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EVALUATING TIMBER STAND IMPROVEMENT OPPORTUNITIES IN NORTHERN LOWER MICHIGAN USING THE DECISION-TREE APPROACH

By

A. Jeff Martin

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ABSTRACT

EVALUATING TIMBER STAND IMPROVEMENT OPPORTUNITIES IN NORTHERN LOWER MICHIGAN USING THE DECISION-TREE APPROACH

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A. Jeff Martin

Data were collected from 25 small privately-owned woodlands within a five-county area of northern Lower Michigan which had received a timber stand improvement treatment in 1962 and remuneration for part of the estimated cost through the Agricultural Conservation Program. The stands were second-growth northern hardwoods.

In the analysis, each stand was reconstructed as it appeared before and after the timber stand improvement treatment. This afforded a means for simulating the decision-making sequence faced by each individual owner in 1962. The decision-tree approach was employed for purposes of evaluating the formulated model, describing a total of 30 alternatives available to each ownership. Physical growth projections were made under the four major assumptions

of: 1) No TSI in 1962, and no future thinnings, 2) No TSI in 1962, but future thinnings would be performed, 3) TSI in 1962, but no future thinnings, and 4) TSI in 1962, with future thinnings. Additional assumptions concerning prices, costs, cull defect, mortality, and quality change were then applied to the decision model.

To evaluate the model, internal rates of return were calculated for each opportunity, and used as a measure of effectiveness for ascertaining the relative desirability of the various options. IRR values ranged from less than 1 percent to over 20 percent, averaging 8 1/2 percent for the "best" five alternatives. The highest returns were associated with timber stand improvement subsidized by ACP payments, followed by a regular schedule of periodic thinnings, terminating in the marketing of cut products from the woodland. Subsequent to the initial evaluation, the original model was subjected to sensitivity analysis, providing some insight as to how incremental changes in certain parameter values influence the optimal sequence of alternative courses of action. Of the various factors tested, the internal rate of return appeared most sensitive to changes in the annual cost assumption.

ACKNOWLEDGMENTS

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I am deeply indebted to Dr. Victor J. Rudolph, my major professor, for the opportunity of undertaking the study and for the enjoyable and stimulating research environment. I also gratefully acknowledge the helpful suggestions offered by other members of the guidance committee; namely, Dr Bruce T. Allen, Dr. R. Keith Hudson, and Dr. Robert S. Manthy. Above all, I am grateful to my wife Janice, for her understanding, patience, and constant encouragement.

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CHAPTER I

INTRODUCTION

The small woodland segment of Michigan's forest land represents a substantial source of potential timber supply. Of the total commercial forest land in Michigan, 66 percent is in some form of private ownership -- 20 percent is owned by full- and part-time farmers. The farm-woodland category alone contributed timber products valued at $16.3 million in 1957 -- 22 percent of the total from all forests (James, 1960). The amount from all "small" private ownerships would be significantly greater.

Generally, when a woodland owner undertakes forestry practices, he is interested in making a net return from his forest lands. He is usually constrained by a limited budget for investment purposes, and the best procedures for maximizing returns are not specifically known to him. Reliable data concerning the possible fluctuations in net returns from various forest management activities are relatively scarce in all regions, and are practically non-existent in the Lake States. Such data are needed to determine where forestry can be practiced most profitably, and the kinds and intensities of management that can be justified economically.

But aside from justifying small woodland research on the basis of improving the owner's welfare, and/or his income-generating potential, such efforts should strive to achieve more abundant production of consumer goods from small ownerships, products which are more economical and competitive than so-called wood substitutes (Schallau, 1964). Schallau proposes the implementation of small-tract production and marketing research, searching for strategic problems to investigate rather than attempting to study all phases of growing and selling timber.

The present investigation was oriented towards the production phase. It sought to compile needed information on net returns from actual forest stands which have had varying degrees of cultural practices applied to them in keeping with the goals of ownership.

The major objective of this study was to establish management priorities and guidelines for timber stand improvement practices. Such a set of recommendations would be designed for the forest landowner and/or the consulting forester, to use in the management of small northern hardwood stands in northern Lower Michigan.

In attaining this goal, certain secondary objectives were fulfilled in the process: 1) establishing a working model for decision-making by the small forest landowner, concerning the implementation of various cultural activities; 2) determining the effects of cultural treatments in northern hardwood stands on developmental patterns and financial prospects; and 3) ascertaining the relative influence of individual ownership characteristics on the expected net returns.

To accomplish the stated objective, the following steps were required:

1. Select an area for concentrated study.

2. Determine which woodlands should be sampled in the finite population of private landownerships and what sampling intensity should be applied to each.

3. Undertake field measurements to determine the effects of past treatments and to provide a basis for stand projections into the future.

4. Compile the collected data in a form suitable for growth projection and subsequent analysis.

5. Establish a growth projection procedure for predicting future volumes under various intensities of management.

6. Formulate a model for decision-making by developing a set of possible alternatives facing a given woodland owner and to predict future volume growth, as modified by various assumptions regarding mortality, cull defect, quality, etc., for each opportunity.

7. Add various economic assumptions concerning costs and prices to the decision-model.

8. Evaluate the various alternatives for each ownership and establish a list of priorities based on a commonly accepted measure of effectiveness.

9. Based on results of the evaluation, formulate a series of recommendations which would guide a forest landowner in making future management decisions.

10. Identify those factors that are most critical in making such an economic evaluation, by judging their influence on the measure of effectiveness.

CHAPTER II

THE STUDY AREA

General Description

The area selected for study included Benzie, Grand Traverse, Leelanau, Manistee, and Wexford counties in the northern portion of Michigan's Lower Peninsula (Figure 1).

The Michigan Department of Natural Resources subdivides the State into various Regions, Districts, and Areas for administrative purposes, and the entire study area is within Region II and District 6. Benzie, Leelanau, and Manistee Counties comprise the Betsie River Area and will be referred to as Area I in this study, and Grand Traverse and Wexford Counties form the Fife Lake Area, which will be designated as Area II in this project (Figure 1).

The five-county block contains 1,440,000 acres of land (4 percent of the state's total), and 60,160 acres of water (8 percent of the state's total) (Myers and Van Meer, 1966).

The past history of the study area is quite similar to that witnessed throughout the northern half of Michigan's

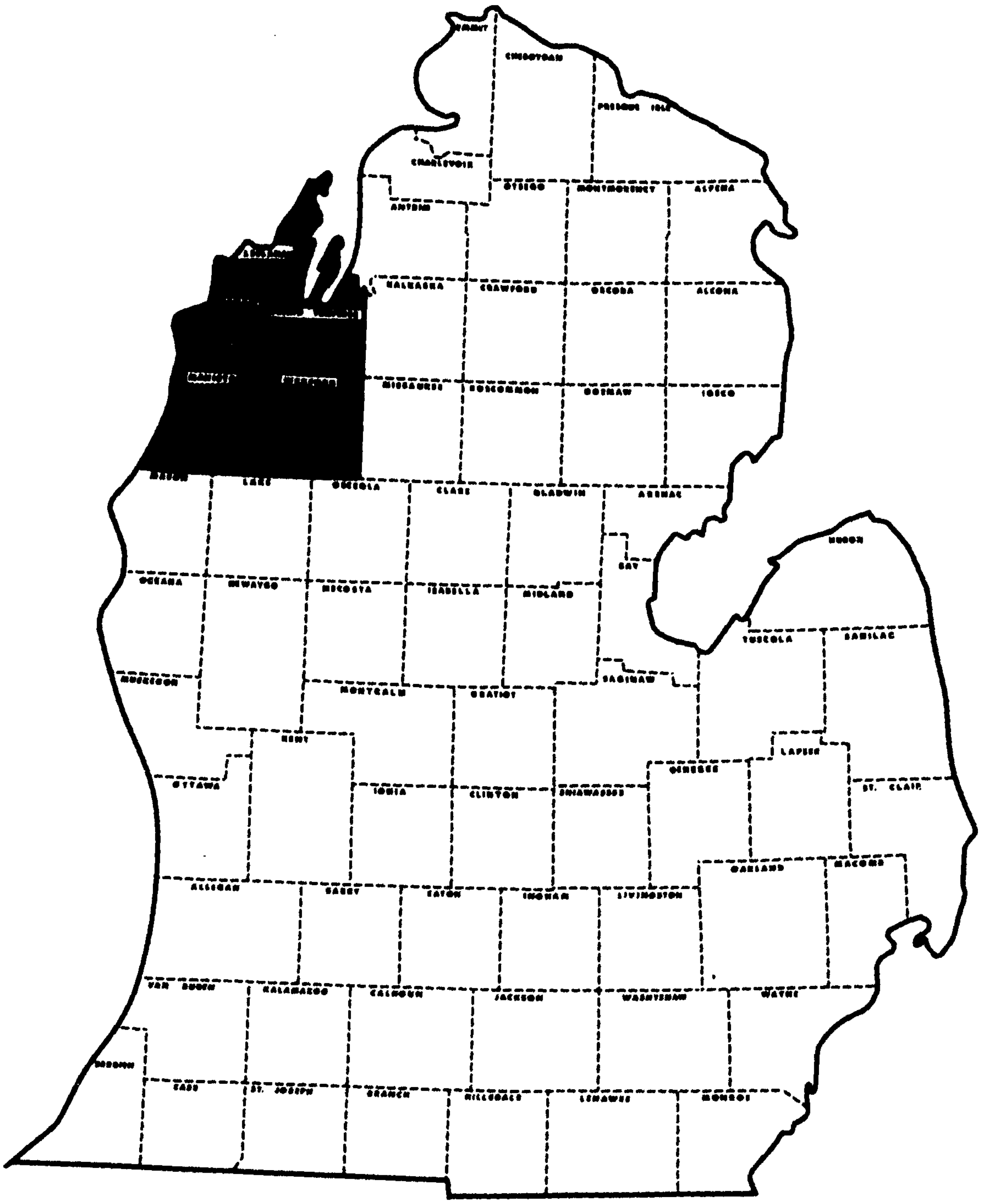

FIGURE 1

MICHIGAN'S LOWER PENINSULA, SHOWING THE STUDY AREA (CROSS-HATCHED) SUB-DIVIDED INTO AREA I AND AREA II.

Lower Peninsula, with most of the region owing its "development" to the lumbering era. Portions of two state forests and one national forest are located in the study area. The Fife Lake State Forest extends into Benzie, Manistee, and Wexford Counties, and the Betsie River Forest is located in Leelanau and Manistee Counties. The Manistee National Forest extends into the southern portion of the study area, comprising a large share of Manistee and Wexford Counties.

The five-county area, as with many sections of the Northern Lower Peninsula, shows extreme contrasts in home dwellings and general economic prosperity within the span of a few miles. A typical shoreline abounds with recreation centers and large, expensive dwellings (generally in absentee ownership), whereas evident prosperity decreases rapidly upon leaving the vicinity of the lake. The area between lakes is largely devoted to farming and fruit orchards, and, except in the case of many orchard ownerships, the properties are rapidly deteriorating into "rural slums." Buildings in disrepair, and croplands reverting to wildlands add testimony to a decline in "small-parcel" farming.

The 1960 population of 88,153 for the five counties comprised 1 percent of the state's total, with nearly half

(42 percent) of the area's population residing in the cities of Cadillac (10,112), Manistee (8,324) and Traverse City (18,432) (Myers and Van Meer, 1966).

Four of the five counties in the study area are located adjacent to Lake Michigan and, therefore, experience a modified marine climate most of the year. Wexford County, approximately 20 to 25 miles from the Lake's shore has a climate that alternates between the continental and semimarine, with changing meterological conditions (USDA, 1941).

Three soil associations encompass most of the five counties: 1) Montcalm, Kalkaska, Emmet; 2) Montalm, Wexford, Emmet; and, 3) Rubicon, Roselawn, Grayling (Whiteside, et al., 1968). The soils on the sampled ownerships ranged from medium to very high in potential productivity for northern hardwoods, based on their woodland suitability classification (USDA, 1966).

The region has a well-developed transportation system, with a network of hard-surfaced roads providing excellent access to most areas (Figure 2). In fact, the study area has a higher concentration of main trunklines than any similar-sized area in northern Lower Michigan.

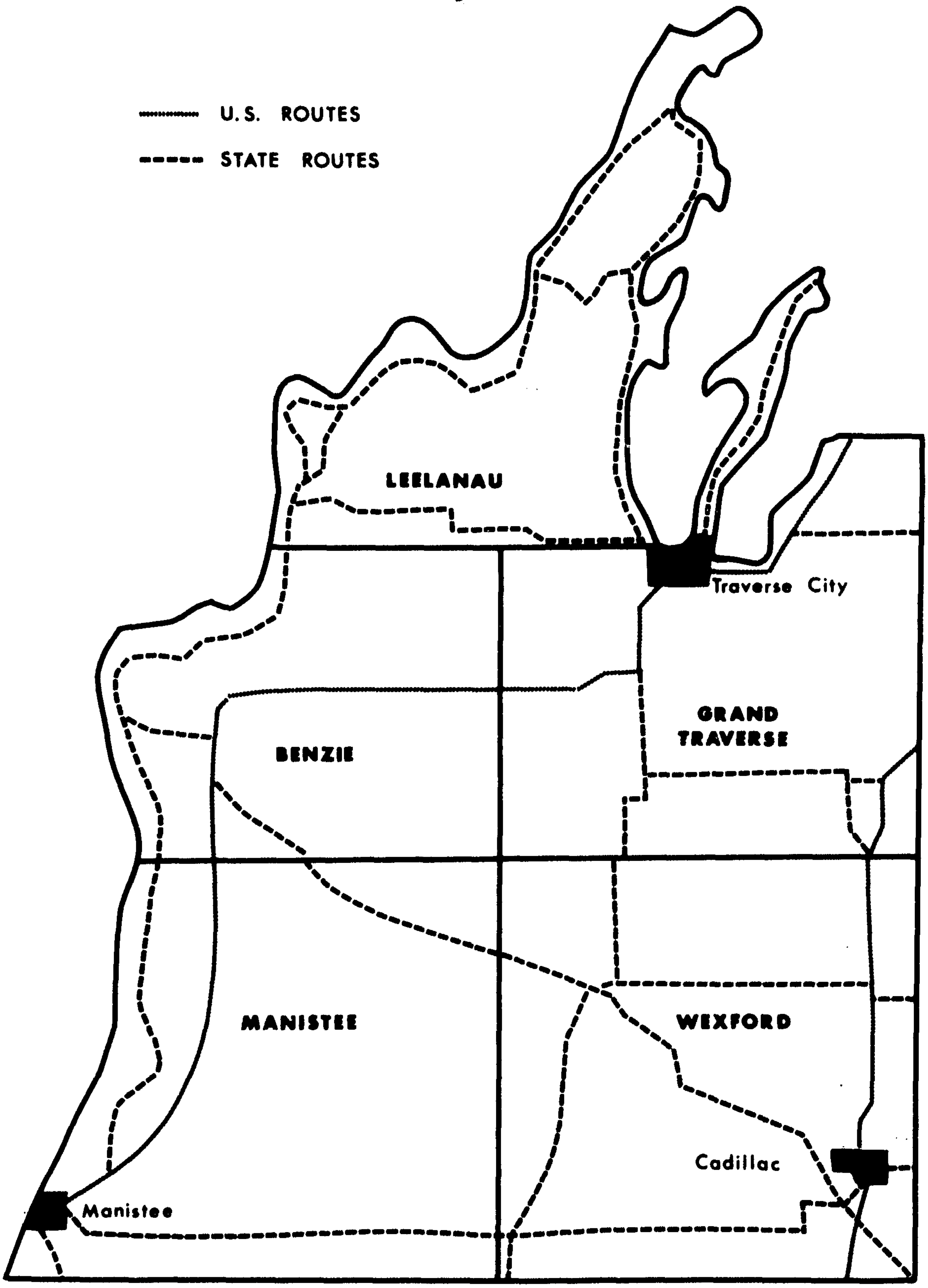

FIGURE 2

PRIMARY HIGHWAY NETWORK FOR THE FIVE-COUNTY STUDY AREA, SHOWING U.S. AND STATE ROUTES

Major roadways that traverse the area include U.S. Highways 131 and 31, and State Highways 22, 37, 42, 55, 72, 109, 110, 113, 115, 186, and 204. This primary network is adequately supported by a good system of secondary roads, which, in the case of most county roads, are hard surfaced.

The median income of families living within the study area is somewhat below that for the state and employment data show that a larger percentage of the study area's labor force is unemployed, relative to the entire state (Myers and Van Meer, 1966). General agriculture, forestry, and fisheries comprise nearly 8 percent of the total employment for the study area, compared to 3.4 percent for the state.

Farming is quite important when considering the scope of this study. The woodland areas sampled in the investigation were generally part of a farm ownership. The ties between farming and forestry in the area are further highlighted when it is noted that 88 percent of the farming units include woodland acreage (James, 1960). Almost one-third of the total acreage in the area was classified as farmland in 1966. In this same year, the total farm ownerships numbered 2,547, with an average size of 160 acres, slightly larger than the state average of 145 acres (Myers and Van Meer, 1966).

The recreational picture has been considerably enhanced since the data were collected in 1966 by the introduction of Coho salmon to several streams in the five-county region. This region is also the location of Sleeping Bear Sand Dunes, for which a National Lakeshore status has been proposed. As with most of Michigan, the recreation aspects in the area are largely water-oriented; and the five counties have approximately 30 lakes which provide excellent facilities for boating, fishing and camping.

Timber Resources

The five counties contain 13 percent of the total land area in the northern half of Michigan's Lower Peninsula, and 12 percent of the total forest land. In the study area, commercial forest land comprises 99 percent of all forest land, and represents 12 percent of the commercial forest in the northern Lower Peninsula (Ostrom, 1967). Table 1 presents additional forest-land information from the most recent Forest Survey in Michigan.

TABLE 1.--Total and forest area in the five counties, 1966

County	Total Land Area	All Forest Land	Non-Commercial Forest Land	Commercial Forest Land	Commercial Forest as a Percent of Land Area
	Thousand Acres				Percent
Benzie	202.2	124.7	2.7	122.1	60.3
Grand Traverse	297.0	161.7	0.6	161.1	54.2
Leelanau	223.[illegible]	114.2	1.0	113.2	50.7
Manistee	357.1	221.3	1.1	220.2	61.7
Wexford	360.3	221.9	1.5	220.4	61.2
Total	1,440.0	843.8	6.9	836.9	57.6
Northern Lower Peninsula	11,387.4	7,051.7	57.7	6,994.0	61.4

Source: Ostrom, 1967.

In a study of Michigan's farm woodlands (James, 1960), it was pointed out that 36 percent of the farm area was woodland in northern Lower Michigan, with the average size of each woodlot being 67 acres. In this same area, the farm woodlot sector represents 18 percent of the total forest area.

Yoho's classic work involving private forest land ownership in northern Lower Michigan (1957), estimated that in the "Cadillac Block" of counties,[1] 31 percent of the privately held commercial forest acreage was owned by full-time farmers, 13 percent by part-time farmers, and 7 percent by industry. Thus, farm ownership constitutes a large share of the commercial forest land in this region (44 percent), and undoubtedly, a similar pattern holds throughout the study area.

The Northern Lower Michigan Unit, as designated in the Third Forest Survey, 1964 to 1966, coincides with the 31 counties included in Yoho's study; hence, the data are quite comparable. The Forest Survey data subdivided the commercial forest land area into various cover types, and the northern hardwood component accounts for nearly 27 percent of the forest land in the study area, (Ostrom, 1967). This type, designated as cover Type 25 by the Society of American Foresters (1962), provided nearly all of the sample data in this study. Associated types included Type 26, Sugar maple-basswood, and Type 27, Sugar maple (Society of American Foresters, 1962).

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[1] Benzie, Grand Traverse, Kalkaska, Manistee, Missaukee, and Wexford Counties.

The growing stock volume of sugar maple and yellow birch was 89.4 million cubic feet in the five-county study area (Table 2), which represented 16.8 percent of the total for these species in the northern 31 counties of the Lower Peninsula (Chase, 1968).

Table 2.--Hardwood growing stock volume on commercial forest land, by counties and species groups, 1966.

Species	County					
	Total	Benzie	Grand Traverse	Leelanau	Manistee	Wexford
	Million cubic feet					
Aspen	126.4	20.7	17.2	19.3	34.1	35.1
Paper birch	33.7	5.6	5.7	6.9	7.3	8.2
Oak	108.9	11.4	25.9	8.6	42.4	20.6
Sugar maple-Yellow birch	89.4	16.1	16.2	16.2	17.1	23.8
Other soft hardwoods[a]	168.2	33.8	30.7	24.7	36.8	42.2
Other hard hardwoods[b]	62.5	12.8	11.7	9.5	13.6	14.9
Total	589.1	100.4	107.4	85.2	151.3	144.8

Source: Chase, 1968.

[a]Other soft hardwoods--primarily red maple, black ash, balsam poplar, cottonwood, yellow poplar, basswood, black cherry, the elms, hackberry, and sycamore.

[b]Other hard hardwoods--primarily hickory, beech, white ash, and black walnut.

The northern hardwood cover type (sugar maple, yellow birch, and beech) contributed 23.6 percent of the total hardwood sawtimber volume in the five-county area (Chase, 1968). Two associated species that formed a significant portion of the sample data--basswood and elm consituted another 20.8 percent of the board-foot volume total. This five-species group, making up nearly one-half of the hardwood sawtimber, accounted for 37.4 percent of the board-foot volume for all species in the study area (Chase, 1968). From these data, it is evident that the northern hardwood cover type, and other associated types, comprise the largest share of timber volume in the study area, and represent a very important forest resource for economic research.

Allowable cut data from the Forest Survey completed in 1954 indicate that, for the northern hardwood component, the actual cut of 26 million board feet slightly exceeded the allowable cut of 25 million board feet in the Northern Lower Michigan Survey Unit This relationship probably holds for the study area as well. Annual net growth for the northern Lower Peninsula was 296,300 cords or approximately 24 million cubic feet in 1955 in the northern hardwood type (Findel, et al., 1960). When compared to the 25 million cubic feet of annual allowable cut, it appears that cutting has been maintained at a level approximately consonant with recommended practices, and a similar situation probably existed in the study area in regards to the growth-cut relationship.

As with most of the northern Lower Peninsula, aspen was the principal pulpwood species harvested in the study area, contributing 54 percent of the total in 1966 (Horn, 1963; and Blyth, 1967). In 1964, a total of 290 farms in the study area sold a mix of forest products valued at $426,306 (U.S. Department of Commerce, 1967). These included sawlogs, veneer logs, pulpwood, fuelwood, Christmas trees, maple sap and maple sirup. Manistee County contributed 36 percent of the value of all forest products sold, 60 percent of the pulpwood volume, and 61 percent of the sawtimber and veneer-log volume which was marketed from farm ownerships within the study area during 1964. Thus, timber production from farm woodlands seems to be concentrated in the southwestern portion of the study area, probably influenced by the large pulp and papermill in nearby Filer City.

In the present study, this mill was considered to be the sole purchaser of pulpwood from the five counties. The number of sawmills located within the region is between 30 and 35, and nearly all have an annual production of less than 3,000 MBM (Michigan Department of Conservation, 1964).

CHAPTER III

SAMPLING PROCEDURES

Two important questions had to be answered before actual field investigation could commence, namely, how many properties should be chosen for sampling, and how intensively should each ownership be sampled?

After consultation with personnel in the Forestry Division of the Michigan Department of Natural Resources, and examination of their records, it was decided to confine the study to ownerships which had applied timber stand improvement (TSI) in 1962, and had obtained Agricultural Conservation Program (ACP) cost-sharing payments from the government. During that year, 774 farms in the State of Michigan, totaling 9,574 acres, received remuneration under the B-10 (timber stand improvement) forestry practice of the ACP program. The greatest concentration of these farms that had applied timber stand improvement to northern hardwoods was located in the five counties selected as the study area.

The entire population of woodland ownerships that received ACP payments for the B-10 practice in 1962 within the five-county block totaled 78 referrals.[2] Additional records, exact locations, and aerial photographs were obtained from Department of Natural Resources Field Offices in Beulah and Traverse City.

After considering distance from East Lansing to the study area, estimated time for sampling a referral, and the length of time available for data collection, it was decided that 30 referrals should be sampled from the population of 78. The 78 referrals ranged in size from 1 acre to 30 acres. Before the samples were chosen, the population was stratified on the basis of acreage per ownership into three strata as follows: Stratum I, 1 to 10 acres; Stratum II, 11 to 20 acres; and Stratum III, 21 to 30 acres. The sample allocation to each stratum was in proportion to the total number of referrals per stratum for the entire population. The original 30 samples were selected in a random fashion from the three strata, using a table of random digits (Table 3).

