar.)

Oak-hickory.—Forests in which northern red oak, white oak, bur oak, or hickories, singly or in combination, comprise a plurality of the stocking. (Common associates include jack pine, elm, and maple.)

Elm-ash-soft maple.—Forests in which lowland elm, ash, cottonwood, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include birches, spruce, and balsam fir.)

Maple-birch.—Forests in which sugar maple, basswood, yellow birch, upland American elm, and red maple, singly or in combination, comprise a plurality of the stocking. (Common associates include white pine, elm, and basswood.)

Aspen.—Forests in which quaking aspen or bigtooth aspen, singly or in combination, comprise a

plurality of the stocking. (Common associates include balsam poplar, balsam fir, and paper birch.)

Paper birch.—Forests in which paper birch comprises a plurality of the stocking. (Common associates include maple, aspen, and balsam fir.)

Balsam poplar.—Forests in which balsam poplar comprises a plurality of the stocking. (Common associates include aspen, elm, and ash.)

Gross area.—The entire area of land and water as determined by the Bureau of the Census.

Growing-stock trees.—Live trees of commercial species qualifying as acceptable trees. (Note: Excludes rough, rotten, and dead trees.)

Growing-stock volume.—Net volume in cubic feet of growing-stock trees 5 inches d.b.h. and over, from a 1-foot stump to a minimum 4 inch top diameter outside bark of the central stem. Cubic feet can be converted to cords by dividing by 79 cubic feet per solid wood cord.

Hardwoods.—Dicotyledonous trees, usually broad-leaved and deciduous.

Idle farmland.—Includes former cropland, orchards, improved pastures, and farm sites not tended within the past 2 years and presently less than 16.7 percent stocked with trees.

Improved pasture.—Land currently improved for grazing by cultivating, seeding, irrigating, or clearing of trees or brush and less than 16.7 percent stocked with live trees.

Indian land.—All lands held in trust by the United States for individual Indians or tribes, or all lands, titles to which are held by individual Indians or tribes, subject to federal restrictions against alienation.

Industrial wood.—All roundwood products, except fuelwood.

Land area.—*Bureau of the Census.*—The area of dry land and land temporarily or partly covered by water such as marshes, swamps, and river flood plains (omitting tidal flats below mean high tide); streams, sloughs, estuaries, and canals less than one-eighth of a statute mile wide; and lakes, reservoirs, and ponds less than 40 acres in area.

Forest Inventory and Analysis.—The same as the Bureau of the Census, except minimum width of streams, etc., is 120 feet and minimum size of lakes, etc., is 1 acre.

Live trees.—Growing-stock, rough, and rotten trees 1 inch d.b.h. and larger.

Marsh.—Nonforest land that characteristically supports low, generally herbaceous or shrubby vegetation and that is intermittently covered with water.

Merchantable.—Refers to a pulpwood or saw log section that meets pulpwood or saw log specifications, respectively.

Miscellaneous federal land.—Federal land other than National Forest.

Miscellaneous private land.—Privately owned land other than forest-industry and farmer-owned land.

Mortality.—The volume of sound wood in growing-stock and sawtimber trees that die annually.

National Forest land.—Federal land that has been legally designated as National Forest or purchase units, and other land administered by the USDA Forest Service.

Net annual growth of growing-stock.—The annual change in volume of sound wood in live sawtimber and poletimber trees and the total volume of trees entering these classes through ingrowth, less volume losses resulting from natural causes.

Net annual growth of sawtimber.—The annual change in the volume of live sawtimber trees and the total volume of trees reaching sawtimber size, less volume losses resulting from natural causes.

Net volume.—Gross volume less deductions for rot, sweep, or other defect affecting use for timber products.

Nontimberland.—(a) Woodland and (b) reserved forest land.

Noncommercial species.—Tree species of typically small size, poor form, or inferior quality that normally do not develop into trees suitable for industrial wood products.

Nonforest land.—Land that has never supported forests, and land formerly forested where use for timber management is precluded by development for other uses. (Note: Includes areas used for crops, improved pasture, residential areas, city parks, improved roads of any width and adjoining clearings, powerline clearings of any width, and 1- to 40-acre areas of water classified by the Bureau of the Census as land. If intermingled in forest areas, unimproved roads and nonforest strips must be more than 120 feet wide and more than 1 acre in area to qualify as nonforest land.)

a. *Nonforest land without trees.*—Nonforest land with no live trees present.

b. *Nonforest land with trees.*—Nonforest land with one or more trees per acre at least 5 inches d.b.h.

Nonstocked land.—Timberland less than 16.7 percent stocked with growing-stock trees.

Other removals.—Growing-stock trees removed but not utilized for products, or trees left standing but "removed" from the timberland classification by land use change. Examples are removals from cultural operations such as timber stand improvement work, land clearing, and changes in land use.

Ownership.—Property owned by one owner, regardless of the number of parcels in a specified area.

Pasture and range.—Land which is currently improved for grazing by cultivation, seeding, or irrigation, plus land on which the natural plant cover is composed principally of native grasses, forbs, or shrubs valuable for forage.

Pastured timberland.—Timberland for which the primary use is wood production, but is presently used for grazing.

Physiographic class.—A measure of soil and water conditions that affect tree growth on a site. The physiographic classes are:

Xeric sites.—Very dry soils where excessive drainage seriously limits both growth and species occurrence. Example: sandy jack pine plains.

Xeromesic sites.—Moderately dry soils where excessive drainage limits growth and species occurrence to some extent. Example: dry oak ridge.

Mesic sites.—Deep, well-drained soils. Growth and species occurrence are limited only by climate.

Hydromesic sites.—Moderately wet soils where insufficient drainage or infrequent flooding limits growth and species occurrence to some extent. Example: better drained bottomland hardwood sites.

Hydric sites.—Very wet sites where excess water seriously limits both growth and species occurrence. Example: frequently flooded river bottoms and spruce bogs.

Poletimber stands.—(See stand-size class.)

Poletimber trees.—Growing-stock trees of commercial species at least 5 inches d.b.h. but smaller than sawtimber size.

Reserved forest land.—Forest land sufficiently productive to qualify as timberland but withdrawn from timber utilization through statute, administrative regulation, designation, or exclusive use for Christmas tree production, as indicated by annual shearing.

Rotten trees.—Live trees of commercial species that do not contain at least one 12-foot saw log or two saw logs 8 feet or longer, now or prospectively, and/or do not meet regional specifications for freedom from defect primarily because of rot; that is, when more than 50 percent of extra cull volume in a tree is rotten.

Rough trees.—(a) Live trees of commercial species that do not contain at least one merchantable 12-foot saw log or two saw logs 8 feet or longer, now or prospectively, and/or do not meet regional specifications for freedom from defect primarily because of roughness or poor form, and (b) all live trees of noncommercial species.

Salvable dead trees.—Standing or down dead trees that are considered merchantable by regional standards.

Saplings.—Live trees 1 to 5 inches d.b.h.

Sapling-seedling stands.—(See stand-size class.)

Saw log.—A log meeting minimum standards of diameter, length, and defect, including logs at least 8 feet long, sound and straight and with a minimum diameter outside bark (d.o.b.) for softwoods of 7 inches (9 inches for hardwoods) or other combinations of size and defect specified by regional standards.

Saw log portion.—That part of the bole of sawtimber trees between the stump and the saw log top.

Saw log top.—The point on the bole of sawtimber trees above which a saw log cannot be produced. The minimum saw log top is 7 inches d.o.b. for softwoods and 9 inches d.o.b. for hardwoods.

Sawtimber stands.—(See stand-size class.)

Sawtimber trees.—Growing-stock trees of commercial species containing at least a 12-foot saw log or two noncontiguous saw logs 8 feet or longer, and meeting regional specifications for freedom from defect. Softwoods must be at least 9 inches d.b.h. Hardwoods must be at least 11 inches d.b.h.

Sawtimber volume.—Net volume of the saw log portion of live sawtimber in board feet, International 1/4-inch rule, from stump to a minimum 7 inches top d.o.b. for softwoods and a minimum 9 inches top d.o.b. for hardwoods.

Seedlings.—Live trees less than 1 inch d.b.h. that are expected to survive. Only softwood seedlings more than 6 inches tall and hardwood seedlings more than 1 foot tall are counted.

Short-log (rough tree).—Sawtimber-size trees of commercial species that contain at least one merchantable 8- to 11-foot saw log but not a 12-foot saw log.

Site class.—A classification of forest land in terms of inherent capacity to grow crops of industrial wood based on fully stocked natural stands.

Site index.—An expression of forest site quality based on the total height of free-growing dominant or codominant trees of a representative species in the forest type at age 50.

Softwoods.—Coniferous trees, usually evergreen, having needles or scale-like leaves.

Stand.—A growth of trees on a minimum of 1 acre of forest land that is stocked by forest trees of any size.

Stand-age class.—Age of the main stand. Main stand refers to trees of the dominant forest type and stand-size class.

Stand-area class.—The extent of a continuous forested area of the same forest type, stand-size class, and stand-density class.

Stand-size class.—A classification of forest land based on the size class of all live trees; that is, sawtimber, poletimber of seedlings and saplings. Only those types contributing to no more than 16 percent stocking at a point will be used to determine stand size class. Remember that stands with less than 16.7 percent stocking in growing stock trees will be classified as non-stocked. Non-commercial trees are not used for determining stand size classes.

Sawtimber stands.—Stands with at least the all live stocking in sawtimber and poletimber trees and with the sawtimber stocking equal to or larger than the poletimber stocking.

Poletimber stands.—Stands with at least half of the all live stocking in sawtimber and poletimber trees and with the poletimber stocking larger than the sawtimber stocking.

Sapling-seedling stands.—Stands with more than half of the all live stocking in saplings and/or seedlings.

State land.—Land owned by States, or land leased to these governmental units for 50 years or more.

Stocking.—The degree of occupancy of land by trees, measured by basal area and/or the number of trees in a stand by size or age and spacing, compared to the basal area and/or number of trees required to fully utilize the growth potential of the land; that is, the stocking standard. A stocking percent of 100 indicates full utilization of the site and is equivalent to 80 square feet of basal area per acre in trees 5 inches d.b.h. and larger. In a stand of trees less than 5 inches d.b.h., a stocking percent of 100 would indicate that the present number of trees is sufficient to produce 80 square feet of basal area per acre when the trees reach 5 inches d.b.h. Stands are grouped into the following stocking classes:

Overstocked stands.—Stands in which stocking of trees is 134.0 percent or more.

Fully stocked stands.—Stands in which stocking of trees is from 101.0 to 133.9 percent.

Medium stocked stands.—Stands in which stocking of trees is from 61.0 to 100.9 percent.

Poorly stocked stands.—Stands in which stocking of trees is from 16.7 to 60.9 percent.

Nonstocked areas.—Timberland on which stocking of trees is less than 16.7 percent.

Timber removals from growing stock.—The volume of sound wood in live sawtimber and poletimber trees removed annually for forest products (including roundwood products and logging residues) and for other removals. Roundwood products are logs, bolts, or other round sections cut from trees. Logging residues are the unused portions of cut trees plus unused trees killed by logging. Other removals are growing-stock trees removed by cultural operations such as timber stand improvement work, and by land clearing and changes in land use.

Timber removals from sawtimber.—The net board-foot volume of live sawtimber trees removed for forest products annually (including roundwood products and logging residues) and for other removals.

Timberland.—Forest land producing or capable of producing crops of industrial wood and not withdrawn from timber utilization. (Note: Areas qualifying as timberland are capable of producing more than 20 cubic feet per acre per year of annual growth under management. Currently inaccessible and inoperable areas are included, except when the areas involved are small and unlikely to become suitable for producing of industrial wood in the foreseeable future.) Also see definition of pastured timberland.

Tree biomass.—The total aboveground weight (including the bark) of all live trees.

Tree size class.—A classification of trees based on diameter at breast height, including sawtimber trees, poletimber trees, saplings, and seedlings.

Upper stem portion.—That part of the bole of sawtimber trees above the saw log top to a minimum top diameter of 4 inches outside bark or to the point where the central stem breaks into limbs.

Urban and other areas.—Areas within the legal boundaries of cities and towns; suburban areas developed for residential, industrial, or recreational purposes; schoolyards; cemeteries; roads; railroads; airports; beaches; power lines; and other rights-of-way; or other nonforest land not included in any other specified land use class.

Water.—*Bureau of the Census.*—Permanent inland water surfaces, such as lakes, reservoirs, and ponds having 40 acres or more of area; streams, sloughs, estuaries, and canals one-eighth of a statute mile or more in width.

Noncensus.—Permanent inland water surfaces, such as lakes, reservoirs, and ponds having 1 to 39.9 acres of area; streams, sloughs, estuaries, and canals 120 feet to one-eighth of a statute mile in width.

Windbreak.—A group of trees less than 120 feet wide used for the protection of soil, cropfields, and buildings in use.

Wooded pasture.—Improved pasture with more than 16.7 percent stocking in live trees but less than 25 percent stocking in growing-stock trees. Area is currently improved for grazing or there is other evidence of grazing.

Wooded strip.—An acre or more of natural continuous forest land that would otherwise meet survey standards for timberland except that it is less than 120 feet wide.

Woodland.—Forest land incapable of producing 20 cubic feet per acre of annual growth or of yielding crops of industrial wood under natural conditions because of adverse site conditions. (Note: Adverse conditions include shallow soils, dry climate, poor drainage, high elevation, steepness, and rockiness).

TABLES

Table 1.--Area of land by land class and Forest Survey Unit, Minnesota, 1977 and 1987

(In thousand acres)

Land use class	All units		Forest survey unit: Aspen-birch		Northern pine		Central hardwood		Prairie	
	1977	1987	1977	1987	1977	1987	1977	1987	1977	1987
Forest land										
Timberland										
Jack pine	496.9	468.1	167.2	157.6	318.4	300.2	11.3	10.3	-	-
Red pine	262.9	310.4	118.6	119.9	133.8	173.6	10.5	16.9	-	-
White pine	65.7	65.7	34.6	34.6	24.1	24.1	7.0	7.0	-	-
Balsam fir	812.2	801.8	594.9	588.2	209.7	206.0	7.6	7.6	-	-
White spruce	118.1	121.8	87.6	89.2	30.5	32.6	-	-	-	-
Black spruce	1,058.1	1,037.3	768.1	756.5	272.2	264.1	17.8	16.7	-	-
Northern white-cedar	479.0	496.0	297.4	306.4	181.6	189.6	-	-	-	-
Tamarack	473.5	468.4	157.3	157.3	284.1	284.1	31.1	26.0	1.0	1.0
Oak-hickory	893.3	873.7	5.3	5.3	247.1	237.7	571.4	561.2	69.5	69.5
Elm-ash-cottonwood	725.4	712.8	245.0	255.0	296.6	293.5	129.2	114.6	54.6	49.7
Maple-basswood	1,275.4	1,290.3	203.9	220.9	467.7	471.7	486.3	490.5	117.5	107.2
Aspen	5,328.2	5,278.0	1,950.2	1,933.9	2,564.3	2,551.0	560.6	550.1	253.1	243.0
Paper birch	959.3	963.6	511.3	511.3	368.3	372.6	79.7	79.7	-	-
Balsam poplar	547.8	550.3	205.6	205.6	298.9	304.8	10.7	12.6	32.6	27.3
Nonstocked	138.1	138.1	44.6	44.6	60.1	60.1	27.7	27.7	5.7	5.7
Subtotal	13,633.9	13,576.3	5,391.6	5,386.3	5,757.4	5,765.7	1,950.9	1,920.9	534.0	503.4
Woodland	1,834.4	1,834.4	969.8	969.8	706.9	706.9	119.1	119.1	38.6	38.6
Reserved	1,178.4	1,178.4	1,050.6	1,050.6	46.9	46.9	72.3	72.3	8.6	8.6
Total	16,646.7	16,589.1	7,412.0	7,406.7	6,511.2	6,519.5	2,142.3	2,112.3	581.2	550.6
Nonforest land										
Cropland	26,426.5	26,386.0	330.3	330.3	2,006.0	1,971.0	7,252.9	7,247.4	16,837.3	16,837.3
Pasture and range	1,124.8	1,124.8	95.4	95.4	581.0	581.0	290.2	290.2	158.2	158.2
Other	6,846.8	6,644.9	795.7	801.0	1,956.9	1,983.6	2,233.8	2,269.3	1,560.4	1,591.0
Total	34,098.1	34,155.7	1,221.4	1,226.7	4,543.9	4,535.6	9,776.9	9,806.9	18,555.9	18,586.5
Total land	50,744.8	50,744.8	8,633.4	8,633.4	11,055.1	11,055.1	11,919.2	11,919.2	19,137.1	19,137.1
Water (Bureau of Census)	3,058.7	3,058.7	715.1	715.1	1,437.7	1,437.7	581.9	581.9	324.0	324.0
Total land and water	53,803.5	53,803.5	9,348.5	9,348.5	12,492.8	12,492.8	12,501.1	12,501.1	19,461.1	19,461.1

Table 2.--Area of timberland by ownership class and Forest Survey Unit, Minnesota, 1987

(In thousand acres)

Ownership class	All units	Forest survey unit: Aspen-birch	Northern pine	Central hardwood	Prairie
National forest	1,668.8	1,108.0	560.8	-	-
Bureau of land mgmt.	43.6	8.0	35.6	-	-
Miscellaneous fed.	111.7	20.3	62.1	20.3	9.0
State	2,656.7	1,128.6	1,237.3	246.2	44.6
County and municipal	2,333.9	1,180.8	1,093.9	59.2	-
Indian	464.6	98.1	362.2	4.3	-
Forest industry	791.2	531.2	256.5	0.5	3.0
Farmer	3,346.1	540.1	1,312.9	1,121.1	372.0
Misc. private-corp.	471.2	247.7	154.9	63.0	5.6
Misc. private-indiv.	1,688.5	523.5	689.5	406.3	69.2
All owners	13,576.3	5,386.3	5,765.7	1,920.9	503.4

Table 3.--Area of timberland by forest type, stand-age class, and Forest Survey Unit, Minnesota, 1987

(In thousand acres)

ALL UNITS

Forest type	All ages	Stand-age class(years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
Jack pine	468.1	115.1	25.8	37.6	108.2	106.6	57.5	13.2	4.1	-	-
Red pine	310.4	75.0	10.4	21.9	73.7	25.8	14.8	18.8	30.5	31.2	8.3
White pine	65.7	-	3.3	-	5.0	6.9	4.2	9.8	13.0	22.2	1.3
Balsam fir	801.8	56.4	70.8	77.3	98.4	227.0	150.5	61.1	42.0	18.3	-
White spruce	121.8	33.2	35.0	5.3	4.2	10.7	13.4	4.3	15.7	-	-
Black spruce	1,037.3	117.2	106.9	172.8	145.2	108.1	111.3	98.2	145.2	28.1	4.3
Northern white-cedar	496.0	5.5	11.2	26.1	22.7	20.4	43.3	63.0	120.6	81.4	101.8
Tamarack	468.4	37.2	75.5	48.6	31.0	37.0	60.3	26.4	77.1	46.9	28.4
Oak-hickory	873.7	91.1	37.6	12.9	54.9	141.9	126.3	138.6	181.5	88.9	-
Elm-ash-cottonwood	712.8	77.0	50.4	45.8	38.1	77.1	113.5	102.0	131.1	69.7	8.1
Maple-basswood	1,290.3	33.2	56.2	40.3	92.0	192.2	235.8	197.2	275.1	131.7	36.6
Aspen	5,278.0	1,065.4	528.7	422.8	796.9	1,130.9	836.6	286.7	161.2	45.3	3.5
Paper birch	963.6	49.1	45.9	38.7	107.3	240.1	251.9	123.7	80.8	23.4	2.7
Balsam poplar	550.3	67.4	76.0	44.4	89.8	120.3	79.1	38.7	32.9	1.7	-
Nonstocked	138.1	127.6	2.8	1.6	1.3	4.8	-	-	-	-	-
All types	13,576.3	1,950.4	1,136.5	996.1	1,668.7	2,449.8	2,098.5	1,181.7	1,310.8	588.8	195.0

ASPEN-BIRCH

Jack pine	157.6	67.8	9.0	2.7	47.4	17.0	10.4	3.3	-	-	-
Red pine	119.9	2.1	3.7	1.1	68.6	5.8	9.5	10.0	16.6	1.2	1.3
White pine	34.6	-	1.4	-	-	-	-	3.8	8.5	19.6	1.3
Balsam fir 1/	588.2	44.0	45.9	50.8	80.7	165.7	115.5	38.7	29.9	17.0	-
White spruce	89.2	17.9	33.7	1.5	4.2	10.7	5.5	1.4	14.3	-	-
Black spruce	756.5	73.6	87.1	113.2	108.3	85.2	81.1	70.1	113.5	23.0	1.4
Northern white-cedar	306.4	3.7	8.5	17.4	18.5	15.6	26.7	31.6	75.4	39.9	69.1
Tamarack	157.3	15.9	31.1	21.4	14.0	15.1	14.7	11.8	15.1	12.0	6.2
Oak-hickory	5.3	-	-	-	1.2	2.7	1.4	-	-	-	-
Elm-ash-cottonwood	255.0	30.5	21.7	10.2	12.7	31.2	38.3	34.9	43.2	28.1	4.2
Maple-basswood	220.9	6.5	17.5	6.1	15.2	47.2	37.7	15.5	39.6	15.2	20.4
Aspen	1,933.9	397.3	178.8	160.0	241.3	376.7	346.1	117.2	74.3	38.7	3.5
Paper birch	511.3	36.8	27.9	21.5	45.5	121.2	140.6	67.2	45.3	3.9	1.4
Balsam poplar	205.6	24.6	15.0	11.4	34.4	52.2	34.9	15.2	16.6	1.3	-
Nonstocked	44.6	44.6	-	-	-	-	-	-	-	-	-
All types	5,386.3	765.3	481.3	417.3	692.0	946.3	862.4	420.7	492.3	199.9	108.8

NORTHERN PINE

Jack pine	300.2	45.8	16.8	32.7	57.3	86.5	47.1	9.9	4.1	-	-
Red pine	173.6	67.4	4.6	14.6	5.1	18.6	5.3	8.8	12.2	30.0	7.0
White pine	24.1	-	-	-	5.0	6.9	2.8	3.0	3.8	2.6	-
Balsam fir	206.0	12.4	22.9	26.5	17.7	57.0	33.7	22.4	12.1	1.3	-
White spruce	32.6	15.3	1.3	3.8	-	-	7.9	2.9	1.4	-	-
Black spruce	264.1	43.6	18.3	52.3	36.2	21.4	26.1	26.5	31.7	5.1	2.9
Northern white-cedar	189.6	1.8	2.7	8.7	4.2	4.8	16.6	31.4	45.2	41.5	32.7
Tamarack	284.1	21.3	39.4	25.5	16.4	16.2	41.5	12.1	58.7	32.1	20.9
Oak-hickory	237.7	23.5	15.4	7.4	18.1	59.5	45.0	29.5	29.4	9.9	-
Elm-ash-cottonwood	293.5	25.4	17.4	23.6	16.1	21.2	45.1	42.2	68.6	31.4	2.5
Maple-basswood	471.7	6.8	14.5	13.9	35.6	79.3	110.5	66.0	86.2	46.8	12.1
Aspen	2,551.0	496.7	267.5	200.7	393.1	566.1	405.5	140.0	74.8	6.6	-
Paper birch	372.6	8.2	11.0	11.9	45.0	98.7	97.7	52.1	27.2	19.5	1.3
Balsam poplar	304.8	36.5	54.8	29.9	48.4	58.5	39.4	22.5	14.4	0.4	-
Nonstocked	60.1	58.5	-	-	-	1.6	-	-	-	-	-
All types	5,765.7	863.2	486.6	451.5	698.2	1,096.3	924.2	469.3	469.8	227.2	79.4

(Table 3 continued on next page)

(Table 3 continued)

CENTRAL HARDWOOD

Forest type	All ages	Stand-age class(years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
Jack pine	10.3	1.5	-	2.2	3.5	3.1	-	-	-	-	-
Red pine	16.9	5.5	2.1	6.2	-	1.4	-	-	1.7	-	-
White pine	7.0	-	1.9	-	-	-	1.4	3.0	0.7	-	-
Balsam fir	7.6	-	2.0	-	-	4.3	1.3	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	16.7	-	1.5	7.3	0.7	1.5	4.1	1.6	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	26.0	-	4.0	1.7	0.6	5.7	4.1	2.5	3.3	2.8	1.3
Oak-hickory	561.2	58.8	20.9	5.5	34.3	73.7	77.2	99.0	128.6	63.2	-
Elm-ash-cottonwood	114.6	16.8	11.3	6.3	4.1	15.8	20.5	17.7	16.9	5.2	-
Maple-basswood	490.5	18.7	18.4	15.4	39.8	60.9	72.0	92.5	117.8	51.9	3.1
Aspen	550.1	104.1	42.3	38.3	122.2	144.2	69.6	22.0	7.4	-	-
Paper birch	79.7	4.1	7.0	5.3	16.8	20.2	13.6	4.4	8.3	-	-
Balsam poplar	12.6	1.6	1.6	-	-	3.7	3.8	-	1.9	-	-
Nonstocked	27.7	23.1	1.4	1.6	-	1.6	-	-	-	-	-
All types	1,920.9	234.2	114.4	89.8	222.0	336.1	267.6	242.7	286.6	123.1	4.4