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[2]Referral is the term applied to an ownership that has applied for assistance under the Agricultural Conservation Program.

Table 3.--Population and original sample distribution by individual stratum

Stratum	Size	No. in population	Percent of total	Samples per stratum
	Acres	Number	Percent	Number
I	0-10	49	63	19
II	11-20	22	28	8
III	21-30	7	9	3
Total	---	78	100	30

Because the referrals were selected in a random manner and without replacement, the method was not independent random sampling: i.e., the probabilities for each remaining choice were changed after a sample was drawn from the population. Thus, it was not a simple random sample with all units having an equal probability of selection, although the sampling design did provide the randomness necessary for statistical analysis (Clelland, et al., 1966).

After an initial trial with the field measurement procedures, it was decided that two BAF 10 point samples would be established on each ownership. Such a design permitted the sampling of one referral in 3 to 4 hours, thus enabling the two-man crew to complete two properties in one working day including the necessary travel time.

When 14 referrals had been measured, a preliminary statistical analysis was made to determine the required sample size needed for a specified sampling error, which would then provide sufficient confidence in the reliability of the data. Two statistical procedures were applied to the preliminary data: 1) The range-mean ratio (Allen, et al., 1960), and 2) The standard sample-size formula for stratified sampling (Cochran, 1953; Freese, 1962). In both cases, average basal area was chosen for the calculations, because this parameter is of most concern to a woodland owner when thinnings or other intermediate cuttings are contemplated for a forest stand.

To obtain a sampling error of 10 percent or less, the range-mean ratio calculations indicated that 25 samples would be necessary. By the standard sample-size formula computations, it was found that 22 samples would be needed. Thus, on the basis of these independent computations, it was decided that the sample size would be reduced to 25 ownerships (Table 4). Five referrals were removed from the list in a random procedure similar to that used in the first selection process.

Table 4.--Population and final sample distribution by individual stratum

Stratum	Number in the population	Percent of the total	Samples taken in each stratum
	Referrals	Percent	Referrals
I	49	63	16
II	22	28	7
III	7	9	2
Total	78	100	25

The study area was divided into two "Areas," based on the administrative units employed by the Michigan Department of Natural Resources. Table 5 presents sample data and average referral size, by stratum for the two areas. The 78 referrals totaled 847 treated acres, and the 25 sampled referrals totaled 268 acres.

After 25 samples had been taken, the range-mean ratio was again computed to obtain a final check on sample adequacy. The results indicated that 20 samples would have been sufficient to obtain a sampling error of 10 percent or less. Hence, the actual sample provided somewhat greater accuracy.

Table 5.--Population and sample distribution by stratum size and administrative area.

Area	County	Stratum	Total in Population	Area in Population: Total	Area in Population: Average	Number in Sample	Area in Sample: Total	Area in Sample: Average
		Acres	Number	Acres	Acres	Number	Acres	Acres
I	Benzie	1-10	9	49.5	5.50	1	3.5	3.50
		11-20	5	66.0	13.20	0	0.0	---
		21-30	0	0.0	---	0	0.0	---
		Total	14	115.5	8.25	1	3.5	3.50
	Leelanau	1-10	9	66.0	7.34	4	35.0	8.75
		11-20	7	135.0	19.29	2	40.0	20.00
		21-30	4	108.5	27.12	1	26.0	26.00
		Total	20	309.5	15.45	7	101.0	14.42
	Manistee	1-10	9	58.0	6.44	3	15.0	5.00
		11-20	0	0.0	---	0	0.0	---
		21-30	1	30.0	30.00	1	30.0	30.00
		Total	10	88.0	8.80	4	45.0	11.25
	Totals for Area I	1-10	27	173.5	6.42	8	53.5	6.69
		11-20	12	201.0	16.75	2	40.0	20.00
		21-30	5	138.5	27.70	2	56.0	28.00
		Total	44	513.0	11.66	12	149.5	12.46
II	Grand Traverse	1-10	14	78.0	5.66	4	22.5	5.63
		11-20	5	84.0	16.80	3	44.0	14.67
		21-30	0	0.0	---	0	0.0	---
		Total	19	162.0	8.52	7	66.5	9.50
	Wexford	1-10	8	46.0	5.75	4	21.0	5.25
		11-20	5	76.0	15.20	2	31.0	15.50
		21-30	2	50.0	25.00	0	0.0	---
		Total	15	172.0	11.46	6	52.0	8.67
	Totals for Area II	1-10	22	124.0	5.64	8	43.5	5.44
		11-20	10	160.0	16.00	5	75.0	15.00
		21-30	2	50.0	25.00	0	0.0	---
		Total	34	334.0	9.83	13	118.5	9.12
	Total for Both Areas	1-10	49	297.5	6.07	16	97.0	6.06
		11-20	22	361.0	16.40	7	115.0	16.43
		21-30	7	188.5	26.90	2	56.0	28.00
		Total	78	847.0	10.87	25	268.0	10.72

CHAPTER IV

FIELD PROCEDURES

The field information collected from each referral was obtained from ten mechanically located BAF 10 point samples within the treated area. A wedge prism was used to determine which trees should be included in the tally. The sampling design required establishment of two major point samples and eight minor point samples on each ownership. The data obtained from the two major point samples were quite detailed, and were recorded on an individual tree basis, whereas the information gathered from the eight minor point samples involved only tree and stump counts for calculating the basal area.

The initial major point, which determined the location of all other point samples on the ownership, was established by rectangular coordinates. If the woodlot was approximately square, the first point was located two chains from one of the corners and two chains into the woodlot (measured along cardinal compass directions). For properties having a rectangular shape, the point was located two chains from a corner and one chain into the woodlot.

If the woodlot was very small, such as one or two acres, the coordinate dimensions were changed to one chain by one chain to confine the samples to interior portions of the treated area. The second major point sample was systematically placed two chains from the first, in one of the four cardinal compass directions, depending on orientation of the area and position of the initial point.

The minor point samples were arranged in circular fashion one chain from the major point, four minor points to each major point on predetermined compass bearings (Figure 3). For ownerships in which the two major point samples had to be oriented east-west, the sampling scheme was oriented accordingly.

From the selected trees at each major point, a subsample of five was chosen from which increment cores were then taken for age determination. For all trees tallied at the major points, the following information was obtained:

1. Species.

2. DBH (diameter at breast height)--using a diameter

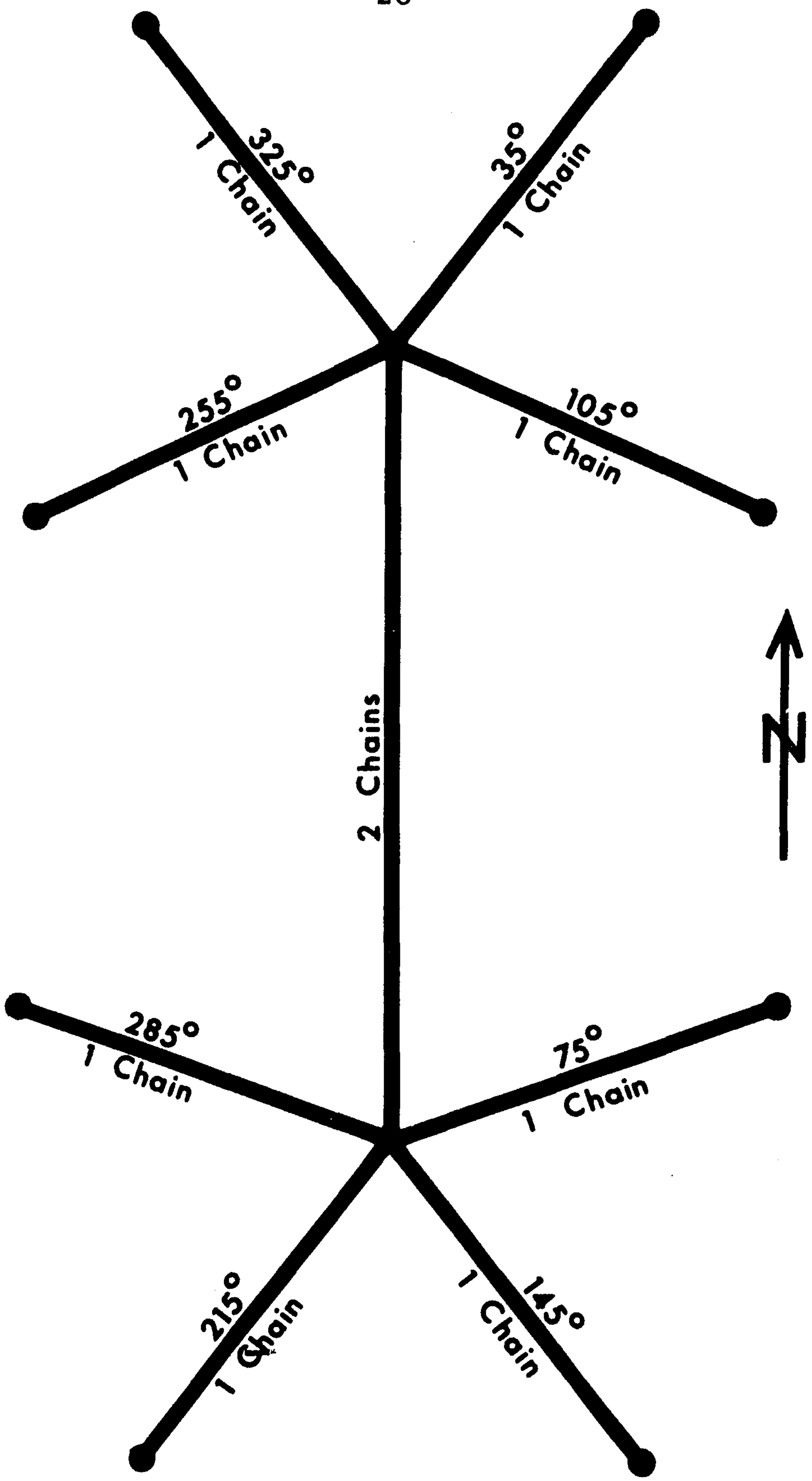

FIGURE 3

THE POINT-SAMPLE DISTRIBUTION AND ORIENTATION FOR A NORTH-SOUTH DESIGN; THE AZIMUTH READINGS ARE MEASURED CLOCKWISE FROM DUE NORTH tape, and recorded to the nearest 1/10 of an inch--on all trees 1 inch DBH and larger.

3. Total height to the nearest foot, using the Blum-Liess Altimeter.

4. Merchantable height to the nearest foot for all saw-timber-sized stems, 9.5 inches DBH or larger, measured to a variable top diameter determined in the field. The merchantable height for all stems less than 9.5 inches DBH (merchantable as cordwood only) was measured to a 3-inch top DOB (diameter outside bark).

5. Grade--determined in accordance with the Northern Hardwoods Tree-Grading Classification (U.S. Forest Service, 1949), for trees 9.5 inches DBH and larger.

6. Cull--estimated for each tree according to the seven cull defect classes established for this cover type, for trees 9.5 inches DBH and larger (Zillgitt and Gevorkiantz, 1946).

7. Crown class--determined for all stems, using the Society of American Foresters' (1958) definitions;

i.e., dominant, codominant, intermediate, or suppressed (overtopped).

8. Vigor class--established in accordance with the four northern hardwoods tree vigor and risk classes, for all stems (Goetzen, 1943).

All stumps from trees cut during the 1962 operation and located "within" the point sample in 1962 before cutting were also measured and tallied by species. To ascertain whether a cut tree was "in" or "out" of the point sample in 1962, each stump in the immediate area of the point center was measured, and its diameter at stump height (DSH) was converted to a DBH value by means of a previously constructed table. From the distance of the stump to the point center, and the reconstructed DBH, it was established whether the tree would have been tallied in 1962 or not.

The DSH-DBH conversion table was prepared by regression analysis from tree data collected in the sample area. The equation was:

$$\text{Estimated DBH} = 0.15 + 0.8335\ (\text{DSH})$$

In addition, each stump was classified on the basis of existing stump sprouts and their level of abundance and vigor into one of four "sprouting-level" classes.

Increment cores were extracted from five trees at each major point for age determination and growth information, one at DBH, and the other at stump height. The trees selected were the first two encountered in a clockwise direction from a line due north from point center. Trees 3 and 4 were the first two encountered in a similar manner from a line extending due south of point center. The fifth was the one closest to the point center.

Data from the core at breast height consisted of the radial growth for the past 10 years, which was subdivided into the 4-year growth after treatment (1962 through 1966), and the 6-year growth prior to treatment. The measurements were made to the closest 0.01 inch.

A separate tally sheet was used for each major point to record crown closure, condition class, cover type, understory and reproduction, sprouting, operability, topography-site, availability of commercial products, incidence of insects and disease, mortality, stand structure, and silvicultural needs. These items were purely subjective in nature based on observable characteristics of the stand immediately adjacent to the point center.

Site Index Determination

The standard concept of site index is generally reserved for even-aged stands of one species. Thus, on theoretical grounds, such a concept would not apply to the study area; however, it was believed that a measure of site, obtained from quantifiable field data, or based on published data, would be useful as a predictive tool in this study.

Since the major species in most referrals was sugar maple,[3] site index curves for that species by Curtis (1962) were used for site index determination (Table 6).

Volume Computation

The merchantable volume in cubic feet, board feet, and cords, was estimated for each measured tree on all referrals, using the tables prepared by Gevorkiantz and Olsen (1955). The individual tree volumes were then converted to per acre volumes for each ownership.

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[3]See Appendix 1 for a listing of common and scientific names for all tree species encountered in the present investigation.

Table 6.--Site index for all referrals, using average heights and average ages for all species, based on Curtis's curves.

Site index[a]	Referral number[b]	Frequency	Percent of the total	
		Number	Percent	
50	1L04			
	1L16	2	8	
55	2W18	1	4	
60	2G01			
	1L13			
	2W17			
	2W23			
	1M24	5	20	
65	2G02			
	1L06			
	2W09			
	2G10			
	2G15			
	1M21	6	24	
70	2G03			
	1L05			
	2W07			84%
	2G08			
	1B14			
	1M19			
	1L25	7	28	
75	2W11			
	1L12			
	2G22	3	12	
85	1M20	1	4	
Total	----	25	100	

[a]Estimates obtained from the formula presented by Curtis (1962), for sugar maple in Vermont.

[b]The Referral Number is coded as follows: The first digit indicates the Area, and the letter represents the county in which the referral was located. The last two digits indicate the referral's number--1 to 25.

Volume in board feet was ascertained for all trees in the 10-inch diameter class and larger. Merchantable cubic-foot and cordwood volumes were determined for the 5-inch diameter class and larger. Appropriate cull deductions as presented by Zillgitt and Gevorkiantz (1946) for northern hardwoods were applied to gross board-foot volumes to obtain net volumes. Individual tree volumes, and per acre values were computed for the two major points for each ownership. The volume data were then grouped by species, grade, and diameter class, as shown in Table 7. By subdividing total stand volume into grade and species categories, the application of differential selling prices was facilitated in the economic analysis portion of the study.

When stand volume is considered solely in terms of board feet, merchantable cubic feet, cords, or some combination thereof, some additional cordwood volume will be available in the tops and larger limbs of sawtimber-sized trees. To determine the amount of such volume, the method presented by Chase and Gevorkiantz (1953) was utilized. The authors present a table of factors for estimating top and limbwood volume per M bd. ft. (International 1/4-inch Rule) for hardwood species. The volume information for each referral, including this additional volume, is summarized in Table 8.

Table 7.--Summary of volume data for Referral No. 2G01, 1966

Species	DBH class	Volume by tree grade 1	2	3	4	Total Volume Bd.ft.	Cu.ft.	Cords
		- - -	Bd. Ft.	- - -				
Sugar maple	3	--	--	--	--	--	--	--
	4	--	--	--	--	--	--	--
	5	--	--	--	--	--	110.5	1.28
	6	--	--	--	--	--	130.1	2.08
	8	--	--	--	--	--	98.5	1.31
	9	--	--	--	--	--	90.3	1.38
	12	--	--	--	362	362	113.8	1.26
Total		0	0	0	362	362	543.2	7.31
Basswood	9	--	--	--	--	--	110.6	1.41
	10	--	434	--	--	434	114.1	1.14
	11	--	1091	322	--	1413	445.8	4.74
	12	1091	572	--	--	1663	357.5	3.84
	13	454	--	--	--	454	109.3	1.30
Total		1545	2097	322	--	3964	1137.3	12.43
Grand Total		1545	2097	322	362	4326	1680.5	19.74

Table 8.--Volume summary for each of the 25 referrals (ownerships) in the study area. The entire volume is expressed in three different forms: board feet, cubic feet, and cords; in addition the available volume in topwood (expressed in cords) is also presented. (data for 1966)

Referral	Total volume of stand expressed in: board feet per acre	cubic feet per acre	cords per acre	Additional volume in topwood[a]
				cords/acre
2G01	4,326	1,680.5	19.74	2.52
2G02	4,070	2,698.6	26.64	3.74
2G03	6,529	2,383.4	23.98	3.01
1L04	3,875	1,923.4	24.58	2.07
1L05	7,111	2,573.9	24.71	2.90
1L06	698	1,368.7	15.05	1.27
2W07	7,186	2,662.5	24.05	4.51
2G08	6,318	3,076.2	32.03	3.20
2W09	1,476	2,441.6	28.46	1.64
2G10	165	869.7	11.34	0.18
2W11	722	1,675.0	20.83	0.78
1L12	9,164	4,091.1	38.91	4.49
1L13	4,523	2,393.2	25.84	2.06
1B14	6,989	2,721.2	27.48	3.12
2G15	5,556	2,488.7	22.32	3.92
1L16	5,631	2,038.5	21.15	3.18
2W17	5,493	2,347.0	21.82	2.84
2W18	1,259	1,364.2	16.98	1.69
1M19	4,365	1,977.7	19.01	2.70
1M20	5,555	2,244.2	21.49	2.03
1M21	6,940	2,611.8	23.11	4.84
2G22	8,359	3,157.5	29.01	4.27
2W23	6,933	2,831.9	30.60	5.22
1M24	2,993	1,746.7	19.71	2.62
1L25	2,998	1,413.8	15.35	2.65
Average	4,804	2,263.8	23.21	2.90

[a]Material which is also available when the stand volume is expressed in terms of board feet; however, this is included in the cubic-foot and cordwood volume figures.

Additional Stand Measurements and Characteristics

Additional stand data including average DBH, mean DBH, average tree height, average age, number of trees per acre, and basal area per acre were compiled for all 25 referrals. Each parameter was weighted by the number of trees per acre and summarized in Table 9. The basal area estimate was determined from the 10 point samples, whereas other data were tabulated solely from the two major points.

Table 10 summarizes the improvement cutting operations performed in 1962. Stump tallies at each point sample provided information for obtaining the number of trees and basal area removed in the cutting.

Information for each ownership including tree class, vigor, cull percentage, distances to mills, reproduction, soils, topography, sprouting, insects and disease, and mortality is listed in Tables 11 and 12. Table 13 presents species composition information by cubic-foot volume for each ownership.

Table 9.--Summary of diameter, height, age, and basal area data for the 25 ownerships, 1966.

Referral	Average DBH		Mean DBH[a]		Dom. and Codom. trees		Number	Basal
	All trees	Dom. & codom. trees	All trees	Dom. & codom. trees	Average Height	Average Age	of trees/ acre	area per acre
	Inches	Inches	Inches	Inches	Feet	Years	Number	Sq.ft.
2G01	4.9	9.0	5.6	9.2	62.0	54.6	597.0	92
2G02	8.7	10.7	9.2	10.9	71.8	58.0	228.9	128
2G03	9.8	11.7	10.2	11.9	78.6	62.8	166.6	85
1L04	8.2	9.4	8.5	9.6	58.4	69.5	330.1	77
1L05	9.8	11.1	10.2	11.2	79.0	61.8	156.8	89
1L06	8.3	8.3	8.5	8.5	65.6	54.4	171.2	77
2W07	6.2	12.2	7.7	12.6	79.8	64.4	369.0	118
2G08	8.0	10.7	8.4	10.8	80.8	66.0	336.0	115
2W09	6.1	9.0	6.5	9.2	71.2	57.0	627.2	128
2G10	2.9	6.4	3.5	6.6	58.0	39.9	1,095.2	94
2W11	4.1	7.0	4.6	7.2	67.1	41.2	1,001.2	107
1L12	5.0	10.5	3.4	10.6	85.0	64.2	1,128.7	99
1L13	4.9	9.7	5.8	10.0	73.5	77.9	862.6	87
1B14	9.7	12.2	10.2	12.4	81.2	66.0	180.5	83
Average	6.9	9.8	7.3	10.0	72.3	59.8	517.9	98

Table 9.--(Continued)

Referral	Average DBH		Mean DBH[a]		Dom. and Codom. trees		Number	Basal
	All trees	Dom. & codom. trees	All trees	Dom. & codom. trees	Average Height	Average Age	of trees/ acre	area per acre
	Inches	Inches	Inches	Inches	Feet	Years	Number	Sq.ft.
2G15	9.2	15.6	10.5	15.8	81.8	74.2	155.8	99
1L16	8.7	10.1	9.2	10.6	69.0	97.0	218.2	84
2W17	4.7	10.6	5.6	10.9	65.0	61.1	592.6	104
2W18	5.2	8.8	6.0	9.0	57.4	53.0	461.2	98
1M19	9.0	10.5	9.6	10.8	73.8	54.2	171.2	92
1M20	6.6	11.3	7.2	11.7	84.1	49.8	507.4	100
1M21	13.0	15.6	13.4	15.8	81.6	80.3	91.2	94
2G22	8.2	11.9	9.0	12.4	87.7	66.4	270.4	111
2W23	4.8	10.7	6.0	11.0	70.8	64.2	1,582.4	118
1M24	5.3	9.3	5.9	9.5	65.6	57.4	568.4	90
1L25	5.1	9.1	5.9	9.3	68.2	47.9	393.2	79
Average	7.3	11.2	8.0	11.5	73.2	64.1	455.6	97

[a]Diameter of the tree of mean basal area.

Table 10.--Data for material removed in the TSI operation during 1962, for each ownership.

Referral	Material removed in TSI in 1962			Percent of cut by species				
	Basal area per acre	Number of trees per acre	Average DBH of cut trees	Sugar maple	Iron-wood	Elm	Beech	Other[a]
	Sq. ft.	Number	Inches	- - - - - -	- -	Percent	- -	- - - - - -
2G01	37	115.8	7.0	--	--	77	3	20
2G02	18	16.6	12.4	--	59	--	41	--
2G03	25	26.6	13.6	--	--	100	--	--
1L04	17	637.0	3.4	3	94	3	--	--
1L05	31	116.8	6.9	37	--	55	8	--
1L06	25	483.9	6.7	98	--	2	--	--
2W07	23	161.5	7.0	--	--	--	--	100
2G08	28	117.4	8.5	53	--	24	23	--
2W09	25	134.4	3.6	100	--	--	--	--
2G10	31	266.0	5.3	34	--	52	1	13
2W11	24	119.4	7.1	79	--	21	--	--
1L12	20	298.2	5.4	--	70	--	--	30
1L13	31	32.3	10.9	--	--	--	9	91
1B14	13	6.5	16.9	100	--	--	--	--
2G15	43	32.7	14.2	--	--	--	100	--
1L16	18	27.4	11.0	--	78	--	8	14
2W17	14	50.8	8.4	--	--	24	--	76
2W18	19	141.1	6.2	--	100	--	--	--
1M19	47	101.1	10.0	12	--	7	5	76
1M20	22	13.4	14.1	100	--	--	--	--
1M21	13	56.8	9.0	41	--	59	--	--
2G22	28	55.6	11.8	86	--	--	11	3
2W23	22	47.0	6.1	--	72	28	--	--
1M24	37	15.0	11.0	47	--	--	--	53
1L25	23	251.2	5.6	4	92	--	--	4
Average	25.5	126.4	9.0	31	23	18	8	20

[a]The category of "other" species includes the following: basswood, red maple, yellow birch, white ash, black cherry, red oak, and aspen.

Table 11.--Additional referral measurements and characteristics

Referral	Ave. tree class	Ave. % cull	Ave. vigor class	Distance of referral to:[a] Nearest sawmill	Paper-mill	Nearest town	Status of Reproduction Ave. tolerance[b]	Ave. abundance[c]	Ave. desirability[d]
				Miles	Miles	Miles			
2G01	2.2	22	3.4	13.5	67.0	4.2	VT	M	L
2G02	2.2	13	2.5	7.2	58.8	6.5	VT	S	H
2G03	2.2	15	2.7	6.0	60.5	6.0	VT	A	H
1L04	2.1	6	3.4	7.0	61.2	4.5	T	A	L
1L05	2.2	16	2.2	5.8	67.0	2.2	T	A	L
1L06	3.5	45	2.3	2.8	73.8	4.5	VT	S	H
2W07	2.3	21	3.4	4.8	48.0	2.5	T	S	L
2G08	1.9	14	2.8	4.8	65.5	5.8	T	A	H
2W09	3.5	42	3.2	3.2	55.2	7.2	VT	S	H
2G10	2.0	7	3.5	6.0	62.5	5.8	VT	S	H
2W11	2.3	7	3.4	7.2	49.2	3.5	VT	S	H
1L12	2.4	14	2.7	15.2	80.2	5.5	VT	M	H
1L13	2.5	24	3.1	2.5	60.2	3.5	I	A	L
1B14	2.4	22	2.3	2.2	38.0	3.2	T	A	H
2G15	2.2	23	3.1	13.8	55.0	2.8	VT	M	H
1L16	2.0	10	2.9	7.0	61.2	4.5	T	A	L
2W17	2.6	13	3.0	4.5	38.8	1.0	T	S	H
2W18	3.2	42	3.4	4.8	39.0	1.0	T	S	L
1M19	2.5	20	2.4	6.2	33.2	7.8	T	M	H
1M20	2.1	10	3.0	8.0	20.2	6.0	T	S	H
1M21	2.0	11	3.3	7.0	35.2	6.2	T	A	L
2G22	2.6	14	3.1	8.8	65.2	5.8	VT	M	H
2W23	2.7	18	3.6	13.0	49.8	5.5	VT	M	L
1M24	2.0	9	2.8	11.0	39.5	6.2	VT	A	L
1L25	2.1	18	2.7	8.0	64.8	5.8	VT	A	L

[a]See Appendix 2 for a complete description of mileage to mills by road-surface type.

[b]VT, T, I; Very tolerant, tolerant, and intermediate, respectively.

[c]M, A, S; Moderate, abundant, and scarce, respectively.

[d]H, L: High, and low desirability respectively.

Table 12.--Additional referral characteristics

Referral	Relative proximity to roads[a]	Relative slope[b]	Relative portion of stand, of sprout origin[c]	Relative no. of stump sprouts[d]	Insect and disease incidence[e]	Relative amounts of mortality[f]	Woodland suitability classification[g]
2G01	F	L	M	L	L	L	E
2G02	C	U	S	L	H	L	A
2G03	M	L	S	M	N	L	C
1L04	C	U	M	H	H	H	C
1L05	C	U	S	H	M	L	C
1L06	M	H	M	H	N	M	A
2W07	C	L	S	M	N	M	A
2G08	C	L	M	H	H	M	E
2W09	M	L	S	H	N	H	C
2G10	M	U	H	H	M	H	E
2W11	C	H	S	H	M	M	C
1L12	M	H	S	H	N	M	C
1LI3	C	U	M	H	L	L	E
1B14	C	U	S	L	L	L	E
2G15	C	H	S	M	L	M	D
1L16	C	U	S	L	M	M	C
2W17	M	H	S	M	L	M	C
2W18	C	H	M	M	M	M	C
1M19	M	L	S	H	H	H	C
1M20	M	U	M	L	L	M	C
1M21	M	U	S	M	H	H	E
2G22	C	L	S	M	N	M	C
2W23	M	U	M	M	M	L	A
1M24	M	U	M	L	L	L	C
1L25	M	L	S	M	N	M	C

[a]F, M, C; Greater than 1 mile, between 1/4 and 1 mile, and less than 1/4 mile from the nearest road respectively.

[b]L, U, H; Level, undulating, and hilly respectively.

[c]S, M, H; Slight, moderate, and high incidence of sprout origin respectively.

[d]L, M, H; Low, moderate, and high amount of stump sprouting respectively.

[e]L, M, H; Low, moderate, and high incidence of insect and/or disease infestation respectively. N--No indication of insects or disease present.

[f]L, M, H; Low, moderate, and high mortality respectively.

[g]Woodland suitability classification; Soils in group A have very high potential productivity for northern hardwoods (i.e., a growth rate of more than 325 bd. ft./acre/year; or more than 1.2 cords/acre per year); Groups B and C have high potential productivity (i.e., 275-325 bd. ft./A/yr.; or 0.8-1.2 cords/A/yr.); Groups D and E have medium potential productivity (i.e., 200-275 bd. ft./A/yr.; or 0.5-0.8 cords/A/yr.) (USDA, 1966.)

Table 13.--Species composition of each referral by cubic-foot volume per acre, 1966.

Referral	Percent of each referral by species							
	Sugar maple	Beech	Yellow birch	Elm	Bass-wood	Ash	Black cherry	Other[a]
	Percent							
2G01	32	--	--	--	68	--	--	--
2G02	39	--	--	52	9	--	--	--
2G03	94	--	--	6	--	--	--	--
1L04	35	--	--	41	24	--	--	--
1L05	57	--	--	37	6	--	--	--
1L06	91	--	--	9	--	--	--	--
2W07	--	14	--	--	--	--	--	86
2G08	54	--	--	31	15	--	--	--
2W09	70	7	--	--	5	6	12	--
2G10	20	--	--	13	9	58	--	--
2W11	80	--	--	16	--	--	--	4
1L12	--	--	--	2	37	31	--	30
1L13	98	--	--	--	--	--	--	2
1B14	92	3	--	5	--	--	--	--
2G15	49	38	--	7	--	--	6	--
1L16	37	12	--	41	--	7	3	--
2W17	31	20	--	21	23	5	--	--
2W18	30	--	--	22	40	--	--	8
1M19	28	13	--	33	--	26	--	--
1M20	67	--	--	7	--	7	--	19
1M21	17	6	--	77	--	--	--	--
2G22	78	11	--	--	--	6	--	5
2W23	39	18	--	4	29	10	--	--
1M24	53	--	--	3	4	--	6	34
1L25	34	10	--	--	8	43	--	5

[a]Includes oak, aspen, ironwood, hemlock, and red maple.

CHAPTER VI

GROWTH PREDICTION AND VOLUME PROJECTION

Basal Area and Height Growth

After comparing the results of several different methods of growth prediction, Spurr's Two-Way Growth Prediction Procedure (Spurr, 1952) was selected for use. Results using his procedure were about the same as those from the stand table projection procedure, and the two-way method is considerably faster in application. Predicting volume by means of yield tables would have necessitated less time; however, existing tables contained no provision for the influence of management activities. The two-way method provided a measure of volume growth which was more sensitive to changes induced by various management regimes, thus, was more responsive to the results of each alternative investigated in the study. Although basal area growth projection was of a straight-line nature, tempered only by mortality assumptions, the resulting volume predictions indicated accurate relative differences even though the absolute values may be somewhat inflated.

The two-way approach combines separate estimates of basal area and height growth as the basis for determining future volume. Growth in average stand height was estimated from the appropriate site index curve applicable to each ownership.

Basal area growth was estimated by the method outlined in the Service Forester Handbook (USDA, 1961) using the following formula:

$$Rob = [1 - \Sigma(DBH - 2r)^2 /n] \; 100$$

where: Rob = the ratio of 10-year basal area increment to present basal area per acre expressed as a percent.

DBH = the present diameter at breast height.

n = the number of growth sample trees.

r = the 10-year radial growth in inches.

The radial growth for the 6-year period before timber stand improvement, and for the 4-year period after treatment were converted to a 10-year basis by multiplying by 1.667 and 2.5, respectively. A modification involved a 5 percent addition to the radial wood growth to adjust for bark growth. Values for the factor $(DBH - 2r)^2$ were available in tabular form in the Service Forester Handbook (USDA, 1961), and were multiplied by the number of trees in each diameter class within the five-tree growth subsample of each point sample. An example of the basic computations using the before treatment growth rate is given in Table 14, and for the after treatment growth rate in Table 15, for Referral 2G01.

The results in Tables 14 and 15 were used to compute the basal area growth percents for before and after treatment conditions. For Referral No. 2G01, for the before treatment conditions, the computations were as follows:

<u>Point No. 1</u>

$$Rob = [1-(163.70/261.40)]\ 100$$

$$Rob = 37.38\%$$

<u>Point No. 2</u>

$$Rob = [1-(91.85/128.60)]\ 100$$

$$Rob = 28.58\%$$

<u>The Referral Average</u>

$$Rob = (37.38 + 28.58)/2$$

Rob = 32.98% (the 10-year growth percentage; or 3.298% per year)

For the after treatment condition for the same referral, the computations were:

Table 14.--Basal area growth calculations for Referral 2G01 using the before treatment growth rate.

DBH class	No. of trees per acre	Past radial growth	Past radial growth adjusted to 10-year basis	10-year radial growth adj. for bark growth	$(DBH-2r)^2$	$(DBH-2r)^2$ weighted by no. of trees
(1)	(2)	(3)	(4)	(5)	(6)	(7)
In.	Number	Inches	Inches	Inches		
			Point sample no. 1			
11	16.0	.35	.583[a]	.61[b]	.79[c]	12.64[d]
5	79.4	.27	.450	.48	.64	50.82
11	16.0	.42	.700	.74	.76	12.16
6	51.0	.32	.533	.56	.64	32.64
4	99.0	.28	.467	.49	.56	55.44
Total	261.4	--	---	--	--	163.70
			Point sample no. 2			
5	62.9	.31	.517	.54	.64	40.26
8	30.1	.24	.400	.42	.81	24.38
9	23.1	.32	.533	.56	.74	17.09
12	12.5	.34	.567	.59	.81	10.12
Total	128.6	--	---	--	--	91.85

[a]Column (3) X 1.667, to adjust the 6-year growth before treatment in 1962 to a 10-year basis.

[b]Column (4) X .05, to adjust for 5 percent bark growth.

[c]From the Service Forester Handbook (USDA, 1961).

[d]Column (2) X column (6).

Table 15.--Basal area growth calculations for Referral 2G01 using the after treatment growth rate.

DBH class	No. of trees per acre	Past radial growth	Past radial growth adjusted to 10-year basis	10-year radial growth adj. for bark growth	$(DBH-2r)^2$	$(DBH-2r)^2$ weighted by no. of trees
(1)	(2)	(3)	(4)	(5)	(6)	(7)
In.	Number	Inches	Inches	Inches		
			Point sample no. 1			
11	16.0	.27	.675[a]	.71[b]	.76[c]	12.16[d]
5	79.4	.20	.500	.52	.64	50.82
11	16.0	.28	.700	.74	.76	12.16
6	51.0	.14	.350	.39	.74	37.74
4	99.0	.17	.425	.44	.64	63.36
Total	261.4	---	----	---	---	176.24
			Point sample no. 2			
5	62.9	.21	.525	.55	.58	36.48
8	30.1	.28	.700	.74	.67	20.17
9	23.1	.19	.475	.50	.77	17.79
12	12.5	.29	.725	.76	.74	9.25
Total	128.6	---	----	---	---	83.69

[a]Column (3) X 2.5, to adjust the 4-year growth after treatment in 1962 to a 10-year basis.

[b]Column (4) X .05, to adjust for 5 percent bark growth.

[c]From the Service Forester Handbook (USDA, 1961).

[d]Column (2) X column (6).

Point No. 1

$$Rob = [1-(176.24/261.40)]\ 100$$

$$Rob = 32.58\%$$

Point No. 2

$$Rob = [1-(83.69/128.60)]\ 100$$

$$Rob = 34.92\%$$

The Referral Average

$$Rob = (32.58 + 34.92)/2$$

$$Rob = 33.75\%\ \text{(the 10-year growth percentage; or 3.375\% per year)}$$

The basal area growth percents were then used to compute past and future basal area values. The past basal area, immediately after the TSI in 1962 (the residual basal area), was determined as follows:

$$\text{Past basal area per acre} = \text{Present basal area per acre} - \left[\text{Basal area growth percent for length of projection period} \times \text{Present basal area per acre}\right]$$

For Referral No. 2G01, these computations became:

$$\text{Basal area per acre after TSI in 1962} = \text{Basal area in 1962} - \left[\text{4 years} \times \text{annual growth percent} \times \text{basal area in 1962}\right]$$

= 92 - (4 X 3.375 X 92)

= 92 - 20

= 80 square feet per acre.

The basal area per acre before the TSI in 1962 was obtained by adding the basal area removed in the TSI to the residual basal area. For Referral No. 2G01, the cut-stump tally totaled 37 square feet of basal area per acre (from Table 10). Thus, the basal area before TSI in 1962 was:

80 + 37 = 117 square feet per acre.

The future basal area at the end of any desired projection period was obtained as follows:

$$\text{Future basal area per acre} = \text{Present basal area per acre} + \left[\text{Basal area growth percent for length of projection period} \times \text{Present basal area per acre}\right]$$

If Referral No. 2G01, with 117 square feet of basal area in 1962, had not been treated, its basal area by 1966 would have become:

$$\text{Basal area per acre in 1966} = \text{Basal area in 1962} + \left[\text{4 years} \times \text{Annual growth percent} \times \text{Basal area in 1962}\right]$$

= 117 + (4 X 3.298 X 117)

= 117 + 15

= 132 square feet per acre.

Annual basal area growth values for each ownership are presented in Table 16. Basal area data on a per acre basis for stand conditions before TSI, removed in TSI, after TSI, and four years later at the time of measurement in 1966, are presented in Table 17.

By comparing the average growth rates before treatment and after TSI in 1962, very little difference can be observed. The basal area increment without TSI (before treatment) was 2.86 percent, and the figure with TSI (after treatment) was 2.92 percent. These values were so close that no statistical difference could be noted; hence, it can not be stated that timber stand improvement caused any acceleration in growth. However, the period between cutting and measurement was very short, so perhaps the true response has yet to be realized.

Table 16.--Annual basal area growth for each referral with and without TSI.

Referral	Basal area increment with TSI treatment		Basal area increment without TSI treatment	
	Percent	Square feet	Percent	Square feet
2G01	3.38	3.1	3.30	3.9
2G02	2.27	2.9	2.68	3.6
2G03	2.44	2.1	2.76	2.8
1L04	1.90	1.5	1.96	1.7
1L05	2.52	2.2	3.11	3.4
1L06	2.76	2.1	2.82	2.7
2W07	3.71	4.4	3.97	4.9
2G08	3.08	3.5	2.79	3.6
2W09	3.79	4.8	3.84	5.1
2G10	4.40	4.1	3.95	4.3
2W11	3.45	3.7	3.03	3.5
1L12	2.38	2.4	2.51	2.7
1L13	3.01	2.6	3.43	3.7
1B14	2.74	2.3	2.98	2.6
2G15	3.20	3.2	2.65	3.4
1L16	2.66	2.2	2.21	2.1
2W17	2.64	2.7	2.05	2.2
2W18	2.97	2.9	2.98	3.1
1M19	3.13	2.9	2.61	3.3
1M20	2.88	2.9	2.80	3.1
1M21	1.37	1.3	1.63	1.7
2G22	3.81	4.2	3.00	3.7
2W23	2.43	2.9	2.55	3.3
1M24	2.33	2.1	2.95	3.5
1L25	3.81	3.0	3.58	3.2
Average	2.92	2.86	2.86	3.21

Table 17.--Basal area data for stand conditions before TSI, removed in TSI, after TSI, and in 1966 for each ownership.

Referral	Basal area per acre:			
	Before TSI in 1962	Removed in TSI in 1962	After TSI in 1962	In 1966
	Sq. ft.	Sq. ft.	Sq. ft.	Sq. ft.
2G01	117	37	80	92
2G02	134	18	116	128
2G03	102	25	77	85
1L04	88	17	71	77
1L05	111	31	80	89
1L06	94	25	69	77
2W07	123	23	100	118
2G08	129	28	101	115
2W09	134	25	109	128
2G10	109	31	78	94
2W11	116	24	92	107
1L12	109	20	89	99
1L13	108	31	77	87
1B14	87	13	74	83
2G15	129	43	86	99
1L16	93	18	75	84
2W17	107	14	93	104
2W18	105	19	86	98
1M19	127	47	80	92
1M20	110	22	88	100
1M21	102	13	89	94
2G22	122	28	94	111
2W23	128	22	106	118
1M24	119	37	82	90
1L25	90	23	67	79
Average	112.0	25.5	86.5	97.5

Volume Projection

The volume in cubic feet per acre formed the basis for all volume projections. The past or future volume per acre was computed by the following equation (Spurr, 1952; USDA, 1961):

$$\frac{V_p}{(H_p)\ (BA_p)} = \frac{V_n}{(H_n)\ (BA_n)}$$

where: V_p = the present cubic-foot volume per acre.

V_n = the cubic-foot volume per acre in year n.

H_p = the present stand height.

H_n = the average stand height in year n.

BA_p = the present basal area per acre.

BA_n = the basal area per acre in year n.

These computations were made to obtain an estimate of volume for each referral in 1962, both before and after the TSI operation, as well as predicting volume for any year in the remaining portion of the rotation. The basic data for Referral No. 2G01, and the computation of the volume in 1962 after timber stand improvement is as follows:

The present volume = 1,680.5 cubic feet per acre

Present basal area = 92 square feet per acre

The present stand height = 62 feet

Stand height in 1962 = 60 feet (from site index curves)

Residual basal area in 1962 = 80 square feet per acre

$$\frac{1,680.5}{62 \times 92} = \frac{V_n}{60 \times 80}$$

V_n = 1,414.2 cubic feet per acre.

The volume per acre in 1962 before TSI could also be computed easily by merely replacing the 60 square feet of residual basal area with 117 square feet, which was the basal area before the TSI. However, it was desired to have the volumes by individual species, and this was not possible by a simple backward projection. The reason for this is that the 37 square feet of basal area removed was tallied from the stumps of trees cut in the thinning operation, and backward projection would provide only the total volume before TSI -- not by each individual species. Therefore, the volume removed in timber stand improvement was estimated separately, and then added to the residual volume.

To accomplish the initial volume calculation, a separate regression was first computed for each referral, regressing height on DBH. By determining the DBH of a "cut" tree from its stump diameter (as previously described), and then calculating its height by the regression equation, its cubic-foot contents could be read directly from the volume table. Individual tree volumes were then multiplied by the representative number of trees per acre and summed to obtain the total volume per acre. The two point-sample estimates were averaged to obtain the referral mean (Table 18).

For Referral No. 2G01, this amounted to 514.2 cubic feet per acre removed in the TSI activity (Table 18); hence, the volume before TSI was 1,414.2 + 514.2, or 1,928.4 cubic feet per acre. Thus, the volume of 1,928.4 cubic feet in 1962 had been reduced by TSI by 514.2 cubic feet, and the residual volume of 1,414.2 cubic feet per acre had grown to 1,680.5 cubic feet per acre by 1966.

From these and earlier computations, it was a simple matter to portray the stand volume for each species and size class in 1966, as shown for Referral No. 2G01 in Table 19, and also the residual volume after TSI in 1962, the volume removed in TSI, and the volume before TSI, as shown in Table 20.

Table 18.--Computation of volume removed by TSI in 1962 on Referral No. 2G01

Species[a]	Stump Diameter	DBH[b]	Total height[c]	Number of trees	Merchantable volume per tree[d]	Total Merchantable volume[e]
	Inches	In.	Feet	No.	Cubic feet	Cubic feet
52	11.4	9.7	62	19.5	9.7	189.2
52	7.1	6.1	51	49.3	2.5	123.2
52	6.2	5.3	49	65.4	1.7	111.2
52	7.5	6.4	52	44.8	3.2	143.4
60	7.4	6.3	52	46.3	3.2	148.2
62	20.4	17.2	84	6.2	50.5	313.1
Totals for 2 point samples				231.5	----	1,028.3
Total per acre				115.8	----	514.2

[a]52 = elm; 60 = basswood; and 62 = beech.

[b]From the regression equation: DBH = 0.15 + (.8335) (DSH).

[c]From the regression equation: HT. = 33.3 + (2.976) (DBH).

[d]From Gevorkiantz and Olsen (1955), using the estimated DBH and height values.

[e](Number of trees) X (Volume per tree).

Table 19.--Volume by species and size class for Referral No. 2G01 in 1966--per acre basis.

Item	Species		
	Maple	Basswood	Total
Total volume; cubic feet	543.2	1,137.3	1,680.5
Percent of total	32.3	67.7	100.0
Percent by size	100.0	100.0	100.0
Volume in poletimber-sized trees, cubic feet	431.3	30.7	462.0
Percent of total	25.7	1.8	27.5
Percent by size	79.4	2.7	27.5
Volume in sawtimber-sized trees, cubic feet	111.9	1,106.6	1,218.5
Percent of total	6.6	65.9	72.5
Percent by size	20.6	97.3	72.5

Table 20.--Volume by species and size class for Referral No. 2G01 in 1962--per acre basis.

Item	Species				
	Maple	Elm	Basswood	Beech	Total
Total initial vol., cubic feet	456.8	283.5	1,031.5	156.6	1,928.4
Percent of total	23.7	14.7	53.5	8.1	100.0
Percent by size	100.0	100.0	100.0	100.0	100.0
Poletimber volume, cubic feet	362.7	188.9	99.9	---	651.5
Percent of total	18.8	9.8	5.2	---	33.8
Percent by size	79.4	66.6	9.7	---	33.8
Sawtimber volume, cubic feet	94.1	94.6	931.6	156.6	1,276.9
Percent of total	4.9	4.9	48.3	8.1	66.2
Volume removed in TSI, cubic feet	----	283.5	74.1	156.6	514.2
Residual volume, cubic feet	456.8	---	957.4	---	1,414.2

At this point, the volume and growth computations did not include adjustments for mortality, cull defect, or quality changes throughout the projection period. Also, the basis for converting cubic-foot volume into either board feet or cords had not been determined. Such steps were needed before the economic analysis could be made; however, before these aspects of the prediction model could be developed and merged for application, the formal analysis model itself had to be identified, and the basic alternatives and decision-making framework specified.

CHAPTER VII

THE DECISION-TREE MODEL AND UNDERLYING ASSUMPTIONS

Development of the Model

The formulation of a model for prediction and evaluation purposes began with the premise that each of the 25 woodland owners was faced with a set of alternative courses of action in 1962 and, therefore, was confronted with the necessity of making a set of decisions. Such a sequence of decisions would, over time, influence the physical processes of stand growth and development and consequently, financial returns to the owner.

In order to provide a clear representation of the various alternatives facing an owner, as well as providing a means for evaluating the different opportunities, decision tree analysis was selected. The decision tree approach is a relatively new analytical tool of applied statistical decision theory. Foundations of statistical decision theory were pioneered by Robert Schlaifer of the Harvard Business School

(1959), and the decision tree technique received its greatest impetus from John Magee, also of Harvard (1964).

A decision tree accomplishes two functions with its implementation. First, it provides a clear visual representation of the complete decision-making process faced by a business manager, as it is actually composed on paper, and the various "tree branches" portray the relevant alternatives. It contains the available courses of action, their associated costs and possible outcomes, probabilities of occurrence, and the consequences involved, for an entire decision-making sequence. Second, the method employs a computational algorithm for evaluating each opportunity, and determining which course of action should be pursued. This "best" set of policies is the optimal sequence, in terms of expected net returns for the duration of a planning horizon.

The decision tree approach recognizes that long-range planning consists not of one decision--but rather a series of decisions--made at various times throughout the planning period. As expressed by Peter F. Drucker (1959), "Long-range planning does not deal with future decisions. It deals with the futurity of present decisions."

The decision tree for the study at hand was prepared in stages, starting with fundamental alternatives and chance outcomes, to which were added various modifications indicative of the model's many ramifications. In this analysis, there were two basic decisions which affected the potential physical yields from a given referral: 1) In 1962, the owner had to decide whether he was going to undertake a timber stand improvement operation or not; and 2) In future years he would have to decide whether the woodland would be allowed to grow unmanaged for the remainder of the rotation. When paired, these two options resulted in four general "branches" to the owner's decision tree (Figure 4).

This created the need of four separate schedules to project the physical data for each ownership. To fulfill this requirement, individual growth projections were made for each of the following situations:

1. The assumption that TSI was performed in 1962, and that thinnings would be interspersed throughout the balance of the rotation. This was based on the basal area growth rate measured after the actual TSI operation.