PRAIRIE

Jack pine	-	-	-	-	-	-	-	-	-	-	-
Red pine	-	-	-	-	-	-	-	-	-	-	-
White pine	-	-	-	-	-	-	-	-	-	-	-
Balsam fir	-	-	-	-	-	-	-	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	-	-	-	-	-	-	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	1.0	-	1.0	-	-	-	-	-	-	-	-
Oak-hickory	69.5	8.8	1.3	-	1.3	6.0	2.7	10.1	23.5	15.8	-
Elm-ash-cottonwood	49.7	4.3	-	5.7	5.2	8.9	9.6	7.2	2.4	5.0	1.4
Maple-basswood	107.2	1.2	5.8	4.9	1.4	4.8	15.6	23.2	31.5	17.8	1.0
Aspen	243.0	67.3	40.1	23.8	40.3	43.9	15.4	7.5	4.7	-	-
Paper birch	-	-	-	-	-	-	-	-	-	-	-
Balsam poplar	27.3	4.7	4.6	3.1	7.0	5.9	1.0	1.0	-	-	-
Nonstocked	5.7	1.4	1.4	-	1.3	1.6	-	-	-	-	-
All types	503.4	87.7	54.2	37.5	56.5	71.1	44.3	49.0	62.1	38.6	2.4

1/ The reader is cautioned to review the highlights section of this report particularly the section titled "Net Growth", before further analysis

Table 4.--Area of timberland by forest type, site-index class, and Forest Survey Unit, Minnesota, 1987

(In thousand acres)

ALL UNITS

Forest type	All classes	Site-index class (feet) 11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91+
Jack pine	468.1	-	-	14.8	105.8	170.0	115.0	56.3	5.0	1.2
Red pine	310.4	-	-	5.7	80.8	66.0	76.0	60.0	21.9	-
White pine	65.7	-	-	8.7	16.5	29.2	8.5	2.8	-	-
Balsam fir	801.8	-	20.8	155.0	280.1	235.6	95.4	11.0	3.9	-
White spruce	121.8	-	-	12.4	59.5	15.3	34.6	-	-	-
Black spruce	1,037.3	20.4	290.0	399.4	242.4	77.3	6.7	1.1	-	-
Northern white-cedar	496.0	95.0	259.2	99.2	28.2	10.3	4.1	-	-	-
Tamarack	468.4	4.4	91.8	172.9	130.4	53.5	12.4	3.0	-	-
Oak-hickory	873.7	-	7.5	160.3	288.8	220.0	144.1	38.4	11.8	2.8
Elm-ash-cottonwood	712.8	-	2.9	139.2	228.8	225.1	81.0	28.8	5.6	1.4
Maple-basswood	1,290.3	-	-	65.0	277.5	484.7	319.5	117.0	26.6	-
Aspen	5,278.0	1.3	3.2	74.0	398.8	1,202.6	1,753.0	1,323.6	459.5	62.0
Paper birch	963.6	-	3.1	27.7	165.2	364.1	307.8	74.4	19.8	1.5
Balsam poplar	550.3	-	-	25.1	110.3	132.5	172.0	75.4	30.9	4.1
Nonstocked	138.1	4.3	20.9	30.5	30.8	29.5	13.9	8.2	-	-
All types	13,576.3	125.4	699.4	1,389.9	2,443.9	3,315.7	3,144.0	1,800.0	585.0	73.0
ASPEN-BIRCH										
Jack pine	157.6	-	-	2.7	53.5	61.4	27.8	12.2	-	-
Red pine	119.9	-	-	1.3	17.5	21.5	28.5	29.2	21.9	-
White pine	34.6	-	-	8.7	12.5	12.0	1.4	-	-	-
Balsam fir	588.2	-	13.1	116.6	209.6	176.2	67.3	2.6	2.8	-
White spruce	89.2	-	-	12.4	36.0	12.1	28.7	-	-	-
Black spruce	756.5	15.0	201.7	290.9	182.8	59.9	5.1	1.1	-	-
Northern white-cedar	306.4	61.5	160.7	54.8	18.4	6.9	4.1	-	-	-
Tamarack	157.3	1.2	40.6	51.8	44.0	17.0	2.7	-	-	-
Oak-hickory	5.3	-	-	-	1.2	1.4	1.4	1.3	-	-
Elm-ash-cottonwood	255.0	-	-	64.8	98.3	78.0	10.9	3.0	-	-
Maple-basswood	220.9	-	-	16.2	60.4	99.0	41.3	2.9	1.1	-
Aspen	1,933.9	-	-	23.5	154.7	524.8	652.7	438.6	117.3	22.3
Paper birch	511.3	-	1.5	17.5	95.1	223.8	144.8	27.1	1.5	-
Balsam poplar	205.6	-	-	8.4	28.5	51.7	63.5	32.9	17.8	2.8
Nonstocked	44.6	-	3.5	9.3	13.4	7.2	8.4	2.8	-	-
All types	5,386.3	77.7	421.1	678.9	1,025.9	1,352.9	1,088.6	553.7	162.4	25.1
NORTHERN PINE										
Jack pine	300.2	-	-	12.1	50.7	105.4	85.2	40.6	5.0	1.2
Red pine	173.6	-	-	4.4	57.8	39.3	43.4	28.7	-	-
White pine	24.1	-	-	-	2.6	14.6	5.5	1.4	-	-
Balsam fir	206.0	-	7.7	36.4	69.0	55.3	28.1	8.4	1.1	-
White spruce	32.6	-	-	-	23.5	3.2	5.9	-	-	-
Black spruce	264.1	5.4	86.8	95.9	57.0	17.4	1.6	-	-	-
Northern white-cedar	189.6	33.5	98.5	44.4	9.8	3.4	-	-	-	-
Tamarack	284.1	3.2	49.4	118.3	72.2	32.4	7.3	1.3	-	-
Oak-hickory	237.7	-	4.6	33.1	77.7	64.6	44.6	9.1	4.0	-
Elm-ash-cottonwood	293.5	-	1.3	55.6	96.6	88.7	40.0	10.0	1.3	-
Maple-basswood	471.7	-	-	21.8	90.5	177.4	118.5	53.4	10.1	-
Aspen	2,551.0	1.3	1.7	35.0	144.6	430.5	832.1	737.8	328.3	39.7
Paper birch	372.6	-	-	4.8	50.1	117.9	139.6	40.4	18.3	1.5
Balsam poplar	304.8	-	-	12.5	66.6	69.5	101.1	40.7	13.1	1.3
Nonstocked	60.1	4.3	15.8	11.6	10.4	11.5	1.1	5.4	-	-
All types	5,765.7	47.7	265.8	485.9	879.1	1,231.1	1,454.0	977.2	381.2	43.7

(Table 4 continued on next page)

(Table 4 continued)

CENTRAL HARDWOOD

Forest type	All classes	Site-index class(feet) 11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91+
Jack pine	10.3	-	-	-	1.6	3.2	2.0	3.5	-	-
Red pine	16.9	-	-	-	5.5	5.2	4.1	2.1	-	-
White pine	7.0	-	-	-	1.4	2.6	1.6	1.4	-	-
Balsam fir	7.6	-	-	2.0	1.5	4.1	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-
Black spruce	16.7	-	1.5	12.6	2.6	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-
Tamarack	26.0	-	0.8	2.8	14.2	4.1	2.4	1.7	-	-
Oak-hickory	561.2	-	1.6	96.1	191.7	141.1	92.1	28.0	7.8	2.8
Elm-ash-cottonwood	114.6	-	1.6	11.0	23.8	40.7	19.7	13.5	4.3	-
Maple-basswood	490.5	-	-	20.8	105.9	169.1	136.0	44.7	14.0	-
Aspen	550.1	-	1.5	2.6	36.2	150.0	220.1	125.8	13.9	-
Paper birch	79.7	-	1.6	5.4	20.0	22.4	23.4	6.9	-	-
Balsam poplar	12.6	-	-	1.9	3.4	3.5	2.0	1.8	-	-
Nonstocked	27.7	-	1.6	9.6	2.7	9.4	4.4	-	-	-
All types	1,920.9	-	10.2	164.8	410.5	555.4	507.8	229.4	40.0	2.8

PRAIRIE

Jack pine	-	-	-	-	-	-	-	-	-	-
Red pine	-	-	-	-	-	-	-	-	-	-
White pine	-	-	-	-	-	-	-	-	-	-
Balsam fir	-	-	-	-	-	-	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-
Black spruce	-	-	-	-	-	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-
Tamarack	1.0	-	1.0	-	-	-	-	-	-	-
Oak-hickory	69.5	-	1.3	31.1	18.2	12.9	6.0	-	-	-
Elm-ash-cottonwood	49.7	-	-	7.8	10.1	17.7	10.4	2.3	-	1.4
Maple-basswood	107.2	-	-	6.2	20.7	39.2	23.7	16.0	1.4	-
Aspen	243.0	-	-	12.9	63.3	97.3	48.1	21.4	-	-
Paper birch	-	-	-	-	-	-	-	-	-	-
Balsam poplar	27.3	-	-	2.3	11.8	7.8	5.4	-	-	-
Nonstocked	5.7	-	-	-	4.3	1.4	-	-	-	-
All types	503.4	-	2.3	60.3	128.4	176.3	93.6	39.7	1.4	1.4

Table 5.--Area of timberland by forest type, stand-size class, and Forest Survey Unit, Minnesota, 1987

(In thousand acres)

Forest type	All classes	Stand size class: Sawtimber	Poletimber	Sapling & seedling	Nonstocked
ALL UNITS					
Jack pine	468.1	95.8	209.7	162.6	-
Red pine	310.4	110.6	59.7	140.1	-
White pine	65.7	54.7	7.7	3.3	-
Balsam fir	801.8	140.5	441.2	220.1	-
White spruce	121.8	22.4	26.7	72.7	-
Black spruce	1,037.3	21.7	387.7	627.9	-
Northern white-cedar	496.0	157.2	261.6	77.2	-
Tamarack	468.4	43.6	201.0	223.8	-
Oak-hickory	873.7	389.4	342.6	141.7	-
Elm-ash-cottonwood	712.8	164.5	365.5	182.8	-
Maple-basswood	1,290.3	678.0	494.4	117.9	-
Aspen	5,278.0	754.4	2,690.3	1,833.3	-
Paper birch	963.6	137.0	703.0	123.6	-
Balsam poplar	550.3	117.5	248.6	184.2	-
Nonstocked	138.1	-	-	-	138.1
All types	13,576.3	2,887.3	6,439.7	4,111.2	138.1
ASPEN-BIRCH					
Jack pine	157.6	23.2	56.1	78.3	-
Red pine	119.9	41.8	27.9	50.2	-
White pine	34.6	33.2	-	1.4	-
Balsam fir	588.2	108.1	328.1	152.0	-
White spruce	89.2	15.2	19.6	54.4	-
Black spruce	756.5	15.2	299.0	442.3	-
Northern white-cedar	306.4	117.2	134.3	54.9	-
Tamarack	157.3	9.9	53.5	93.9	-
Oak-hickory	5.3	-	5.3	-	-
Elm-ash-cottonwood	255.0	42.9	140.9	71.2	-
Maple-basswood	220.9	92.0	97.9	31.0	-
Aspen	1,933.9	266.3	977.8	689.8	-
Paper birch	511.3	56.0	376.7	78.6	-
Balsam poplar	205.6	48.5	104.9	52.2	-
Nonstocked	44.6	-	-	-	44.6
All types	5,386.3	869.5	2,622.0	1,850.2	44.6
NORTHERN PINE					
Jack pine	300.2	71.3	147.7	81.2	-
Red pine	173.6	67.1	25.0	81.5	-
White pine	24.1	16.4	7.7	-	-
Balsam fir	206.0	30.0	109.9	66.1	-
White spruce	32.6	7.2	7.1	18.3	-
Black spruce	264.1	6.5	83.7	173.9	-
Northern white-cedar	189.6	40.0	127.3	22.3	-
Tamarack	284.1	26.9	135.5	121.7	-
Oak-hickory	237.7	56.0	134.0	47.7	-
Elm-ash-cottonwood	293.5	59.4	160.2	73.9	-
Maple-basswood	471.7	199.8	236.5	35.4	-
Aspen	2,551.0	419.1	1,275.9	856.0	-
Paper birch	372.6	67.2	275.6	29.8	-
Balsam poplar	304.8	69.0	119.3	116.5	-
Nonstocked	60.1	-	-	-	60.1
All types	5,765.7	1,135.9	2,845.4	1,724.3	60.1

(Table 5 continued on next page)

(Table 5 continued)

CENTRAL HARDWOOD

Forest type	All classes	Stand size class: Sawtimber	Poletimber	Sapling & seedling	Nonstocked
Jack pine	10.3	1.3	5.9	3.1	-
Red pine	16.9	1.7	6.8	8.4	-
White pine	7.0	5.1	-	1.9	-
Balsam fir	7.6	2.4	3.2	2.0	-
White spruce	-	-	-	-	-
Black spruce	16.7	-	5.0	11.7	-
Northern white-cedar	-	-	-	-	-
Tamarack	26.0	6.8	12.0	7.2	-
Oak-hickory	561.2	292.0	185.3	83.9	-
Elm-ash-cottonwood	114.6	34.1	48.5	32.0	-
Maple-basswood	490.5	300.2	148.0	42.3	-
Aspen	550.1	62.7	329.8	157.6	-
Paper birch	79.7	13.8	50.7	15.2	-
Balsam poplar	12.6	-	9.4	3.2	-
Nonstocked	27.7	-	-	-	27.7
All types	1,920.9	720.1	804.6	368.5	27.7

PRAIRIE

Jack pine	-	-	-	-	-
Red pine	-	-	-	-	-
White pine	-	-	-	-	-
Balsam fir	-	-	-	-	-
White spruce	-	-	-	-	-
Black spruce	-	-	-	-	-
Northern white-cedar	-	-	-	-	-
Tamarack	1.0	-	-	1.0	-
Oak-hickory	69.5	41.4	18.0	10.1	-
Elm-ash-cottonwood	49.7	28.1	15.9	5.7	-
Maple-basswood	107.2	86.0	12.0	9.2	-
Aspen	243.0	6.3	106.8	129.9	-
Paper birch	-	-	-	-	-
Balsam poplar	27.3	-	15.0	12.3	-
Nonstocked	5.7	-	-	-	5.7
All types	503.4	161.8	167.7	168.2	5.7

Table 6.--Net volume of growing stock on timberland by forest type, stand-age class, and Forest Survey Unit, Minnesota, 1987

(In thousand cubic feet)

ALL UNITS

Forest type	All ages	Stand-age class(years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
Jack pine	441,543	24,720	20,049	39,236	125,742	156,022	64,486	6,558	4,730	-	-
Red pine	523,614	7,641	18,837	42,417	154,000	60,366	29,223	40,406	72,969	76,631	21,124
White pine	125,406	-	615	-	9,142	14,527	10,849	19,608	24,548	44,016	2,101
Balsam fir	841,156	22,638	37,614	58,246	112,823	311,996	170,451	67,287	46,819	13,282	-
White spruce	113,352	5,880	21,678	6,526	8,537	17,982	21,677	8,335	22,737	-	-
Black spruce	593,220	10,525	40,996	62,897	56,847	78,387	92,071	86,193	143,771	19,098	2,435
Northern white-cedar	548,935	3,062	3,801	13,365	18,812	22,090	44,146	71,442	154,000	88,692	129,525
Tamarack	254,113	5,794	21,314	18,240	11,847	27,820	46,151	19,838	52,284	37,542	13,283
Oak-hickory	923,845	8,282	18,327	6,505	63,721	192,062	176,502	179,804	209,589	69,053	-
Elm-ash-cottonwood	712,795	15,899	24,167	29,069	34,153	101,439	142,222	128,212	152,592	75,459	9,583
Maple-basswood	1,677,989	16,094	32,803	27,630	110,869	252,058	344,929	274,852	391,806	179,400	47,548
Aspen	5,116,323	270,324	314,847	416,661	1,064,072	1,623,356	967,583	262,632	156,147	40,701	-
Paper birch	1,250,056	12,926	29,333	36,419	141,013	355,863	364,556	167,138	103,656	35,597	3,555
Balsam poplar	577,042	23,825	32,011	35,868	98,298	174,757	107,096	56,402	45,669	3,116	-
Nonstocked	12,032	10,675	665	-	224	468	-	-	-	-	-
All types	13,711,421	438,285	617,057	793,079	2,010,100	3,389,193	2,581,942	1,388,707	1,581,317	682,587	229,154

ASPEN-BIRCH

Jack pine	108,052	18,315	9,877	2,192	40,854	25,131	10,508	1,175	-	-	-
Red pine	247,710	2,501	486	3,066	143,356	12,576	17,387	23,854	40,364	2,134	1,986
White pine	64,326	-	615	-	-	-	-	8,346	15,756	37,508	2,101
Balsam fir 1/	613,020	18,680	28,251	35,018	96,710	222,074	127,582	39,392	33,043	12,270	-
White spruce	89,861	5,880	21,253	1,216	8,537	17,982	10,663	3,235	21,095	-	-
Black spruce	479,165	8,187	37,691	46,615	46,123	63,448	74,982	68,623	117,005	16,070	421
Northern white-cedar	345,833	2,327	2,515	8,747	15,041	16,101	26,369	37,882	103,681	42,419	90,751
Tamarack	70,102	2,672	7,512	9,444	3,849	9,948	8,237	9,051	8,753	8,545	2,091
Oak-hickory	8,527	-	-	-	1,220	4,507	2,800	-	-	-	-
Elm-ash-cottonwood	243,961	7,014	10,520	6,287	7,628	35,128	46,963	43,496	52,846	29,149	4,930
Maple-basswood	263,952	4,694	15,595	3,673	16,664	52,833	45,402	21,367	56,577	24,976	22,171
Aspen	1,909,244	114,827	124,741	148,490	320,240	542,628	432,461	111,343	82,246	32,268	-
Paper birch	651,705	10,079	20,501	20,515	59,057	184,565	206,763	83,064	60,323	4,860	1,978
Balsam poplar	256,035	10,307	8,742	8,555	45,417	83,086	47,140	22,978	27,384	2,426	-
Nonstocked	5,256	5,256	-	-	-	-	-	-	-	-	-
All types	5,356,749	210,739	288,299	293,818	804,696	1,270,007	1,057,257	473,806	619,073	212,625	126,429

NORTHERN PINE

Jack pine	321,967	6,405	10,172	35,561	79,129	126,609	53,978	5,383	4,730	-	-
Red pine	252,232	5,140	8,308	31,199	10,644	45,234	11,836	16,552	29,684	74,497	19,138
White pine	49,421	-	-	-	9,142	14,527	5,372	6,366	7,506	6,508	-
Balsam fir	221,223	3,958	8,559	23,228	16,113	84,449	42,233	27,895	13,776	1,012	-
White spruce	23,491	-	425	5,310	-	-	11,014	5,100	1,642	-	-
Black spruce	106,520	2,338	3,226	13,568	10,510	14,586	14,280	16,204	26,766	3,028	2,014
Northern white-cedar	203,102	735	1,286	4,618	3,771	5,989	17,777	33,560	50,319	46,273	38,774
Tamarack	162,736	3,122	10,861	7,821	7,694	12,440	33,829	8,990	41,465	27,204	9,310
Oak-hickory	263,681	2,616	8,109	3,542	19,895	84,214	62,539	43,084	31,619	8,063	-
Elm-ash-cottonwood	307,074	4,782	7,971	13,446	15,133	30,029	60,355	57,029	79,256	35,570	3,503
Maple-basswood	697,615	2,612	7,914	8,272	50,098	118,679	182,940	105,934	133,583	67,922	19,661
Aspen	2,534,960	108,220	145,219	214,236	555,304	855,910	453,074	131,380	63,184	8,433	-
Paper birch	516,652	2,471	6,347	12,160	65,868	144,730	140,712	77,168	34,882	30,737	1,577
Balsam poplar	294,259	11,162	21,354	25,673	47,698	83,279	55,875	31,733	16,795	690	-
Nonstocked	3,231	3,103	-	-	-	128	-	-	-	-	-
All types	5,958,164	156,664	239,751	398,634	890,999	1,620,803	1,145,814	566,378	535,207	309,937	93,977

(Table 6 continued on next page)

(Table 6 continued)

CENTRAL HARDWOOD

Forest type	All ages	Stand-age class (years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
Jack pine	11,524	-	-	1,483	5,759	4,282	-	-	-	-	-
Red pine	23,672	-	10,043	8,152	-	2,556	-	-	2,921	-	-
White pine	11,659	-	-	-	-	-	5,477	4,896	1,286	-	-
Balsam fir	6,913	-	804	-	-	5,473	636	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	7,535	-	79	2,714	214	353	2,809	1,366	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	20,942	-	2,608	975	304	5,432	4,085	1,797	2,066	1,793	1,882
Oak-hickory	578,566	3,610	10,218	2,963	39,800	97,153	107,196	125,931	146,059	45,636	-
Elm-ash-cottonwood	108,083	3,689	5,676	3,113	3,562	24,287	25,468	19,778	18,235	4,275	-
Maple-basswood	583,099	8,788	7,208	12,386	42,406	74,614	97,265	116,400	157,346	61,930	4,756
Aspen	492,096	29,340	23,720	36,089	143,880	171,631	68,369	12,216	6,851	-	-
Paper birch	81,699	376	2,485	3,744	16,088	26,568	17,081	6,906	8,451	-	-
Balsam poplar	9,037	195	635	-	-	3,582	3,135	-	1,490	-	-
Nonstocked	2,266	2,092	120	-	-	54	-	-	-	-	-
All types	1,937,091	48,090	63,596	71,619	252,013	415,985	331,521	289,290	344,705	113,634	6,638

PRAIRIE

Jack pine	-	-	-	-	-	-	-	-	-	-	-
Red pine	-	-	-	-	-	-	-	-	-	-	-
White pine	-	-	-	-	-	-	-	-	-	-	-
Balsam fir	-	-	-	-	-	-	-	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	-	-	-	-	-	-	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	333	-	333	-	-	-	-	-	-	-	-
Oak-hickory	73,071	2,056	-	-	2,806	6,188	3,967	10,789	31,911	15,354	-
Elm-ash-cottonwood	53,677	414	-	6,223	7,830	11,995	9,436	7,909	2,255	6,465	1,150
Maple-basswood	133,323	-	2,086	3,299	1,701	5,932	19,322	31,151	44,300	24,572	960
Aspen	180,023	17,937	21,167	17,846	44,648	53,187	13,679	7,693	3,866	-	-
Paper birch	-	-	-	-	-	-	-	-	-	-	-
Balsam poplar	17,711	2,161	1,280	1,640	5,183	4,810	946	1,691	-	-	-
Nonstocked	1,279	224	545	-	224	286	-	-	-	-	-
All types	459,417	22,792	25,411	29,008	62,392	82,398	47,350	59,233	82,332	46,391	2,110

1/ The reader is cautioned to review the highlights section of this report particularly the section titled "Net Growth", before further analysis

Table 7.--Net volume of sawtimber on timberland by forest type, stand-age class, and Forest Survey Unit, Minnesota, 1987