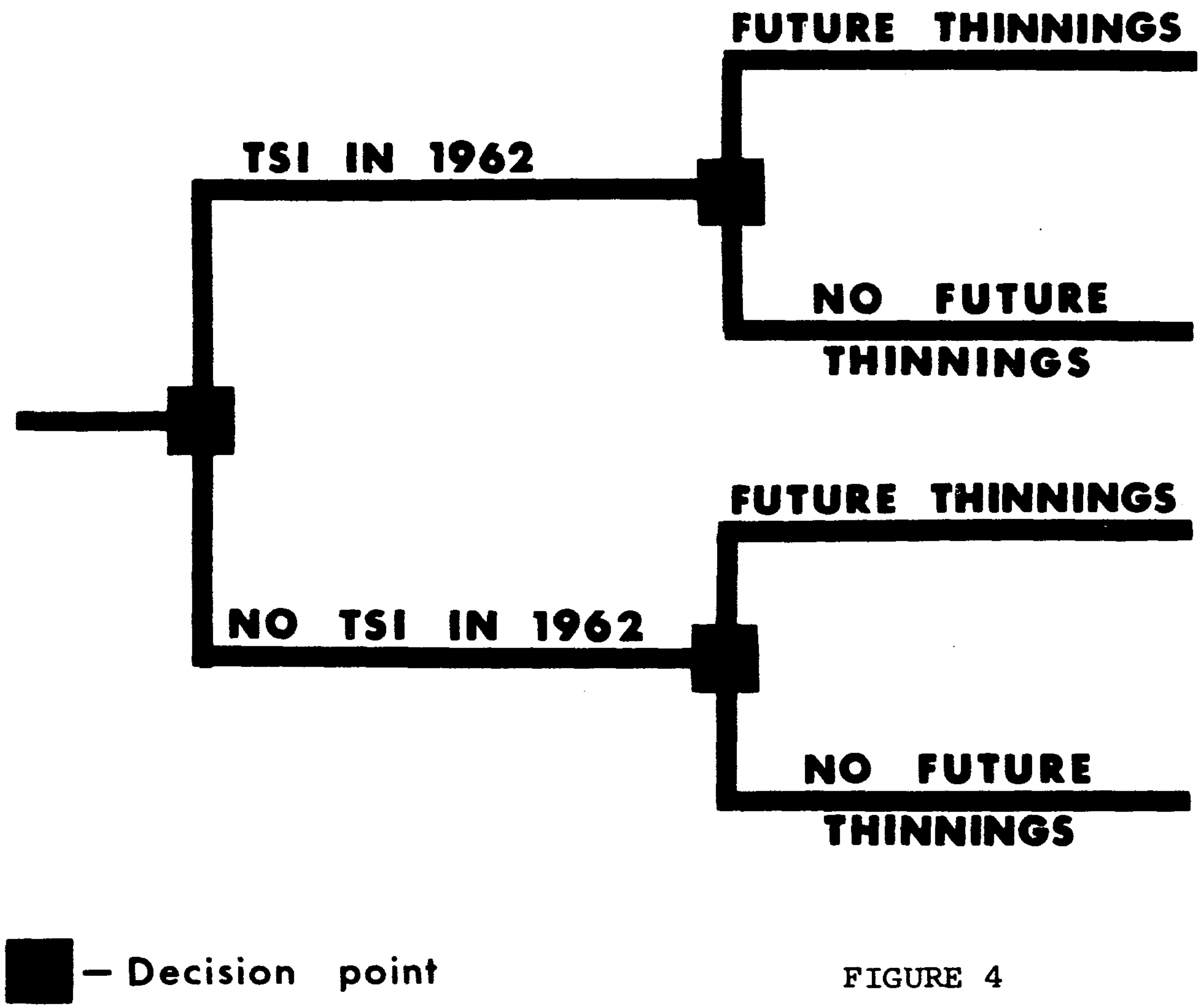

FIGURE 4

BASIC DECISION TREE FOR A WOODLAND OWNER FACED WITH A DECISION ON TIMBER STAND IMPROVEMENT IN 1962.

2. The assumption that TSI was performed in 1962; however, no thinnings would occur in the future. This also relied on the growth rate determined after TSI, but projection was greatly simplified as compared to No. (1) since the stand was allowed to grow directly to the end of the rotation before a cut was made.

3. The assumption that TSI was not undertaken in 1962; however, future thinning operations would be performed when warranted by physical and financial characteristics of the stand. This schedule was based on growth rate calculations for the period preceeding the actual TSI program.

4. The assumption that TSI was not undertaken in 1962, and that future thinnings would not be part of the management plan. No cultural work whatsoever would be applied in the intervening years before a final harvest cut.

The next phase in the model-building process was to extend the basic framework into a more sophisticated representation of the decision-sequence which would confront a woodland owner. It was impossible to include all of the myriad alternatives available to a manager, because many such avenues would not be recognized by the analyst or even the owner himself. If a complete enumeration were included, the computational phase would be extremely time-consuming, even with the aid of high-speed computers. In addition, many alternatives in such an exhaustive list would be extraneous to the major objective of evaluating timber stand improvement opportunities. For example, it was assumed that the woodland owner would retain his woodlot in a forested condition until commercial products were available. Thus, investment (or disinvestment) alternatives which would remove the timber, such as clearing for farmland, selling for residential construction, etc., although possibly highly profitable in the long run, were not included in the decision tree.

The "branch" dealing with TSI in 1962 was expanded as to: 1) Who assumed the financial burden for the operation, and 2) How the undesirable stems were removed. In actuality, all 25 referrals received monetary reimbursement through the Agricultural Conservation Program (ACP), and all TSI consisted of cutting trees, with only a small portion of the cut material removed and sold in product form. However, this pattern was not the only recourse; the owner could have assumed the financial responsibility himself, and the stems might have been girdled, treated with silvicide, or cut and sold. Therefore, two additional points of decision were added to the basic "tree" for each ownership.

Initially, it was thought that the costs of TSI should be differentiated by the method of removal, whether girdled, cut, or treated with silvicide. However, most of the research on this aspect (Chaiken, 1951; Walker, 1956; MacConnell, 1962; Lindmark, 1965), reported the results on a per acre or diameter-inch basis only. Such information was inadequate for application to different ownerships, where the stocking, material to be removed, species composition, age, growth rate, etc., were all different, because, regardless of these parameters, the same cost figure would be used. The most useful guidelines that were available gave a cost schedule dependent on the amount of basal area removed, and in the recommendations most germane to this study, cost structure was independent of removal method (USDA, 1961; Haskins, 1961).

For these reasons, and for further simplification in model construction, only two alternatives were considered in the removal of undesirable stems, namely, cutting and selling the material, and deadening the stems. Thus, by adding these alternatives, and whether the TSI was self-financed or ACP cost-shared, the decision tree now had a total of ten "branches" (Figure 5).

Additional modifications concerned the manner of selling merchantable products from an ownership. The two primary opportunities available to an owner were the selling of stumpage, or the marketing of cut products. It was conceivable that an owner, contemplating several future thinning operations plus a final harvest, would select both means of sale over the rotational period, and cordwood and sawlogs could be handled differently for a given thinning. For example, an owner might sell all of the material from the first thinning, which would consist mainly of cordwood, as stumpage, whereas when the second thinning was undertaken, he could market cut products, including more sawlogs than before, at the mill site. When a subsequent thinning or final harvest cut was made, he could sell his merchantable pole-sized stems as cordwood

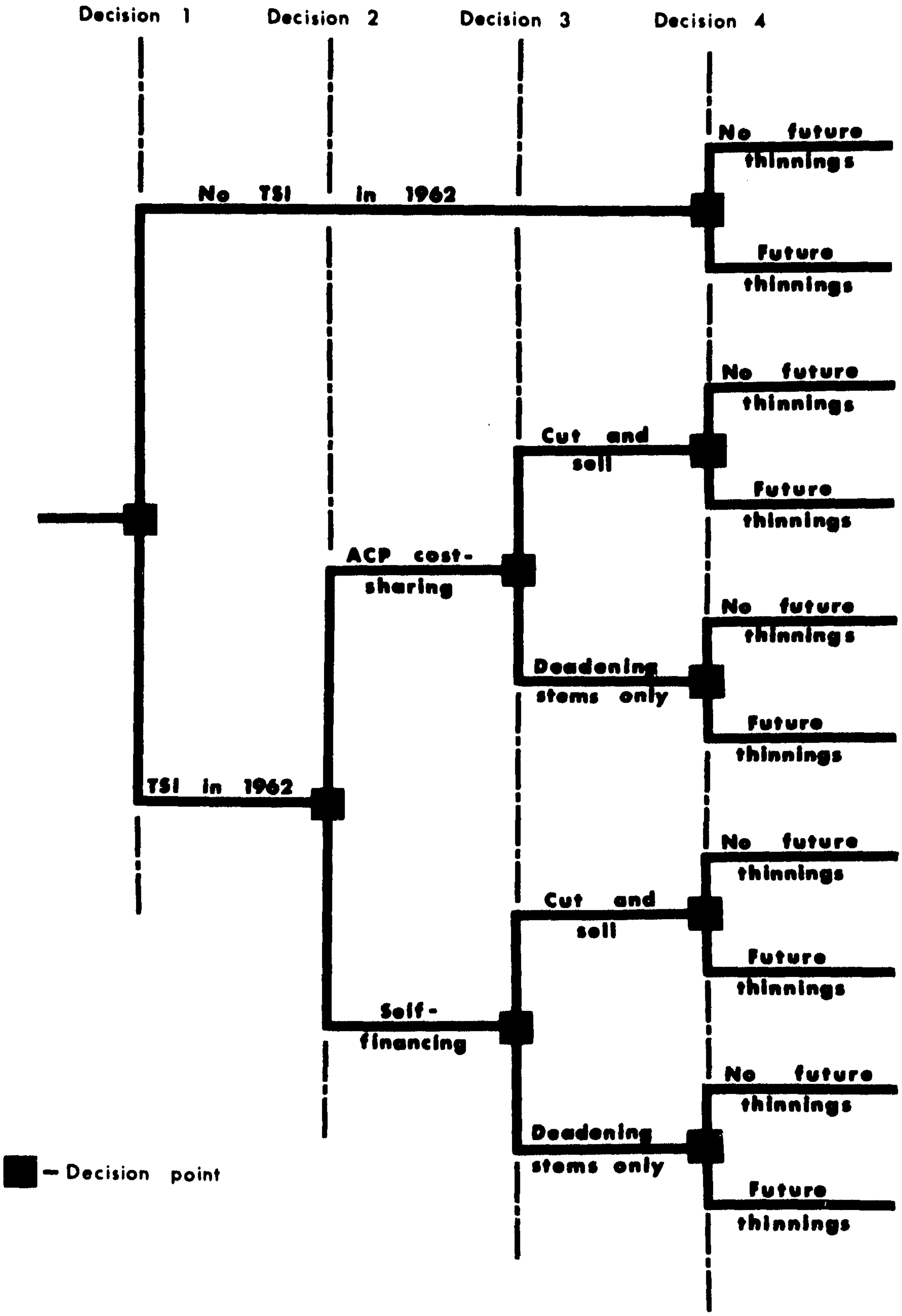

FIGURE 5

DECISION TREE SHOWING ADDITIONAL ALTERNATIVES
FACING A TYPICAL OWNER IN 1962.

stumpage along with the poorer saw-timber-sized trees, and market the higher grade sawlogs delivered at the local mill.

Thus, it was readily apparent that a realistic pattern of choice would be infinitely variable and extremely complex for analytical purposes. The pattern would vary by owner, and would be determined by many factors which were not included in the study. Because of their nature, many would be non-quantifiable or at best semi-quantifiable, such as length of tenure, age of owner, number of college-bound children, educational levels, aversions to risk and uncertainty, and basic attitudes towards forest management.

Such complexities would increase the number of computations at a geometric rate. For example, starting with one of the 5 "branches" dealing with future thinnings, a decision occurred at the time of thinning No. 1: whether to sell stumpage or market the cut material. If it is then assumed that each alternative has the potential of either a low, medium, or high income (a chance event), six additional "branches" would be created. This process would then be repeated for thinning No. 2, and each of the six "branches" for the first thinning would result in an additional six for the next cutting operation--a new total of 6 X 6, or 36 "branches." If three thinnings were planned before the final harvest, this compounding would involve 1,296 "branches" at the end of the rotation; however, if another thinning was possible, the number would spiral to 7,776; and this, for only <u>one</u> of the "future-thinnings branches!" If this sequence were applied to all the "future-thinnings" alternatives, and the "no-thinning" alternative added, the grand total would be approximately 39,000 "branches!" Furthermore, this excluded many other possibilities, such as the owner selling only cordwood, or only sawtimber, or a combination of the two products; and, the owner selling part of his timber as stumpage, and marketing the remainder. Therefore, it was necessary to restrict the system by certain simplifying assumptions.

One very important assumption was that, once an owner had determined the manner in which his products would be harvested and sold for the first thinning, he would consistently follow such a procedure for all additional cutting operations. The author believes that such an assumption is quite realistic for most small woodland owners; unless a man goes bankrupt in an initial timber transaction, it seems quite reasonable that subsequent ventures would exhibit identical characteristics. If a substantial loss were experienced by the owner, he would probably avoid further forestry activities, rather than seek professional assistance for his management problems.

Another assumption was that all yields from thinnings would be treated as cordwood in the estimation of product value. Although this aspect may become less realistic as the stand matures, it should suffice for the early thinnings, which remove the smaller stems, and even with later cuts which take larger trees, the quality would be low and cull percentage high, thus necessitating usage primarily for pulpwood. The final yield was considered to be sawtimber, with cordwood from the tops and larger limbs. Hence, part of this assumption was that all owners were aiming toward an eventual crop of quality hardwood sawtimber stumpage or harvested sawlogs.

Obviously, this assumption may not be realistic for some owners, because properties change hands, goals associated with ownership fluctuate, product markets and technology change, etc. However, the evaluation of alternatives using the discounted cash flow technique, resulted in a measure of <u>expected future value</u> in 1962, when the initial decision had to be made. This expectation about potential returns must form the basis for present-day decision-making concerning future changes in management objectives or property useage (e.g., disposal of forest land by selling or clearing); it becomes a form of opportunity cost when deviations are made from the optimum schedule.

It was questionable whether the stumpage-sale alternative should be included, as much past research showed this to be less profitable than marketing products at roadside or mill site (Filip and Leak, 1962; Aughanbaugh, 1963). However, at least one investigation indicated the opposite case in some instances (Fenton and Broomall, 1963), and it was quite likely that many owners would sell stumpage regardless of the monetary consequences, because they lack either the time and/or the equipment for harvesting and hauling timber products. For these reasons it was decided that the stumpage provision should be retained.

Another facet concerned the absence of explicit probability data on the decision tree. In the literature dealing with statistical decision theory and the concepts of decision trees, probability estimates are applied to each chance event. This information is used to obtain the discounted value from each "branch," and the alternative yielding greatest expected returns is selected as the optimum path to pursue. However, a recent investigation in Christmas tree investment opportunities (Bentley and Kaiser, 1967), employed the decision tree approach without directly using probability estimates. They were applied implicitly by using average or "most likely" values for certain parameters in the initial solution, which was then followed by sensitivity analysis of various factors to gauge their influence on the optimal sequence.

This latter approach was followed in the present analysis, using "medium" or "most probable" estimates for each parameter in the model's initial solution. Later, by means of sensitivity analysis, certain parameters were allowed to vary, to judge the responsiveness of the optimal sequence. Such techniques eliminated the need for formally grappling with probability estimates, and they would give a manager some insight as to which factors have the greatest impact, and thus require the most attention in measurement and/or estimation.

The final form of the decision tree used in this investigation is presented in Figure 6. It contains 30

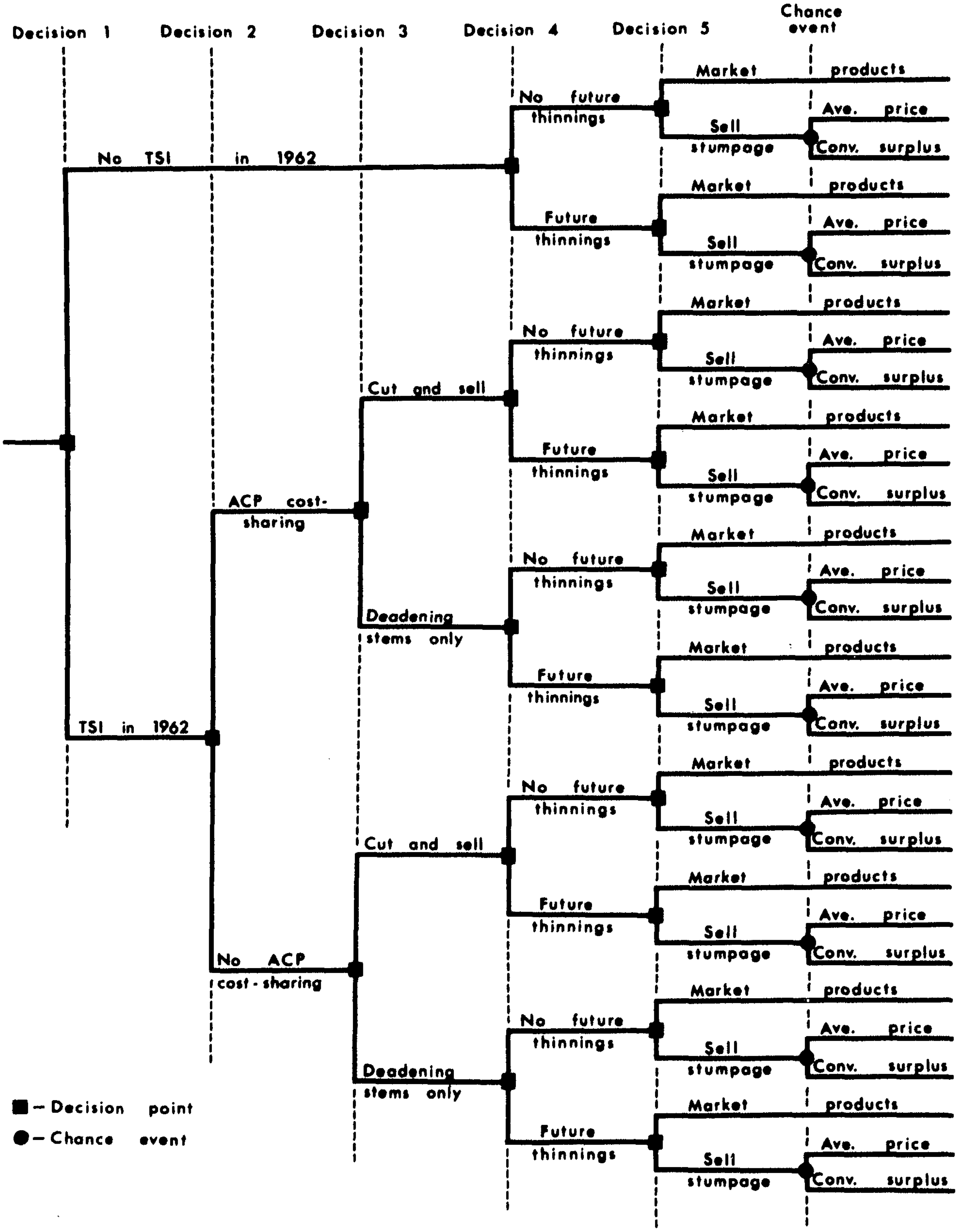

FIGURE 6

THE DECISION TREE IN ITS FINAL FORM.

"branches," indicative of the alternatives available to each of the 25 owners in the sample. However, before the evaluation began, additional assumptions about certain physical and economic aspects, including mortality, cull, quality, prices, costs, etc., were needed.

Rotation Length and Thinning Interval

The rotation used in the initial formulation was 120 years. This guideline was consistent with management recommendations for even-aged stands of northern hardwoods. "Even-aged, second-growth forests, especially those on good sites, can yield high-value products. Where the species are mostly yellow birch, beech, and sugar maple, high-value yields will be associated with long rotations (100 to 120 years) . . ." (Gilbert and Jensen, 1958). This permitted the projection of all referrals at least 20 years into the future (one ownership averaged 93 years of age in 1962).

The interval between successive intermediate cuts was 10 to 20 years, as advocated by Arbogast (1957), Blum and Filip (1963), Eyre and Zillgitt (1953), Gilbert and Jensen (1958), and Zon and Scholz (1929). Gilbert and

Jensen (1958) state that most stands composed of sugar maple and other tolerant species will respond to a thinning even after age 60; therefore, all ownerships were considered to be suitable for thinning, even though response might be negligible in some of the older stands.

In making each hypothetical cut throughout the projection period, a guideline of 92 square feet of residual basal area per acre was followed (Arbogast, 1957; Eyre and Zillgitt, 1953; Society of American Foresters, 1959).

Mortality

After consulting several research reports dealing with mortality (Conover and Ralston, 1959; Eyre and Longwood, 1951; Eyre and Zillgitt, 1953; Leak, 1961; Longwood, 1952, 1953; Meteer, 1953; Meyer, 1954; Stott, 1965), the assumptions used in the model were derived primarily from studies conducted at the U. S. Forest Service Northern Hardwoods Research Laboratory in Michigan's Upper Peninsula. Their results indicated that in uncut stands over a period of 20 to 25 years, the mortality loss was nearly 70 percent of the net growth--hence, a net increase in total stand volume of

30 percent of the net growth. However, for use in the present study, this seemed a bit severe. Most of the uncut stands at the Northern Hardwoods Research Laboratory were mature or over-mature old-growth northern hardwoods, whereas ownerships in the present study were immature to mature second-growth stands. Therefore, it was assumed that uncut stands in the study area would lose only 50 percent of the growth to mortality; one-half the projected growth would be lost and the remainder would be the net increase.

Eyre and Longwood (1951) also reported, ". . . that the average mortality on all the cutting plots was only 1/4 of that in uncut timber is perhaps the most noteworthy feature of the entire study." Therefore, in the present investigation, the assumption was made that 1/4 of 1/2, or 1/8 of the growth would be lost to mortality when partial cuts were made at relatively frequent intervals.

When only one thinning was performed, as in the case of an initial TSI treatment not followed by future thinning operations, the mortality, although reducing growth by 1/8 after cutting, would gradually approach the 50 percent loss level in an uncut stand. Therefore, it was decided that a reduction factor of 1/4 should be applied to the growth when a stand received the TSI treatment in 1962, but no additional intermediate cuts in the future. This provided an average between the 1/8 mortality loss corresponding to intensive management, and the 1/2 mortality loss for uncut stands. Examples of the various assumptions concerning mortality are presented in Figure 7.

Converting Cubic-Foot Volume to Cordwood or Board Feet

In computing the growth for each alternative, cubic-foot volumes were used; however, for those schedules involving future thinnings, the cubic-foot volumes were converted to cords, so that appropriate monetary valuations could be made. It was assumed that one standard cord would be equivalent to 92 cubic feet of wood and bark (Gevorkiantz and Olsen, 1955). Therefore, it was a simple matter to divide the cubic-foot volume (less the mortality deduction) by 92, and obtain the volume in cords at the time a thinning was made.

For converting cubic-foot volumes to board feet, yield tables for northern hardwoods in the Lake States by Gevorkiantz and Duerr (1937), were used. From their

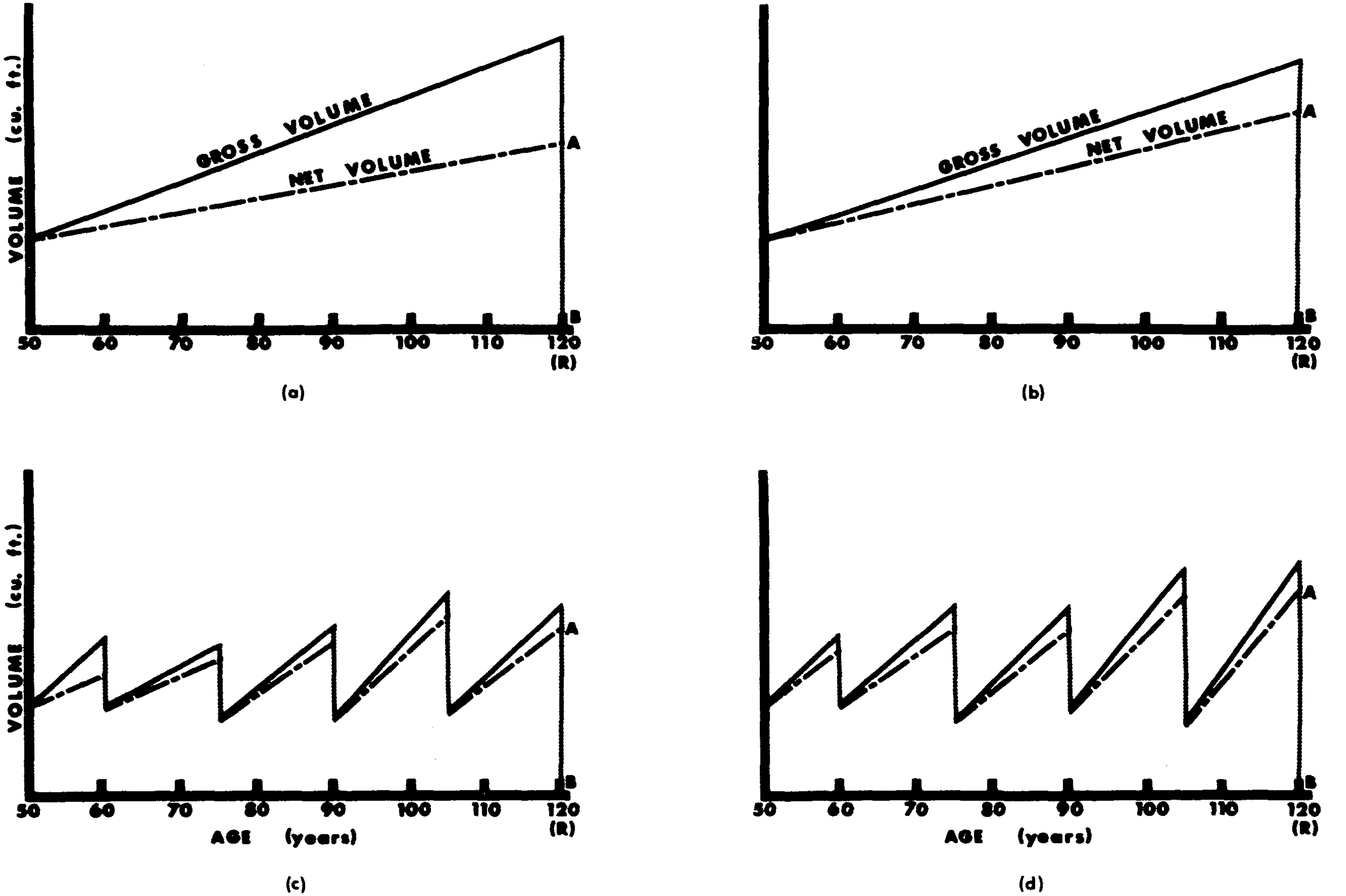

FIGURE 7. GROWTH FOR A TYPICAL REFERRAL FROM 1962 UNTIL THE END OF THE ROTATION 70 YEARS HENCE. (a) NO TSI IN 1962, AND NO FUTURE THINNINGS; (b) TSI IN 1962, BUT NO FUTURE THINNINGS; (c) NO TSI IN 1962, HOWEVER FUTURE THINNINGS WERE PERFORMED; (d) TSI IN 1962, AND FUTURE THINNINGS. LINE AB IS THE VOLUME AVAILABLE FOR HARVEST AT THE END OF THE ROTATION.

information, the following conversion factor for a stand at 120 years of age was obtained:

$$Y = 2.924\ X$$

where: Y = the net board-foot volume per acre.

X = the merchantable cubic-foot volume per acre for all trees.

Changes in Cull Defect

Several researchers have discussed the amount of cull expected in old-growth northern hardwood stands (Eyre and Longwood, 1951; Eyre and Zillgitt, 1953; Zillgitt and Gevorkiantz, 1946), indicating that the deduction may range from 30 to 50 percent of the gross volume (45 to 50 percent for very defective old-growth stands). On areas which received some type of partial cut, the cull varied from 15 to 24 percent, and was approximately 37 percent on uncut areas.

With these findings serving as a rather rough guideline, the following assumptions concerning cull reduction at the end of a rotation were applied:

1. If no initial TSI was performed, and no future thinnings were made, the deduction for cull at the harvest cut would be 35 percent. In the case of a referral having more than 35 percent cull in 1962, the deduction was increased to 45 percent.

2. If TSI was performed in 1962, but no intermediate cuts were made in the remaining years, cull deduction at the time of final cut was 25 percent of the gross volume. In the case of a referral having more than 35 percent cull in 1962, the deduction was increased to 35 percent, so that there would be no change in the projected net volume.

3. In the case of a management schedule with no timber stand improvement in 1962, but with periodic thinnings in the future, cull deduction would be 10 percent of the gross volume. In stands where the cull defect was greater than 35 percent in 1962, the deduction would be 20 percent of the harvest volume.

4. For ownerships that had TSI in 1962, and would be managed very intensively over the remainder of the rotation, the cull deduction would be 5 percent,

except for ownerships where the 1962 level of cull defect exceeded 35 percent, where the deduction would be set at 15 percent.

Changes in Quality

During the stand inventory, each tallied tree was classified by tree grade, based on the log grade of the butt log. This distribution was projected "backwards" to 1962, assuming no change in the grade proportion of the residual stems during the intervening four years. For the two major alternatives involving no TSI, the material actually removed in 1962 was added, with the simplifying assumption that it was all in tree grade 4.

The next phase was to establish log-grade conversion factors for each of the three tree grades. In a recent study in Northern Michigan, Meteer (1966) constructed tables showing the percentage of each log grade in a given tree grade for individual species and species groups. The percentages from his report which were used in the present study are shown in Table 21.

Table 21.--Log grade yield from trees of given butt-log tree grades for sugar maple and "other hardwoods"

Species	Tree Grade	Proportion of the volume by log grade:		
		#1	#2	#3
		Percent		
sugar maple	1	47.4	33.8	18.8
	2	----	68.4	31.6
	3	----	4.4	95.6
	4	----	----	100.0
other hardwoods	1	59.1	28.3	12.6
	2	----	68.3	31.7
	3	----	----	100.0
	4	----	----	100.0

Source: Meteer, 1966.

With these factors, the board-foot volumes by log grade and species at the beginning of the projection (investment) period in 1962, and at the end of the rotation were computed for each of the four major alternatives.

In reference to the assumptions dealing with cull defect, mortality, and quality, Farrell (1964) has stated: "Such adjustments are somewhat arbitrary, but are necessary to reduce gross yield estimates to realistic levels before applying value. For specific tracts, foresters may apply experience values of their own choice." Other authors advancing a similar viewpoint made the following statement: "Projection of quality may sometimes be difficult because information about the effect of time and treatment on quality is less abundant than information on volume and size. Yet it is necessary to make these projections, even when the basis is at best doubtful. An objective estimate, even though based on limited data, is better than a completely subjective one" (Marty, et al., 1966).

The only available information on quality changes following partial cutting in northern hardwoods was the 20-year study by Eyre and Zillgitt (1953) which compared the results of nine different forms of thinning with an uncut reserve area. Their findings indicated that the volume in grade 1 logs remained fairly constant, regardless of whether the stand was thinned or not. On the other hand, thinning to this level increased the volume in grade 2 logs by 15 percent, and decreased the grade 3 category by approximately 15 percent. This information provided a rather general guideline for the following grade change assumptions:

1. If there were no initial TSI and no future thinnings, there would be a 5 percent increase in the amount of material in log grade no. 2, and a 5 percent decrease

in grade 3. It was assumed that some change would occur, even though the stand received no cultural treatment; primarily due to the increase in size of individual trees. Improvement in grade through increased size would slightly offset any decline in quality caused by increases in cull defect. The increase in defect would be reflected more by an increase in cull, rather than a change in log grade.

2. If there were no initial TSI, but future thinnings were applied, there would be a 15 percent increase in the volume of grade 2 logs, and a 15 percent decrease in the grade 3 category.

3. If initial TSI were applied but no future thinnings, there would be a 10 percent reduction in log grade no. 2, and a 10 percent reduction in log grade no. 3.

4. With initial TSI and future thinnings, there would be a 15 percent improvement in log grade no. 2, and a 15 percent decrease in log grade 3. Thus, it was assumed that a TSI operation followed by periodic thinnings would result in the same grade distribution

as periodic thinnings without an initial TSI treatment.

Once the projection of volume was accomplished, based on the grade distribution in 1962, the quality improvement factors were applied to obtain an estimate of net board-foot volume in each species-log grade category at rotation age.

Determination of the Additional Volume in Topwood

When the projected cubic-foot volume was converted to board feet per acre at the end of the rotation, it was possible to determine how much additional cordwood volume would be available in the tops and limbs of sawlog trees, using the procedure recommended by Chase and Gevorkiantz (1953), as outlined in an earlier chapter (page 33). To facilitate this conversion on a per acre basis, using the board-foot volume at the time of final harvest, the following regression equation was computed and utilized:

$$Y = 0.746 + 0.000367\ X$$

where: Y = the additional cordwood volume per acre in topwood.

X = the net board-foot volume per acre.

Computational Steps in Volume Projection

The calculations of volume per acre at the time of each proposed thinning, and at the time of final harvest, for Referral No. 2G01, are presented in Tables 22 to 25.

Percentages in these computations indicate the volume in each species category, and changes in species composition induced by each thinning operation, since the cuttings were designed to encourage high-value species and to remove those of lower value. The percentages, which changed after each cut was made, were utilized to determine the volume distribution by species before the next scheduled thinning. For example, sugar maple in Referral No. 2G01 would increase from 23.7 percent to 81.3 percent of the total volume over the remaining years of the rotation, if the schedule of intermediate cutting were followed (Table 24). For each proposed thinning, data are given for the volume per acre before thinning, volume removed, and the residual volume per acre. The board-foot volumes are not adjusted for the assumed

Table 22.--Computational steps in volume projection and calculation of final yield by species and log grade, for Referral No. 2G01, with no TSI and no future thinnings, per acre basis.

Age	Ave. Ht.	Basal Area	Gross Volume	Mortality	Gross Vol. Less Mortality	Volume by Species--Cords & Percent				
						Entire Stand	Sugar Maple	Basswood	Elm	Beech
Yrs.	Ft.	Sq.Ft.	Cu.Ft.	Cu.Ft.	Cu.Ft.					
						100%	23.7%	53.5%	14.7%	8.1%
51	60	117	1,928.4	-------	1,928.4	21.0	5.0	11.2	3.1	1.7
						100%	23.7%	53.5%	14.7%	8.1%
120	89	386[a]	9,437.1	3,754.4	5,682.7	61.8	14.6	33.1	9.1	5.0
Additional volume in topwood--cords[b]						5.8	1.4	3.1	0.8	0.5

Distribution of final board-foot yield by tree and log grades based on the initial distribution in 1962:

Species	Total Net Volume[c]	Volume by Tree Grades				Volume by Log Grades		
		1	2	3	4	1	2	3
Sugar Maple	3,938	----	----	----	3,938	----	----	3,938
Basswood	8,890	3,467	4,703	720	----	2,049	4,193	2,648
Elm	2,443	----	----	----	2,443	----	----	2,443
Beech	1,345	----	----	----	1,345	----	----	1,345
Total	16,616	3,467	4,703	720	7,726	2,049	4,193	10,374

[a]This represents the basal area corresponding to the projected volume, before a reduction for mortality had been applied.

[b]Cordwood available at the time of final harvest in addition to the sawtimber volume.

[c]Based on the cull defect percentage in 1962.

Table 23.--Computational steps in volume projection and calculation of final yield by species and log grade, for Referral No. 2G01, with TSI in 1962, but no future thinnings were performed, per acre basis.

Age[a]	Ave. Ht.	Basal Area	Gross Volume	Mortality	Gross Vol. Less Mortality	Volume by Species--Cords & Percent				
						Entire Stand	Sugar Maple	Basswood	Elm	Beech
Yrs.	Ft.	Sq.Ft.	Cu.Ft.	Cu.Ft.	Cu.Ft.					
						100%	23.7%	53.5%	14.7%	8.1%
51_I	60	117	1,928.4	-----	1,928.4	21.0	5.0	11.2	3.1	1.7
51_C	60	37	514.2	-----	514.2	5.6	---	0.8	3.1	1.7
51_R	60	80	1,414.2	-----	1,414.2	15.4	5.0	10.4	---	---
						100%	32.5%	67.5%	---	---
120	89	294[b]	7,709.1	1,573.7	6,135.4	66.7	21.7	45.0	---	---
Additional volume in topwood--cords[c]						7.1	2.3	4.8	---	---

Distribution of final board-foot yield by tree and log grades based on the initial distribution in 1962:

Species	Total Net Volume[d]	Volume by Tree Grades				Volume by Log Grades		
		1	2	3	4	1	2	3
Sugar Maple	5,831	----	----	---	5,831	----	----	5,831
Basswood	12,109	4,723	6,406	980	----	2,791	5,712	3,606
Total	17,940	4,723	6,406	980	5,831	2,791	5,712	9,437

[a]I, C, and R indicate initial stand conditions, material cut, and residual stand conditions respectively at a given age.

[b]This represents the basal area corresponding to the projected volume, before a reduction for mortality had been applied.

[c]Cordwood available at the time of final harvest in addition to the sawtimber volume.

[d]Based on the cull defect percentage in 1962.

Table 24.--Computational steps in volume projection and calculations of final yield by species and log grade, for Referral No. 2G01, with no TSI in 1962, however, future thinnings were performed, per acre basis.

Age[a]	Ave. ht.	Basal area	Gross Volume	Mortality	Gross vol. less mortality	Volume by species-cords & percent				
						Entire Stand	Sugar Maple	Basswood	Elm	Beech
Yrs.	Ft.	Sq.ft.	Cu.ft.	Cu.ft.	Cu.ft.					
						100%	23.7%	53.5%	14.7%	8.1%
51	60	117	1,928.4	------	1,928.4	21.0	5.0	11.2	3.1	1.7
						100%	23.7%	53.5%	14.7%	8.1%
60_I	65	152[b]	2,714.0	392.8	2,321.2	25.2	6.0	13.5	3.7	2.0
60_C	65	60	--------	------	678.5	7.3	----	1.6	3.7	2.0
60_R	65	92	1,642.7	------	1,642.7	17.9	6.0	11.9	---	---
						100%	33.5%	66.5%	---	---
80_I	74	152	3,089.8	180.9	2,908.9	31.6	10.6	21.0	---	---
80_C	74	60	--------	------	1,038.7	11.3	----	11.3	---	---
80_R	74	92	1,870.2	------	1,870.2	20.3	10.6	9.7	---	---
						100%	52.2%	47.8%	---	---
100_I	82	152	3,423.9	194.2	3,229.7	35.1	18.3	16.8	---	---
100_C	82	60	--------	------	1,157.3	12.6	----	12.6	---	---
100_R	82	92	2,072.4	------	2,072.4	22.5	18.3	4.2	---	---
						100%	81.3%	18.7%	---	---
120	89	152	3,716.2	205.5	3,510.7	38.2	31.1	7.1	---	---
Additional volume in topwood - cords[c]						5.1	4.1	1.0	---	---

Table 24.--(Continued)

Species	Total net volume[d]	Distribution of final board-foot yield by tree and log grades based on the initial distribution in 1962: Volume by tree grades: 1	2	3	4	Volume by log grades: 1	2	3
Sugar maple	8,345	----	----	----	8,345	----	----	8,345
asswood	1,920	749	1,016	155	-----	433	906	571
Total	10,265	749	1,016	155	8,345	433	906	8,916

[a]I, C, and R indicate initial stand conditions, material cut, and residual stand conditions respectively at a given age.

[b]This represents the basal area corresponding to the projected volume, before a reduction for mortality had been applied.

[c]Cordwood available at the time of final harvest in addition to the sawtimber volume.

[d]Based on the cull defect percentage in 1962.

Table 25.--Computational steps in volume projection and calculations of final yield by species and log grade, for Referral No. 2G01, with TSI in 1962, and future thinnings, per acre basis.

Age[a]	Ave. ht.	Basal area	Gross Volume	Mortality	Gross vol. less mortality	Volume by species-cords & percent				
						Entire Stand	Sugar Maple	Basswood	Elm	Beech
Yrs.	Ft.	Sq.ft.	Cu.ft.	Cu.ft.	Cu.ft.					
						100%	23.7%	53.5%	14.7%	8.1%
51_I	60	117	1,928.4	------	1,928.4	21.0	5.0	11.2	3.1	1.7
51_C	60	37	514.2	------	514.2	5.6	---	0.8	3.1	1.7
51_R	60	80	1,414.2	------	1,414.2	15.4	5.0	10.4	---	---
						100%	32.5%	67.5%	---	---
70_I	70	139[b]	2,866.7	181.6	2,685.1	29.2	9.5	19.7	---	---
70_C	70	47	--------	------	787.7	8.6	---	8.6	---	---
70_R	70	92	1,897.4	------	1,897.4	20.6	9.5	11.1	---	---
						100%	46.1%	53.9%	---	---
90_I	78	154	3,539.1	205.2	3,333.9	36.2	16.7	19.5	---	---
90_C	78	62	--------	------	1,219.7	13.2	----	13.2	---	---
90_R	78	92	2,114.2	------	2,114.2	23.0	16.7	6.3	---	---
						100%	72.6%	27.4%	---	---
120	89	185	4,850.9	342.1	4,508.8	49.0	35.6	13.4	---	---
Additional volume in topwood - cords[c]						6.6	4.8	1.8	---	---

Table 25.--(Continued)

Distribution of final board-foot yield by tree and log grades based on the initial distribution in 1962:

Species	Total net volume[d]	Volume by tree grades:				Volume by log grades:		
		1	2	3	4	1	2	3
Sugar maple	9,572	----	----	----	9,572	----	-----	-----
Basswood	3,612	1,409	1,911	292	-----	833	1,704	1,075
Total	13,184	1,409	1,911	292	9,572	833	1,704	10,647

[a] I, C, and R indicate initial stand conditions, material cut, and residual stand conditions respectively at a given age.

[b] This represents the basal area corresponding to the projected volume before a reduction for mortality had been applied.

[c] Cordwood available at the time of final harvest in addition to the sawtimber volume.

[d] Based on the cull defect percentage in 1962.

changes in cull and quality; however, it is subdivided by tree grade and log grade, based on the 1962 distribution.

The next step incorporated the various assumptions concerning cull defect changes and log-grade improvement (Table 26). Although the changes are presented in Table 26, they were actually applied in the computer program used in the economic evaluation. This was much simpler, since it eliminated many preparatory calculations. With these expected changes, the assumptions involving physical yield data were concluded, and the remaining aspects of model formulation entailed various economic considerations.

Periodic Cost Assumptions

The completed decision-tree model (Figure 6) considered two alternative methods that an owner might use for selling his timber products: 1) Marketing sawlogs and cordwood, or, 2) Selling the material as stumpage. The harvesting costs would be quite different for the two possibilities.

If the decision were made to market the products at either a sawmill or pulpmill, the owner would incur the costs of felling, bucking, skidding, loading, hauling, and unloading,

Table 26.--Volume per acre at rotation age for each of the four major alternatives for Referral No. 2G01, by species and log grade after cull and quality adjustments were made.

Species and Log Grade	Net volume by alternative cutting schedule:			
	No TSI and no future thinnings	No TSI, but future thinnings	TSI in 1962 but no future thinnings	TSI in 1962 and future thinnings
	Board Feet			
Sugar maple:				
Grade 1	164	1,444	561	1,749
2	3,116	8,186	5,048	9,910
Basswood:				
Grade 1	1,707	511	2,685	1,015
2	3,603	1,145	5,842	2,271
3	2,096	560	3,122	1,113
Elm:				
Grade 3	2,035	----	----	----
Beech:				
Grade 3	1,120	----	----	----
Total adjusted net volume	13,841	11,846	17,258	16,058

or else enlist the services of a contractor. The per unit costs for each operation in the production process are presented in Table 27.

Although a recent study was made of timber harvesting costs in northern hardwoods (Gardner, 1966), the information from the Service Forester Handbook (USDA, 1961), was considered to be more applicable, because only the data available for consideration by the owner in 1962 would be relevant, and information from the Handbook would usually provide the basis for actual cost determination by the consulting Service Forester for ACP cost-sharing purposes.

Hauling and unloading costs were based on a differential rate depending on the type of road surface (Table 28). Rates were in dollars per unit of volume per unit of distance; therefore, accurate determination of the mileage from each ownership to a market location was needed. The market for sawtimber was assumed to be the closest sawmill to each property. It was assumed that all pulpwood would be sold to the mill in Filer City. The requisite mileage was ascertained from county maps by road-surface category (Appendix 2).

Table 27.--Production costs on a per-unit basis for an owner choosing to market sawlogs and cordwood at the mill site.

Operation	Cost: Sawtimber per MBF	Cost: Pulpwood per cord
Marking, felling, and bucking, including supervision	$5.99 variable	$4.28 variable
Skidding[a]	5.70 variable	3.71 variable
Loading	1.40 variable	.47 variable
Hauling and unloading[b]	Fixed--based on the mileage and type of road surface	Fixed--based on the mileage and type of road surface
Total logging cost	Summation of the previous items	Summation of the previous items
Overhead (20 percent of the logging cost)	Fixed	Fixed
Total production cost	Summation of the previous items	Summation of the previous items

Source: USDA, 1961.

[a]The cost of $5.70 represents the expense of skidding sawlogs with a small tractor, on slopes of 10 percent or less, for a distance of 200 feet, and for a stand with an average DBH of 16 inches.

[b]See Table 28.

Table 28.--Schedule of hauling and unloading costs

Operation	Cost[a]	
	Sawtimber: ($7.00/hour and a load of 2 MBF)	Pulpwood: ($7.00/hour and a load of 6 cords)
	Per MBF per mile	Per cord per mile
Standby, delay, and unloading	$1.40	$ .47
Hauling:		
Highway (45 mph)	.16	.05
Main haul (25 mph)	.28	.09
Secondary (15 mph)	.44	.15
Woods road (8 mph)	.88	.29

Source: USDA, 1961.

[a]The minimum hauling costs including unloading in 1961 were $2.00 per cord and $4.00 per MBF.

The computations of harvesting costs for Referral No. 2G01 are as follows:

Sawtimber, per MBH:

Marking, felling, and bucking, including supervision		$5.99
Skidding		5.70
Loading		1.40
Hauling and unloading:		
Standby, delay, and unloading	$1.40	
Highway (6 miles)	.96	
Main (6 miles)	1.68	
Secondary (.5 miles)	.22	
Woods road (1 mile)	.88	
Total		5.14
Total logging cost		$18.23
Overhead (20 percent of the logging cost)		3.65
Total production cost		$21.88

Pulpwood, per cord:

Marking, felling, and bucking, including supervision		$4.28
Skidding		3.71
Loading		.47
Hauling and unloading:		
Standby, delay, and unloading	$ .47	
Highway (64.5 miles)	3.22	
Main (1 mile)	.09	
Secondary (.5 miles)	.08	
Woods road (1 mile)	.29	
Total		4.15
Total logging cost		$12.61
Overhead (20 percent of the logging cost)		2.52
Total production cost		$15.13

If an owner decided to sell stumpage, he would still have the responsibility of marking timber for cutting, and supervising the harvesting operation. Such items, whether done by the owner himself or by a professional consultant, would involve a cost that must be included in the analysis. In the present study it was assumed that marking and supervisory costs would be $1.50 per MBF for the final harvest of sawtimber, and $.40 per cord for each intermediate cut (Marty and Trimble, 1967). The sawtimber cost was applied to the gross volume removed at the time a harvest cut was made.

Costs of Timber Stand Improvement

A woodland owner contemplating timber stand improvement, was assumed to have four possibilities available. The associated costs and their computation differ somewhat for each alternative.

One alternative would be a TSI operation completely financed by the owner, where the marked trees were either cut and left where they fell, or where the undesirable stems were girdled or treated with silvicide. The actual cost for such a program was determined from the Service Forester Handbook (USDA, 1961), which provided data on TSI cost per acre per square foot of basal area to be removed.

For Referral 2G01, the computation of total cost per acre for this option proceeded as follows:

DBH class Inches	Basal area removed Sq. Ft.	Cost per square foot of basal area removed	Total cost per acre
6	25	$.588	$14.70
10	6	.362	2.17
18	6	.214	1.28
Total	37	---	$18.15

Thus, if the owner of Referral No. 2G01 had chosed to finance timber stand improvement from his own pocket, and the unwanted trees were not sold for pulpwood, the cost would be $18.15 per acre.

It was possible, however, that an owner might have been able to cut and sell the undesirable stems, and therefore, generate a monetary return which might offset the cost involved. This opportunity would have hinged primarily on prevailing market conditions, and the costs would have been computed in the same manner as for other commercial thinnings. If the material was marketed at a mill site, the total production costs would be applied to the volume removed, or, if a stumpage sale was selected by the owner, the costs of marking and supervision would be involved. In the case of Referral No. 2G01, where 5.6 cords per acre were removed in 1962, the total cost of TSI per acre would be:

5.6 X \$15.13 = \$84.73 per acre if the cordwood was marketed at a mill site.

5.6 X \$ .40 = \$2.24 per acre if the cordwood was sold as stumpage.

Actually, the option taken by all referrals in the study area was cost-sharing payments for TSI under the ACP program. In general, ACP payments are 80 percent of the Service Forester's estimate of total cost per acre, and the payment is not to exceed \$25.00 per acre. However, in Michigan, the Department of Natural Resources, which administers the program on a local level, has established a system of reducing the total estimated cost when merchantable products will be obtained from the thinning. Thus, an 80 percent payment could not be realized by ownerships which removed a volume greater than the specified minimum; nearly all sampled referrals did not receive the full 80 percent remuneration.