(In thousand board feet) 1/

Forest type	All ages	Stand-age class(years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
ALL UNITS											
Jack pine	1,008,842	28,147	11,870	53,123	251,873	432,680	186,753	21,276	23,120	-	-
Red pine	1,846,604	18,298	4,225	44,735	442,844	189,143	130,840	178,379	348,755	386,118	103,267
White pine	514,904	-	2,923	-	27,537	51,485	51,561	86,640	97,086	185,635	12,037
Balsam fir	1,862,704	55,075	80,196	99,439	213,559	656,962	390,914	187,095	132,907	46,557	-
White spruce	276,762	-	33,608	6,953	20,508	56,123	51,416	28,568	79,586	-	-
Black spruce	628,475	14,031	47,096	30,899	41,600	88,117	126,172	92,096	182,400	5,615	449
Northern white-cedar	1,260,617	6,007	7,898	14,450	24,431	39,825	80,318	109,276	343,602	202,137	432,673
Tamarack	361,296	9,141	29,514	12,402	9,371	27,694	80,918	33,683	78,280	64,217	16,076
Oak-hickory	2,752,096	16,890	48,938	9,187	125,741	381,287	484,012	582,568	804,775	298,698	-
Elm-ash-cottonwood	1,603,932	31,829	42,404	31,912	53,495	197,558	312,961	306,173	398,854	195,127	33,619
Maple-basswood	5,105,256	47,561	63,756	39,920	211,870	537,982	941,455	921,692	1,450,899	701,104	189,017
Aspen	10,075,853	577,165	402,319	598,929	1,755,367	3,390,436	2,204,025	590,477	451,770	105,365	-
Paper birch	2,213,685	10,839	42,723	21,659	213,079	548,207	621,265	333,410	264,802	145,816	11,885
Balsam poplar	1,319,024	42,136	48,809	25,087	172,524	386,768	301,348	183,566	149,123	9,663	-
Nonstocked	26,244	24,677	487	-	-	1,080	-	-	-	-	-
All types	30,856,294	881,796	866,766	988,695	3,563,799	6,985,347	5,963,958	4,805,959	2,346,052	2,346,052	799,023
ASPEN-BIRCH											
Jack pine	205,620	13,556	530	5,149	79,058	81,271	24,654	1,402	-	-	-
Red pine	852,364	10,565	771	5,867	406,066	44,765	82,741	95,802	188,183	9,638	7,966
White pine	263,111	-	2,923	-	-	-	-	36,692	60,070	151,389	12,037
Balsam fir	1,352,921	40,194	72,675	59,032	179,798	455,104	301,477	95,542	106,702	42,397	-
White spruce	220,163	-	31,892	5,634	20,508	56,123	20,576	12,403	73,027	-	-
Black spruce	503,629	9,740	43,839	16,402	32,000	72,019	105,475	65,307	155,221	3,177	449
Northern white-cedar	867,205	4,339	6,319	8,423	21,584	32,197	47,457	64,714	256,302	108,940	316,930
Tamarack	94,742	6,988	13,884	2,371	6,314	7,999	8,792	13,531	16,807	12,713	5,343
Oak-hickory	16,989	-	-	-	3,585	7,573	5,831	-	-	-	-
Elm-ash-cottonwood	468,288	11,578	17,844	2,617	12,164	55,136	71,755	91,246	123,269	66,845	15,834
Maple-basswood	728,287	11,021	26,914	5,867	24,225	106,649	99,842	66,642	206,769	93,705	86,653
Aspen	3,675,483	232,167	153,522	251,141	554,058	1,057,542	882,923	219,342	242,205	82,583	-
Paper birch	1,056,702	6,761	32,919	9,294	83,411	284,873	326,690	148,643	135,889	22,442	5,780
Balsam poplar	607,876	23,482	13,528	9,159	95,882	179,592	113,855	73,369	91,484	7,525	-
Nonstocked	11,015	11,015	-	-	-	-	-	-	-	-	-
All types	10,924,395	381,406	417,560	380,956	1,518,653	2,440,843	2,092,068	984,635	1,655,928	601,354	450,992
NORTHERN PINE											
Jack pine	776,896	14,591	11,340	44,443	160,042	341,387	162,099	19,874	23,120	-	-
Red pine	971,158	7,733	2,233	35,450	36,778	139,079	48,099	82,577	147,428	376,480	95,301
White pine	194,369	-	-	-	27,537	51,485	22,475	26,958	31,668	34,246	-
Balsam fir	493,143	14,881	7,521	40,407	33,761	187,085	87,570	91,553	26,205	4,160	-
White spruce	56,599	-	1,716	1,319	-	-	30,840	16,165	6,559	-	-
Black spruce	118,199	4,291	3,257	10,528	9,600	16,098	18,019	26,789	27,179	2,438	-
Northern white-cedar	393,412	1,668	1,579	6,027	2,847	7,628	32,861	44,562	87,300	93,197	115,743
Tamarack	221,943	2,153	10,854	9,763	2,752	14,750	58,530	15,111	56,215	43,220	8,595
Oak-hickory	564,701	2,234	17,760	3,122	25,137	130,914	133,059	118,292	102,012	32,171	-
Elm-ash-cottonwood	688,670	9,836	13,682	11,330	17,441	46,358	152,666	130,242	206,485	88,094	12,536
Maple-basswood	1,901,225	9,787	16,208	6,917	92,647	233,902	479,246	300,742	444,392	240,719	76,665
Aspen	5,280,121	263,764	190,825	300,750	950,226	1,924,136	1,116,852	334,799	175,987	22,782	-
Paper birch	1,002,192	2,017	7,744	9,403	100,653	222,068	263,104	169,393	98,331	123,374	6,105
Balsam poplar	671,032	16,643	31,768	14,838	70,660	194,508	180,157	104,390	55,930	2,138	-
Nonstocked	8,100	7,563	-	-	-	537	-	-	-	-	-
All types	13,341,760	357,161	316,487	494,297	1,530,081	3,509,935	2,785,577	1,481,447	1,488,811	1,063,019	314,945

(Table 7 continued on next page)

(Table 7 continued)

CENTRAL HARDWOOD

Forest type	All ages	Stand-age class(years) 1-20	21-30	31-40	41-50	51-60	61-70	71-80	81-100	101-120	121+
Jack pine	26,326	-	-	3,531	12,773	10,022	-	-	-	-	-
Red pine	23,082	-	1,221	3,418	-	5,299	-	-	13,144	-	-
White pine	57,424	-	-	-	-	-	29,086	22,990	5,348	-	-
Balsam fir	16,640	-	-	-	-	14,773	1,867	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	6,647	-	-	3,969	-	-	2,678	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	44,611	-	4,776	268	305	4,945	13,596	5,041	5,258	8,284	2,138
Oak-hickory	1,899,995	7,938	31,178	6,065	90,064	224,617	335,091	425,097	580,883	199,062	-
Elm-ash-cottonwood	291,795	9,390	10,878	6,588	6,946	63,459	56,639	58,756	61,649	17,490	-
Maple-basswood	1,936,429	26,753	16,016	17,918	89,715	176,489	294,214	423,210	612,036	259,059	21,019
Aspen	874,534	64,833	33,664	33,717	199,793	314,466	181,160	23,315	23,586	-	-
Paper birch	154,791	2,061	2,060	2,962	29,015	41,266	31,471	15,374	30,582	-	-
Balsam poplar	19,357	1,130	3,513	-	-	6,782	6,223	-	1,709	-	-
Nonstocked	5,560	5,017	-	-	-	543	-	-	-	-	-
All types	5,357,191	117,122	103,306	78,436	428,611	862,661	952,025	973,783	1,334,195	483,895	23,157

PRAIRIE

Jack pine	-	-	-	-	-	-	-	-	-	-	-
Red pine	-	-	-	-	-	-	-	-	-	-	-
White pine	-	-	-	-	-	-	-	-	-	-	-
Balsam fir	-	-	-	-	-	-	-	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-	-	-
Black spruce	-	-	-	-	-	-	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-	-	-
Tamarack	-	-	-	-	-	-	-	-	-	-	-
Oak-hickory	270,411	6,718	-	-	6,955	18,183	10,031	39,179	121,880	67,465	-
Elm-ash-cottonwood	155,179	1,025	-	11,377	16,944	32,605	31,901	25,929	7,451	22,698	5,249
Maple-basswood	539,315	-	4,618	9,218	5,283	20,942	68,153	131,098	187,702	107,621	4,680
Aspen	245,715	16,401	24,308	13,321	51,290	94,292	23,090	13,021	9,992	-	-
Paper birch	-	-	-	-	-	-	-	-	-	-	-
Balsam poplar	20,759	881	-	1,090	5,982	5,886	1,113	5,807	-	-	-
Nonstocked	1,569	1,082	487	-	-	-	-	-	-	-	-
All types	1,232,948	26,107	29,413	35,006	86,454	171,908	134,288	215,034	327,025	197,784	9,929

1/ International 1/4 inch rule.

Table 8.--Growing stock volume and periodic growth on timberland by forest type, component of growth, and Forest Survey Unit, Minnesota, 1977-1987

(In thousand cubic feet)

ALL UNITS

Forest type	1977 growing stock volume 1/	Components: Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	1987 growing stock volume
Jack pine	475,351	100,465	36,740	49,178	-59,953	126,430	-130,027	-30,211	441,543
Red pine	380,987	106,619	50,038	19,573	-10,374	165,856	-23,229	-	523,614
White pine	98,460	29,842	2,060	1,930	-3,677	30,155	-3,209	-	125,406
Balsam fir	663,733	224,433	66,786	51,451	-89,073	253,597	-66,931	-9,243	841,156
White spruce	62,406	34,764	11,968	23,215	-6,884	63,063	-12,117	-	113,352
Black spruce	580,795	107,688	60,078	39,813	-122,174	85,405	-64,300	-8,680	593,220
Northern white-cedar	468,710	84,557	33,442	25,878	-53,079	90,798	-10,573	-	548,935
Tamarack	229,222	44,125	23,857	12,511	-32,177	48,316	-19,927	-3,498	254,113
Oak-hickory	901,544	179,552	17,391	32,208	-58,737	170,414	-128,094	-20,019	923,845
Elm-ash-cottonwood	665,574	130,429	43,743	42,826	-68,116	148,882	-82,432	-19,229	712,795
Maple-basswood	1,430,114	338,577	46,742	62,573	-131,719	316,173	-54,977	-13,321	1,677,989
Aspen	4,648,232	1,300,858	360,335	481,502	-566,323	1,576,372	-1,070,990	-37,291	5,116,323
Paper birch	995,854	264,149	76,160	43,174	-72,905	310,578	-56,376	-	1,250,056
Balsam poplar	407,908	174,063	32,288	29,809	-54,591	181,569	-10,395	-2,040	577,042
Nonstocked	8,476	3,205	1,214	1,194	-1,071	4,542	-986	-	12,032
All types	12,017,366	3,123,326	862,842	916,835	-1,330,853	3,572,150	-1,734,563	-143,532	13,711,421

ASPEN-BIRCH

Jack pine	129,853	25,966	11,447	15,556	-18,224	34,745	-45,825	-10,721	108,052
Red pine	177,665	59,518	20,131	6,558	-5,556	80,651	-10,606	-	247,710
White pine	51,339	14,628	572	737	-1,947	13,990	-1,003	-	64,326
Balsam fir	468,570	170,961	54,556	41,068	-65,673	200,912	-50,644	-5,818	613,020
White spruce	49,860	27,863	8,337	17,258	-4,520	48,938	-8,937	-	89,861
Black spruce	470,525	87,523	47,921	33,021	-101,899	66,566	-52,694	-5,232	479,165
Northern white-cedar	295,451	54,916	22,772	16,860	-36,157	58,391	-8,009	-	345,833
Tamarack	59,339	13,254	9,248	5,494	-9,934	18,062	-7,299	-	70,102
Oak-hickory	6,353	2,274	163	26	-289	2,174	-	-	8,527
Elm-ash-cottonwood	208,698	49,631	17,756	24,187	-23,721	67,853	-32,590	-	243,961
Maple-basswood	188,505	62,454	13,735	25,478	-16,757	84,910	-9,463	-	263,952
Aspen	1,715,921	505,198	164,838	209,950	-232,441	647,545	-442,618	-11,604	1,909,244
Paper birch	508,435	145,648	46,216	24,775	-40,469	176,170	-32,900	-	651,705
Balsam poplar	184,726	80,869	13,615	11,727	-27,800	78,411	-7,102	-	256,035
Nonstocked	3,194	1,667	490	596	-429	2,324	-262	-	5,256
All types	4,518,434	1,302,370	431,797	433,291	-585,816	1,581,642	-709,952	-33,375	5,356,749

NORTHERN PINE

Jack pine	335,083	71,333	24,826	32,038	-40,271	87,926	-82,473	-18,569	321,967
Red pine	191,867	42,078	24,055	9,857	-4,481	71,509	-11,144	-	252,232
White pine	38,026	12,608	1,488	1,187	-1,682	13,601	-2,206	-	49,421
Balsam fir	189,860	51,917	11,785	10,047	-22,674	51,075	-16,287	-3,425	221,223
White spruce	12,546	6,901	3,631	5,957	-2,364	14,125	-3,180	-	23,491
Black spruce	104,124	18,581	11,501	6,191	-19,244	17,029	-11,462	-3,171	106,520
Northern white-cedar	173,259	29,641	10,670	9,018	-16,922	32,407	-2,564	-	203,102
Tamarack	148,372	27,257	13,118	6,606	-20,214	26,767	-12,403	-	162,736
Oak-hickory	244,701	57,035	7,734	9,462	-17,091	57,140	-28,630	-9,530	263,681
Elm-ash-cottonwood	285,462	52,979	20,087	12,967	-27,223	58,810	-34,176	-3,022	307,074
Maple-basswood	581,091	142,896	20,290	20,027	-43,248	139,965	-23,441	-	697,615
Aspen	2,385,095	631,277	145,171	236,255	-279,121	733,582	-571,854	-11,863	2,534,960
Paper birch	419,045	102,531	26,423	16,821	-27,956	117,819	-20,212	-	516,652
Balsam poplar	203,101	84,714	17,228	15,258	-23,255	93,945	-2,787	-	294,259
Nonstocked	2,525	768	294	452	-555	959	-253	-	3,231
All types	5,314,157	1,332,516	338,301	392,143	-546,301	1,516,659	-823,072	-49,580	5,958,164

(Table 8 continued on next page)

(Table 8 continued)

CENTRAL HARDWOOD

Forest type	1977 growing stock volume 1/	Components							1987 growing stock volume
		Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	
Jack pine	10,415	3,166	467	1,584	-1,458	3,759	-1,729	-921	11,524
Red pine	11,455	5,023	5,852	3,158	-337	13,696	-1,479	-	23,672
White pine	9,095	2,606	-	6	-48	2,564	-	-	11,659
Balsam fir	5,303	1,555	445	336	-726	1,610	-	-	6,913
White spruce	-	-	-	-	-	-	-	-	-
Black spruce	6,146	1,584	656	601	-1,031	1,810	-144	-277	7,535
Northern white-cedar	-	-	-	-	-	-	-	-	-
Tamarack	21,190	3,561	1,491	407	-1,984	3,475	-225	-3,498	20,942
Oak-hickory	583,180	108,037	8,417	21,454	-37,733	100,175	-94,300	-10,489	578,566
Elm-ash-cottonwood	115,195	18,289	4,082	4,198	-10,003	16,566	-12,665	-11,013	108,083
Maple-basswood	509,393	111,215	11,710	14,473	-48,588	88,810	-15,104	-	583,099
Aspen	407,536	117,812	35,811	26,329	-34,819	145,133	-52,463	-8,110	492,096
Paper birch	68,374	15,970	3,521	1,578	-4,480	16,589	-3,264	-	81,699
Balsam poplar	6,783	2,628	149	1,884	-2,257	2,404	-150	-	9,037
Nonstocked	2,115	580	-	129	-87	622	-471	-	2,266
All types	1,756,180	392,026	72,601	76,137	-143,551	397,213	-181,994	-34,308	1,937,091

PRAIRIE

Jack pine	-	-	-	-	-	-	-	-	-
Red pine	-	-	-	-	-	-	-	-	-
White pine	-	-	-	-	-	-	-	-	-
Balsam fir	-	-	-	-	-	-	-	-	-
White spruce	-	-	-	-	-	-	-	-	-
Black spruce	-	-	-	-	-	-	-	-	-
Northern white-cedar	-	-	-	-	-	-	-	-	-
Tamarack	321	53	-	4	-45	12	-	-	333
Oak-hickory	67,310	12,206	1,077	1,266	-3,624	10,925	-5,164	-	73,071
Elm-ash-cottonwood	56,219	9,530	1,818	1,474	-7,169	5,653	-3,001	-5,194	53,677
Maple-basswood	151,125	22,012	1,007	2,595	-23,126	2,488	-6,969	-13,321	133,323
Aspen	139,680	46,571	14,515	8,968	-19,942	50,112	-4,055	-5,714	180,023
Paper birch	-	-	-	-	-	-	-	-	-
Balsam poplar	13,298	5,852	1,296	940	-1,279	6,809	-356	-2,040	17,711
Nonstocked	642	190	430	17	-	637	-	-	1,279
All types	428,595	96,414	20,143	15,264	-55,185	76,636	-19,545	-26,269	459,417

1/ Figures have been adjusted from those published after the 1977 survey to conform to changes in survey definitions and procedures.

2/ Includes growth on ingrowth, mortality and removals.

Table 9.--Growing stock volume and periodic growth on timberland by species group, component of growth, and Forest Survey Unit, Minnesota, 1977-1987

(In thousand cubic feet)

ALL UNITS

Species group	1977 growing stock volume 1/	Components							1987 growing stock volume
		Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	
Softwoods									
Jack pine	517,900	98,025	27,262	52,624	-81,888	96,023	-155,949	-24,794	433,180
Red pine	426,989	116,341	56,262	28,730	-807	200,526	-56,218	-2,349	568,948
White pine	196,373	55,617	1,054	10,619	-4,408	62,882	-33,338	-814	225,103
White spruce	185,701	142,048	18,859	41,407	-6,532	195,782	-29,908	-969	350,606
Black spruce	577,723	96,788	46,500	42,217	-146,259	39,246	-70,134	-7,568	539,267
Balsam fir 3/	809,707	323,835	80,056	92,594	-132,437	364,048	-93,185	-6,319	1,074,251
Tamarack	285,924	50,119	28,100	13,664	-38,163	53,720	-21,269	-4,599	313,776
Eastern redcedar	3,723	1,412	535	77	-	2,024	-	-38	5,709
Northern white-cedar	446,978	87,858	32,796	17,284	-11,652	126,286	-10,339	-1,056	561,869
Other softwoods	1,064	422	-	-	-	422	-	-	1,486
Total	3,452,082	972,465	291,424	299,216	-422,146	1,140,959	-470,340	-48,506	4,074,195
Hardwoods									
Select white oak	384,254	73,773	10,213	6,552	-1,325	89,213	-25,015	-7,310	441,142
Select red oak	653,067	148,619	5,865	23,153	-49,351	128,286	-74,951	-11,504	694,898
Other red oak	13,100	1,974	-	533	-1,858	649	-1,735	-230	11,784
Select hickory	12,380	2,248	734	114	-684	2,412	-381	-211	14,200
Other hickory	5,997	1,100	-	88	-456	732	-228	-147	6,354
Basswood	469,392	133,247	11,390	12,579	-17,514	139,702	-12,383	-4,973	591,738
Yellow birch	13,800	2,198	129	722	-1,716	1,333	-310	-15	14,808
Hard maple	251,181	67,149	32,474	12,465	-7,263	104,825	-7,599	-1,263	347,144
Soft maple	175,487	52,461	36,781	9,976	-8,713	90,505	-6,070	-2,074	257,848
Elm	465,624	92,262	4,683	20,769	-101,657	16,057	-39,436	-9,094	433,151
Black ash	533,315	88,177	63,824	21,098	-51,134	121,965	-28,924	-7,478	618,878
White & green ash	110,490	28,118	4,899	3,027	-6,704	29,340	-1,367	-2,618	135,845
Cottonwood	27,651	3,614	-	919	-3,456	1,077	-2,693	-1,498	24,537
Willow	23,638	4,623	-	109	-636	4,096	-	-2,298	25,436
Hackberry	4,476	1,397	-	106	-354	1,149	-136	-180	5,309
Balsam poplar	523,789	230,760	19,020	47,969	-81,344	216,405	-39,502	-4,014	696,678
Bigtooth aspen	194,539	60,927	3,727	19,007	-27,092	56,569	-46,015	-1,822	203,271
Quaking aspen	3,283,216	859,758	245,811	392,893	-479,168	1,019,294	-906,352	-28,596	3,367,562
Paper birch	1,366,347	286,441	128,161	44,049	-64,064	394,587	-69,608	-7,534	1,683,792
River birch	441	211	-	-	-	211	-	-35	617
Black cherry	11,936	2,741	1,411	381	-107	4,426	-510	-193	15,659
Black walnut	6,886	1,430	-	199	-662	967	-486	-212	7,155
Butternut	7,883	1,887	366	58	-127	2,184	-118	-112	9,837
Other hardwoods	26,395	5,746	1,930	853	-3,322	5,207	-404	-1,615	29,583
Total	8,565,284	2,150,861	571,418	617,619	-908,707	2,431,191	-1,264,223	-95,026	9,637,226
All species	12,017,366	3,123,326	862,842	916,835	-1,330,853	3,572,150	-1,734,563	-143,532	13,711,421

(Table 9 continued on next page)

(Table 9 continued)

ASPEN-BIRCH

Species group	1977 growing stock volume 1/	Components							1987 growing stock volume
		Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	
Softwoods									
Jack pine	158,752	26,861	3,574	18,223	-26,478	22,180	-62,249	-8,242	110,441
Red pine	165,197	52,984	22,155	10,790	-136	85,793	-24,084	-662	226,244
White pine	99,535	26,048	282	6,469	-3,411	29,388	-22,788	-432	105,703
White spruce	135,205	104,912	12,834	27,503	-4,468	140,781	-20,035	-612	255,339
Black spruce	452,018	77,153	35,878	32,161	-116,346	28,846	-51,759	-4,907	424,198
Balsam fir 3/	516,104	222,443	60,578	66,916	-90,290	259,647	-58,549	-3,949	713,253
Tamarack	88,851	16,815	12,431	6,920	-13,646	22,520	-11,196	-475	99,700
Eastern redcedar	109	50	165	16	-	231	-	-	340
Northern white-cedar	273,532	56,844	24,761	12,100	-8,525	85,180	-8,582	-639	349,491
Other softwoods	-	-	-	-	-	-	-	-	-
Total	1,889,303	584,110	172,658	181,098	-263,300	674,566	-259,242	-19,918	2,284,709
Hardwoods									
Select white oak	4,941	1,384	163	102	-	1,649	-	-71	6,519
Select red oak	10,792	3,581	345	691	-1,034	3,583	-270	-12	14,093
Other red oak	-	-	-	-	-	-	-	-	-
Select hickory	-	-	-	-	-	-	-	-	-
Other hickory	-	-	-	-	-	-	-	-	-
Basswood	34,246	14,010	1,823	3,180	-1,358	17,655	-365	-85	51,451
Yellow birch	8,747	1,365	-	564	-986	943	-96	-4	9,590
Hard maple	58,872	20,226	12,576	5,839	-1,820	36,821	-740	-42	94,911
Soft maple	38,718	14,944	17,247	5,056	-2,173	35,074	-1,128	-108	72,556
Elm	45,609	11,723	571	3,316	-10,390	5,220	-1,871	-57	48,901
Black ash	199,668	38,870	27,428	11,252	-20,436	57,114	-5,638	-439	250,705
White & green ash	9,647	3,817	694	870	-321	5,060	-439	-28	14,240
Cottonwood	418	151	-	-	-	151	-	-22	547
Willow	-	-	-	-	-	-	-	-	-
Hackberry	-	-	-	-	-	-	-	-	-
Balsam poplar	228,683	102,434	6,721	21,880	-38,333	92,702	-20,503	-718	300,164
Bigtooth aspen	36,465	10,886	1,337	4,125	-6,168	10,180	-8,056	-116	38,473
Quaking aspen	1,282,891	343,382	111,711	172,415	-209,056	418,452	-384,467	-8,904	1,307,972
Paper birch	669,191	151,373	78,523	22,887	-30,441	222,342	-27,137	-2,851	861,545
River birch	-	-	-	-	-	-	-	-	-
Black cherry	105	45	-	-	-	45	-	-	150
Black walnut	-	-	-	-	-	-	-	-	-
Butternut	-	-	-	-	-	-	-	-	-
Other hardwoods	138	69	-	16	-	85	-	-	223
Total	2,629,131	718,260	259,139	252,193	-322,516	907,076	-450,710	-13,457	3,072,040
All species	4,518,434	1,302,370	431,797	433,291	-585,816	1,581,642	-709,952	-33,375	5,356,749

(Table 9 continued on next page)

(Table 9 continued)

NORTHERN PINE

Species group	1977 growing stock volume 1/	Components							1987 growing stock volume
		Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	
Softwoods									
Jack pine	347,807	68,795	22,904	32,163	-53,653	70,209	-89,647	-15,697	312,672
Red pine	244,202	56,242	27,378	14,127	-671	97,076	-29,385	-1,548	310,345
White pine	82,612	24,994	519	3,813	-949	28,377	-10,024	-225	100,740
White spruce	48,009	35,838	5,931	13,507	-2,064	53,212	-9,873	-276	91,072
Black spruce	120,702	18,536	10,024	9,686	-28,983	9,263	-18,375	-2,475	109,115
Balsam fir 3/	287,022	98,611	19,299	24,827	-40,833	101,904	-34,345	-2,245	352,336
Tamarack	168,599	28,469	14,295	6,343	-21,899	27,208	-9,837	-552	185,418
Eastern redcedar	381	164	-	-	-	164	-	-12	533
Northern white-cedar	173,446	31,014	8,035	5,184	-3,127	41,106	-1,757	-417	212,378
Other softwoods	-	-	-	-	-	-	-	-	-
Total	1,472,780	362,663	108,385	109,650	-152,179	428,519	-203,243	-23,447	1,674,609
Hardwoods									
Select white oak	130,633	28,895	7,078	2,686	-521	38,138	-5,478	-2,158	161,135
Select red oak	257,810	66,724	3,287	10,007	-22,396	57,622	-23,711	-5,076	286,645
Other red oak	1,102	273	-	215	-270	218	-	-	1,320
Select hickory	-	-	-	-	-	-	-	-	-
Other hickory	570	102	-	29	-	131	-123	-14	564
Basswood	237,311	72,549	5,871	5,070	-7,274	76,216	-5,759	-743	307,025
Yellow birch	4,864	815	129	147	-730	361	-108	-11	5,106
Hard maple	110,394	27,323	16,090	4,747	-3,375	44,785	-3,998	-140	151,041
Soft maple	81,154	24,069	12,794	3,412	-3,392	36,883	-3,794	-499	113,744
Elm	165,767	42,748	1,970	6,710	-27,698	23,730	-8,485	-1,178	179,834
Black ash	260,101	39,852	32,121	6,599	-24,958	53,614	-10,132	-1,752	301,831
White & green ash	27,017	7,750	2,125	591	-1,574	8,892	-517	-111	35,281
Cottonwood	87	17	-	-	-	17	-	-	104
Willow	77	34	-	-	-	34	-	-	111
Hackberry	-	-	-	-	-	-	-	-	-
Balsam poplar	258,400	112,037	10,783	22,224	-38,205	106,839	-14,957	-844	349,438
Bigtooth aspen	124,860	39,249	1,802	12,129	-16,443	36,737	-32,110	-1,281	128,206
Quaking aspen	1,597,070	394,345	97,344	190,722	-219,849	462,562	-475,363	-9,031	1,575,238
Paper birch	579,405	111,801	37,548	17,016	-27,283	139,082	-35,137	-3,232	680,118
River birch	-	-	-	-	-	-	-	-	-
Black cherry	1,273	354	472	128	-	954	-157	-8	2,062
Black walnut	-	-	-	-	-	-	-	-	-
Butternut	1,661	428	-	-	-	428	-	-34	2,055
Other hardwoods	1,821	488	502	61	-154	897	-	-21	2,697
Total	3,841,377	969,853	229,916	282,493	-394,122	1,088,140	-619,829	-26,133	4,283,555
All species	5,314,157	1,332,516	338,301	392,143	-546,301	1,516,659	-823,072	-49,580	5,958,164