The appropriate payment schedules for 1962 were obtained from the Michigan Department of Natural Resouces. "Generally, volumes of less than 2 standard cords per acre will not be considered merchantable. Otherwise, the following is suggested as the amount to reduce the total estimated cost in computing the Federal Cost Share" (Haskins, 1961):

Cords per acre	Approximate allowance per acre
2	$0.00 - $1.00
3	1.00 - 1.50
4	1.50 - 3.00
5 and over	3.00 - 4.00

Although the actual cost of a TSI operation may differ from the estimated expense, the Service Forester computed each cost-share on the basis of his own determination of total cost. The reduction for merchantable volume would then be applied to his estimate, as described above. The Michigan Department of Natural Resources used the following schedule for estimating costs of timber stand improvement prior to 1964 (Haskins, 1961):

$1.25 per square foot of basal area--saplings 1 to 5 inches DBH cut or girdled.

$ .75 per square foot of basal area--poletimber 5 to 11 inches DBH cut or girdled.

$ .50 per square foot of basal area--sawtimber over 11 inches DBH cut or girdled.

The federal cost-share payment was equal to 80 percent of the difference between total estimated cost and the reduction for merchantability. For Referral No. 2G01, the cost-share was calculated as follows:

1. Estimate total cost per acre:

Size class	Basal area Sq. ft.	Cost per sq. ft.	Total cost per acre
Saplings	--	---	----
Poletimber	31	$.75	$23.25
Sawtimber	6	.50	3.00
Total	37	---	$26.25

2. Determine the reduction for merchantable products:

5.6 cords were cut; hence, the reduction would be $3.50 per cord, or a total reduction of $3.50 X 5.6 = $19.60 per acre.

3. Determine the federal cost-share:

   The total estimated cost minus the reduction allowance: $26.25 - $19.60, leaves $6.25; and 80 percent of $6.25 is $5.32. This is the cost-share payment per acre for the owner of Referral No. 2G01.

Once the cost-share had been computed, it was deducted from the actual cost per acre, to find the true cost of the owner's TSI operation. For example, if the owner of Referral No. 2G01 had chosen to obtain ACP reimbursement for deadening the undesirable stems, the true cost would equal the actual cost of eliminating the trees either by cutting, girdling, or treating with silvicide, minus the cost-sharing payment: $18.16 - $5.32, or $12.83 per acre.

On the other hand, if the owner had decided to cut and sell the marked material, his true cost would have been:

$84.73 - $5.32, or $79.41 per acre if the pulpwood was marketed at the mill site.

$2.24 - $5.32, or - $3.08 per acre if the pulpwood was sold as stumpage. This resulted in a negative cost, thus it was actually an income of $3.08, due to the federal cost-share.

In all cases, the actual cost of timber stand improvement as determined from information in the Service Forester Handbook was lower than the actual Service Forester's estimate.

This fact has caused the Michigan Department of Natural Resources to revise its cost estimates downward beginning in 1961. The latest reduction in 1964 dropped the cost in each size class by $.20 to $.25 per square foot of basal area (Haskins, 1965), which now makes the actual costs of TSI and the basis for determining cost-sharing payments closer together.

A similar discrepancy between actual costs and ACP-estimated costs was also observed in a Wisconsin study of timber stand improvement by Montambo and Sylvester (1965). Their findings for three woodlots ranging from 7.5 acres to 8.8 acres in size, indicated the actual expense of TSI by girdling was from 8 to 43 percent below the ACP estimate.

Annual Cost Assumptions

With the computer program used in the evaluation phase of this study (Row, 1963), it was possible to investigate several annual cost assumptions simultaneously. Also, it was permissable to start with a base annual cost, and to increase it every year by a predetermined percentage.

Consequently, the following assumptions were selected for evaluation, representing a low, medium, and high annual cost.

	Beginning base annual cost	Annual Increase Applied to the base
		Percent
Low	$0.00	0
Medium	1.00	1
High	1.50	3

The annual cost included taxes, administration, fire protection, etc., which would be paid each year regardless of whether any cultural activities were performed or not.

The annual increase was a simple interest rate, and in the case of the "medium" assumption, the annual cost would be $1.00 the first year, $1.01 in the second year, $1.02 in the third year, and so on for the entire investment period.

Selling Price Assumptions

The various prices used were obtained from several sources (Michigan Department of Conservation, 1963; University of Wisconsin, 1967; Wisconsin Department of Agriculture, 1963; Office of Iron Range Resources and Rehabilitation, 1965; Stott, 1965) which were coalesced into a single price for each species and grade category (Tables 29 and 30). Major emphasis was given to the 1963 data from the Michigan Department of Conservation (presently the Department of Natural Resources), which were published for the northern portion of Michigan's Lower Peninsula.

The various opportunities concerned with selling stumpage, instead of marketing cut products, were handled in a twofold manner with respect to stumpage price. The first was termed an average price; i.e., the price which usually prevailed in the study area (Tables 29 and 30). The second set of stumpage prices was calculated in the "textbook" fashion. They were computed as conversion surplus (or residual) prices; i.e., what was "left over" after the costs of production plus a margin for profit were deducted from the final selling price. Conversion surplus was calculated in the following manner (USDA, 1961):

1. Calculation of Margin for Profit:

   Margin for Profit = 10 percent of the selling price of final product which in this case was either sawlogs or pulpwood.

Table 29.--Prices for sawlogs delivered at the mill site, and for sawtimber stumpage, per MBF.

Species	Sawlog prices by log grade: 1	2	3	Stumpage prices by log grade: 1	2	3
Ash	$ 70	$40	$25	$19.80	$10.00	$1.65
Aspen	40	30	15	6.00	3.00	.50
Basswood	85	50	25	24.00	12.00	2.00
Beech	60	30	20	15.60	7.75	1.30
Yellow birch	140	60	25	10.80	5.50	.90
Black cherry	85	45	30	24.00	12.00	2.00
Elm	60	40	25	19.80	10.00	1.65
Hemlock[a]	---	45	--	-----	10.00	----
Hard maple	100	60	35	33.00	16.50	2.75
Red oak	85	50	30	15.00	7.50	1.25
Soft maple	70	40	20	13.20	6.75	1.10

Source: Michigan Department of Conservation (1963-1965); Minnesota Forest Products Marketing and Pricing Review (1965); Wisconsin Department of Agriculture (1963); Stott (1965).

[a]Hemlock was not priced by grades.

Table 30.--Prices for pulpwood delivered at the mill site, and for pulpwood stumpage, per cord.

Species	Delivered at the mill	Sold as Stumpage
Aspen	$14.50	$1.30
Basswood	14.00	.80
Hemlock	19.00	3.00
Mixed hardwoods	16.00	1.00
Oak	15.00	1.00

Source: Michigan Department of Conservation (1963 - 1965); Minnesota Forest Products Marketing and Pricing Review (1965); Wisconsin Department of Agriculture (1963); Stott (1965).

For example: the selling price of grade 1 ash saw-logs was $70 per MBF (Table 29), hence the margin for profit would be:

10% of $70 = $7.00

2. Calculation of total operating costs:

Total operating costs = total production costs + margin for profit; and, to continue the example, using cost figures from Referral No. 2G01:

Total operating costs = $21.88 + $7.00 = $28.88

3. Calculation of the conversion surplus (i.e., the stumpage price per unit of volume):

Stumpage price = Selling price - Total operating costs

= $70.00 - $28.88

Stumpage price = $41.12 per MBF

The calculation of conversion surplus resulted in a considerably higher stumpage price than was usually paid on the average; e.g., $41.12 compared to $19.80 (see Table 29). However, with pulpwood, because of the cost structure involved, the reverse was often noted; i.e., average stumpage price was higher than conversion surplus for some species.

As with the annual cost assumption, Row's computer program (1963) facilitated investigating various changes in prices. To provide a low, medium, and high range in expected future prices, differing annual-percentage changes were applied to the base price for each species-grade category. The following changes were applied, and permitted some insight into the model's sensitivity to potential variation in price:

	Annual increase applied to the base price	
	Sawtimber Percent	Pulpwood Percent
Low	0	0
Medium	1	1/2
High	2	1

To simplify matters, the changes were allocated uniformly to each species and grade combination.

CHAPTER VIII

EVALUATION OF THE DECISION-TREE MODEL

The Computer Program

The computer program published by Row (1963) was used to evaluate each "branch" of the decision tree. Subsequent to Row's original publication, the program received certain modifications (Marty, *et al.*, 1966) which increased its sophistication and computational capacity. Prior to its use in the present investigation, the program was streamlined somewhat to save compilation time on the computer, and the output format was modified to minimize the lines of print and number of pages (see Appendix 4).

The program's structure permitted simultaneous evaluation of six alternatives from one data deck. Therefore, five sets of data cards were required for each referral to accomodate the complete schedule of 30 alternatives. The data cards, containing both physical and economic information, numbered nearly 4,000 for the entire analysis.

Measure of Effectiveness

The measure of effectiveness was the internal rate of return (IRR). This is the compound interest rate which equates the discounted value of all future returns to the discounted value of all future costs; i.e., the rate which generates a present net worth of zero. This criterion enables the analyst to rank various alternatives on the basis of their financial desirability; the higher the IRR, the more attractive the investment.

The essence of the evaluation phase was to compute an internal rate of return for each alternative under "medium" conditions for all parameters. This established rates of return which could be expected as payoffs for each of the 30 "branches" on the decision tree. The "branch" possessing the highest IRR value is the one which should have been followed, if it can be assumed that the "medium" or average conditions were valid.

Once various alternatives are ranked in descending order on the basis of their rates of return, a decision-maker can then guage the relative desirability of all opportunities. Such a ranking would permit him to see the financial loss, in terms of a percent, that would result if he were to pursue another alternative in lieu of the optimal choice.

The Initial Solution

Results of the initial solution for average or "medium" conditions are presented in tabular form for all alternatives or "branches" for each referral in Table 31. In several tables in this chapter, and Appendix 3, the category of "cut-leave" is used. This merely refers to all removal methods which simply deaden the undesirable stems in place, without any utilization or sale of the material thus eliminated from the stand.

Although the optimum alternative varied somewhat from ownership to ownership, the results indicated certain trends. This was especially true when the top five alternatives from each referral were considered. To extract meaningful information from the initial results, the values were considered in terms of an initial solution (IS) matrix. The matrix dimensions were 30 x 25, representing the 30 alternatives and the 25 referrals, for a total of 750 cells.

Table 31.--Internal rates of return for each referral for the 30 alternatives, under "medium" or average conditions for all parameters.

Alternative	Referral No. 2G01	2G02	2G03	1L04	1L05	1L06	2W07	2G08	2W09	2G10
I. No TSI in 1962										
(A) No Future Thinning										
(1) Market Products	4.6	4.8	6.6	4.8	6.4	3.2	5.8	7.6	4.4	2.0
(2) Sell Stumpage										
A. Ave. Price	1.6	1.6	3.6	1.2	3.8	0.2	1.8	5.0	0.2	0.2
B. Conv. Surplus	3.6	3.2	5.8	3.6	5.6	2.2	4.6	7.0	3.6	0.2
(B) Future Thinnings										
(1) Market Products	5.2	8.4	9.2	7.6	8.2	5.2	14.2	9.0	7.8	4.4
(2) Sell Stumpage										
A. Ave. Price	1.4	1.6	5.6	3.8	6.0	1.0	3.8	8.0	1.4	0.2
B. Conv. Surplus	3.0	3.2	6.4	5.6	6.4	3.2	5.0	7.0	2.8	0.2
II. TSI in 1962										
(A) No Future Thinning										
(1) Market Products										
A-No ACP, Cut-Sell	5.8	6.2	8.0	6.2	6.6	4.2	9.8	7.4	6.2	3.0
B-No ACP, Cut-Leave	4.6	5.4	6.6	4.8	5.8	3.4	5.4	7.0	4.8	2.2
C-ACP, Cut-Sell	6.2	6.2	8.0	25.2	6.6	a	9.8	7.4	6.2	5.2
D-ACP, Cut-Leave	4.8	5.4	6.6	5.8	5.8	4.4	5.4	7.0	6.6	2.6
(2) Sell Stumpage										
A. Ave. Price										
1-No ACP, Cut-Sell	3.2	3.0	5.4	2.6	5.0	0.2	3.0	9.0	2.4	0.2
2-No ACP, Cut-Leave	2.2	2.4	4.2	1.6	3.4	0.2	1.8	4.4	1.4	0.2
3-ACP, Cut-Sell	3.8	3.0	5.4	5.2	5.0	0.8	3.0	9.0	2.4	0.2
4-ACP, Cut-Leave	2.4	2.4	4.2	2.2	3.4	0.2	1.8	4.4	2.6	0.2
B. Conv. Surplus										
1-No ACP, Cut-Sell	4.6	4.4	6.2	4.8	5.8	3.2	5.4	6.4	5.0	0.2
2-No ACP, Cut-Leave	3.8	4.2	6.0	3.8	5.0	2.4	4.0	6.2	3.8	0.2
3-ACP, Cut-Sell	5.2	4.4	6.2	7.6	5.8	a	5.4	6.4	5.0	0.4
4-ACP, Cut-Leave	4.0	4.2	6.0	4.6	5.0	3.2	4.0	6.2	5.4	0.2
(B) Future Thinnings										
(1) Market Products										
A-No ACP, Cut-Sell	5.4	8.4	9.0	7.6	7.4	5.2	15.0	7.8	8.4	5.0
B-No ACP, Cut-Leave	4.4	6.6	7.6	6.0	6.6	4.4	8.0	7.4	5.8	3.4
C-ACP, Cut-Sell	6.0	8.4	9.0	25.2	7.4	a	15.0	7.8	8.4	33.4
D-ACP, Cut-Leave	4.8	6.6	7.6	7.2	6.6	5.6	8.0	7.4	9.8	4.2
(2) Sell Stumpage										
A. Ave. Price										
1-No ACP, Cut-Sell	2.6	1.2	6.2	4.0	6.2	1.4	4.4	a	2.4	0.2
2-No ACP, Cut-Leave	1.4	0.8	4.6	2.8	4.2	0.6	2.2	5.0	1.2	0.2
3-ACP, Cut-Sell	3.2	1.2	6.2	a	6.2	a	4.4	a	2.4	0.2
4-ACP, Cut-Leave	1.6	0.8	4.6	3.6	4.2	1.4	2.2	5.0	2.8	0.2
B. Conv. Surplus										
1-No ACP, Cut-Sell	3.8	2.8	6.2	5.6	6.2	3.6	5.4	5.8	3.6	1.0
2-No ACP, Cut-Leave	3.0	2.6	6.0	4.6	5.4	2.8	3.8	5.6	2.6	0.8
3-ACP, Cut-Sell	4.2	2.8	6.2	a	6.2	a	5.4	5.8	3.6	1.6
4-ACP, Cut-Leave	3.2	2.6	6.0	5.6	5.4	3.6	3.8	5.6	3.8	1.0

[a]It was impossible to obtain these values through iteration in the computer program. This was caused by either multiple or imaginary roots to the cost-revenue polynomial. A practical solution which would provide a rough approximation of the relative rate earned, is to simply interpolate between two known IRR values for the missing value.

Table 31.--Continued

2W11	1L12	1L13	1B14	2G15	1L16	2W17	2W18	1M19	1M20	1M21	2G22	2W23	1M24	1L25
4.0	6.0	8.4	7.0	5.8	10.2	4.8	1.2	5.0	5.2	6.6	7.2	5.0	4.4	3.6
0.4	3.0	4.6	4.0	3.2	6.4	1.4	0.2	2.2	2.2	3.2	4.2	1.8	0.4	1.0
2.6	4.6	7.4	6.4	4.2	10.2	3.6	0.2	3.8	4.4	5.6	6.4	3.6	3.4	2.2
8.8	7.6	11.6	10.4	11.6	15.4	8.8	5.4	16.8	10.0	10.4	9.2	7.8	5.8	5.8
1.2	4.8	8.2	5.4	6.8	10.2	3.6	0.2	3.8	4.8	5.2	6.8	3.4	1.4	2.4
3.0	5.2	8.4	7.6	6.8	13.4	5.6	2.0	6.6	5.4	7.0	5.2	4.4	2.6	3.4
6.0	5.8	9.8	8.8	9.8	11.2	7.4	3.6	18.8	18.8	9.2	8.0	6.2	5.0	4.8
3.8	6.0	8.2	6.8	6.4	11.4	5.6	2.8	4.4	5.4	6.6	7.2	5.0	4.2	4.2
6.0	5.8	9.8	8.8	9.8	11.2	8.0	a	18.8	18.8	9.2	8.0	a	a	5.4
3.8	6.0	8.2	6.8	6.4	11.4	5.6	3.6	4.4	5.4	6.6	7.2	6.2	5.6	4.6
1.0	4.4	7.4	5.2	6.0	11.4	3.2	0.2	3.4	3.2	4.2	6.2	2.8	1.2	2.6
0.6	3.2	4.8	4.6	3.6	7.0	2.6	0.2	2.0	2.6	3.0	4.6	2.0	0.6	1.8
1.0	4.4	7.4	5.2	6.0	11.4	3.4	0.2	3.4	3.2	4.2	6.2	a	a	3.2
0.6	3.2	4.8	4.6	3.6	7.0	2.8	0.2	2.0	2.6	3.0	4.6	2.8	1.4	2.2
3.2	5.6	8.2	7.6	6.0	11.8	5.2	1.0	5.6	6.2	6.2	7.2	4.4	3.6	3.8
2.6	4.8	7.4	6.8	5.0	10.4	4.4	0.6	3.2	4.6	5.0	6.4	3.6	3.0	3.2
3.2	5.6	8.2	7.6	6.0	11.8	5.4	2.2	5.6	6.2	6.2	7.2	a	a	4.4
2.6	4.8	7.4	6.8	5.0	10.4	4.4	1.2	3.2	4.6	5.0	6.4	4.6	4.2	3.6
12.0	6.4	10.8	12.6	12.0	13.2	13.4	4.6	19.6	21.0	11.2	9.0	8.6	6.0	5.6
5.6	6.6	9.2	9.4	8.6	13.8	8.2	3.4	6.2	8.0	8.2	8.2	6.6	4.8	4.8
12.0	6.4	10.8	12.6	12.0	13.2	15.0	a	19.6	21.0	11.2	9.0	a	a	6.8
5.6	6.6	9.2	9.4	8.6	13.8	8.4	4.8	6.2	8.0	8.2	8.2	9.0	6.8	5.4
0.8	5.0	8.8	6.0	9.2	14.4	4.8	0.4	4.4	3.2	5.6	a	4.0	2.0	2.8
0.4	3.2	5.6	5.4	5.0	9.0	3.8	0.2	2.6	2.4	4.0	5.2	2.8	1.2	1.8
0.8	5.0	8.8	6.0	9.2	14.4	5.0	1.8	4.4	3.2	5.6	a	a	a	4.2
0.4	3.2	5.6	5.4	5.0	9.0	4.0	0.6	2.6	2.4	4.0	5.2	4.2	2.2	2.2
2.6	5.4	8.0	8.6	7.4	13.6	6.8	2.8	a	a	7.0	6.0	4.8	3.4	3.4
2.2	4.8	7.4	7.4	6.4	12.2	5.6	2.2	4.2	4.6	5.8	5.6	4.0	2.8	2.8
2.6	5.4	8.0	8.6	7.4	13.6	7.0	a	a	a	7.0	6.0	a	a	4.0
2.2	4.8	7.4	7.4	6.4	12.2	5.6	3.0	4.2	4.6	5.8	5.6	5.0	3.8	3.2

If the "best" five alternatives on the basis of their IRR values were picked from each ownership, they would comprise 125 cells in the IS matrix. However, a certain amount of duplication occurred because the cost-share on nearly one-half of the referrals was zero, due to the reduction for merchantable products; therefore, the ACP and self-financing "branches" gave identical returns. In addition, the internal rates of return were rounded off to the nearest 0.2 percent in the computer solutions, so that several alternatives had the same rate because of this factor. Consequently, instead of 125, the "best" set actually contained 206 cells (Table 32).

Of the "best" set, 82 percent had received timber stand improvement in 1962. Therefore, the evidence is quite conclusive that TSI would be a favorable option for most referrals in the study area. For that portion of the "best" set which was contained in the TSI option, 63 percent of the cells were found in the category of future thinnings, and those "branches" under the marketing of cut timber products comprised 85 percent. When these two alternatives were considered in combination, the proportion drops to 53 percent.

Table 32.--Number of cells by desirability rank for each alternative in the "best" set.

Alternative	Number of Cells by Desirability Rank: 1	2	3	4	5
I. No TSI in 1962					
(A) No Future Thinning					
(1) Market Products	--	--	--	2	5
(2) Sell Stumpage					
A. Ave. Price	--	--	--	--	--
B. Conv. Surplus	--	--	--	--	--
(B) Future Thinnings					
(1) Market Products	9	8	6	1	1
(2) Sell Stumpage					
A. Ave. Price	--	1	--	--	--
B. Conv. Surplus	--	--	--	2	2
II. TSI in 1962					
(A) No Future Thinning					
(1) Market Products					
A-No ACP, Cut-Sell	--	2	9	5	6
B-No ACP, Cut-Leave	--	--	--	2	2
C-ACP, Cut-Sell	2	3	8	3	3
D-ACP, Cut-Leave	--	--	1	5	3
(2) Sell Stumpage					
A. Ave. Price					
1-No ACP, Cut-Sell	1	--	--	--	--
2-No ACP, Cut-Leave	--	--	--	--	--
3-ACP, Cut-Sell	1	--	--	--	--
4-ACP, Cut-Leave	--	--	--	--	--
B. Conv. Surplus					
1-No ACP, Cut-Sell	--	--	--	--	2
2-No ACP, Cut-Leave	--	--	--	--	--
3-ACP, Cut-Sell	--	1	--	--	3
4-ACP, Cut-Leave	--	--	--	--	--
(B) Future Thinnings					
(1) Market Products					
A-No ACP, Cut-Sell	8	10	5	1	--
B-No ACP, Cut-Leave	--	2	5	7	7
C-ACP, Cut-Sell	12	6	2	--	--
D-ACP, Cut-Leave	4	3	5	8	4
(2) Sell Stumpage					
A. Ave. Price					
1-No ACP, Cut-Sell	--	1	--	1	2
2-No ACP, Cut-Leave	--	--	--	--	--
3-ACP, Cut-Sell	--	1	--	1	2
4-ACP, Cut-Leave	--	--	--	--	--
B. Conv. Surplus					
1-No ACP, Cut-Sell	--	--	--	1	4
2-No ACP, Cut-Leave	--	--	--	--	--
3-ACP, Cut-Sell	--	--	--	1	3
4-ACP, Cut-Leave	--	--	--	--	1

The trends were very similar in those cases where TSI was not undertaken in 1962; 81 percent of the "best" cells in this category were under the option of future thinnings, and the alternative of marketing cut products contained 86 percent. When the percentage for future thinnings is compared to the corresponding value in the TSI category, a difference of nearly 20 percent is noted, indicating that once a stand receives TSI, additional cuts are not as important as they appear before the first cultural operation. Thus, the first treatment seems to have the greatest bearing on future stand development, especially in terms of financial returns, whereas the effect of successive cuttings is apparently to refine the stand developmental pattern. The two alternatives of making future thinnings and marketing cut products, when considered in combination, account for 55 percent of the "best" cells under the TSI option.

If the "best" set is analyzed in its entirety, the results are quite comparable, with 67 percent in the category of future thinnings, 85 percent in the category of marketing the cut timber products, and 55 percent in the combined alternative.

The timber stand improvement option was further subdivided by financing method to provide some insight as to which method was more desirable. The alternatives dealing with ACP cost-sharing contained 51 percent of the cells. Although seemingly quite low, when this is viewed with respect to the reduction in the cost-sharing allowance for merchantable products, it becomes more understandable. Quite obviously, any cost-sharing would defray part of the cost, and increase the owner's financial return; however, because many ownerships had a calculated cost-share of zero, the increased returns were not realized.

The category of cutting and selling material removed in timber stand improvement, occupied only 65 percent of the "best" cells, which also may seem rather low. However, when products are sold, either "on-the-stump," or at the mill, additional expenses are incurred, so that the income is offset to a considerable extent by the added costs.

To investigate the various trends in greater detail, each of the individual ranks 1 through 5 in the "best" set was analyzed separately. It was found that 78.3 percent of the cells, ranking as the number one, or the "best," investment opportunity, occurred in only 3 of the 30 alternatives: 1) No TSI in 1962, future thinnings, and marketing cut products, 24.3 percent; 2) TSI in 1962, future thinnings, marketing cut products, no ACP financing, and cut and sell the material removed in TSI, 21.6 percent; and 3) TSI in 1962, future thinnings, marketing cut products, ACP cost-sharing, and cut and sell the material removed in TSI, 32.4 percent. These three options comprised most of the "second-best" selections as well, occupying 63.2 percent of the cells (Table 33).