(Table 9 continued on next page)

(Table 9 continued)

CENTRAL HARDWOOD

Species group	1977 growing stock volume 1/	Components							1987 growing stock volume
		Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	
Softwoods									
Jack pine	11,022	2,294	784	2,238	-1,757	3,559	-4,053	-855	9,673
Red pine	17,084	7,001	6,729	3,813	-	17,543	-2,749	-139	31,739
White pine	14,226	4,575	253	337	-48	5,117	-526	-157	18,660
White spruce	2,016	1,133	94	397	-	1,624	-	-54	3,586
Black spruce	4,844	1,083	598	366	-885	1,162	-	-186	5,820
Balsam fir 3/	6,491	2,719	179	851	-1,314	2,435	-291	-125	8,510
Tamarack	28,055	4,785	1,374	373	-2,618	3,914	-42	-3,565	28,362
Eastern redcedar	2,265	929	-	28	-	957	-	-16	3,206
Northern white-cedar	-	-	-	-	-	-	-	-	-
Other softwoods	1,064	422	-	-	-	422	-	-	1,486
Total	87,067	24,941	10,011	8,403	-6,622	36,733	-7,661	-5,097	111,042
Hardwoods									
Select white oak	181,546	31,994	1,828	2,948	-756	36,014	-15,816	-3,115	198,629
Select red oak	365,684	74,693	2,233	12,170	-24,532	64,564	-50,084	-5,612	374,552
Other red oak	11,479	1,622	-	308	-1,588	342	-1,626	-223	9,972
Select hickory	12,380	2,248	734	114	-684	2,412	-381	-211	14,200
Other hickory	4,935	898	-	59	-456	501	-105	-108	5,223
Basswood	160,336	39,511	3,450	3,949	-6,464	40,446	-6,259	-998	193,525
Yellow birch	189	18	-	11	-	29	-106	-	112
Hard maple	71,565	17,612	3,808	1,420	-1,407	21,433	-2,091	-246	90,661
Soft maple	51,536	12,990	6,740	1,426	-2,828	18,328	-129	-1,169	68,566
Elm	189,473	32,128	1,937	8,505	-41,490	1,080	-21,827	-2,600	166,126
Black ash	65,775	8,646	3,934	2,825	-5,054	10,351	-10,630	-4,601	60,895
White & green ash	48,718	11,915	1,611	1,273	-3,073	11,726	-178	-399	59,867
Cottonwood	13,188	1,454	-	426	-1,900	-20	-1,663	-470	11,035
Willow	9,161	1,925	-	98	-440	1,583	-	-792	9,952
Hackberry	2,617	853	-	36	-266	623	-	-28	3,212
Balsam poplar	12,409	4,344	281	2,594	-2,679	4,540	-3,648	-215	13,086
Bigtooth aspen	33,173	10,750	588	2,753	-4,481	9,610	-5,849	-425	36,509
Quaking aspen	286,497	83,071	22,367	21,906	-30,730	96,614	-45,857	-5,702	331,552
Paper birch	114,876	22,831	11,400	3,988	-6,159	32,060	-6,723	-1,258	138,955
River birch	441	211	-	-	-	211	-	-35	617
Black cherry	9,407	2,117	509	236	-107	2,755	-353	-185	11,624
Black walnut	5,530	1,174	-	171	-487	858	-486	-114	5,788
Butternut	6,101	1,447	366	58	-127	1,744	-118	-62	7,665
Other hardwoods	12,097	2,633	804	460	-1,221	2,676	-404	-643	13,726
Total	1,669,113	367,085	62,590	67,734	-136,929	360,480	-174,333	-29,211	1,826,049
All species	1,756,180	392,026	72,601	76,137	-143,551	397,213	-181,994	-34,308	1,937,091

(Table 9 continued on next page)

(Table 9 continued)

PRAIRIE

Species group	1977 growing stock volume 1/	Components: Survivor growth	Ingrowth	Other 2/ growth	Mortality	Net growth	Removals	Other removals	1987 growing stock volume
Softwoods									
Jack pine	319	75	-	-	-	75	-	-	394
Red pine	506	114	-	-	-	114	-	-	620
White pine	-	-	-	-	-	-	-	-	-
White spruce	471	165	-	-	-	165	-	-27	609
Black spruce	159	16	-	4	-45	-25	-	-	134
Balsam fir 3/	90	62	-	-	-	62	-	-	152
Tamarack	419	50	-	28	-	78	-194	-7	296
Eastern redcedar	968	269	370	33	-	672	-	-10	1,630
Northern white-cedar	-	-	-	-	-	-	-	-	-
Other softwoods	-	-	-	-	-	-	-	-	-
Total	2,932	751	370	65	-45	1,141	-194	-44	3,835
Hardwoods									
Select white oak	67,134	11,500	1,144	816	-48	13,412	-3,721	-1,966	74,859
Select red oak	18,781	3,621	-	285	-1,389	2,517	-886	-804	19,608
Other red oak	519	79	-	10	-	89	-109	-7	492
Select hickory	-	-	-	-	-	-	-	-	-
Other hickory	492	100	-	-	-	100	-	-25	567
Basswood	37,499	7,177	246	380	-2,418	5,385	-	-3,147	39,737
Yellow birch	-	-	-	-	-	-	-	-	-
Hard maple	10,350	1,988	-	459	-661	1,786	-770	-835	10,531
Soft maple	4,079	458	-	82	-320	220	-1,019	-298	2,982
Elm	64,775	5,663	205	2,238	-22,079	-13,973	-7,253	-5,259	38,290
Black ash	7,771	809	341	422	-686	886	-2,524	-686	5,447
White & green ash	25,108	4,636	469	293	-1,736	3,662	-233	-2,080	26,457
Cottonwood	13,958	1,992	-	493	-1,556	929	-1,030	-1,006	12,851
Willow	14,400	2,664	-	11	-196	2,479	-	-1,506	15,373
Hackberry	1,859	544	-	70	-88	526	-136	-152	2,097
Balsam poplar	24,297	11,945	1,235	1,271	-2,127	12,324	-394	-2,237	33,990
Bigtooth aspen	41	42	-	-	-	42	-	-	83
Quaking aspen	116,758	38,960	14,389	7,850	-19,533	41,666	-665	-4,959	152,800
Paper birch	2,875	436	690	158	-181	1,103	-611	-193	3,174
River birch	-	-	-	-	-	-	-	-	-
Black cherry	1,151	225	430	17	-	672	-	-	1,823
Black walnut	1,356	256	-	28	-175	109	-	-98	1,367
Butternut	121	12	-	-	-	12	-	-16	117
Other hardwoods	12,339	2,556	624	316	-1,947	1,549	-	-951	12,937
Total	425,663	95,663	19,773	15,199	-55,140	75,495	-19,351	-26,225	455,582
All species	428,595	96,414	20,143	15,264	-55,185	76,636	-19,545	-26,269	459,417

1/ Figures have been adjusted from those published after the 1977 survey to conform to changes in survey definitions and procedures.

2/ Includes growth on ingrowth, mortality and removals.

3/ The reader is cautioned to review the highlights section of this report particularly the section titled "Net Growth", before further analysis.

Table 10.--Sawtimber volume and periodic growth on timberland by forest type and component of growth, Minnesota, 1977-1987

(In thousand board feet) 1/

Forest type	1977 sawtimber volume 2/	Components							1987 sawtimber volume
		Survivor growth	Ingrowth	Other growth 3/	Mortality	Net growth	Removals	Other removals	
Jack pine	1,081,762	154,699	241,872	214,551	-146,273	464,849	-466,287	-71,482	1,008,842
Red pine	1,315,883	305,130	241,537	76,570	-22,108	601,129	-70,408	-	1,846,604
White pine	382,913	116,522	23,991	10,959	-14,961	136,511	-4,520	-	514,904
Balsam fir	1,257,348	381,354	394,786	220,832	-164,931	832,041	-209,250	-17,435	1,862,704
White spruce	149,239	61,144	62,765	56,053	-16,525	163,437	-35,914	-	276,762
Black spruce	484,906	88,191	170,954	70,858	-86,505	243,498	-92,912	-7,017	628,475
Northern white-cedar	1,023,892	138,339	192,913	72,385	-128,592	275,045	-38,320	-	1,260,617
Tamarack	258,240	52,753	83,145	25,431	-32,183	129,146	-20,167	-5,923	361,296
Oak-hickory	2,547,760	376,986	382,998	181,595	-154,800	786,779	-528,476	-53,967	2,752,096
Elm-ash-cottonwood	1,410,185	203,223	302,903	139,372	-199,312	446,186	-207,903	-44,536	1,603,932
Maple-basswood	4,074,323	762,634	643,140	230,125	-425,930	1,209,969	-126,950	-52,086	5,105,256
Aspen	7,556,483	1,751,198	2,877,376	2,365,457	-1,036,615	5,957,416	-3,383,646	-54,400	10,075,853
Paper birch	1,429,720	377,555	495,822	185,600	-138,849	920,128	-136,163	-	2,213,685
Balsam poplar	740,000	276,724	298,008	122,835	-104,944	592,623	-11,448	-2,151	1,319,024
Nonstocked	16,248	3,361	8,933	2,821	-2,388	12,727	-2,731	-	26,244
All types	23,728,902	5,049,813	6,421,143	3,975,444	-2,674,916	12,771,484	-5,335,095	-308,997	30,856,294

1/ International 1/4 inch rule.

2/ Figures have been adjusted from those published after the 1977 survey to conform to changes in survey definitions and procedures.

3/ Includes growth on ingrowth, mortality and removals.

Table 11.--Sawtimber volume and periodic growth on timberland by species group and component of growth, Minnesota, 1977-1987

(In thousand board feet) 1/

Species group	1977 sawtimber volume 2/	Components							1987 sawtimber volume
		Survivor growth	Ingrowth	Other 3/ growth	Mortality	Net growth	Removals	Other removals	
Softwoods									
Jack pine	1,393,270	167,279	262,229	253,527	-283,017	400,018	-595,574	-63,704	1,134,010
Red pine	1,880,496	405,760	276,999	128,469	-4,463	806,765	-274,527	-11,138	2,401,596
White pine	970,821	272,243	27,620	59,411	-25,329	333,945	-163,289	-4,169	1,137,308
White spruce	686,800	416,403	203,163	208,909	-25,241	803,234	-117,897	-3,329	1,368,808
Black spruce	467,555	73,124	117,278	76,296	-130,967	135,731	-93,982	-4,570	504,734
Balsam fir	1,256,349	469,142	501,692	310,110	-202,915	1,078,029	-199,961	-9,222	2,125,195
Tamarack	377,534	70,132	115,386	34,759	-47,842	172,435	-26,845	-7,702	515,422
Eastern redcedar	5,978	1,539	4,968	963	-	7,470	-	-37	13,411
Northern white-cedar	1,207,720	188,719	207,586	61,231	-47,140	410,396	-34,490	-2,944	1,580,682
Other softwoods	2,914	671	-	-	-	671	-	-	3,585
Total	8,249,437	2,065,012	1,716,921	1,133,675	-766,914	4,148,694	-1,506,565	-106,815	10,784,751
Hardwoods									
Select white oak	1,140,367	149,457	156,309	33,118	-2,652	336,232	-101,585	-23,518	1,351,496
Select red oak	1,879,382	341,182	331,245	128,567	-92,706	708,288	-335,213	-34,832	2,217,625
Other red oak	52,787	6,303	925	2,297	-7,535	1,990	-8,353	-1,093	45,331
Select hickory	26,974	2,755	7,900	608	-1,503	9,760	-1,792	-538	34,404
Other hickory	7,141	889	1,129	98	-	2,116	-	-119	9,138
Basswood	1,225,526	263,604	236,003	61,877	-44,846	516,638	-39,128	-17,593	1,685,443
Yellow birch	53,037	7,346	637	2,367	-5,086	5,264	-1,347	-	56,954
Hard maple	583,821	112,987	98,540	28,017	-13,077	226,467	-17,927	-3,538	788,823
Soft maple	250,341	36,374	78,402	12,735	-13,330	114,181	-13,912	-4,871	345,739
Elm	1,451,195	171,826	137,610	86,958	-405,779	-9,385	-131,281	-31,510	1,279,019
Black ash	674,855	60,247	252,755	49,255	-91,638	270,619	-52,906	-8,558	884,010
White & green ash	247,584	38,257	80,846	10,658	-5,438	124,323	-3,257	-8,299	360,351
Cottonwood	116,219	12,457	2,727	2,723	-16,419	1,488	-7,855	-6,400	103,452
Willow	66,559	10,329	7,857	964	-2,412	16,738	-	-6,482	76,815
Hackberry	13,211	3,835	2,348	1,284	-996	6,471	-638	-533	18,511
Balsam poplar	939,332	313,558	366,740	196,804	-176,952	700,150	-107,163	-5,929	1,526,390
Bigtooth aspen	355,304	75,063	157,923	113,921	-59,842	287,065	-148,787	-3,255	490,327
Quaking aspen	5,173,649	1,151,255	2,191,399	1,973,388	-882,883	4,433,159	-2,759,862	-35,254	6,811,692
Paper birch	1,105,834	210,561	565,939	132,063	-74,520	834,043	-94,950	-5,720	1,839,207
River birch	369	154	1,176	218	-	1,548	-	-37	1,880
Black cherry	20,348	2,661	4,749	447	-	7,857	-608	-282	27,315
Black walnut	25,719	3,741	5,533	1,020	-1,769	8,525	-1,966	-732	31,546
Butternut	23,369	3,409	4,024	249	-709	6,973	-	-378	29,964
Other hardwoods	46,542	6,551	11,506	2,133	-7,910	12,280	-	-2,711	56,111
Total	15,479,465	2,984,801	4,704,222	2,841,769	-1,908,002	8,622,790	-3,828,530	-202,182	20,071,543
All species	23,728,902	5,049,813	6,421,143	3,975,444	-2,674,916	12,771,484	-5,335,095	-308,997	30,856,294

1/ International 1/4 inch rule.

2/ Figures have been adjusted from those published after the 1977 survey to conform to changes in survey definitions and procedures.

3/ Includes growth on ingrowth, mortality and removals.

Table 12.--Net volume of growing stock on timberland by species group and forest type, Minnesota, 1987

(In thousand cubic feet)

Species group	All types	Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar
Softwoods								
Jack pine	433,180	305,693	30,756	3,608	5,955	2,255	11,648	313
Red pine	568,948	47,624	367,431	19,703	26,525	1,961	1,193	844
White pine	225,103	2,135	31,108	67,913	13,507	1,297	4,045	4,324
White spruce	350,606	3,825	6,116	7,649	69,314	70,150	5,875	4,536
Black spruce	539,267	6,908	3,330	1,979	46,311	1,695	379,140	37,889
Balsam fir	1,074,251	5,697	17,560	4,084	379,608	9,206	35,630	46,629
Tamarack	313,776	126	391	-	11,026	299	58,135	17,374
Eastern redcedar	5,709	-	-	-	-	-	237	-
Northern white-cedar	561,869	-	397	376	50,176	2,603	17,524	380,655
Other softwoods	1,486	-	779	-	-	-	-	-
Total	4,074,195	372,008	457,868	105,312	602,422	89,466	513,427	492,564
Hardwoods								
Select white oak	441,142	1,042	315	914	757	70	-	-
Select red oak	694,898	3,537	2,923	821	942	-	379	-
Other red oak	11,784	-	-	-	-	-	-	-
Select hickory	14,200	-	-	-	-	-	-	-
Other hickory	6,354	-	-	-	-	-	-	-
Basswood	591,738	587	-	612	1,310	-	-	-
Yellow birch	14,808	-	-	-	542	-	-	659
Hard maple	347,144	322	-	207	2,142	1,271	-	-
Soft maple	257,848	203	1,412	727	3,230	-	1,316	101
Elm	433,151	184	92	-	2,140	-	-	217
Black ash	618,878	134	1,361	109	11,971	-	5,973	12,588
White & green ash	135,845	-	-	385	109	-	150	154
Cottonwood	24,537	-	104	-	-	-	-	-
Willow	25,436	-	-	-	-	-	-	-
Hackberry	5,309	-	-	-	-	-	-	-
Balsam poplar	696,678	616	1,189	96	19,831	890	3,613	4,667
Bigtooth aspen	203,271	2,793	2,101	-	1,509	-	977	647
Quaking aspen	3,367,562	46,693	38,053	7,172	87,982	12,457	45,329	6,547
Paper birch	1,683,792	13,117	18,196	9,051	106,269	9,198	22,056	30,791
River birch	617	-	-	-	-	-	-	-
Black cherry	15,659	-	-	-	-	-	-	-
Black walnut	7,155	-	-	-	-	-	-	-
Butternut	9,837	-	-	-	-	-	-	-
Other hardwoods	29,583	307	-	-	-	-	-	-
Total	9,637,226	69,535	65,746	20,094	238,734	23,886	79,793	56,371
All species	13,711,421	441,543	523,614	125,406	841,156	113,352	593,220	548,935

(Table 12 continued)

Species group	Tamarack	Oak-hickory	Elm-ash-cottonwood	Maple-basswood	Aspen	Paper birch	Balsam poplar	Nonstocked
Softwoods								
Jack pine	854	7,749	249	5,098	49,744	7,865	1,185	208
Red pine	618	10,713	567	3,803	63,227	24,357	382	-
White pine	1,867	2,201	1,187	20,746	54,945	19,184	644	-
White spruce	1,620	1,378	7,786	17,493	116,163	28,514	10,187	-
Black spruce	21,030	-	2,428	3,691	28,196	4,239	1,948	483
Balsam fir	4,162	996	34,523	51,668	331,810	102,305	49,894	479
Tamarack	200,497	143	3,876	3,001	10,634	3,049	4,436	789
Eastern redcedar	-	3,149	108	1,336	107	584	188	-
Northern white-cedar	6,719	-	30,457	9,491	31,897	21,988	9,073	513
Other softwoods	-	707	-	-	-	-	-	-
Total	237,367	27,036	81,181	116,327	686,723	212,085	77,937	2,472
Hardwoods								
Select white oak	-	224,611	9,259	77,525	112,981	11,047	2,374	247
Select red oak	261	402,002	1,796	87,627	154,435	39,002	1,173	-
Other red oak	-	7,437	376	2,094	1,590	102	185	-
Select hickory	-	12,506	-	960	-	734	-	-
Other hickory	-	3,358	-	2,768	-	228	-	-
Basswood	-	34,139	14,411	403,807	106,544	26,603	3,725	-
Yellow birch	-	-	1,767	9,290	277	2,015	258	-
Hard maple	-	8,354	3,587	267,093	42,671	18,679	2,368	450
Soft maple	440	9,089	34,870	73,260	101,980	30,220	1,000	-
Elm	1,089	27,411	63,168	218,700	83,077	20,164	16,481	428
Black ash	1,410	4,260	352,282	60,378	100,186	34,041	33,382	803
White & green ash	-	7,699	10,659	86,428	24,584	3,286	2,113	278
Cottonwood	-	1,063	17,172	5,119	1,079	-	-	-
Willow	-	118	18,905	4,812	941	-	347	313
Hackberry	-	1,383	1,075	2,851	-	-	-	-
Balsam poplar	3,023	2,312	26,878	24,725	255,173	38,411	314,139	1,115
Bigtooth aspen	-	13,844	1,968	17,313	147,413	14,430	276	-
Quaking aspen	5,097	61,674	24,576	96,832	2,692,572	147,842	89,923	4,813
Paper birch	5,426	55,929	31,761	103,105	596,709	650,518	31,096	570
River birch	-	-	499	118	-	-	-	-
Black cherry	-	6,266	109	4,359	3,847	442	189	447
Black walnut	-	4,002	740	2,196	127	90	-	-
Butternut	-	6,700	87	2,014	919	117	-	-
Other hardwoods	-	2,652	15,669	8,288	2,495	-	76	96
Total	16,746	896,809	631,614	1,561,662	4,429,600	1,037,971	499,105	9,560
All species	254,113	923,845	712,795	1,677,989	5,116,323	1,250,056	577,042	12,032

Table 13.--Net volume of sawtimber on timberland by species group and forest type, Minnesota, 1987

(In thousand board feet) 1/

Species group	All types	Jack pine	Red pine	White pine	Balsam fir	White spruce	Black spruce	Northern white-cedar
Softwoods								
Jack pine	1,134,010	729,551	72,809	14,056	24,020	8,532	37,642	1,646
Red pine	2,401,596	177,423	1,480,138	91,566	108,572	9,547	6,835	4,855
White pine	1,137,308	7,310	144,098	337,534	73,738	6,839	18,574	24,756
White spruce	1,368,808	13,078	25,083	25,910	284,511	195,057	19,712	16,292
Black spruce	504,734	6,906	988	1,830	65,392	842	274,816	68,646
Balsam fir	2,125,195	10,256	24,985	5,242	708,489	12,516	46,046	64,192
Tamarack	515,422	686	543	-	26,789	1,571	83,286	31,106
Eastern redcedar	13,411	-	-	-	-	-	-	-
Northern white-cedar	1,580,682	-	1,511	562	175,921	11,786	31,604	956,126
Other softwoods	3,585	-	-	-	-	-	-	-
Total	10,784,751	945,210	1,750,155	476,700	1,467,432	246,690	518,515	1,167,619
Hardwoods								
Select white oak	1,351,496	1,164	507	1,141	1,918	-	-	-
Select red oak	2,217,625	4,624	4,056	3,486	539	-	594	-
Other red oak	45,331	-	-	-	-	-	-	-
Select hickory	34,404	-	-	-	-	-	-	-
Other hickory	9,138	-	-	-	-	-	-	-
Basswood	1,685,443	-	-	2,430	4,632	-	-	-
Yellow birch	56,954	-	-	-	1,117	-	-	1,829
Hard maple	788,823	-	-	1,114	705	1,625	-	-
Soft maple	345,739	-	799	681	2,999	-	1,435	-
Elm	1,279,019	536	-	-	4,928	-	-	803
Black ash	884,010	-	-	741	12,560	-	10,808	12,442
White & green ash	360,351	-	-	655	-	-	-	902
Cottonwood	103,452	-	-	-	-	-	-	-
Willow	76,815	-	-	-	-	-	-	-
Hackberry	18,511	-	-	-	-	-	-	-
Balsam poplar	1,526,390	541	1,974	-	39,008	785	4,364	7,292
Bigtooth aspen	490,327	5,336	4,641	-	3,604	-	1,518	1,180
Quaking aspen	6,811,692	45,246	66,921	21,616	174,307	13,391	72,247	17,944
Paper birch	1,839,207	6,185	17,551	6,340	148,955	14,271	18,994	50,606
River birch	1,880	-	-	-	-	-	-	-
Black cherry	27,315	-	-	-	-	-	-	-
Black walnut	31,546	-	-	-	-	-	-	-
Butternut	29,964	-	-	-	-	-	-	-
Other hardwoods	56,111	-	-	-	-	-	-	-
Total	20,071,543	63,632	96,449	38,204	395,272	30,072	109,960	92,998
All species	30,856,294	1,008,842	1,846,604	514,904	1,862,704	276,762	628,475	1,260,617

(Table 13 continued on next page)

(Table 13 continued)

Species group	Tamarack	Oak-hickory	Elm-ash-cottonwood	Maple-basswood	Aspen	Paper birch	Balsam poplar	Nonstocked
Softwoods								
Jack pine	2,840	24,457	-	22,076	165,201	29,052	2,128	-
Red pine	3,591	49,914	3,286	12,167	320,990	130,507	2,205	-
White pine	9,448	10,551	6,533	114,420	277,320	102,429	3,758	-
White spruce	5,023	6,917	38,591	81,206	485,342	121,898	50,188	-
Black spruce	12,972	-	4,918	6,331	42,207	11,430	7,024	432
Balsam fir	7,219	2,405	72,232	144,570	676,294	223,415	125,768	1,566
Tamarack	278,147	789	11,451	9,074	37,429	9,678	21,129	3,744
Eastern redcedar	-	6,661	622	2,987	-	2,032	1,109	-
Northern white-cedar	17,050	-	109,192	44,495	112,592	83,821	33,324	2,698
Other softwoods	-	3,585	-	-	-	-	-	-
Total	336,290	105,279	246,825	437,326	2,117,375	714,262	246,633	8,440
Hardwoods								
Select white oak	-	747,508	32,347	286,979	248,820	24,217	5,977	918
Select red oak	1,285	1,345,321	2,730	338,649	410,583	101,491	4,267	-
Other red oak	-	30,116	1,853	9,694	2,785	-	883	-
Select hickory	-	29,155	-	1,286	-	3,963	-	-
Other hickory	-	2,805	-	5,678	-	655	-	-
Basswood	-	81,276	49,883	1,306,971	186,941	47,893	5,417	-
Yellow birch	-	-	6,040	39,239	518	6,808	1,403	-
Hard maple	-	11,970	7,857	709,632	39,422	14,046	2,452	-
Soft maple	-	12,710	120,626	129,884	63,910	11,673	1,022	-
Elm	1,020	73,092	183,750	733,978	185,152	44,605	49,899	1,256
Black ash	-	2,641	543,005	108,969	113,463	40,987	38,394	-
White & green ash	-	17,725	35,895	261,437	32,612	6,475	3,025	1,625
Cottonwood	-	4,786	73,405	21,221	4,040	-	-	-
Willow	-	500	55,256	15,631	4,038	-	-	1,390
Hackberry	-	5,198	4,296	9,017	-	-	-	-
Balsam poplar	5,262	3,846	73,932	72,194	538,075	93,609	685,508	-
Bigtooth aspen	-	45,667	6,715	52,853	329,109	39,170	534	-
Quaking aspen	11,437	132,241	73,532	292,157	5,248,711	411,391	219,633	10,918
Paper birch	6,002	43,556	55,634	220,899	543,865	651,224	53,977	1,148
River birch	-	-	1,880	-	-	-	-	-
Black cherry	-	13,939	-	12,655	721	-	-	-
Black walnut	-	19,124	1,941	9,249	663	569	-	-
Butternut	-	20,157	-	6,152	3,008	647	-	-
Other hardwoods	-	3,484	26,530	23,506	2,042	-	-	549
Total	25,006	2,646,817	1,357,107	4,667,930	7,958,478	1,499,423	1,072,391	17,804
All species	361,296	2,752,096	1,603,932	5,105,256	10,075,853	2,213,685	1,319,024	26,244

1/ International 1/4 inch rule.