In the 3rd, 4th, and 5th ranks, the pendulum swings somewhat, so that more alternatives are encompassed by the majority position. Hence, it takes more alternatives to constitute 50 percent or more of the cells. In addition, those alternatives contributing the most to this majority percentage were not the same as in the first and second ranks. Therefore, it becomes more difficult to differentiate between various alternatives when one goes down the list of opportunities ranked in descending order on the basis of their desirability. This is most noticeable in the fifth rank, where it takes 5 alternatives to contribute 52 percent of the cells in this position.

Table 33.--The summarized "best" set for the most favorable alternatives.

Alternative	Percentage of the total number of cells in each alternative by rank: 1	2	3	4	5
No TSI in 1962					
No Future Thinning					
Market Products:	----	----	----	5.0	10.0
Future Thinning					
Market Products:	24.3	21.1	14.6	2.5	2.0
TSI in 1962					
No Future Thinning					
Market Products					
No ACP, Cut-Sell:	----	5.3	22.0	12.5	12.0
ACP, Cut-Sell:	5.4	7.9	19.5	7.5	6.0
ACP, Cut-Leave:	----	----	2.4	12.5	6.0
Future Thinnings					
Market Products					
No ACP, Cut-Sell:	21.6	26.3	12.2	2.5	----
No ACP, Cut-Leave:	----	5.3	12.2	17.5	14.0
ACP, Cut-Sell:	32.4	15.8	4.9	----	----
ACP, Cut-Leave:	10.8	7.9	12.2	20.0	8.0
Sell Stumpage					
Conv. Surplus					
No ACP, Cut-Sell:	----	----	----	2.5	8.0
Other:	5.5	10.4	----	17.5	34.0
Total	100.0	100.0	100.0	100.0	100.0

It is also quite important to determine what factors or characteristics of a given ownership seem to be strongly related to the internal rate of return. In an attempt to answer this question, regression analysis was used, regressing various attributes on the IRR values. Instead of using a single rate of return, IRR values for the top 5 alternatives were averaged for each referral. This provided a rate which may be more realistic and representative of an ownership's potential, since many of the rates are very close together and it is difficult to say that one alternative is definitely better than the next most desireable opportunity. Also, some of the "best" alternatives had internal rates of return much higher than the remaining options, thus not truely indicative of the overall financial prospects. The following items were used as independent variables in the calculations:

1. Site Index.
2. 1/Hauling Cost of Pulpwood per cord.
3. 1/Actual Cost of TSI per acre.
4. Basal Area Growth Rate before 1962.
5. 1/Cull Defect Percentage in 1962.
6. Initial Basal Area in 1962.
7. 1/Initial Basal Area in 1962

8. Age of the Stand in 1962.

9. 1/Age of the Stand in 1962.

10. Initial Volume in Cubic Feet per acre in 1962.

11. 1/Initial Volume in Cu. Ft. per acre in 1962.

A computer program was used which repeatedly solved the regression model while deleting the least significant variable before each successive computation. The original solution contained all 11 variables; however, after the deletion process, only three variables were needed to satisfy the .05 significance criterion. The 11-term model explained 76 percent of the variation in IRR values, whereas the 3-term expression accounted for 59 percent. The regression coefficients for the complete 11-term model and the simple correlation coefficients are presented in Table 34.

The regression model in equation form is as follows:

$$IRR = -102.52 + 0.03X_1 + 30.52X_2 - 14.81X_3 + 0.10X_4 + 20.05X_5 + 0.28X_6 + 0.34X_7 + 0.001X_8 + 3666.16X_9 + 658.28X_{10} - 1036.44X_{11}$$

However, more important than a predictive tool, is the correlation between certain factors and the internal rate of return. Those variables having the strongest relationship

Table 34.--Regression coefficients and simple correlation coefficients for the 11-term regression on average IRR values.

Variable	Regression coefficient	Simple correlation coefficient between the variable and the average IRR
Xi	bi	R
Constant term	-102.52	---
Site index - X_1	0.03	.020
1/Hauling cost for pulpwood - X_2	30.52	.508
1/Actual cost of TSI - X_3	-14.81	.328
Basal area growth rate - X_4	0.10	-.219
1/Cull defect - X_5	20.05	.282
Initial basal area - X_6	0.28	-.056
Age of the stand - X_7	0.34	.392
Initial volume - X_8	0.001	.185
1/initial basal area - X_9	3,666.16	.063
1/age of the stand - X_{10}	658.28	-.271
1/initial volume - X_{11}	-1,036.44	-.284

to the average IRR were: 1) Hauling cost for pulpwood; R (the simple correlation coefficient) = .508; 2) Age; R = .392; and, 3) Actual cost of TSI; R = .328. Thus, on the average, the referral having the lowest pulpwood hauling costs will have the greatest rate of return, and, a similar situation exists for timber stand improvement costs. Also, the oldest stands in the sample generally had the highest returns.

Actually, these correlation coefficients are too low to infer even a weak cause-and-effect relationship. However, they do indicate the relative importance of several characteristics, some of which could be manipulated within certain limits by the woodland manager when planning developmental activities.

Sensitivity Analysis

Even though the initial solution for average conditions provided sufficient information to formulate certain guidelines and recommendations, additional analyses were made. The IS matrix was computed on the basis of average conditions for all parameters involved, and although their values were estimated from the best information available, the "real world" often fails to conform to average conditions. The "medium" values may adequately describe the ownerships in total, but a given property has individual characteristics that cause deviations in the average values for one or more factors in the model. Data were needed to ascertain how possible changes in a given parameter would effect the optimal ranking of alternatives. Such divergences from the average occur, because each ownership and/or stand of timber differ, and when the analyst or owner is making an evaluation, he must make projections and estimates which are always susceptible to varying degrees of error.

To gain an appreciation of the effects such potential variation would have, sensitivity analysis was applied to the initial solution. This is a technique whereby one factor is varied over a predetermined range of values while holding all other factors constant. The results enable the decision-maker to guage the relative importance of each parameter. Those factors having the greatest effect should receive the most emphasis in measurement or estimation. If the effects are quite pronounced, the optimal schedule of alternatives may change, indicating that another option is to be preferred.

Items included in the sensitivity analysis were selling prices, annual cost, periodic costs, and series of percentage changes in cull defect, volume production, mortality, etc. A "low" value and a "high" value were used for each factor, generating additional internal rates of return for the complete model. This, in conjunction with the initial solution, resulted in IRR values for low, medium, and high levels of the parameter in question.

The three variations for selling price and annual cost were discussed in Chapter 7. Changes in periodic costs were implemented by a percentage alteration to the average value. For a "low" level, each periodic cost in an investment schedule was reduced by 10 percent, and for "high" levels, an increase of 10 percent was applied. The "high" level represents a close approximation to the actual increase in harvesting costs between 1961 and 1966. Based on guidelines in the Service Forester Handbook (1961), the computed production costs for sawtimber in the present study averaged nearly $21.00 per MBF. It was reported that in 1966, production costs were nearly $24.00 per MBF for northern hardwoods in the Lake States (Gardner, 1966). This represents an increase of slightly more than 10 percent, which occurred over a 5-year period; hence, the 10 percent change may be very conservative for long-range planning.

The three levels of periodic costs also correspond to the approach used by Herrick and Morse (1968), in which they assumed that a decision-maker could choose the one which best reflected the characteristics of a specific timber stand. They stated: "Such factors as stand accessibility, steepness, and ground condition, as well as techniques, could determine which cost level would represent a particular stand."

The percentage changes applied were: ± 5 percent, ± 10 percent, ± 15 percent, and ± 20 percent; a minus value represents a lower level, and a plus indicating a higher level. Row's computer program is structured in a manner which allows a "quality index factor" to be applied to each volume category. In the computations, the timber volume is multiplied by the selling price and this result is multiplied by the quality index. Thus, it was a simple matter to alter this item in successive computer "runs" by the "change" percentages. Such changes could be viewed as increases or decreases in the projected volume, the selling price for a given species-grade combination, the amount of cull defect, the level or mortality, the assumed growth rates, etc. Specific use would be left to the discretion of the decision-maker involved. His knowledge of the particular tract of timber would afford him the means for deciding which measurement or parameter estimate had the greatest variance, and thus would be most critical in an evaluation. For example, if he had confidence in all aspects of his decision model, except the physical growth rate used, he could determine the effects of a ± 5 or ± 10 percent change in that parameter.

Results of the sensitivity analysis for Referral No. 2G01 are presented in Table 35 as internal rates of return generated from the model when each modification was applied.

To provide rationalization for the merits of sensitivity analysis, changes in the optimal sequence for modifications of the selling price, annual cost, and periodic cost assumptions are shown in Tables 36, 37 and 38 for Referral No. 2G01. It can be observed from these results that moderate changes in certain factors can have a very

Table 35.--Results of the sensitivity analysis for Referral No. 2G01; values are internal rates of return.

Alternative	Medium	Selling Price		Annual Cost		Periodic Costs		Percentage Changes: 5%		10%		15%		20%	
		Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
I. No TSI in 1962															
(A) No Future Thinning															
(1) Market Products	4.6	0.4	6.0	17.8	3.0	5.0	4.4	4.6	4.8	4.6	4.8	4.4	4.8	4.4	5.0
(2) Sell Stumpage															
A. Ave. Price	1.6	0.2	2.8	15.8	0.2	1.8	1.6	1.4	2.0	1.0	2.2	0.4	2.4	0.2	2.6
B. Conv. Surplus	3.6	2.0	4.4	17.2	1.6	3.6	3.6	3.4	3.6	3.2	3.8	3.2	4.0	3.0	4.0
(B) Future Thinnings															
(1) Market Products	5.2	1.6	7.2	9.4	3.6	7.0	4.0	4.8	5.8	4.4	6.4	4.0	7.2	3.6	8.0
(2) Sell Stumpage															
A. Ave. Price	1.4	0.2	2.6	a	0.2	1.6	1.4	0.4	2.6	0.2	4.0	0.2	5.8	0.2	9.6
B. Conv. Surplus	3.0	1.4	3.8	7.2	1.0	3.0	2.8	2.4	3.6	1.8	4.2	1.4	5.0	1.0	6.0
II. TSI in 1962															
(A) No Future Thinning															
(1) Market Products															
A-No ACP, Cut-Sell	5.8	3.4	6.8	8.6	4.4	7.0	5.0	5.4	6.0	5.2	6.4	5.0	6.8	4.8	7.6
B-No ACP, Cut-Leave	4.6	2.4	5.6	6.0	3.8	4.8	4.4	4.6	4.6	4.6	4.8	4.6	4.8	4.4	4.8
C-ACP, Cut-Sell	6.2	3.8	7.4	12.0	4.6	9.0	5.4	6.0	6.8	5.6	7.4	5.4	8.8	5.2	15.8
D-ACP, Cut-Leave	4.8	2.6	5.8	6.4	3.8	5.0	4.6	4.8	5.0	4.8	5.0	4.8	5.0	4.8	5.0
(2) Sell Stumpage															
A. Ave. Price															
1-No ACP, Cut-Sell	3.2	1.6	4.2	a	1.0	3.2	3.2	2.8	3.6	2.4	4.2	2.0	5.0	1.6	a
2-No ACP, Cut-Leave	2.2	0.8	3.0	4.0	0.6	2.2	2.0	2.0	2.4	1.8	2.4	1.6	2.6	1.2	2.8
3-ACP, Cut-Sell	3.8	1.8	4.8	a	1.0	3.8	3.8	3.2	4.4	2.8	a	2.2	a	1.8	a
4-ACP, Cut-Leave	2.4	0.8	3.2	4.6	0.6	2.4	2.2	2.2	2.6	2.0	2.6	1.6	2.8	1.4	3.0
B. Conv. Surplus															
1-No ACP, Cut-Sell	4.6	3.4	5.4	8.4	3.0	4.6	4.6	4.4	5.0	4.2	5.4	3.8	5.8	3.6	6.4
2-No ACP, Cut-Leave	3.8	2.6	4.4	5.2	2.6	3.8	3.6	3.6	3.8	3.6	4.0	3.6	4.0	3.4	4.0
3-ACP, Cut-Sell	5.2	3.8	6.0	a	3.2	5.2	5.2	4.8	5.6	4.4	6.2	4.2	a	4.0	a
4-ACP, Cut-Leave	4.0	2.8	4.8	5.8	2.8	4.0	4.0	4.0	4.0	3.8	4.2	3.8	4.2	3.6	4.2
(B) Future Thinnings															
(1) Market Products															
A-No ACP, Cut-Sell	5.4	2.6	7.0	8.0	4.2	7.6	4.4	5.0	6.0	4.6	6.6	4.4	7.6	4.0	9.0
B-No ACP, Cut-Leave	4.4	2.0	5.8	5.8	3.6	5.0	4.0	4.2	4.6	4.2	4.8	4.0	5.0	3.8	5.2
C-ACP, Cut-Sell	6.0	3.0	7.8	10.4	4.4	10.4	4.6	5.4	6.8	5.0	7.8	4.6	10.0	4.2	16.0
D-ACP, Cut-Leave	4.8	2.2	6.0	6.2	3.8	5.4	4.2	4.6	5.0	4.4	5.2	4.2	5.4	4.0	5.6
(2) Sell Stumpage															
A. Ave. Price															
1-No ACP, Cut-Sell	2.6	0.6	3.6	a	0.2	2.6	2.4	1.6	3.8	0.8	6.0	0.2	a	0.2	a
2-No ACP, Cut-Leave	1.4	0.2	2.4	3.8	0.2	1.6	1.4	1.0	2.0	0.4	2.4	0.2	3.0	0.2	3.4
3-ACP, Cut-Sell	3.2	0.8	4.4	a	0.2	3.2	3.0	2.0	5.6	1.0	a	0.2	a	0.2	a
4-ACP, Cut-Leave	1.6	0.2	2.6	4.4	0.2	1.8	1.6	1.2	2.2	0.4	2.8	0.2	3.2	0.2	3.6
B. Conv. Surplus															
1-No ACP, Cut-Sell	3.8	2.4	4.6	7.2	2.2	3.8	3.8	3.2	4.4	2.8	5.2	2.4	6.4	2.0	a
2-No ACP, Cut-Leave	3.0	1.8	3.8	4.6	1.8	3.2	3.0	2.8	3.4	2.4	3.6	2.2	3.8	2.0	4.2
3-ACP, Cut-Sell	4.2	2.8	5.0	a	2.4	4.2	4.2	3.6	5.0	3.0	6.4	2.6	a	2.2	a
4-ACP, Cut-Leave	3.2	2.0	4.0	5.0	2.0	3.4	3.2	3.0	3.6	2.6	3.8	2.4	4.2	2.0	4.4

[a]It was impossible to obtain these values through iteration in the computer program. This was caused by either multiple or imaginary roots to the cost-revenue polynomial.

Table 36.--Changes in the optimal sequence of investment opportunities as a result of the sensitivity analysis of selling price, Referral No. 2G01.

Alternative[a]	Internal rates of return and rankings (in parentheses) for the three parameter levels.		
	Low	Medium	High
No TSI in 1962			
Future Thinnings			
Market Products:	---[a]	5.2 (5)	7.2 (3)
TSI in 1962			
No Future Thinning			
Market Products			
No ACP, Cut-Sell:	3.4 (2)	5.8 (3)	6.8 (5)
ACP, Cut-Sell:	3.8 (1)	6.2 (1)	7.4 (2)
ACP, Cut-Leave:	2.6 (5)	---	---
Sell Stumpage			
Conv. Surplus			
No ACP, Cut-Sell:	3.4 (2)	---	---
No ACP, Cut-Leave:	2.6 (5)	---	---
ACP, Cut-Sell:	3.8 (1)	5.2 (5)	---
ACP, Cut-Leave:	2.8 (4)	---	---
Future Thinnings			
Market Products			
No ACP, Cut-Sell:	2.6 (5)	5.4 (4)	7.0 (4)
ACP, Cut-Sell:	3.0 (3)	6.0 (2)	7.8 (1)
Sell Stumpage			
Conv. Surplus			
ACP, Cut-Sell:	2.8 (4)	---	---

[a]Only those alternatives ranking 1, 2, 3, 4, or 5 in either the low, medium, or high categories are included.

Table 37.--Changes in the optimal sequence of investment opportunities as a result of the sensitivity analysis of annual cost, Referral No. 2G01.

Alternative[a]	Internal rates of return and rankings (in parentheses) for the three parameter levels		
	Low	Medium	High
No TSI in 1962			
No Future Thinning			
Market Products:	17.8 (1)	---[a]	---
Sell Stumpage			
Ave. Price:	15.8 (3)	---	---
Conv. Surplus:	17.2 (2)	---	---
Future Thinnings			
Market Products:	---	5.2 (5)	3.6 (5)
TSI in 1962			
No Future Thinning			
Market Products			
No ACP, Cut-Sell:	---	5.8 (3)	4.4 (2)
No ACP, Cut-Leave:	---	---	3.8 (4)
ACP, Cut-Sell:	12.0 (4)	6.2 (1)	4.6 (1)
ACP, Cut-Leave:	---	---	3.8 (4)
Sell Stumpage			
Conv. Surplus			
ACP, Cut-Sell:	---	5.2 (5)	---
Future Thinnings			
Market Products			
No ACP, Cut-Sell:	---	5.4 (4)	4.2 (3)
No ACP, Cut-Leave:	---	---	3.6 (5)
ACP, Cut-Sell:	10.4 (5)	6.0 (2)	4.4 (2)
ACP, Cut-Leave:	---	---	3.8 (4)

[a]Only those alternatives ranking 1, 2, 3, 4, or 5 in either the low, medium, or high categories are included.

Table 38.--Changes in the optimal sequence of investment opportunities as a result of the sensitivity analysis of periodic costs, Referral No. 2G01.

Alternative[a]	Internal rates of return and rankings (in parentheses) for the three parameter levels.		
	Low	Medium	High
No TSI in 1962			
No Future Thinning			
Market Products:	---[a]	---	4.4 (5)
Future Thinnings			
Market Products:	7.0 (4)	5.2 (5)	---
TSI in 1962			
No Future Thinning			
Market Products			
No ACP, Cut-Sell:	7.0 (4)	5.8 (3)	5.0 (3)
No ACP, Cut-Leave:	---	---	4.4 (5)
ACP, Cut-Sell:	9.0 (2)	6.2 (1)	5.4 (1)
ACP, Cut-Leave:	---	---	4.6 (4)
Sell Stumpage			
Conv. Surplus			
No ACP, Cut-Sell:	---	---	4.6 (4)
ACP, Cut-Sell:	---	5.2 (5)	5.2 (2)
Future Thinnings			
Market Products			
No ACP, Cut-Sell:	7.6 (3)	5.4 (4)	4.4 (5)
ACP, Cut-Sell:	10.4 (1)	6.0 (2)	4.6 (4)
ACP, Cut-Leave:	5.4 (5)	---	---

[a]Only those alternatives ranking 1, 2, 3, 4, or 5 in either the low, medium, or high categories are included.

pronounced effect on the ranking of investment opportunities. For example, the effect of a 1 percent increase in the selling price of sawtimber and a 1/2 percent increase in pulpwood prices, thus comparing "medium" to "high" conditions, was to cause a complete shift in the first and second choices. Such a reversal would mean the difference between performing future thinnings on the property, and of not doing so. Assuming this owner has the economic and/or physical facilities for choosing between the two, a change of this sort would represent a major alteration in his management policy.

If the sensitivity analysis is viewed in its entirety, it appears that changes in the annual costs have a greater influence than do those of any other factor. This is especially true for those alternatives which do not include future thinnings. When intermediate cuttings, along with the necessary costs, are not part of the picture, the annual expense assumes a greater role in the overall cost structure, so that changes in its value have a significant impact on the internal rate of return.

Changes in the selling price assumptions have an intermediate effect on the IRR and the optimal sequence, whereas fluctuations in periodic costs, and the percentage applied to the quality index appear to have the least influence. Even a ± 20 percent change indicated only a slight response in many instances.

In Appendix 3, a series of tables is presented which shows the sensitivity analysis for all factors tested for six of the 25 referrals. Only six were selected since most referrals exhibited very similar patterns in their responsiveness to the sensitivity analysis. These six encompass the extremes for each of the three factors most highly correlated with the IRR, as determined from the previous regression analysis. The referrals chosen, and the basis for their inclusion, are as follows:

1L06--This referral had the highest hauling cost for pulpwood--$5.17 per cord, and the third highest actual TSI cost--$18.50 per acre. Average IRR = 4.6 percent.

2W09--This referral had the highest actual TSI cost --$21.70 per acre. Average IRR = 7.8 percent.

2G01--This referral supported the youngest stand of timber in the sample, averaging 36 years of age.

Also, it had the second highest actual TSI cost --$18.90 per acre. Average IRR = 10.4 percent.

1B14--This referral had the lowest actual TSI cost-- $2.94 per acre, and the third lowest hauling cost for pulpwood--$2.54 per cord. Average IRR = 10.0 percent.

1L16--This referral had the lowest site index--50, and supported the oldest stand of timber in the sample, averaging 93 years of age. Average IRR = 14.1 percent.

1M20--This referral had the highest site index--85, and had the lowest cost for pulpwood--$2.06 per cord. Average IRR = 12.8 percent.

Although site index was very poorly correlated with the average IRR, it is appropriate that the two extremes be included in the tabulation of results, since traditionally, site index has often formed the basis for determining various inputs and outputs in the productive processes in forest management. The average IRR for each of the six selected referrals is the arithmetic mean of the "best" five alternatives for each ownership.

Additional Results

In an earlier chapter, it was mentioned that the five-county area comprised two administrative units of the Forestry Division, Michigan Department of Natural Resources. These were termed Area I (Benzie, Leelanau, and Manistee Counties), and Area II (Grand Traverse and Wexford Counties), and showed certain differences between stand structural types. An interesting difference is noted when the stocking levels before and after TSI in 1962 are compared (Table 39). It can be seen from the basal area data that, although the initial stocking level was greater in Area II, nearly the same amount was removed by TSI in both areas; thus, residual stocking was also higher in Area II.

Table 39--Stocking levels by administrative area.

Administrative Area	Basal area per acre:		
	Initial	Removed in TSI	Residual
	Sq. Ft.	Sq. Ft.	Sq. Ft.
Area I	103.2	29.9	73.3
Area II	119.6	26.4	93.2
All referrals	111.7	26.1	85.6

The divergency between areas leads this investigator to surmise that little or no regard was given to the desired residual stand when marking was conducted by the Service Forester. Apparently he was more concerned with marking a specified amount of material, rather than marking to a predetermined residual level. This may have been a doubtful silvicultural practice for some ownerships, even though it may have created a more equitable distribution of ACP payments within the two areas. If this was the goal, then perhaps such a procedure was justified; however, in these instances, the timber stand improvement and resulting ACP cost-sharing was simply a contrivance for conveying welfare payments.

By comparing average annual basal area growth rates (Table 40), it can be observed that there was very little difference between growth following TSI in 1962 and growth without TSI. There undoubtedly was some shock effect of the cutting, and a delay before its influence upon growth could be noticed. However, Area II, with the higher initial and residual stocking levels, had the higher growth rate. Thus, stands averaging approximately 90 square feet of basal area per acre had greater growth than stands with 70 square feet per acre.

Table 40.--Basal area growth rate with and without TSI in the two areas, 1962-1966.

Administrative Area	Annual basal area growth rate	
	With TSI in 1962	Without TSI in 1962
	Percent	Percent
Area I	2.62	2.71
Area II	3.19	3.05
All referrals	2.92	2.89

The internal rate of return showed an inverse relationship with basal area stocking levels; the highest interest rate was associated with the lowest residual basal area (Table 41).

Table 41.--Internal rate of return comparisons by area.

Administrative Area	Average internal rate of return for the "best" five alternatives from each referral
	Percent
Area I	9.14
Area II	8.12
All referrals	8.61

The observations outlined in Tables 39-41 are supported by the simple correlation coefficients obtained concurrently with the regression analysis of various factors on the average IRR. For example, the simple correlation between basal area growth rate and the initial stocking level was .24--indicating a weak positive relationship. The simple correlation coefficient between average IRR and initial basal area was -0.06--indicating almost no relationship; however, it was negative, corresponding to the average data found in Table 41. Therefore, even though marking intensity essentially ignored the initial conditions and was not geared towards a desired residual level, the differences were minor; thus apparently the consequences are relatively unimportant to the referral and its financial prospects.

CHAPTER IX

CONCLUSIONS AND RECOMMENDATIONS

The results of the study provide the foundations for making the following conclusions and recommendations:

1. When the proper age has been attained, timber stand improvement should be applied to immature overstocked northern hardwood stands as a means of increasing financial returns to ownership.