Table 14.--Net volume of growing stock on timberland by species group and diameter class, Minnesota, 1987

(In thousand cubic feet)

Species group	All classes	Diameter class (inches at breast height) 5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-28.9	29.0+
Softwoods												
Jack pine	433,180	84,443	130,299	110,948	64,747	31,604	8,950	2,189	-	-	-	-
Red pine	568,948	84,963	64,501	73,345	89,881	65,165	65,020	48,937	38,486	23,512	14,974	164
White pine	225,103	5,104	9,438	11,784	25,184	25,732	26,188	30,592	24,444	15,366	39,675	11,596
White spruce	350,606	38,546	41,348	51,470	57,221	51,244	41,110	33,881	15,616	10,315	9,855	-
Black spruce	539,267	236,986	190,256	72,096	24,624	10,855	2,120	1,765	369	-	196	-
Balsam fir	1,074,251	284,267	317,285	235,898	144,325	59,243	22,036	8,067	2,808	322	-	-
Tamarack	313,776	116,646	100,455	53,876	23,998	12,884	3,420	2,026	325	-	146	-
Eastern redcedar	5,709	1,593	1,833	1,186	688	294	115	-	-	-	-	-
Northern white-cedar	561,869	121,378	134,247	121,163	78,178	53,642	29,050	14,461	6,667	1,565	1,518	-
Other softwoods	1,486	305	545	101	116	306	113	-	-	-	-	-
Total	4,074,195	974,231	990,207	731,867	508,962	310,969	198,122	141,918	88,715	51,080	66,364	11,760
Hardwoods												
Select white oak	441,142	46,760	65,917	70,198	67,332	56,996	44,978	28,633	21,850	13,822	20,577	4,079
Select red oak	694,898	32,791	90,575	124,802	118,772	97,004	82,528	55,558	39,128	21,072	27,230	5,438
Other red oak	11,784	370	863	1,125	603	1,654	1,862	2,021	1,373	578	1,239	96
Select hickory	14,200	2,413	2,501	2,856	2,388	2,047	1,001	686	199	109	-	-
Other hickory	6,354	1,047	2,203	1,349	786	582	160	-	227	-	-	-
Basswood	591,738	51,797	86,521	108,992	91,674	77,739	58,364	47,938	26,898	18,872	18,225	4,718
Yellow birch	14,808	996	650	1,507	1,484	3,052	1,618	1,747	1,561	1,262	931	-
Hard maple	347,144	79,238	61,581	49,080	41,806	33,075	31,145	23,830	14,096	5,421	6,774	1,098
Soft maple	257,848	87,936	65,716	36,578	19,408	15,247	7,910	7,050	5,388	2,931	5,743	3,941
Elm	433,151	26,539	55,943	65,073	63,699	54,480	49,525	37,775	24,931	16,981	29,041	9,164
Black ash	618,878	195,945	162,494	114,640	72,787	39,453	19,116	7,680	4,066	1,447	1,146	104
White & green ash	135,845	19,551	25,156	25,470	21,885	15,433	12,584	5,393	4,642	2,601	3,024	106
Cottonwood	24,537	388	346	666	1,308	1,036	1,016	2,325	2,766	2,622	4,152	7,912
Willow	25,436	139	2,410	4,685	4,867	4,028	3,443	1,985	1,667	410	1,335	467
Hackberry	5,309	297	451	562	621	433	838	149	516	541	741	160
Balsam poplar	696,678	60,184	117,271	166,363	136,683	103,866	59,465	30,509	14,346	4,546	3,445	-
Bigtooth aspen	203,271	11,697	30,636	55,090	49,403	29,556	15,268	8,440	2,613	406	162	-
Quaking aspen	3,367,562	516,196	701,151	776,281	669,440	386,449	192,434	83,498	28,303	9,844	3,966	-
Paper birch	1,683,792	455,257	488,860	383,679	201,789	96,643	36,071	13,957	3,650	2,569	1,317	-
River birch	617	-	118	95	299	105	-	-	-	-	-	-
Black cherry	15,659	3,153	4,223	3,471	1,696	879	1,168	659	256	154	-	-
Black walnut	7,155	239	568	792	1,098	1,352	1,732	395	632	132	215	-
Butternut	9,837	1,252	1,611	1,728	1,713	694	1,429	821	263	118	208	-
Other hardwoods	29,583	6,264	8,022	5,398	3,524	3,248	1,203	903	582	266	173	-
Total	9,637,226	1,600,449	1,975,787	2,000,480	1,575,065	1,025,051	624,858	361,952	199,953	106,704	129,644	37,283
All species	13,711,421	2,574,680	2,965,994	2,732,347	2,084,027	1,336,020	822,980	503,870	288,668	157,784	196,008	49,043

Table 15.--Net volume of sawtimber on timberland by species group and diameter class, Minnesota, 1987

(In thousand board feet) 1/

Species group	All classes	Diameter class (inches at breast height) 9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-28.9	29.0+
Softwoods										
Jack pine	1,134,010	576,129	335,377	164,048	46,868	11,588	-	-	-	-
Red pine	2,401,596	420,378	513,870	370,727	370,682	280,339	221,561	135,992	87,085	962
White pine	1,137,308	46,216	117,822	130,635	139,704	169,117	138,771	88,981	235,062	71,000
White spruce	1,368,808	235,026	279,440	260,782	215,651	181,201	84,847	56,757	55,104	-
Black spruce	504,734	305,075	119,100	56,166	11,435	9,741	2,093	-	1,124	-
Balsam fir	2,125,195	990,742	670,575	291,899	112,754	42,421	15,062	1,742	-	-
Tamarack	515,422	282,692	129,003	70,554	19,033	11,434	1,851	-	855	-
Eastern redcedar	13,411	7,090	3,966	1,688	667	-	-	-	-	-
Northern white-cedar	1,580,682	604,490	402,719	283,390	156,560	79,222	36,929	8,789	8,583	-
Other softwoods	3,585	567	643	1,735	640	-	-	-	-	-
Total	10,784,751	3,468,405	2,572,515	1,631,624	1,073,994	785,063	501,114	292,261	387,813	71,962
Hardwoods										
Select white oak	1,351,496	-	383,994	302,025	228,218	142,611	107,126	67,462	100,041	20,019
Select red oak	2,217,625	-	588,049	478,233	407,129	275,549	195,097	106,255	138,879	28,434
Other red oak	45,331	-	2,982	7,782	8,833	9,633	6,646	2,827	6,142	486
Select hickory	34,404	-	13,612	10,774	4,992	3,505	983	538	-	-
Other hickory	9,138	-	4,325	2,985	737	-	1,091	-	-	-
Basswood	1,685,443	-	442,263	375,189	284,746	236,451	134,100	95,041	93,000	24,653
Yellow birch	56,954	-	6,257	13,945	7,776	8,869	8,180	6,781	5,146	-
Hard maple	788,823	-	201,660	163,351	156,769	122,140	73,501	28,723	36,570	6,109
Soft maple	345,739	-	110,548	78,869	38,810	33,883	25,287	13,591	26,533	18,218
Elm	1,279,019	-	275,727	237,473	219,880	170,188	114,250	78,918	137,595	44,988
Black ash	884,010	-	472,521	232,040	104,927	40,425	20,747	7,206	5,638	506
White & green ash	360,351	-	133,677	84,328	65,280	27,340	22,722	12,305	14,194	505
Cottonwood	103,452	-	5,419	4,273	4,284	9,830	12,056	11,460	18,572	37,558
Willow	76,815	-	20,330	16,524	14,339	8,418	7,202	1,808	6,018	2,176
Hackberry	18,511	-	2,797	1,880	3,836	717	2,384	2,536	3,583	778
Balsam poplar	1,526,390	-	551,060	451,578	270,616	143,740	69,602	22,474	17,320	-
Bigtooth aspen	490,327	-	222,756	137,674	73,026	41,030	12,963	2,055	823	-
Quaking aspen	6,811,692	-	3,159,856	1,948,008	1,012,516	454,312	157,897	56,043	23,060	-
Paper birch	1,839,207	-	1,021,100	505,765	193,500	76,330	20,398	14,516	7,598	-
River birch	1,880	-	1,394	486	-	-	-	-	-	-
Black cherry	27,315	-	10,487	5,081	6,251	3,443	1,303	750	-	-
Black walnut	31,546	-	6,852	7,982	9,564	2,121	3,274	676	1,077	-
Butternut	29,964	-	10,704	3,948	7,883	4,427	1,349	599	1,054	-
Other hardwoods	56,111	-	19,950	18,364	6,793	5,120	3,349	1,532	1,003	-
Total	20,071,543	-	7,668,320	5,088,557	3,130,705	1,820,082	1,001,507	534,096	643,846	184,430
All species	30,856,294	3,468,405	10,240,835	6,720,181	4,204,699	2,605,145	1,502,621	826,357	1,031,659	256,392

1/ International 1/4 inch rule.

Table 16.--Annual net growth, mortality and removals of growing stock and sawtimber on timberland by softwoods and harwoods, Minnesota, 1976 and 1986

Species group	Growing stock		Sawtimber	
	1976	1986	1976	1986 1/
	Thousand cubic feet		Thousand board feet	
NET GROWTH				
Softwoods	119,781	160,431	380,319	585,105
Hardwoods	229,139	333,548	731,145	1,169,243
All species	348,920	493,979	1,111,464	1,754,348
MORTALITY				
Softwoods	33,728	44,452	50,462	81,228
Hardwoods	107,813	97,494	212,531	207,267
All species	141,541	141,946	262,993	288,494
REMOVALS				
Softwoods	68,800	57,200	269,942	141,300
Hardwoods	124,800	194,000	290,365	452,000
All species	193,600	251,200	560,307	593,300

1/ International 1/4 inch rule

Table 17.--Net volume in short-log trees on timberland by species group and diameter class, Minnesota, 1987

(In thousand cubic feet)

Species group	All classes	Diameter class (inches at breast height) 9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-28.9	29.0+
Softwoods										
Jack pine	3,033	904	1,075	942	112	-	-	-	-	-
Red pine	1,038	-	256	264	234	-	171	113	-	-
White pine	3,233	105	181	255	613	603	157	148	1,003	168
White spruce	640	-	351	-	289	-	-	-	-	-
Black spruce	2,249	937	404	764	144	-	-	-	-	-
Balsam fir	4,701	882	2,665	662	-	340	152	-	-	-
Tamarack	2,092	816	612	416	-	106	142	-	-	-
Eastern redcedar	557	219	183	-	78	-	77	-	-	-
Northern white-cedar	17,200	5,016	5,269	2,906	1,926	1,249	631	203	-	-
Total	34,743	8,879	10,996	6,209	3,396	2,298	1,330	464	1,003	168
Hardwoods										
Select white oak	17,621	-	2,924	3,661	3,576	2,223	1,124	1,864	1,483	766
Select red oak	17,775	-	1,390	5,169	3,287	2,649	2,903	482	1,520	375
Other red oak	622	-	-	209	85	-	234	94	-	-
Select hickory	281	-	-	170	111	-	-	-	-	-
Basswood	9,065	-	1,438	1,621	1,678	1,069	607	283	1,653	716
Yellow birch	1,989	-	182	848	393	125	308	-	133	-
Hard maple	12,406	-	923	2,901	3,319	1,564	1,834	945	484	436
Soft maple	4,235	-	221	320	901	782	360	485	322	844
Elm	21,148	-	2,924	4,899	3,359	3,177	2,151	897	2,884	857
Black ash	3,114	-	1,311	973	262	369	-	88	111	-
White & green ash	1,926	-	823	540	94	242	127	100	-	-
Cottonwood	439	-	-	185	-	-	-	-	110	144
Willow	613	-	-	103	-	126	264	-	120	-
Hackberry	405	-	-	-	-	144	120	-	141	-
Balsam poplar	6,220	-	1,313	1,640	1,030	990	1,113	134	-	-
Bigtooth aspen	2,977	-	-	1,177	805	446	549	-	-	-
Quaking aspen	51,009	-	5,601	16,450	14,760	8,766	2,997	1,831	604	-
Paper birch	15,432	-	2,665	6,045	3,934	1,306	624	99	759	-
River birch	221	-	-	-	-	221	-	-	-	-
Black cherry	91	-	-	-	91	-	-	-	-	-
Black walnut	212	-	-	-	-	212	-	-	-	-
Butternut	878	-	-	111	-	531	106	-	-	130
Other hardwoods	2,309	-	481	978	552	228	70	-	-	-
Total	170,988	-	22,196	48,000	38,237	25,170	15,491	7,302	10,324	4,268
All species	205,731	8,879	33,192	54,209	41,633	27,468	16,821	7,766	11,327	4,436

Table 18.--Net volume in short-log trees on timberland by species group and diameter class, Minnesota, 1987

(In thousand board feet) 1/

Species group	All classes	Diameter class (inches at breast height) 9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.9	19.0-20.9	21.0-22.9	23.0-28.9	29.0+
Softwoods										
Jack pine	10,543	3,096	3,750	3,308	389	-	-	-	-	-
Red pine	4,212	-	1,046	1,058	946	-	698	464	-	-
White pine	11,804	306	541	828	2,165	2,184	583	562	3,961	674
White spruce	2,910	-	1,536	-	1,374	-	-	-	-	-
Black spruce	6,611	2,487	1,202	2,450	472	-	-	-	-	-
Balsam fir	12,720	2,204	7,113	1,902	-	1,033	468	-	-	-
Tamarack	8,976	3,442	2,611	1,797	-	482	644	-	-	-
Eastern redcedar	2,925	1,183	932	-	404	-	406	-	-	-
Northern white-cedar	61,028	17,230	18,500	10,410	7,067	4,670	2,379	772	-	-
Total	121,729	29,948	37,231	21,753	12,817	8,369	5,178	1,798	3,961	674
Hardwoods										
Select white oak	47,687	-	8,760	10,230	9,582	5,739	2,872	4,746	3,799	1,959
Select red oak	40,019	-	3,090	11,495	7,354	5,967	6,607	1,104	3,517	885
Other red oak	1,435	-	-	478	198	-	541	218	-	-
Select hickory	776	-	-	480	296	-	-	-	-	-
Basswood	19,677	-	3,037	3,403	3,610	2,302	1,337	620	3,724	1,644
Yellow birch	4,677	-	390	1,891	919	317	794	-	366	-
Hard maple	30,326	-	2,128	6,813	8,093	3,859	4,591	2,417	1,266	1,159
Soft maple	11,153	-	664	942	2,444	2,057	916	1,213	799	2,118
Elm	54,030	-	7,103	12,156	8,449	8,208	5,604	2,387	7,738	2,385
Black ash	8,878	-	4,003	2,742	709	943	-	217	264	-
White & green ash	4,886	-	2,220	1,360	242	553	288	223	-	-
Cottonwood	1,390	-	-	544	-	-	-	-	357	489
Willow	1,897	-	-	306	-	389	813	-	389	-
Hackberry	1,075	-	-	-	-	368	324	-	383	-
Balsam poplar	14,861	-	2,926	3,792	2,488	2,465	2,842	348	-	-
Bigtooth aspen	4,935	-	-	1,897	1,330	759	949	-	-	-
Quaking aspen	120,215	-	12,191	37,490	35,172	21,493	7,560	4,726	1,583	-
Paper birch	43,281	-	7,144	16,719	11,197	3,742	1,846	298	2,335	-
River birch	736	-	-	-	-	736	-	-	-	-
Black cherry	242	-	-	-	242	-	-	-	-	-
Black walnut	574	-	-	-	-	574	-	-	-	-
Butternut	2,301	-	-	320	-	1,392	274	-	-	315
Other hardwoods	8,441	-	1,758	3,586	2,009	834	254	-	-	-
Total	423,492	-	55,414	116,644	94,334	62,697	38,412	18,517	26,520	10,954
All species	545,221	29,948	92,645	138,397	107,151	71,066	43,590	20,315	30,481	11,628

1/ International 1/4 inch rule.

Table 19.--All live tree biomass on timberland
by species group and tree biomass component, Minnesota, 1987

ALL UNITS

Species group	All components	Component: Growing stock: Bole	Component: Growing stock: Tops and limbs	Component: Cull: Bole	Component: Cull: Tops and limbs	Component: 1- to 5-inch trees	Average weight per cubic foot (including bark)
	Green tons						Pounds
Softwoods							
Jack pine	17,331,969	11,969,961	2,378,336	994,635	199,207	1,789,830	46
Red pine	19,288,897	15,466,199	2,760,052	176,686	32,848	853,112	46
White pine	7,892,736	6,102,842	1,031,440	454,867	87,920	215,667	45
White spruce	13,386,659	8,844,662	3,163,416	246,413	94,668	1,037,500	45
Black spruce	36,071,817	14,077,859	6,118,435	668,613	295,444	14,911,466	45
Balsam fir	63,700,491	29,622,887	12,464,231	1,588,712	666,867	19,357,794	47
Tamarack	17,207,796	9,588,749	2,121,607	1,429,464	319,624	3,748,352	52
Eastern redcedar	411,277	141,347	62,300	57,924	22,418	127,288	43
Northern white-cedar	28,051,349	11,865,748	5,244,902	4,415,380	1,908,050	4,617,269	36
Other softwoods	117,033	38,129	14,983	12,664	6,364	44,893	44
Total	203,460,024	107,718,383	35,359,702	10,045,358	3,633,410	46,703,171	45
Hardwoods							
Select white oak	30,233,537	16,019,887	6,884,854	3,105,654	1,281,074	2,942,068	58
Select red oak	43,896,746	26,932,453	10,498,527	4,463,655	1,684,873	317,238	64
Other red oak	737,134	465,617	169,778	75,802	25,937	-	64
Select hickory	907,925	534,848	228,577	54,573	21,225	68,702	63
Other hickory	400,799	222,650	97,872	14,716	6,597	58,964	59
Basswood	25,586,526	15,158,288	6,114,318	2,017,425	787,675	1,508,820	42
Yellow birch	1,914,562	557,560	213,217	745,228	280,327	118,230	61
Hard maple	31,216,604	13,052,605	5,526,872	5,943,985	2,343,457	4,349,685	63
Soft maple	22,814,603	8,494,008	3,774,163	3,937,915	1,650,497	4,958,020	55
Elm	26,868,974	14,517,431	5,979,610	3,233,221	1,284,184	1,854,528	55
Black ash	37,375,637	18,660,328	8,798,307	2,114,623	989,174	6,813,205	50
White & green ash	7,485,616	4,234,410	1,761,245	690,358	278,053	521,550	51
Cottonwood	1,127,154	764,800	237,824	73,256	21,264	30,010	51
Willow	1,289,741	746,777	291,363	175,751	64,983	10,867	48
Hackberry	328,396	170,099	65,621	56,108	20,854	15,714	52
Balsam poplar	39,891,453	22,712,482	8,922,093	3,483,480	1,381,381	3,392,017	53
Bigtooth aspen	10,080,677	6,292,556	1,889,971	1,290,732	377,013	230,405	50
Quaking aspen	196,842,007	105,146,943	34,250,469	30,393,992	9,579,890	17,470,713	50
Paper birch	105,646,168	55,812,282	24,904,316	9,225,073	4,003,676	11,700,821	55
River birch	67,933	20,695	8,122	28,917	10,199	-	55
Black cherry	1,425,539	454,599	197,172	264,901	122,937	385,930	49
Black walnut	366,551	236,646	90,107	25,734	9,248	4,816	54
Butternut	717,763	272,103	110,898	230,592	88,227	15,943	45
Other hardwoods	2,815,466	859,801	393,357	827,235	346,755	388,318	46
Noncommercial spp.	3,404,271	-	-	773,536	397,125	2,233,610	50
Total	593,441,782	312,339,868	121,408,653	73,246,462	27,056,625	59,390,174	53
All species	796,901,806	420,058,251	156,768,355	83,291,820	30,690,035	106,093,345	51

(Table 19 continued on next page)

(Table 19 continued)

ASPEN-BIRCH

Species group	All components	Component: Growing stock: Bole	Component: Growing stock: Tops and limbs	Component: Cull: Bole	Component: Cull: Tops and limbs	Component: 1- to 5-inch trees	Average weight per cubic foot (including bark)
	Green tons						Pounds
Softwoods							
Jack pine	4,124,075	3,052,865	597,791	218,847	40,681	213,891	46
Red pine	7,616,412	6,152,625	1,120,664	89,529	17,116	236,478	46
White pine	3,654,286	2,867,594	481,964	206,320	42,075	56,333	45
White spruce	9,741,324	6,442,726	2,289,624	178,135	70,655	760,184	45
Black spruce	26,815,196	11,073,742	4,803,206	372,856	157,428	10,407,964	45
Balsam fir	43,663,456	19,672,799	8,394,758	1,044,471	443,833	14,107,595	47
Tamarack	5,894,047	3,048,347	681,731	487,634	109,014	1,567,321	52
Eastern redcedar	25,734	8,427	4,294	3,373	1,058	8,582	43
Northern white-cedar	17,102,280	7,374,559	3,254,485	2,421,358	1,030,944	3,020,934	36
Other softwoods	-	-	-	-	-	-	-
Total	118,636,810	59,693,684	21,628,517	5,022,523	1,912,804	30,379,282	44
Hardwoods							
Select white oak	422,826	236,939	104,298	15,870	6,219	59,500	58
Select red oak	929,315	546,251	219,383	117,557	46,124	-	64
Other red oak	-	-	-	-	-	-	-
Select hickory	-	-	-	-	-	-	-
Other hickory	-	-	-	-	-	-	-
Basswood	2,199,491	1,318,766	548,375	180,391	73,416	78,543	42
Yellow birch	1,215,417	361,051	130,282	509,399	182,210	32,475	61
Hard maple	10,177,444	3,582,980	1,617,288	2,342,838	959,302	1,675,036	63
Soft maple	8,043,006	2,398,435	1,129,818	1,697,835	750,257	2,066,661	55
Elm	2,911,179	1,639,484	671,968	351,063	139,814	108,850	55
Black ash	14,841,726	7,564,516	3,587,838	712,054	331,966	2,645,352	50
White & green ash	815,764	444,111	195,414	85,088	33,050	58,101	51
Cottonwood	45,897	17,087	7,256	12,331	4,236	4,987	51
Willow	12,088	-	-	8,444	3,644	-	48
Hackberry	-	-	-	-	-	-	-
Balsam poplar	17,144,747	9,788,618	3,796,614	1,718,531	652,164	1,188,820	53
Bigtooth aspen	1,712,909	1,191,694	364,816	119,229	37,170	-	50
Quaking aspen	74,366,860	40,863,109	13,424,801	10,008,013	3,156,145	6,914,792	50
Paper birch	55,003,911	28,561,301	12,816,929	4,883,157	2,075,525	6,666,999	55
River birch	-	-	-	-	-	-	-
Black cherry	68,277	4,344	2,061	4,436	2,140	55,296	49
Black walnut	-	-	-	-	-	-	-
Butternut	-	-	-	-	-	-	-
Other hardwoods	59,245	6,439	3,424	24,765	11,376	13,241	46
Noncommercial spp.	761,120	-	-	134,550	69,949	556,621	50
Total	190,731,222	98,525,125	38,620,565	22,925,551	8,534,707	22,125,274	53
All species	309,368,032	158,218,809	60,249,082	27,948,074	10,447,511	52,504,556	49

(Table 19 continued on next page)

(Table 19 continued)

NORTHERN PINE

Species group	All components	Component: Growing stock: Bole	Component: Growing stock: Tops and limbs	Component: Cull: Bole	Component: Cull: Tops and limbs	Component: 1- to 5-inch trees	Average weight per cubic foot (including bark)
	Green tons						Pounds
Softwoods							
Jack pine	12,782,651	8,638,641	1,725,203	760,537	155,477	1,502,793	46
Red pine	10,467,832	8,433,355	1,467,583	74,411	13,346	479,137	46
White pine	3,571,777	2,729,088	464,720	201,593	37,354	139,022	45
White spruce	3,489,601	2,296,019	838,336	62,891	22,251	270,104	45
Black spruce	8,817,667	2,848,656	1,244,219	285,961	134,228	4,304,603	45
Balsam fir	19,505,279	9,711,237	3,970,429	529,835	217,755	5,076,023	47
Tamarack	10,054,860	5,664,820	1,253,767	879,422	197,933	2,058,918	52
Eastern redcedar	52,528	13,231	5,457	24,565	9,275	-	43
Northern white-cedar	10,949,069	4,491,189	1,990,417	1,994,022	877,106	1,596,335	36
Other softwoods	-	-	-	-	-	-	-
Total	79,691,264	44,826,236	12,960,131	4,813,237	1,664,725	15,426,935	45
Hardwoods							
Select white oak	11,818,320	5,853,125	2,684,823	868,120	386,570	2,025,682	58
Select red oak	18,666,628	11,105,233	4,551,591	1,992,562	796,802	220,440	64
Other red oak	80,525	52,139	22,630	4,006	1,750	-	64
Select hickory	-	-	-	-	-	-	-
Other hickory	37,691	19,753	8,445	-	-	9,493	59
Basswood	13,478,120	7,863,171	3,293,156	982,050	394,720	945,023	42
Yellow birch	624,478	192,298	81,279	199,596	82,256	69,049	61
Hard maple	13,516,986	5,670,557	2,416,892	2,448,953	959,516	2,021,068	63
Soft maple	9,335,125	3,741,468	1,675,090	1,525,533	627,523	1,765,511	55
Elm	11,024,443	6,024,326	2,591,136	1,141,067	475,587	792,327	55
Black ash	18,353,756	9,098,684	4,278,522	1,029,704	483,734	3,463,112	50
White & green ash	2,124,112	1,099,241	479,460	165,289	72,362	307,760	51
Cottonwood	4,697	3,227	1,470	-	-	-	51
Willow	4,613	3,237	1,376	-	-	-	48
Hackberry	-	-	-	-	-	-	-
Balsam poplar	19,788,766	11,389,217	4,491,858	1,426,884	587,005	1,893,802	53
Bigtooth aspen	6,490,588	3,967,583	1,186,293	888,088	259,737	188,887	50
Quaking aspen	92,007,334	49,162,073	15,776,078	14,773,388	4,575,522	7,720,273	50
Paper birch	41,909,093	22,539,003	9,956,740	3,803,281	1,690,098	3,919,971	55
River birch	-	-	-	-	-	-	-
Black cherry	390,931	59,788	28,243	118,589	59,346	124,965	49
Black walnut	-	-	-	-	-	-	-
Butternut	105,334	56,768	23,486	15,939	5,882	3,259	45
Other hardwoods	270,430	78,350	35,776	86,235	37,349	32,720	46
Noncommercial spp.	896,045	-	-	165,940	84,874	645,231	50
Total	260,928,015	137,979,241	53,584,344	31,635,224	11,580,633	26,148,573	53
All species	340,619,279	182,805,477	66,544,475	36,448,461	13,245,358	41,575,508	51

(Table 19 continued on next page)

(Table 19 continued)

CENTRAL HARDWOOD

Species group	All components	Component: Growing stock: Bole	Component: Growing stock: Tops and limbs	Component: Cull: Bole	Component: Cull: Tops and limbs	Component: 1- to 5-inch trees	Average weight per cubic foot (including bark)
	Green tons						Pounds
Softwoods							
Jack pine	412,278	267,542	53,290	15,251	3,049	73,146	46
Red pine	1,184,991	863,301	169,061	12,746	2,386	137,497	46
White pine	666,673	506,160	84,756	46,954	8,491	20,312	45
White spruce	135,534	90,525	30,648	5,387	1,762	7,212	45
Black spruce	433,637	151,950	69,204	9,796	3,788	198,899	45
Balsam fir	519,389	234,665	96,909	14,406	5,279	168,130	47
Tamarack	1,240,657	866,524	184,118	62,408	12,677	114,930	52
Eastern redcedar	201,939	79,385	33,519	20,143	7,288	61,604	43
Northern white-cedar	-	-	-	-	-	-	-
Other softwoods	117,033	38,129	14,983	12,664	6,364	44,893	44
Total	4,912,131	3,098,181	736,488	199,755	51,084	826,623	47
Hardwoods							
Select white oak	13,352,467	7,211,693	2,987,564	1,799,574	716,429	637,207	58
Select red oak	23,120,238	14,521,001	5,449,642	2,247,484	805,313	96,798	64
Other red oak	629,863	393,938	139,942	71,796	24,187	-	64
Select hickory	904,548	534,848	228,577	52,011	20,410	68,702	63
Other hickory	334,703	183,022	80,897	14,716	6,597	49,471	59
Basswood	8,338,995	4,958,488	1,915,553	730,940	275,520	458,494	42
Yellow birch	64,036	4,211	1,656	29,053	12,410	16,706	61
Hard maple	6,825,396	3,403,760	1,344,380	1,057,210	390,346	629,700	63
Soft maple	5,194,604	2,255,901	933,353	630,229	249,273	1,125,848	55
Elm	10,410,229	5,570,694	2,240,472	1,350,240	523,695	725,128	55
Black ash	3,795,442	1,833,093	854,682	331,322	153,382	622,963	50
White & green ash	3,073,646	1,866,346	774,207	211,001	87,246	134,846	51
Cottonwood	513,150	343,802	103,709	31,980	8,636	25,023	51
Willow	540,824	292,325	107,979	95,398	34,255	10,867	48
Hackberry	195,330	102,925	40,255	27,832	10,334	13,984	52
Balsam poplar	821,545	426,407	171,046	132,106	55,313	36,673	53
Bigtooth aspen	1,873,704	1,130,716	337,949	283,415	80,106	41,518	50
Quaking aspen	20,200,334	10,351,096	3,408,491	3,606,434	1,173,115	1,661,198	50
Paper birch	8,549,835	4,606,739	2,082,207	524,691	231,592	1,104,606	55
River birch	67,933	20,695	8,122	28,917	10,199	-	55
Black cherry	814,314	337,499	143,379	114,125	48,784	170,527	49
Black walnut	290,095	191,467	72,613	15,688	5,511	4,816	54
Butternut	599,218	212,093	86,471	211,136	80,655	8,863	45
Other hardwoods	1,273,766	398,999	182,385	377,570	155,126	159,686	46
Noncommercial spp.	1,513,009	-	-	399,899	203,809	909,301	50
Total	113,297,224	61,151,758	23,695,531	14,374,767	5,362,243	8,712,925	55
All species	118,209,355	64,249,939	24,432,019	14,574,522	5,413,327	9,539,548	54

(Table 19 continued on next page)

(Table 19 continued)

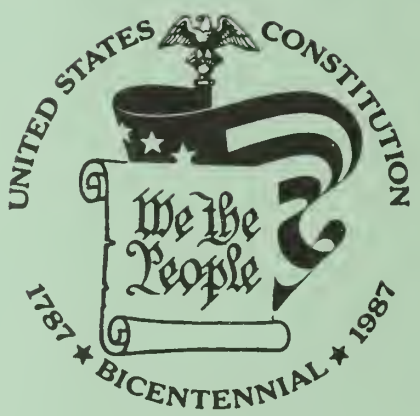
PRAIRIE

Species group	All components	Component: Growing stock: Bole	Component: Growing stock: Tops and limbs	Component: Cull: Bole	Component: Cull: Tops and limbs	Component: 1- to 5-inch trees	Average weight per cubic foot (including bark)
	Green tons						Pounds
Softwoods							
Jack pine	12,965	10,913	2,052	-	-	-	46
Red pine	19,662	16,918	2,744	-	-	-	46
White pine	-	-	-	-	-	-	-
White spruce	20,200	15,392	4,808	-	-	-	45
Black spruce	5,317	3,511	1,806	-	-	-	45
Balsam fir	12,367	4,186	2,135	-	-	6,046	47
Tamarack	18,232	9,058	1,991	-	-	7,183	52
Eastern redcedar	131,076	40,304	19,030	9,843	4,797	57,102	43
Northern white-cedar	-	-	-	-	-	-	-
Other softwoods	-	-	-	-	-	-	-
Total	219,819	100,282	34,566	9,843	4,797	70,331	45
Hardwoods							
Select white oak	4,639,924	2,718,130	1,108,169	422,090	171,856	219,679	58
Select red oak	1,180,565	759,968	277,911	106,052	36,634	-	64
Other red oak	26,746	19,540	7,206	-	-	-	64
Select hickory	3,377	-	-	2,562	815	-	63
Other hickory	28,405	19,875	8,530	-	-	-	59
Basswood	1,569,920	1,017,863	357,234	124,044	44,019	26,760	42
Yellow birch	10,631	-	-	7,180	3,451	-	61
Hard maple	696,778	395,308	148,312	94,984	34,293	23,881	63
Soft maple	241,868	98,204	35,902	84,318	23,444	-	55
Elm	2,523,123	1,282,927	476,034	390,851	145,088	228,223	55
Black ash	384,713	164,035	77,265	41,543	20,092	81,778	50
White & green ash	1,472,094	824,712	312,164	228,980	85,395	20,843	51
Cottonwood	563,410	400,684	125,389	28,945	8,392	-	51
Willow	732,216	451,215	182,008	71,909	27,084	-	48
Hackberry	133,066	67,174	25,366	28,276	10,520	1,730	52
Balsam poplar	2,136,395	1,108,240	462,575	205,959	86,899	272,722	53
Bigtooth aspen	3,476	2,563	913	-	-	-	50
Quaking aspen	10,267,479	4,770,665	1,641,099	2,006,157	675,108	1,174,450	50
Paper birch	183,329	105,239	48,440	13,944	6,461	9,245	55
River birch	-	-	-	-	-	-	-
Black cherry	152,017	52,968	23,489	27,751	12,667	35,142	49
Black walnut	76,456	45,179	17,494	10,046	3,737	-	54
Butternut	13,211	3,242	941	3,517	1,690	3,821	45
Other hardwoods	1,212,025	376,013	171,772	338,665	142,904	182,671	46
Noncommercial spp.	234,097	-	-	73,147	38,493	122,457	50
Total	28,485,321	14,683,744	5,508,213	4,310,920	1,579,042	2,403,402	52
All species	28,705,140	14,784,026	5,542,779	4,320,763	1,583,839	2,473,733	52

Hahn, Jerold T.; Smith, W. Brad.
1987. Minnesota's forest statistics, 1987: an inventory update. Gen. Tech. Rep. NC-118. St. Paul, MN: U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station. 44 p.

The Minnesota 1987 inventory update, derived by using tree growth models, reports 13.5 million acres of timberland, a decline of less than 1 percent since 1977. This bulletin presents findings from the inventory update in tables detailing timber land area, volume, and biomass.

KEY WORDS: Forest area, timberland, forest inventory, land use, update.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United States Department of Agriculture

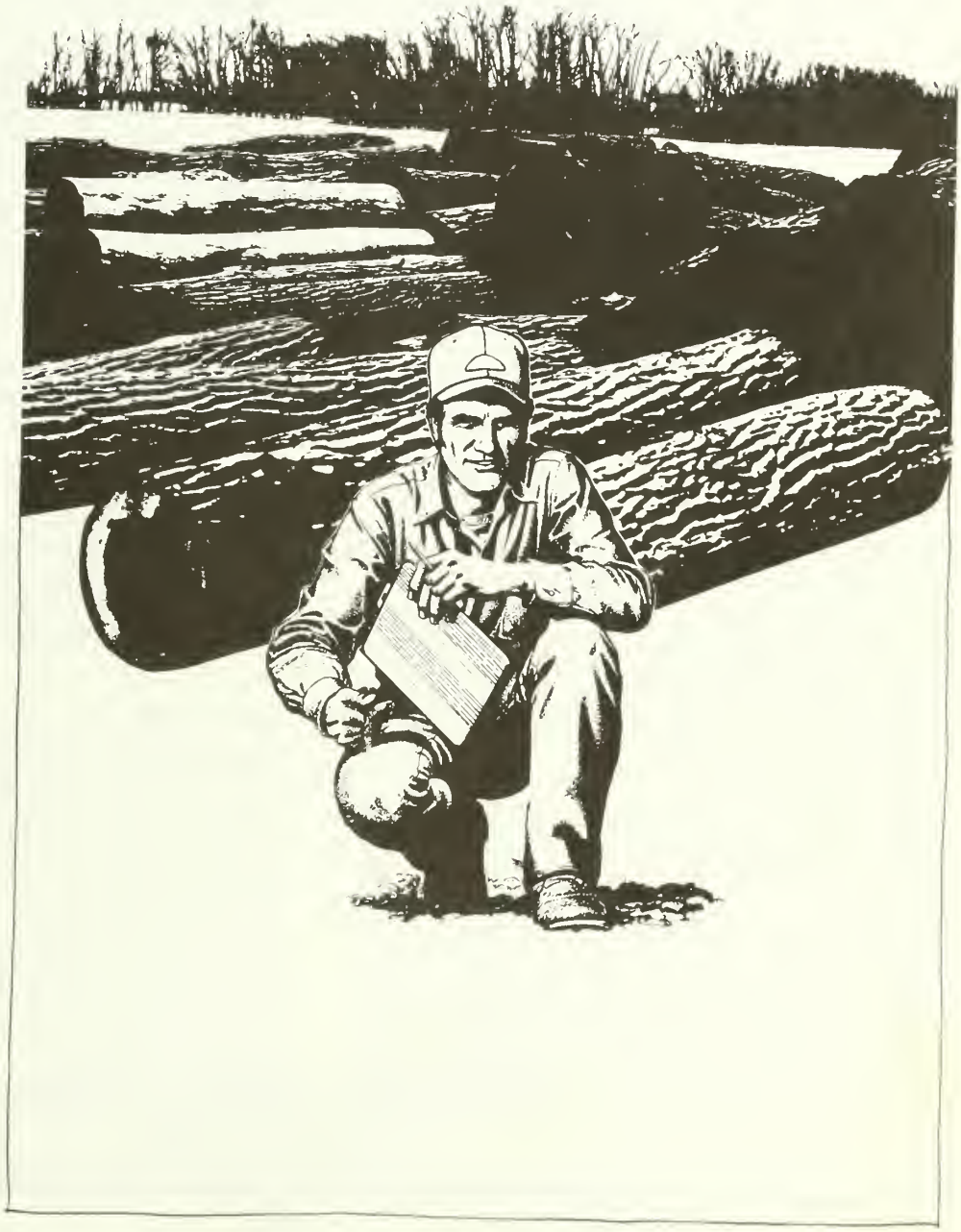
Forest Service

North Central Forest Experiment Station

General Technical Report **NC-119**

Central States Forest Management Guides as Applied in STEMS

Nancy R. Walters



Walters, Nancy R.
1988. Central States forest management guides as applied in STEMS. Gen. Tech. Rep. NC-119. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 22 p.

Describes a management prescription system for Central States cover types developed for use in the Central States Stand and Tree Evaluation and Modeling System (STEMS). It includes one management guide for each of the six major covertypes in the region. Each guide consists of a decision key that prescribes management, based on stand characteristics and a set of marking rules that carries out the prescription. This management component can be used within STEMS or apart from it as a guide to making silvicultural decisions in the Central States.

KEY WORDS: Silvicultural guidelines, computer model, growth and yield, timber management.

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CENTRAL STATES FOREST MANAGEMENT GUIDES AS APPLIED IN STEMS

Nancy R. Walters

Growth and yield projection models have become one of the tools commonly used by forest managers and planners in making decisions about the forest resource. Growth simulators aid in resource assessment by providing a means to update forest inventories and estimate future yields. Growth models become particularly useful when, in addition to projecting the growth of stands, they can simulate management (tree cutting) and describe how those management actions will affect future stand development.

The Stand and Tree Evaluation and Modeling System (STEMS) is an example of such a growth model (Miner and Walters 1984). Scientists at the North Central Forest Experiment Station developed STEMS for use by forest managers and planners wanting to evaluate many stands simultaneously, such as in regional analysis. It operates on a mainframe computer and is being used by forest industries, States, and the USDA Forest Service Forest Inventory and Analysis group, among others. Two variants are available: Lake States STEMS, intended for use in Minnesota, Wisconsin, and Michigan; and Central States STEMS, for use in Missouri, Illinois, and Indiana.

The management component in STEMS was designed with the understanding that users would be evaluating many forest stands at one time and that the stands would represent a wide variety of forest types and conditions. To be of value in a system such as STEMS, the management component needed to be able to prescribe and apply management actions as well as be flexible enough to allow the user to alter those prescriptions. To achieve these goals, a set of computerized management guides was developed that has the capacity to automatically assess a stand's condition and apply an appropriate management prescription. The user can easily modify these guides, tailoring the management prescription to fit specific conditions or objectives.

This paper describes the management component developed for use in the **Central States** variant of STEMS. Similar guides have been developed for Lake States STEMS (Brand 1981).

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MANAGEMENT GUIDES WITHIN THE STEMS FRAMEWORK

The management component of Central States STEMS includes six management guides, one for each major covertype of the Central States region:

Eastern redcedar	Elm-ash-cottonwood
Shortleaf pine	Pin oak
Oak-hickory	Tolerant hardwoods

Each computerized guide is a synthesis of existing information on managing the particular forest type. Published information widely used by forest managers as well as unpublished information from foresters who are experienced in managing Central States forests provided the basis for these guides. A complete list of the sources used to develop the guidelines is included in the Literature Cited.

The guidelines prescribe treatments for individual stands using stand information that is provided as input to STEMS. This information is in the form of a tree list that is altered as trees grow, die, and are cut. For each tree on a sample plot, the STEMS tree list includes the species, diameters, crown ratio and tree quality codes as well as stand age and site index (Miner and Walters 1984). These data provide the only information required by STEMS for projecting tree growth and mortality, deciding on a management prescription, and selecting trees to cut.

Using the information supplied in the tree list, STEMS determines the covertype of the stand and

then selects the appropriate management guide (Belcher 1981). The management guide for each covertype consists of a decision key and a set of marking rules. The *decision key* (Appendix A) is an algorithm that determines the stand characteristics and prescribes appropriate management. The *marking rules* (Appendix B) carry out the silvicultural prescription, assigning the sequence in which trees will be cut.

THE DECISION KEY

The decision key is like a map of roads branching in different directions, each leading to different silvicultural prescriptions (fig. 1). At each intersection or decision point, true/false questions about characteristics of the stand are answered based on the stand and tree information. True statements are followed until enough stand information is accumulated to make a silvicultural prescription.

Depending on the covertype being considered, the "map", or decision key, may be very complex or relatively simple. The silvicultural prescriptions are based on a variety of stand characteristics, depending on the covertype being evaluated. In some covertypes it is necessary to know stand density to make management recommendations. In others, treatments are prescribed based on the age and/or site index of the stand. Table 1 describes that array of stand characteristics used at the decision points of the keys. These characteristics provide the basis for making the prescription, and some or all of them, in varying combinations, are used in each of the six keys.

Obviously, forest management decisions in the real world are based on many other factors besides those

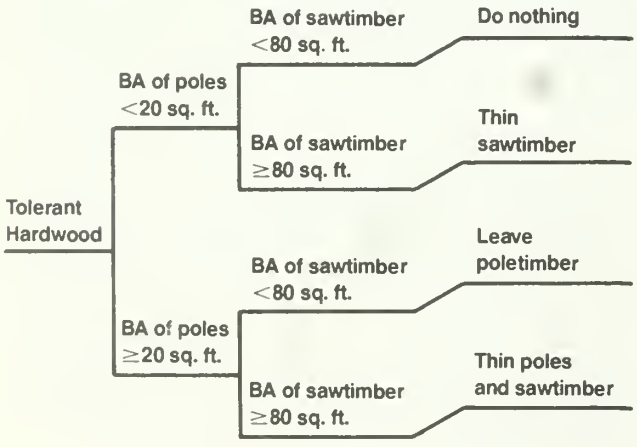


Figure 1.—*Simplified tolerant hardwood decision key (BA = Basal Area).*

Table 1.—*Description of terms used in decision keys*

Symbol	Units	Description
Age	Years	Stand Age
BA	sq.ft./acre	Basal area of all live trees on the stand (acceptable and unacceptable growing stock)
BA/AGS	sq.ft./acre	Basal area of acceptable growing-stock trees
BLINE	sq.ft./acre	Basal area at the minimum stocking level (see decision keys for calculation)
BASAW	sq.ft./acre	Basal area of all live sawtimber-size trees
BAPOLE	sq.ft./acre	Basal area of all live poletimber-size trees
BASAP	sq.ft./acre	Basal area of all live saplings
$\overline{DBH}$	inches	Average diameter at breast height of live trees on the stand
NT	trees/acre	Number of live trees per acre on the stand
QMDBH	inches	D.b.h. of tree of average basal area: square root of (BA/0.005454 • NT)
SI	feet	Stand site index (50 year basis)
Rough & Rotten	number of trees	Unacceptable growing stock trees
<		as in a < b: a is less than b
≤		as in a ≤ b: a is less than or equal to b
>		as in a > b: a is greater than b
≥		as in a ≥ b: a is greater than or equal to b

listed in table 1. The stand's health, its location, insect and disease problems, and the current market conditions are just a few of the additional factors considered in determining silvicultural prescriptions. Because, in modeling, so many of these dynamic characteristics cannot easily be considered, a few initial assumptions are made. One of the basic assumptions is that STEMS does not account for shrubs or intertree spacing so it therefore does not reflect the effects they may have on tree growth. In addition to this basic assumption, special assumptions are made for each covertype (see Decision Keys in Appendix A).

Figure 2 illustrates the decision key for the tolerant hardwood covertype. The circled numbers pertain to marking rules that will be discussed later. This management guide operates on the above basic assumption as well as the assumption that all-aged stands will be maintained or developed and that the management objective is timber.

The guide for this covertype bases its management prescriptions on the density distribution in the stand. At the first decision point the amount of basal area in poletimber (BAPOLE) is assessed. At the next decision point basal area in sawtimber-size trees (BASAW) is determined. At each of these decision points STEMS compares the stand's characteristics calculated from the tree list to the decision values built into the management guides. Those values

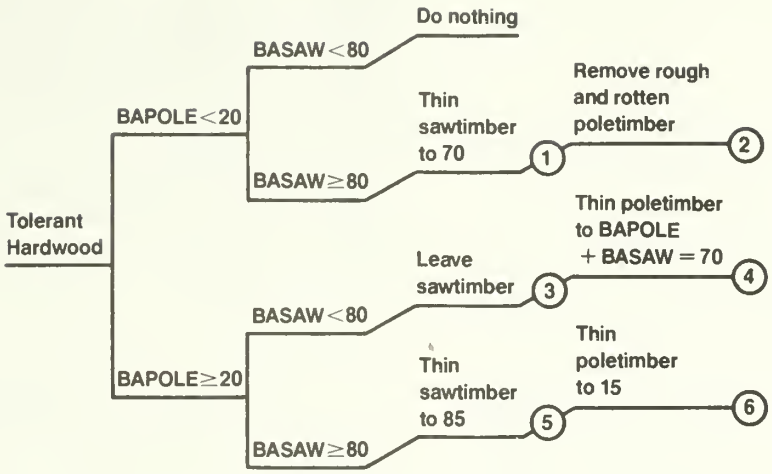


Figure 2.—*Tolerant hardwood decision key.*

associated with the stand characteristics at each decision point are called "critical values". In this decision key the critical value for BAPOLE is 20 square feet. Stands with less than 20 square feet in poletimber (BAPOLE < 20) follow the top branch. Those stands with 20 square feet or more in poletimber (BAPOLE ≥ 20) follow the lower branch. Similarly, the critical value for BASAW in this key is 80 square feet. The critical value for BASAW happens to be the same for each of the two sets of branches, but they may be different for each set of branches in other keys. Default critical values, based on published management guidelines, are established for each decision key and are used unless changed by the user.

To demonstrate how a decision key is used to determine a silvicultural prescription, assume we have a sugar maple-beech stand (ie., tolerant hardwood covertype) with 100 square feet total basal area including: *18 square feet in poletimber*, and *82 square feet in sawtimber* (fig. 3).

To determine the prescription for this stand, the basal area in poletimber (BAPOLE) of 18 square feet is compared to 20 square feet, the critical value at the first decision point. Because the stand has less than 20 square feet in poletimber, the upper branch is followed. At the next decision point, because the basal area in sawtimber (BASAW) of 82 square feet is more than the critical value of 80 square feet, the

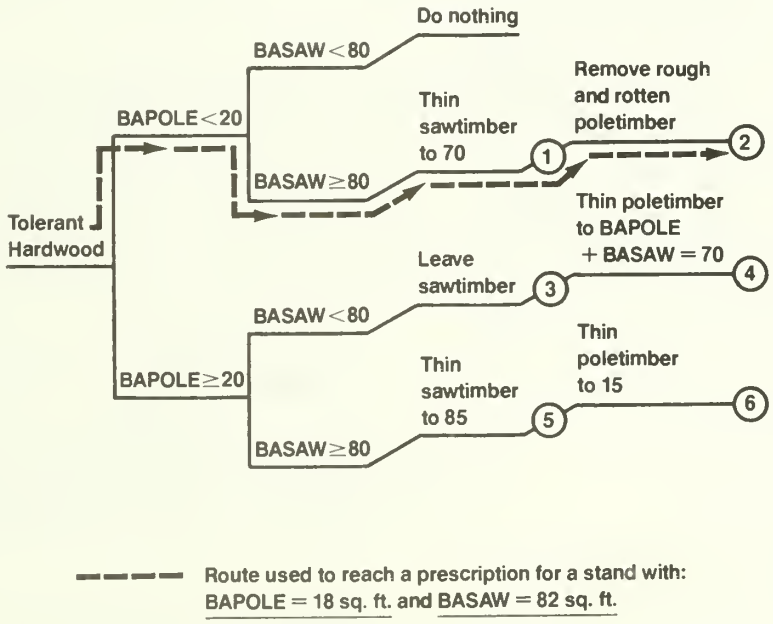


Figure 3.—*Example of how a decision key is used.*

lower branch is taken. That lower branch leads to a prescription that thins the sawtimber size class to 70 square feet and removes rough and rotten poletimber.

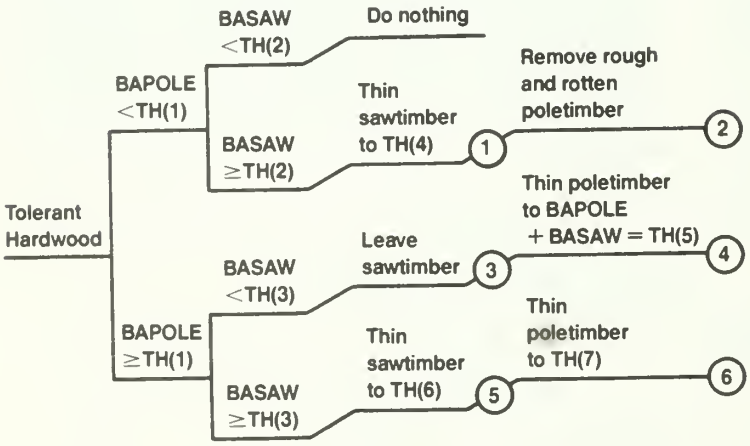
Although the silvicultural prescriptions made by these management guides are usually reasonable, for many different reasons they sometimes are not. Perhaps the assumptions don't apply in the user's situation or the market conditions make the prescribed management impractical. In these situations, users can do one of two things. One option is to choose one of the other available guides rather than the one chosen by STEMS. For instance, the oak-hickory guide provides guidelines for even-aged management and may not be useful to those having uneven-aged managment goals for upland hardwood stands. In this case the user could chose to use the tolerant hardwood guide, which provides guidelines for uneven-aged management, and override the assigned even-aged management guide.

The other option is to modify the key so that a different outcome is produced. This flexibility is provided by allowing the user to change the critical values at each decision point. The stand characteristic itself (e.g., BAPOLE, BASAW), cannot be changed, nor can the framework be altered; only the value at each intersection is variable.

To provide this flexibility, the critical values that may be changed are designated by symbols. In the tolerant hardwood key, the critical values are denoted as TH(1), TH(2)...TH(7) (fig. 4). TH(8) allows the user to set the lower limit for the sawtimber size class (see fig. 4, assumption 3). The values assigned to each symbol are stored in an auxillary data file and are used in STEMS unless changed by the user. Using the default values as printed in figure 4, this generalized key would produce the same prescription for any given stand as would the specific key in figure 3.

As an example of how these critical values are used to provide flexibility in management, let's use the same sugar maple-beech stand and add an assumption. Assume market conditions are such that it is not economically feasible to enter the stand as often as would be silviculturally advisable (fig. 5). Let's say we'd want to have 90 square feet of sawtimber present before entering stands with a small proportion of poletimber.

By changing TH(2) from 80 to 90 square feet, the prescription will be to "do nothing" for any stand with less than 20 square feet in poletimber and less than 90 square feet in sawtimber. Because our example stand has 18 square feet of poletimber and 83 square feet in sawtimber, we follow the path to the "do



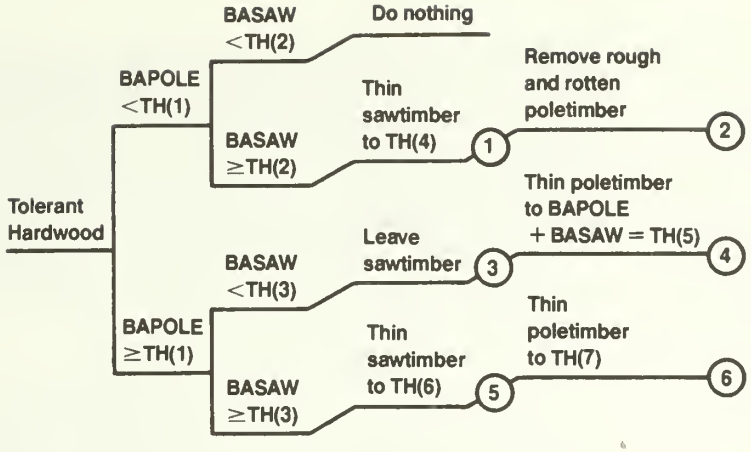
Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 80. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 70. sq. ft./ac
TH(5) = 85. sq. ft./ac
TH(6) = 70. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).

Figure 4.—*Generalized tolerant hardwood key.*



Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 90. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 60. sq. ft./ac
TH(5) = 75. sq. ft./ac
TH(6) = 80. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).
4. *Market conditions are poor.*

Figure 5.—*Modified tolerant hardwood key.*

nothing" prescription. In keeping with our new assumption, when treatment is warranted, we may also want to thin more heavily than the guide suggests. If this is the case, we could also lower the values for TH(4), TH(5), and TH(6) so that when, and if, we took any of the three lower branches, the stand would be thinned to a lower residual basal area.

MARKING RULES

Once the decision key determines a prescription, STEMS automatically applies that treatment to the stand. The circled numbers on the right hand side of the decision keys correspond to a set of marking rules that apply the prescription (for example, see figs. 4 or 5). Certain prescriptions are easy to apply and don't need marking rules, as in "do nothing", where all the trees are left to grow, and in "clearcut", where all the trees in the stand are harvested. The "thin" prescription, on the other hand, requires a sequence of priorities assigning which trees to cut first to produce the desired residual stand. This procedure is outlined in a set of marking rules for each decision key (Appendix B). The criteria used to assign trees for cut are tree species, diameter at breast height (d.b.h.), tree quality, and crown ratio.

In the case of tolerant hardwoods, the marking rules are paired so that poletimber and sawtimber classes can be managed separately. Marking rules 1 and 2 specify that the sawtimber size class be thinned and that all rough and rotten poletimber be removed (fig. 6). *Marking rule 1* calls for rough and rotten sawtimber to be removed first (procedure 1), then less desirable species are thinned from above, down to 18 inches d.b.h. (procedure 2). If the basal area limit is not reached before this point, more desirable species will be thinned from above, down to 22 inches d.b.h. (procedure 3). The last two procedures in marking rule 1 thin from the remaining sawtimber-size trees of the undesirable species and then the desirable species, in that order. Cutting stops when the residual basal area prescribed in the decision key is reached. *Marking rule 2* calls for all rough and rotten poletimber-size trees to be removed and is applied regardless of the action taken through marking rule 1. Marking rules 3 through 6 follow similar logic and are found in Appendix B. As with the decision keys, these marking rules can be tailored to fit the user's particular situation by modifying an auxillary data file. Appendix C outlines the method for changing marking rules.

APPLICATIONS

This management component in and of itself has potential for far-reaching applications. Thus far, however, most uses have been made within STEMS.

MARKING RULE 1

Remove rough and rotten sawtimber, thin from above favoring hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(4).

Trees are removed in this order until basal area limit is reached:

Procedure

1. **Remove rough and rotten sawtimber.**
2. **Remove non-hard maple, other commercial upland hardwoods, walnut, ash more than 18 inches d.b.h.**
3. **Remove hard maple, other commercial upland hardwoods, walnut, ash more than 22 inches d.b.h.**
4. **Remove non-hard maple, other commercial upland hardwoods, walnut, ash sawtimber.**
5. **Remove hard maple, other commercial upland hardwoods, walnut, ash sawtimber.**

MARKING RULE 2

Remove all rough and rotten poletimber.

Figure 6.—Tolerant hardwood marking rules 1 and 2.

Managed as well as unmanaged forest inventories have been projected into the future and updated from past to present, and effects of various management strategies have been evaluated. One specific application of management guides within the framework of Lake States STEMS has been the update of statewide forest inventories to provide interim information between major field inventories. In this application, the management guidelines were modified and applied to estimate the total volume of wood that would have been harvested during the update period (Raile and Smith 1982). In another Lake States application, predicted yields were calculated from selected cutting prescriptions using area control constraints, and future deficiencies and surpluses in the forest resource were identified (Jakes and Smith 1980). Management guides have also been used to help assess current treatment opportunities for the forest resource in the North Central States. Forested areas in a State were considered for several classes of silvicultural treatments based on the stand characteristics. Cut volumes generated from simulated silvicultural operations were calculated, and the results represented the volumes that could have been expected if all treatments were carried out (Smith and Jakes 1981).

When using the guides within STEMS, note that there are no built in constraints on the amount of volume or number of acres cut. Actual silvicultural treatments prescribed when projecting the growth of many stands over a large area will probably be applied with some economic or market-related limits in mind. Therefore, when doing regional updates or projections, such as those mentioned earlier, users may have to supplement the management guides with some constraints on acres cut or on the allowable harvest.

These management guidelines can be used outside the framework of STEMS. For example, the guides can be used manually with other growth and yield predictors that do not offer silvicultural guides, such as the TWIGS program, a version of STEMS that operates on mini- and micro-computers (Miner *et al.* In prep.). In contrast to STEMS, TWIGS is ideal for intensive evaluation of one stand at a time. Its management component consists of a menu list of treatment options—but offers no guidelines about which treatment to choose. The management guidelines described in this publication, along with TWIGS and a professional's good judgment, make up a useful set of decisionmaking tools for the natural resource professional.

CONCLUSION

Computerized silvicultural guidelines, based on accepted management practices, have been developed for incorporation into the Central States variant of STEMS. One set of management guidelines for each of six major forest covertypes in the Central States is included in STEMS' management component. Each set of guidelines includes a decision key that prescribes silvicultural treatments and a set of marking rules that implements the prescriptions. The keys use stand and tree characteristics supplied by the user to determine silvicutural prescriptions. Within STEMS the guidelines can automatically be applied to a stand, or they can easily be modified to create a silvicultural prescription that better suits a particular situation. Although these management guides were written to be included in STEMS, they can readily be incorporated into other growth projection

systems or used as a field reference when preparing management prescriptions.

The management guidelines increase the ease, flexibility, and realism of simulating forest management and growth. With this capability, foresters are better able to update past resources and predict future ones, and evaluate the effects of alternative management strategies.

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APPENDIX A

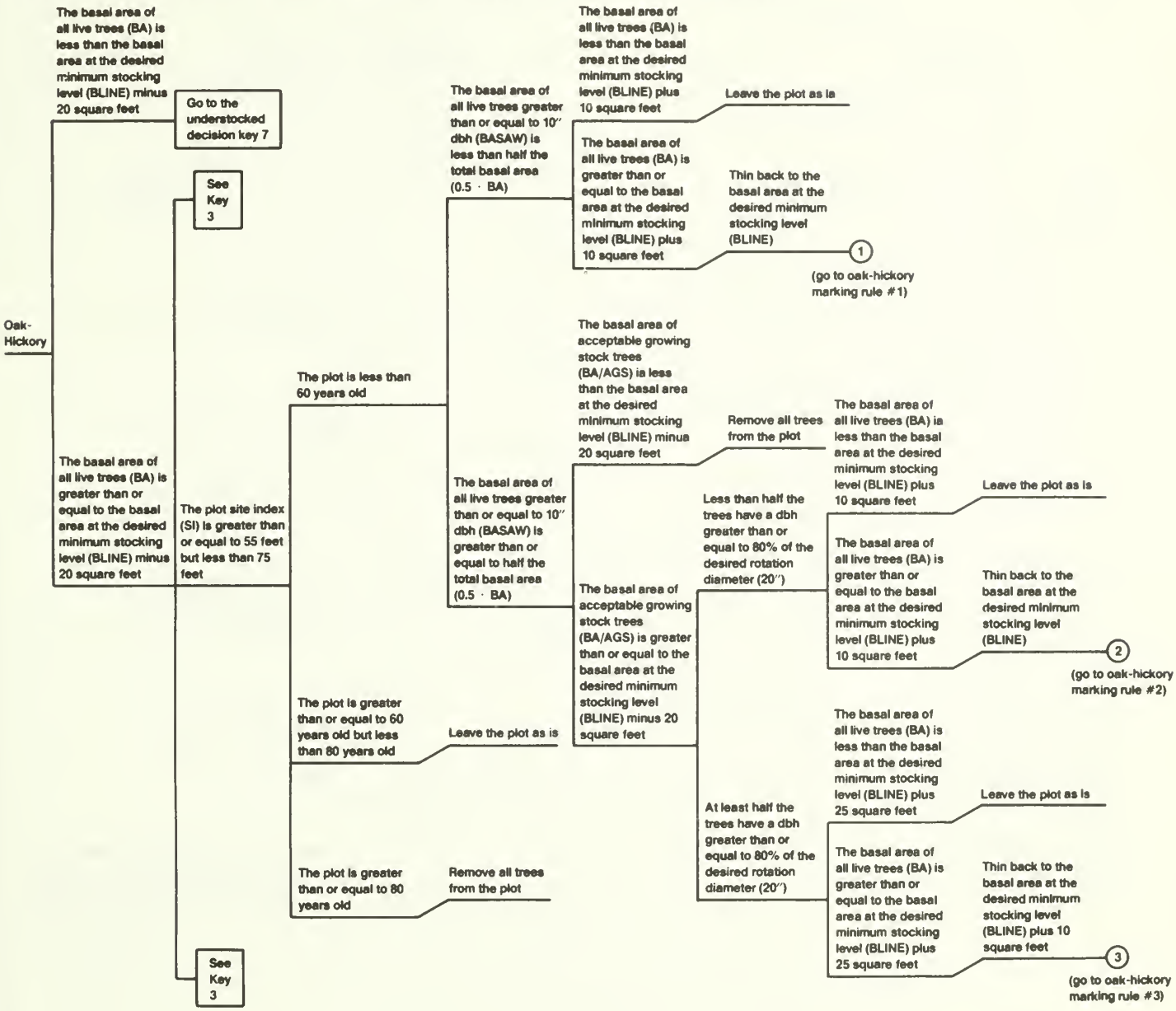
Decision Keys

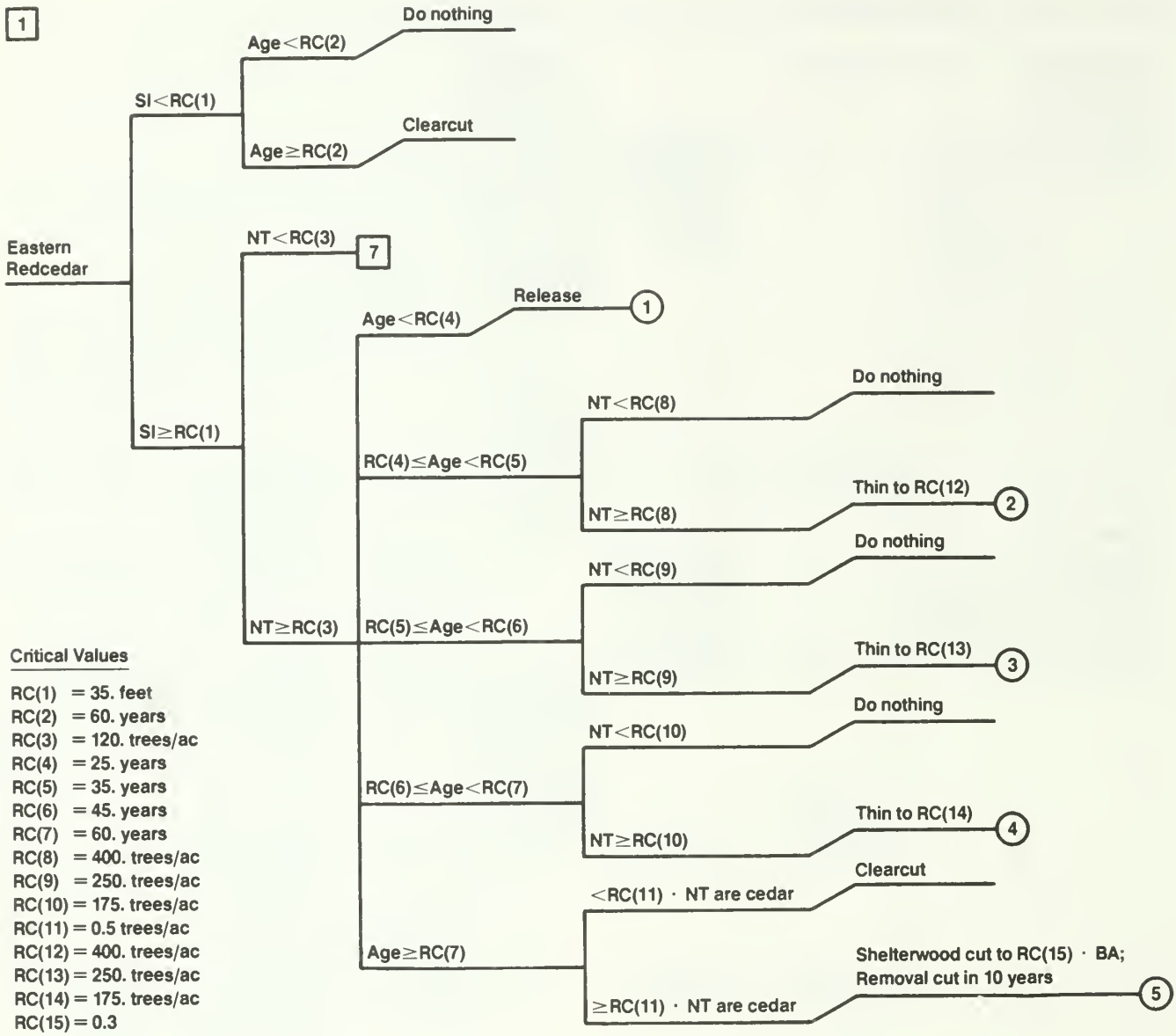
Guide number	Covertype
1	Eastern redcedar
2	Shortleaf pine
3	Central States oak-hickory
4	Elm-ash-cottonwood
5	Pin oak
6	Tolerant hardwood
7	Understocked

Decision key numbers appear within squares. If a key leads to a number within a square, go to the key with that number to determine the management prescription. Numbers that appear within circles indicate the set of marking rules that will be applied. The marking rules are found in Appendix B.

The following key illustrates how to read the center branch of the oak-hickory decision key.

As an example of how to read the decision keys, this page "talks" you through the center branch of the oak-hickory key [3] (see page 12).

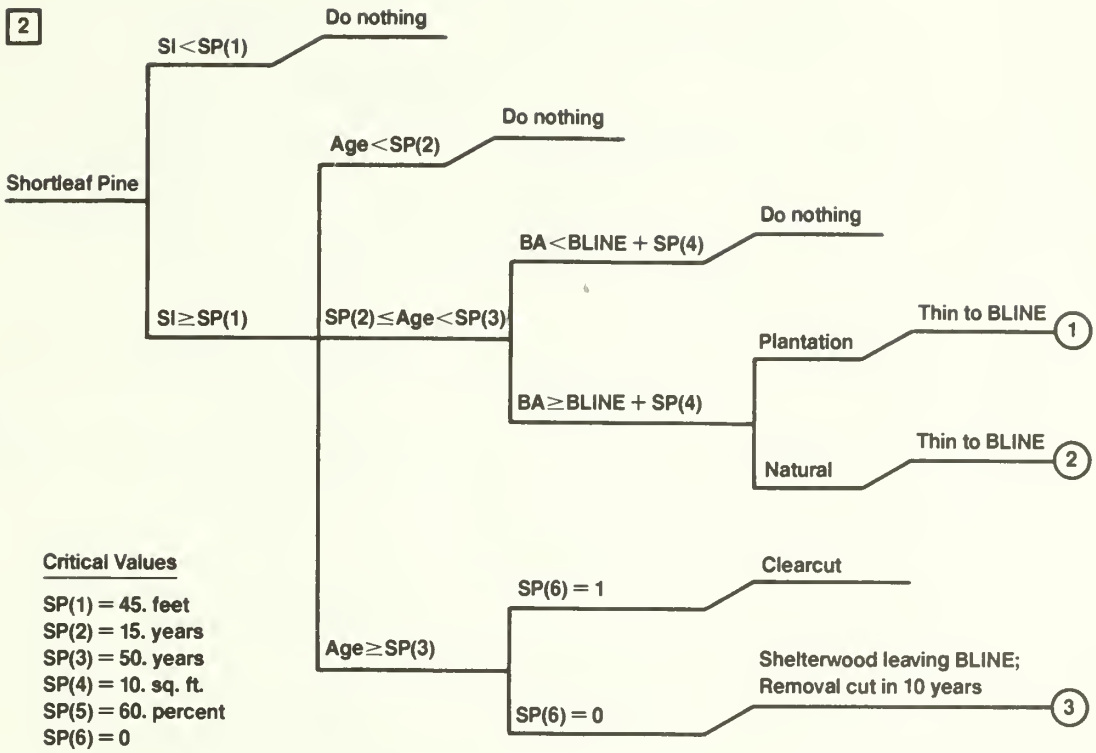




Eastern Redcedar Assumptions

1. Market is such that it is appropriate to manage for eastern redcedar.
2. Management objectives are for saw log production under an even-aged system with rotation age at 60 years.

References: Ferguson *et al.* 1968, Lawson 1985, USDA 1976.



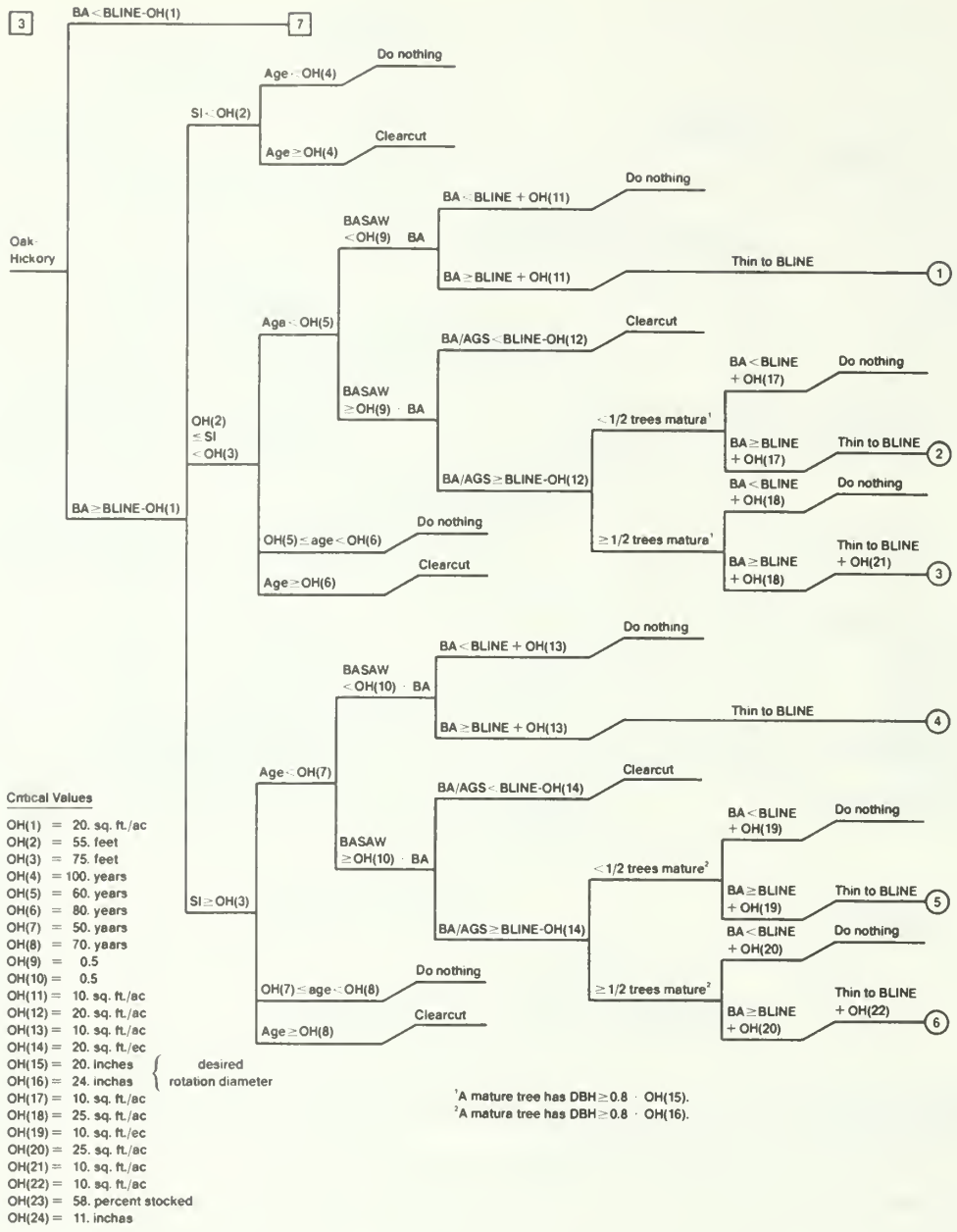
Shortleaf Pine Assumptions

1. Shortleaf pine type consists of sawtimber or poletimber stands in which pine comprises 50 percent or more of the cubic volume, or seedling or sapling stands in which more than half the number of trees are pine.
2. The stand is even-aged.
3. Conditions are appropriate for using the clearcut silvicultural system.
4. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering SP(5) in the following equation. This equation describes the B-line of the stocking guide in Rogers 1982.

$$BLINE = SP(5)\left[\ (0.05454\ QMDBH^2)/(0.088 + 0.094\ \overline{DBH} + 0.025\ QMDBH^2)\right]$$

5. SP(6) enables the user to determine the harvest method where: 0 = shelterwood cut and 1 = clearcut.

References: Brinkman and Rogers 1967, Brinkman and Smith 1969, Rogers 1982, USDA 1980.

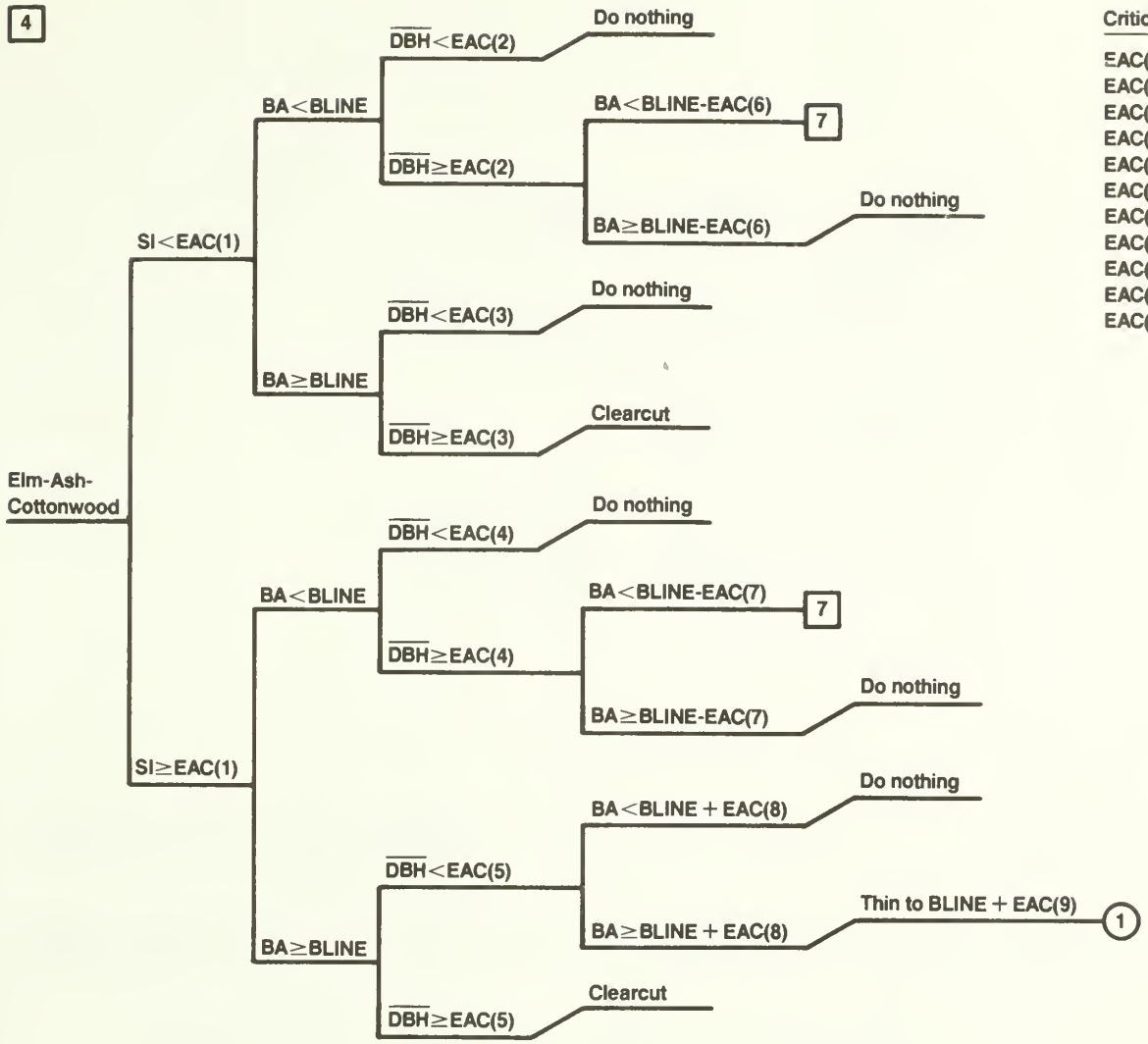


Oak-Hickory Assumptions

1. Management objectives are to favor tolerant hardwoods where the oak site index is high, favor oaks on medium sites, and maintain oaks or convert to another species after clearcutting where the oak site index is low.
2. Manage for timber, particularly large products if possible.
3. Advanced regeneration will be present before clearcutting.
4. Minimum sawtimber DBH for BASAW is OH(24).
5. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering OH(23) in the following equation. This equation describes the B-line of the stocking guide in Sander 1977.

$$\text{BLINE} = \text{OH(23)} \left[(0.05454\ \text{QMDBH}^2)/(-0.0507 + 0.1698\ \overline{\text{DBH}} + 0.0317\ \text{QMDBH}^2) \right]$$

References: Gingrich 1971, Roach and Gingrich 1968, Sander 1977, USDA 1981.



Critical Values

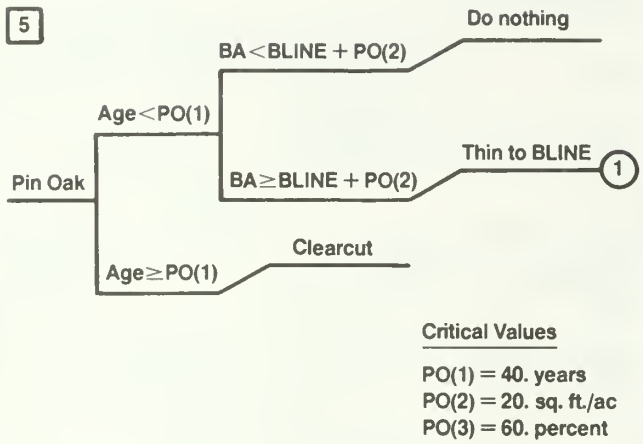
EAC(1)	=	70. feet
EAC(2)	=	5. inches
EAC(3)	=	12. inches
EAC(4)	=	5. inches
EAC(5)	=	24. inches
EAC(6)	=	10. sq. ft./ac
EAC(7)	=	10. sq. ft./ac
EAC(8)	=	20. sq. ft./ac
EAC(9)	=	0. sq. ft./ac
EAC(10)	=	119. sq. ft./ac
EAC(11)	=	0.072

Elm-Ash-Cottonwood Assumptions

1. It is silviculturally appropriate to use even-aged silviculture in the stand.
2. Management objectives can be met using even-aged silviculture.
3. Timber production is the primary objective, particularly large products on good or better sites, pulpwood on poorer sites.
4. Understocked stands can be regenerated to trees.
5. Adequate seed source exists in adjacent stands or the area will be planted after clearcutting.
6. Competing vegetation is controlled in young stands.
7. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of full stocking considered acceptable can be changed by altering EAC(10) and EAC(11) in the following equation. This equation describes the B-line of the stocking guide in Myers and Buchman 1984.

$$BLINE = EAC(10)(1\text{-}e^{-EAC(11)\cdot QMDBH})$$

References: Myers and Buchman 1984, Putnam *et al.* 1960, Schlesinger (personal communication).

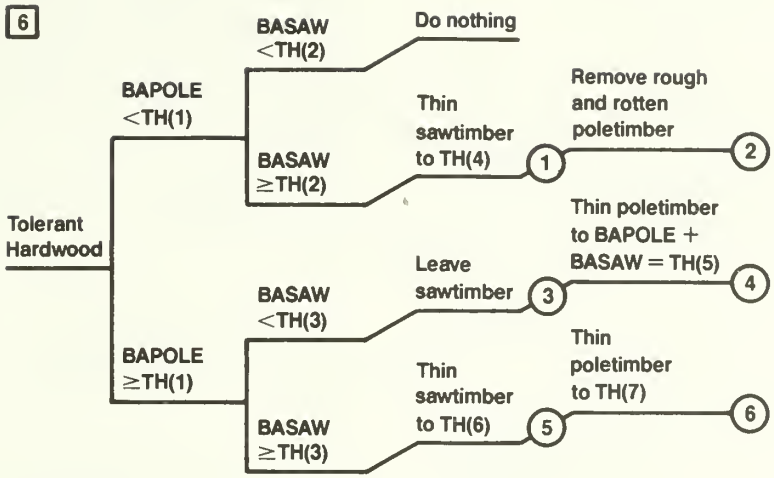


Pin Oak Assumptions

1. A management decision has been made to manage pin oak on a 40-year rotation to produce pilings.
2. The clearcut prescription assumes > 1,500 well spaced desirable hardwood seedlings per acre for advance regeneration.
3. The minimum acceptable stand basal area is dependent on the size of the trees present. That is, it is a measure of stocking. The percent of the full stocking considered acceptable can be changed by altering PO(3) in the following equation. This equation describes the B-line of the stocking guide in Sander 1977.

$$\text{BLINE} = \text{PO(3)} \left[(0.05454 \bullet \text{QMDBH}) / (-0.0507 + 0.1698\ \overline{\text{DBH}} + 0.0317\ \text{QMDBH}^2) \right]$$

References: Putnam 1951, SAF 1981, USDA 1979, 1980.



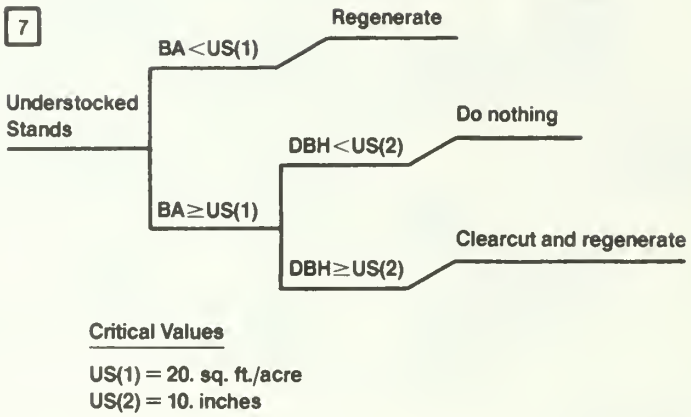
Critical Values

TH(1) = 20. sq. ft./ac
TH(2) = 80. sq. ft./ac
TH(3) = 80. sq. ft./ac
TH(4) = 70. sq. ft./ac
TH(5) = 85. sq. ft./ac
TH(6) = 70. sq. ft./ac
TH(7) = 15. sq. ft./ac
TH(8) = 10. inches

Tolerant Hardwood Assumptions

1. Maintain or develop all-aged tolerant hardwood stands.
2. Manage for timber, particularly large products if possible.
3. Minimum sawtimber d.b.h. for BASAW is TH(8).

References: Tubbs 1977, USDA 1973.



Understocked Stand Assumptions/

1. Stands with a basal area less than 20 square feet are open enough so that they can be regenerated without removing the understory.
2. Stands with a basal area greater than 20 square feet will be operable if the average diameter is greater than 10 inches.

Reference: Brand 1981.

APPENDIX B

Marking Rules

Marking rules consist of a number of removal procedures that carry out the prescription determined by the covertype decision key. The procedures indicate how the cut will be made using tree species, diameter at breast height, crown ratio and quality as criteria. For each covertype, the marking rule numbers refer to the numbers along the right side of the corresponding decision key (Appendix A). For instructions on how to modify these marking rules, see Appendix C.

Eastern Redcedar

Marking Rule 1: Remove all woody competition regardless of position. (BATOT = BA of eastern redcedar).

Procedure: 1. Remove species other than eastern redcedar, taking the smallest diameter trees first.

Marking Rule 2: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(12).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 3: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(13).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 4: Remove rough and rotten trees and thin from below, favoring eastern redcedar, until number of trees per acre is less than RC(14).

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than eastern redcedar, taking the smallest diameter trees first.
3. Remove eastern redcedar, taking the smallest diameter trees first.

Marking Rule 5: Make a shelterwood cut, leaving 30 percent of existing basal area in seed cutting (favor eastern redcedar), and make a removal cut 10 years later.

Procedure: 1. Remove rough and rotten trees.
2. Leave largest d.b.h., highest crown ratio, eastern redcedar.

Shortleaf Pine

Marking Rule 1: Manage for pine on a 40-year rotation for posts and poles. Eliminate all non-shortleaf pine, then row thin until basal area is less than the minimum acceptable stocking level (BLINE).

Procedure: 1. Remove species other than shortleaf pine.
2. Remove every third shortleaf pine.

Marking Rule 2: Manage for pine on a 40-year rotation for posts and poles. Thin until basal area is less than BLINE, eliminating inferior and competing hardwoods.

Procedure: 1. Remove rough and rotten trees.
2. Remove species other than shortleaf and loblolly pine, taking the smallest diameter trees first.
3. Remove shortleaf and loblolly pine, taking the smallest diameter trees first.

Marking Rule 3: Make a shelterwood cut leaving the minimum acceptable stocking level (BLINE) in the seed cutting, favoring shortleaf pine. Make a removal cut 10 years later.

Procedure: 1. Remove rough and rotten trees.
2. Leave largest d.b.h., highest crown ratio shortleaf pine.

Central States Oak-Hickory

Marking Rules 1, 2, and 3: Remove rough and rotten trees and thin from below, discriminating against undesirable species and favoring shortleaf pine and valuable oaks.

Procedure: 1. Remove rough and rotten trees.
2. Remove tupelo, beech, elm, and non-commercial species, taking the smallest diameter trees first.
3. Remove soft maple, hard maple, other upland hardwoods, and other lowland species, taking the smallest diameter trees first.
4. Remove species other than red oak, black oak, white oak, and shortleaf pine, taking the smallest diameter trees first.

5. Remove red oak, black oak, white oak, and shortleaf pine, taking the smallest diameter trees first.

Marking Rules 4, 5, and 6: Remove rough and rotten trees and thin from below, discriminating against undesirable species and favoring valuable oaks, black walnut, and white ash.

Procedure:
1. Remove rough and rotten trees.
2. Remove tupelo, beech, elm and non-commercial species, taking the smallest diameter trees first.
3. Remove soft maple, hard maple, other upland hardwoods, and other lowland species, taking the smallest diameter trees first.
4. Remove species other than red oak, black oak, black walnut, and white ash, taking the smallest diameter trees first.
5. Remove red oak, black oak, black walnut, and white ash, taking the smallest diameter trees first.

Elm-Ash-Cottonwood

Marking Rule 1: Remove rough and rotten trees and thin from below, favoring green ash, silver maple, cottonwood, and sycamore, until basal area is less than the minimum acceptable stocking level (BLINE).

Procedure:
1. Remove rough and rotten trees.
2. Remove species other than green ash, silver maple, cottonwood, black walnut, and sycamore, taking the smallest diameter trees first.
3. Remove green ash, silver maple, cottonwood, black walnut, and sycamore, taking the smallest diameter trees first.

Tolerant Hardwoods

Marking Rules 1 and 2: Remove rough and rotten sawtimber; thin, favoring hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(4); and remove all rough and rotten poles.

Sawtimber procedure:
1. Remove rough and rotten sawtimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash more than 18 inches d.b.h., taking the largest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash more than 22 inches d.b.h., taking the largest diameter trees first.
4. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.
5. Remove hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.

Poletimber procedure:
1. Remove rough and rotten poletimber.

Marking Rules 3 and 4: Leave sawtimber; remove rough and rotten poletimber; and thin poletimber from below, favoring hard maple, other commercial upland hardwoods, walnut, and ash until poletimber and sawtimber basal area combined is less than TH(5).

Sawtimber procedure:
1. Do nothing to the sawtimber.

Poletimber procedure:
1. Remove rough and rotten poletimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.

Marking Rules 5 and 6: Remove rough and rotten sawtimber and poletimber; thin sawtimber, favoring immature hard maple, other commercial upland hardwoods, walnut, and ash until sawtimber basal area is less than TH(6); and thin poletimber from

below, favoring hard maple, other commercial upland hardwoods, walnut, and ash until poletimber basal area is less than TH(7).

Sawtimber procedure:
1. Remove rough and rotten sawtimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash more than 18 inches d.b.h., taking the largest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash more than 22 inches d.b.h., taking the largest diameter trees first.
4. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.
5. Remove hard maple, other commercial upland hardwoods, walnut, and ash sawtimber, taking the smallest diameter trees first.

Poletimber procedure:
1. Remove rough and rotten poletimber.
2. Remove species other than hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.
3. Remove hard maple, other commercial upland hardwoods, walnut, and ash poletimber, taking the smallest diameter trees first.

APPENDIX C

Modifying the Marking Rules

Appendices A and B outline the prescriptions and marking rules that are systematically applied to stands projected by STEMS. As mentioned, STEMS users can modify both the marking rules and the prescription to fit their particular situations. Appendix C explains how to modify the marking rules; a discussion of how to modify the prescription is found in the text.

As seen in Appendix B, each covertype marking rule consists of a number of removal procedures. The procedures use tree species, diameter, crown ratio, and quality to indicate how the cut will be made. This information is stored in a series of codes in an auxiliary data file. Each procedure is characterized using a field of 13 digits; the first number indicates how the cut will be made (procedure codes in table 2) and the following numbers supply the specific information needed to carry out the cut. *The user can modify the removal procedures by changing the codes in the auxiliary file before making a STEMS run.*

The following example demonstrates how the codes are used.

Marking rule 1 in the tolerant hardwood guide outlines a thin with the following procedures:

1. First, remove rough and rotten sawtimber of any species;
2. next, remove undesirable species from above (cut largest diameter trees first) down to 18 inches d.b.h.;
3. then, remove desired species from above down to 22 inches d.b.h.;
4. continue by removing the remaining undesirable sawtimber (starting with the smallest diameter trees);
5. and finally, remove desired species of sawtimber size, removing smallest diameter trees first.

The codes that produce this marking rule are:

	Procedure code	Lower diameter limit	Upper diameter limit	Species group code*	Species group code*	Species group code*	Species group code
Position	1	2 3	4 5	6 7	8 9	10 11	12 13
	1	1 0	9 9	0 0	0 0	0 0	0 0
	3	1 8	9 9	1 8	1 9	0 6	0 0
	5	2 2	9 9	1 8	1 9	0 6	0 0
	2	1 0	9 9	1 8	1 9	0 6	0 0
	4	1 0	9 9	1 8	1 9	0 6	0 0

**species group code 18 is hard maple, 19 is ash, and 6 is walnut. (See table 3 for a complete list of Central States species group codes.)*

Up to five removal procedures can be combined to simulate a marking rule. Using the nine procedure options and the criteria for cuts, many different marking rules can be created.

Table 2.—*Removal procedures*

Procedure CODE	Procedure	Information needed for coding	Digit position	Code/Value
1	Remove rough and rotten trees in designated size class until required BA is achieved. (Tree quality codes are needed for this procedure).	Size class to remove	1 2-3 4-5 6-13	1 Lower diameter limit Upper diameter limit All zeros
2	Remove smallest trees of unspecified species until required BA is achieved.	Size class to remove, 4 species groups to leave.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	2 Lower diameter limit Upper diameter limit 4 species group codes to leave
3	Remove largest trees of unspecified species until required BA is achieved.	Size class to remove, 4 species groups to leave.	1 2-13	3 Same as 2
4	Remove smallest trees of specified species until required BA is achieved.	Size class to remove, 4 species groups to remove.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	4 Lower diameter limit Upper diameter limit 4 species group codes to remove
5	Remove largest trees of specified species until required BA is achieved.	Size class to remove, 4 species groups to remove.	1 2-13	5 Same as 4
6	Shelterwood cut leaving required BA (leave largest d.b.h., highest crown ratio trees).	Size class to remove, 4 species groups to favor.	1 2-3 4-5 6-7, 8-9 10-11, 12-13	6 Lower diameter limit Upper diameter limit 4 species group codes to favor
7	Reduce number of trees.	Number of trees to leave.	1 2-5 6-13	7 Number of trees/acre to leave All zeros
8	Remove all overtopping.	Lower d.b.h. of trees to remove.	1 2-3 4-13	8 Lower d.b.h. of trees to remove All zeros
9	Remove all trees of a certain size and species.	Size class to remove, 4 species groups to remove.	1 2-13	9 Same as 4

Table 3.—*Central States STEMS species codes*

Group code	Species code	Species
1	068	Eastern redcedar
	060	Juniper
2	110	Shortleaf pine
3	132	Virginia pine
	131	Loblolly pine
4		Other softwoods
	129	White pine
5		—
6		Walnut
	602	Black walnut
	601	Butternut
7		Tupelo
	694	Swamp tupelo (blackgum)
	691	Water tupelo
	693	Black tupelo
8		Select hickory
	407	Shagbark hickory
	405	Shellbark hickory
	409	Mockernut hickory
9		Other hickory
	403	Pignut hickory
	400	Hickory spp.
	401	Water hickory
	402	Bitternut hickory
	404	Pecan
	408	Black hickory
10		Beech
	531	American beech
11	543	Black ash
	545	Pumpkin ash
	546	Blue ash
12	742	Cottonwood
13		Soft maple
	316	Red maple
	313	Boxelder
	317	Silver maple
14		Cherry
	762	Black cherry
15		Elm
	972	American elm
	461	Sugarberry
	462	Hackberry
	971	Winged elm
	970	Elm spp.
	974	Siberian elm
	975	Red elm
	977	Rock elm
16	621	Yellow poplar

(Table continued)

Table 3.—*Central States STEMS species codes* (Continued)

Group code	Species code	Species
17		Basswood
	951	American basswood
18		Hard maple
	318	Sugar maple
19		White and green ash
	541	White ash
	540	Ash spp.
	544	Green ash
20	802	White oak
21		Red oak
	833	Northern red oak
	812	Southern red oak
22	837	Black oak
23	806	Scarlet oak
24	824	Blackjack oak
25	826	Chinkapin oak
	804	Swamp white oak
	823	Bur oak
	825	Swamp chestnut oak
26	835	Post oak
	836	Delta post oak
27	832	Chestnut oak
28	830	Pin oak
	809	Northern pin oak
	813	Cherrybark oak
	817	Shingle oak
	822	Overcup oak
	827	Water oak
	828	Nuttall oak
	831	Willow oak
	834	Shumard oak
29		Other upland hardwoods
	931	Sassafras
	331	Ohio buckeye
	452	Catalpa
	521	Persimmon
	550	Honey locust spp.
	552	Honey locust
	741	Balsam poplar
	743	Bigtooth aspen
	746	Quaking aspen
	901	Black locust
30		Other lowland species
	731	Sycamore
	221	Baldcypress
	373	River birch
	611	Sweetgum
	920	Willow spp.
	922	Black willow

(Table continued)

Table 3.—*Central States STEMS species codes (Continued)*

Group code	Species code	Species
31		Noncommercial species
	999	Misc. noncommercial
	391	Blue beech
	471	Redbud
	491	Dogwood spp.
	500	Hawthorn spp.
	571	Kentucky coffeetree
	641	Osage orange
	651	Cucumber tree
	653	Sweetbay
	680	Mulberry
	681	White mulberry
	682	Red mulberry
	701	Ironwood
	711	Sourwood

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