2. The owner should make application for ACP reimbursement, which would help to offset considerably the actual costs of TSI. If an owner received a cost-share of nearly 80 percent of the estimated expense, his rate of return would be increased by an amount ranging from 1/2 to 5 percent, depending on the total cost structure and the management alternatives followed.

3. There seems to be little evidence from this investigation to support a categorical statement concerning the choice between cutting and selling material

from a TSI operation, or of simply deadening the desirable trees. Each owner would have to examine this aspect quite carefully, tempering his decision with knowledge of market availability for the cut material, as well as a full understanding of the requisite costs, including relevant opportunity costs. Based on the actual performance of the 25 sampled owners, it would appear that market availability was very limited in 1962, or knowledge of market conditions was greatly lacking.

4. If an owner has intentions of continuing timber yields from his property, to provide income for successive generations, he should treat the undesirable material with silvicide, or treat the cut stumps. This would reduce or eliminate stump sprouting, which was quite substantial on the sampled referrals in 1966, only 4 years after the cut. Stump sprouts are generally unsatisfactory for sawtimber production and the vigorous sprouts compete with more desirable seedling regeneration (Solomon and Blum, 1967). Such concern might be unwarranted when the owner's planning horizon is short, as it has been historically.

5. Regardless of the owner's approach to initial timber stand improvement, a series of periodic future thinnings will usually increase his return on the investment. A program of intensive management will yield greater dividends than will a single extensive initial TSI treatment.

6. When it becomes desirable to remove timber in intermediate cuts, or when the stand reaches economic maturity and a harvest cut is scheduled, the owner should cut and market the sawlogs and/or pulpwood at the mill site, rather than sell stumpage. If he sells stumpage, as has been traditionally the case with most small woodland owners, he will immediately incur an opportunity cost of approximately 2 to 4 percent. However, because of predominantly absentee ownership in this region many owners are either poorly equipped for timber harvesting, or have goals other than profit maximization from their properties.

7. In light of the sensitivity analysis and the simple correlation coefficients between various factors, it

appears that the most critical cost item is the annual expense. Because of its significant effect, which increases as the number and amount of periodic costs decrease, the owner should strive to minimize his annual costs. Taxes, maintenance, fire protection, and other items which accrue every year should be reduced to their lowest practical levels.

8. Because periodic production costs and selling prices are also very important, the profit-minded owner should make a conscious effort to be cognizant of market fluctuations, and store his timber "on-the-stump" until the price cycle is most attractive. Obviously, this can't be done for long periods, but deviating several years from the proposed cutting schedule could result in greater financial returns, even though physical productivity may not be maximized. Also, responsiveness to market conditions should be balanced with fluctuations in production costs. It does the owner little good, if, when he sells at a higher price, the costs have also risen.

In substance, these conclusions and recommendations are quite obvious and definite; however, many aspects of land ownership influencing a manager's decision-making have not been considered. It has been assumed throughout this study that the woodland owner has chosen to practice some level of forest management, when in reality many other land-use alternatives enter the decision-making process. In addition to economic justification, there are several other factors which influence a forest landowner's attitude towards forest management. Many woodlands are owned by absentee owners and most of these non-residents acquired forest land to satisfy their recreational desires, rather than produce timber products. The land tenure for most small woodland owners averages 10-15 years in the study area (Yoho, 1957), and planning horizons are very short; hence, it might be difficult to encourage forest landowners to pursue the stated recommendations. Public assistance programs should stimulate forest landowners to engage in stand improvement practices; however, the widespread lack of knowledge concerning the availability of these cost-sharing and similar programs almost negates their effectiveness (Yoho and James, 1958). These factors would act as limitations on the implementation of the various guidelines; however, they are very difficult, if not impossible to quantify and consequently were not evaluated in the present study.

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APPENDICIES

APPENDIX I

Common and scientific names
of tree species (Little, 1953)
encountered in the study.

TREE SPECIES

Common Name	Scientific Name
White ash	*Fraxinus americana* L.
Bigtooth aspen	*Populus grandidentata* Michx.
Quaking aspen	*Populus tremuloides* Michx.
American basswood	*Tilia americana* L.
American beech	*Fagus grandifolia* Ehrh.
Yellow birch	*Betula alleghaniensis* Britton
Black cherry	*Prunus serotina* Ehrh.
American elm	*Ulmus americana* L.
Slippery elm	*Ulmus rubra* Muhl.
Eastern hemlock	*Tsuga canadensis* (L.) Carr.
Ironwood	*Ostrya virginiana* (Mill.) K. Koch
Red Maple	*Acer rubrum* L.
Sugar maple	*Acer saccharum* Marsh.
Northern red oak	*Quercus rubra* L.

APPENDIX II

Distance from Referral to Millsite by Road Surface Type for Each of the 25 Referrals.

Table A--Distance from Referral to the Nearest Sawmill by Road Surface Type.

Referral No.	Distance to nearest mill on:				
	Woods Roads	Secondary Roads	Main Roads	Highway	Total
	- - - - - - - - - - - -	- - - -	Miles	- - - -	- - - - - - - -
2G01	1.00	0.50	6.00	6.00	13.50
2G02	0.25	1.00	6.00	----	7.25
2G03	0.50	----	5.50	----	6.00
1L04	----	0.50	5.50	1.00	7.00
1L05	----	2.25	3.50	----	5.75
1L06	0.50	----	2.25	----	2.75
2W07	0.25	1.50	0.50	2.50	4.75
2G08	----	1.50	3.25	----	4.75
2W09	0.50	2.00	0.75	----	3.25
2G10	0.75	0.25	5.00	----	6.00
2W11	0.50	----	2.25	4.50	7.25
1L12	0.75	1.00	10.25	3.25	15.25
1L13	----	0.50	----	2.00	2.50
1B14	----	2.25	----	----	2.25
2G15	----	2.25	6.00	5.50	13.75
1L16	----	0.50	5.50	1.00	7.00
2W17	0.25	0.50	2.50	1.25	4.50
2W18	0.75	0.25	2.50	1.25	4.75
1M19	0.50	0.50	5.25	----	6.25
1M20	0.75	0.50	6.75	----	8.00
1M21	0.50	----	6.50	----	7.00
2G22	0.25	----	8.50	----	8.75
2W23	0.75	3.25	----	9.00	13.00
1M24	0.75	1.50	8.75	----	11.00
1L25	0.50	0.75	3.50	3.25	8.00

Table B.--Distance from Referral to the Pulp and Paper Mill in Filer City, Michigan; by Road Surface Type.

Referral No.	Distance to the Papermill on:				
	Woods Roads	Secondary Roads	Main Roads	Highway	Total
	- - - - - - - - - - - -	- - - - - - - -	Miles	- - - - - - - -	- - - - - - - -
2G01	1.00	0.50	1.00	64.50	67.00
2G02	0.25	1.00	----	57.50	58.75
2G03	0.50	----	1.50	58.50	60.50
1L04	----	0.50	9.75	51.00	61.25
1L05	----	1.75	14.25	51.00	67.00
1L06	0.50	----	22.25	51.00	73.75
2W07	0.25	----	-----	47.75	48.00
2G08	----	0.75	10.75	54.00	65.50
2W09	0.50	----	4.75	50.00	55.25
2G10	0.75	0.25	2.00	59.50	62.50
2W11	0.50	----	----	48.75	49.25
1L12	0.75	----	----	79.50	80.25
1L13	----	----	7.25	53.00	60.25
1B14	----	0.75	2.25	35.00	38.00
2G15	----	0.75	1.75	52.50	55.00
1L16	----	0.50	9.75	51.00	61.25
2W17	0.25	0.50	2.50	35.50	38.75
2W18	0.75	0.25	2.50	35.50	39.00
1M19	0.50	0.50	3.25	29.00	33.25
1M20	0.75	4.00	----	15.50	20.25
1M21	0.50	----	18.25	16.50	35.25
2G22	0.25	----	11.00	54.00	65.25
2W23	0.75	4.00	----	45.00	49.75
1M24	0.75	1.50	20.75	16.50	39.50
1L25	0.50	3.50	9.75	51.00	64.75

APPENDIX III

Internal Rates of Return Resulting From the Sensitivity Analysis, for the Six Selected Referrals:

Tables A - F -- Sensitivity Analysis of the Selling Price Assumption.

Tables G - L -- Sensitivity Analysis of the Annual Cost Assumption.

Tables M - R -- Sensitivity Analysis of the Periodic Cost Assumptions.

Tables S - X -- Sensitivity Analysis Resulting From a 5 Percent change in the Quality Index.

Tables Y - DD -- Sensitivity Analysis Resulting From a 10 Percent Change in the Quality Index.

Tables EE - JJ-- Sensitivity Analysis Resulting From a 15 Percent Change in the Quality Index.

Tables KK - PP-- Sensitivity Analysis Resulting From a 20 Percent Change in the Quality Index.

(A--This entry in the following tables indicates those values which were impossible to obtain through iteration in the computer program. This was caused by either multiple or imaginary roots to the cost-revenue polynomial.)

TABLE A. REFERRAL NO. 1L06. SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	0.2	3.2	4.8
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	0.2
B. CONV. SURPLUS	0.2	2.2	3.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	1.6	5.2	7.0
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	1.0	2.2
B. CONV. SURPLUS	1.8	3.2	4.0
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	0.2	4.2	5.4
B-NO ACP, CUT-LEAVE	0.2	3.4	4.6
C-ACP, CUT-SELL	0.4	A	A
D-ACP, CUT-LEAVE	0.2	4.4	5.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	1.2
2-NO ACP, CUT-LEAVE	0.2	0.2	0.6
3-ACP, CUT-SELL	0.2	0.8	A
4-ACP, CUT-LEAVE	0.2	0.2	1.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	1.6	3.2	4.0
2-NO ACP, CUT-LEAVE	1.0	2.4	3.2
3-ACP, CUT-SELL	4.0	A	A
4-ACP, CUT-LEAVE	1.6	3.2	4.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2.2	5.2	6.6
B-NO ACP, CUT-LEAVE	1.6	4.4	5.6
C-ACP, CUT-SELL	3.6	A	A
D-ACP, CUT-LEAVE	2.4	5.6	7.2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	1.4	2.6
2-NO ACP, CUT-LEAVE	0.2	0.6	1.6
3-ACP, CUT-SELL	0.2	A	A
4-ACP, CUT-LEAVE	0.2	1.4	2.4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2.0	3.6	4.4
2-NO ACP, CUT-LEAVE	1.4	2.8	3.4
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	2.2	3.6	4.4

TABLE B. REFERRAL NO, 2W09, SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	0,2	4,4	6,0
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	1,6
B, CONV, SURPLUS	1,8	3,6	4,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	3,6	7,8	10,8
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	1,4	2,8
B, CONV, SURPLUS	1,4	2,8	3,8
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2,0	6,2	7,4
B-NO ACP, CUT-LEAVE	1,2	4,8	6,0
C-ACP, CUT-SELL	2,0	6,2	7,4
D-ACP, CUT-LEAVE	2,2	6,6	8,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	2,4	3,4
2-NO ACP, CUT-LEAVE	0,2	1,4	2,4
3-ACP, CUT-SELL	0,2	2,4	3,4
4-ACP, CUT-LEAVE	0,2	2,6	3,8
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	3,6	5,0	6,0
2-NO ACP, CUT-LEAVE	2,6	3,8	4,6
3-ACP, CUT-SELL	3,6	5,0	6,0
4-ACP, CUT-LEAVE	4,0	5,4	6,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,4	8,4	11,4
B-NO ACP, CUT-LEAVE	3,0	5,8	7,2
C-ACP, CUT-SELL	4,4	8,4	11,4
D-ACP, CUT-LEAVE	5,0	9,8	13,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	2,4	3,6
2-NO ACP, CUT-LEAVE	0,2	1,2	2,2
3-ACP, CUT-SELL	0,2	2,4	3,6
4-ACP, CUT-LEAVE	0,2	2,8	4,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	2,0	3,6	4,4
2-NO ACP, CUT-LEAVE	1,4	2,6	3,4
3-ACP, CUT-SELL	2,0	3,6	4,4
4-ACP, CUT-LEAVE	2,2	3,8	4,6

TABLE C. REFERRAL NO, 2G10, SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	0,2	2,0	3,4
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	0,4	4,4	6,6
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,2	0,2	1,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	0,2	3,0	4,2
B-NO ACP, CUT-LEAVE	0,2	2,2	3,4
C-ACP, CUT-SELL	0,2	5,2	34,4
D-ACP, CUT-LEAVE	0,2	2,6	3,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	0,2
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	0,2	0,2	1,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,8
3-ACP, CUT-SELL	0,2	0,4	1,8
4-ACP, CUT-LEAVE	0,2	0,2	1,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	1,4	5,0	7,0
B-NO ACP, CUT-LEAVE	0,6	3,4	4,8
C-ACP, CUT-SELL	2,2	33,4	34,4
D-ACP, CUT-LEAVE	1,0	4,2	6,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,6
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	1,6
4-ACP, CUT-LEAVE	0,2	0,2	0,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	0,2	1,0	2,0
2-NO ACP, CUT-LEAVE	0,2	0,8	1,6
3-ACP, CUT-SELL	0,2	1,6	2,6
4-ACP, CUT-LEAVE	0,2	1,0	1,8

TABLE D. REFERRAL NO, 1B14, SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	7,0	4,6	8,4
(2) SELL STUMPAGE			
A, AVE, PRICE	4,0	2,4	5,0
B, CONV, SURPLUS	6,4	5,0	7,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	10,4	7,6	12,0
(2) SELL STUMPAGE			
A, AVE, PRICE	5,4	4,0	6,4
B, CONV, SURPLUS	7,6	6,4	8,6
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5,8	8,8	10,4
B-NO ACP, CUT-LEAVE	4,2	6,8	8,0
C-ACP, CUT-SELL	5,8	8,8	10,4
D-ACP, CUT-LEAVE	4,2	6,8	8,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	3,6	5,2	6,2
2-NO ACP, CUT-LEAVE	3,2	4,6	5,4
3-ACP, CUT-SELL	3,6	5,2	6,2
4-ACP, CUT-LEAVE	3,2	4,6	5,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	6,4	7,6	8,6
2-NO ACP, CUT-LEAVE	5,6	6,8	7,6
3-ACP, CUT-SELL	6,4	7,6	8,6
4-ACP, CUT-LEAVE	5,6	6,8	7,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9,8	12,6	14,6
B-NO ACP, CUT-LEAVE	7,2	9,4	10,8
C-ACP, CUT-SELL	9,8	12,6	14,6
D-ACP, CUT-LEAVE	7,2	9,4	10,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	4,6	6,0	7,0
2-NO ACP, CUT-LEAVE	4,0	5,4	6,2
3-ACP, CUT-SELL	4,6	6,0	7,0
4-ACP, CUT-LEAVE	4,0	5,4	6,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	7,2	8,6	9,4
2-NO ACP, CUT-LEAVE	6,2	7,4	8,2
3-ACP, CUT-SELL	7,2	8,6	9,4
4-ACP, CUT-LEAVE	6,2	7,4	8,2

TABLE E. REFERRAL NO, 1L16, SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5,0	10,2	13,2
(2) SELL STUMPAGE			
A, AVE, PRICE	4,4	6,4	8,0
B, CONV, SURPLUS	8,4	10,2	11,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	12,2	15,4	17,6
(2) SELL STUMPAGE			
A, AVE, PRICE	8,6	10,2	11,6
B, CONV, SURPLUS	12,0	13,4	14,8
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8,8	11,2	12,8
B-NO ACP, CUT-LEAVE	8,6	11,4	13,2
C-ACP, CUT-SELL	8,8	11,2	12,8
D-ACP, CUT-LEAVE	8,6	11,4	13,2
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	9,4	11,4	13,0
2-NO ACP, CUT-LEAVE	5,4	7,0	8,0
3-ACP, CUT-SELL	9,4	11,4	13,0
4-ACP, CUT-LEAVE	5,4	7,0	8,0
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	10,2	11,8	12,8
2-NO ACP, CUT-LEAVE	9,0	10,4	11,6
3-ACP, CUT-SELL	10,2	11,8	12,8
4-ACP, CUT-LEAVE	9,0	10,4	11,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	11,2	13,2	14,6
B-NO ACP, CUT-LEAVE	11,4	13,8	15,4
C-ACP, CUT-SELL	11,2	13,2	14,6
D-ACP, CUT-LEAVE	11,4	13,8	15,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	12,4	14,4	15,8
2-NO ACP, CUT-LEAVE	7,6	9,0	10,0
3-ACP, CUT-SELL	12,4	14,4	15,8
4-ACP, CUT-LEAVE	7,6	9,0	10,0
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	12,2	13,6	14,6
2-NO ACP, CUT-LEAVE	10,8	12,2	13,2
3-ACP, CUT-SELL	12,2	13,6	14,6
4-ACP, CUT-LEAVE	10,8	12,2	13,2

TABLE F. REFERRAL NO, 1M20, SENSITIVITY ANALYSIS OF THE SELLING PRICE ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	2,8	5,2	6,2
(2) SELL STUMPAGE			
A, AVE, PRICE	0,4	2,2	3,0
B, CONV, SURPLUS	3,2	4,4	5,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	6,4	10,0	12,8
(2) SELL STUMPAGE			
A, AVE, PRICE	3,4	4,8	5,6
B, CONV, SURPLUS	4,2	5,4	6,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	17,8	18,8	20,0
B-NO ACP, CUT-LEAVE	3,6	5,4	6,4
C-ACP, CUT-SELL	17,8	18,8	20,0
D-ACP, CUT-LEAVE	3,6	5,4	6,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	1,4	3,2	4,0
2-NO ACP, CUT-LEAVE	1,2	2,6	3,4
3-ACP, CUT-SELL	1,4	3,2	4,0
4-ACP, CUT-LEAVE	1,2	2,6	3,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	4,8	6,2	7,0
2-NO ACP, CUT-LEAVE	3,6	4,6	5,4
3-ACP, CUT-SELL	4,8	6,2	7,0
4-ACP, CUT-LEAVE	3,6	4,6	5,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	19,0	21,0	22,8
B-NO ACP, CUT-LEAVE	5,2	8,0	9,6
C-ACP, CUT-SELL	19,0	21,0	22,8
D-ACP, CUT-LEAVE	5,2	8,0	9,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	1,2	3,2	4,2
2-NO ACP, CUT-LEAVE	0,8	2,4	3,4
3-ACP, CUT-SELL	1,2	3,2	4,2
4-ACP, CUT-LEAVE	0,8	2,4	3,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	5,8	A	A
2-NO ACP, CUT-LEAVE	3,4	4,6	5,4
3-ACP, CUT-SELL	5,8	A	A
4-ACP, CUT-LEAVE	3,4	4,6	5,4

TABLE G. REFERRAL NO. 1L06. SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	16.2	3.2	1.2
(2) SELL STUMPAGE			
A. AVE. PRICE	13.2	0.2	0.2
B. CONV. SURPLUS	16.0	2.2	0.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	10.8	5.2	3.6
(2) SELL STUMPAGE			
A. AVE. PRICE	A	1.0	0.2
B. CONV. SURPLUS	9.4	3.2	1.4
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7.2	4.2	2.8
B-NO ACP, CUT-LEAVE	5.0	3.4	2.4
C-ACP, CUT-SELL	A	A	3.4
D-ACP, CUT-LEAVE	A	4.4	2.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	A	0.2	0.2
2-NO ACP, CUT-LEAVE	2.4	0.2	0.2
3-ACP, CUT-SELL	A	0.8	0.2
4-ACP, CUT-LEAVE	A	0.2	0.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	8.2	3.2	1.2
2-NO ACP, CUT-LEAVE	4.2	2.4	0.8
3-ACP, CUT-SELL	A	A	1.8
4-ACP, CUT-LEAVE	A	3.2	1.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8.0	5.2	3.8
B-NO ACP, CUT-LEAVE	5.8	4.4	3.2
C-ACP, CUT-SELL	A	A	5.0
D-ACP, CUT-LEAVE	A	5.6	4.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	A	1.4	0.2
2-NO ACP, CUT-LEAVE	3.2	0.6	0.2
3-ACP, CUT-SELL	A	A	0.2
4-ACP, CUT-LEAVE	A	1.4	0.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	8.0	3.6	1.8
2-NO ACP, CUT-LEAVE	4.4	2.8	1.4
3-ACP, CUT-SELL	A	A	2.4
4-ACP, CUT-LEAVE	A	3.6	1.8

TABLE H. REFERRAL NO, 2W09, SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	18,0	4,4	2,6
(2) SELL STUMPAGE			
A, AVE, PRICE	15,2	0,2	0,2
B, CONV, SURPLUS	17,6	3,6	1,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	14,8	7,8	5,2
(2) SELL STUMPAGE			
A, AVE, PRICE	A	1,4	0,2
B, CONV, SURPLUS	6,6	2,8	1,0
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	19,6	6,2	4,8
B-NO ACP, CUT-LEAVE	6,0	4,8	4,0
C-ACP, CUT-SELL	19,6	6,2	4,8
D-ACP, CUT-LEAVE	A	6,6	4,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	16,8	2,4	0,2
2-NO ACP, CUT-LEAVE	3,4	1,4	0,2
3-ACP, CUT-SELL	16,8	2,4	0,2
4-ACP, CUT-LEAVE	A	2,6	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	19,0	5,0	3,4
2-NO ACP, CUT-LEAVE	5,2	3,8	2,8
3-ACP, CUT-SELL	19,0	5,0	3,4
4-ACP, CUT-LEAVE	A	5,4	3,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	14,8	8,4	6,0
B-NO ACP, CUT-LEAVE	7,2	5,8	4,6
C-ACP, CUT-SELL	14,8	8,4	6,0
D-ACP, CUT-LEAVE	23,4	9,8	6,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	2,4	0,2
2-NO ACP, CUT-LEAVE	3,8	1,2	0,2
3-ACP, CUT-SELL	A	2,4	0,2
4-ACP, CUT-LEAVE	A	2,8	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	7,0	3,6	1,8
2-NO ACP, CUT-LEAVE	4,0	2,6	1,4
3-ACP, CUT-SELL	7,0	3,6	1,8
4-ACP, CUT-LEAVE	A	3,8	2,0

TABLE I. REFERRAL NO, 2G10, SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	13,0	2,0	0,2
(2) SELL STUMPAGE			
A, AVE, PRICE	10,8	0,2	0,2
B, CONV, SURPLUS	11,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	16,4	4,4	2,2
(2) SELL STUMPAGE			
A, AVE, PRICE	A	0,2	0,2
B, CONV, SURPLUS	5,2	0,2	0,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9,2	3,0	1,2
B-NO ACP, CUT-LEAVE	3,8	2,2	1,0
C-ACP, CUT-SELL	A	5,2	1,4
D-ACP, CUT-LEAVE	5,6	2,6	1,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	0,2	0,2
2-NO ACP, CUT-LEAVE	1,6	0,2	0,2
3-ACP, CUT-SELL	A	0,2	0,2
4-ACP, CUT-LEAVE	3,4	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	5,2	0,2	0,2
2-NO ACP, CUT-LEAVE	2,4	0,2	0,2
3-ACP, CUT-SELL	A	0,4	0,2
4-ACP, CUT-LEAVE	4,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	11,0	5,0	2,6
B-NO ACP, CUT-LEAVE	5,2	3,4	2,0
C-ACP, CUT-SELL	A	33,4	3,4
D-ACP, CUT-LEAVE	8,2	4,2	2,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	0,2	0,2
2-NO ACP, CUT-LEAVE	2,4	0,2	0,2
3-ACP, CUT-SELL	A	0,2	0,2
4-ACP, CUT-LEAVE	5,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	4,8	1,0	0,2
2-NO ACP, CUT-LEAVE	2,6	0,8	0,2
3-ACP, CUT-SELL	A	1,6	0,2
4-ACP, CUT-LEAVE	4,2	1,0	0,2

TABLE J. REFERRAL NO. 1814. SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	23.0	7.0	5.4
(2) SELL STUMPAGE			
A. AVE. PRICE	20.6	4.0	1.8
B. CONV. SURPLUS	22.6	6.4	4.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	29.8	10.4	8.2
(2) SELL STUMPAGE			
A. AVE. PRICE	A	5.4	3.2
B. CONV. SURPLUS	A	7.6	5.8
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	22.0	8.8	6.4
B-NO ACP, CUT-LEAVE	10.4	6.8	5.4
C-ACP, CUT-SELL	22.0	8.8	6.4
D-ACP, CUT-LEAVE	10.4	6.8	5.4
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	A	5.2	3.0
2-NO ACP, CUT-LEAVE	8.6	4.6	2.8
3-ACP, CUT-SELL	A	5.2	3.0
4-ACP, CUT-LEAVE	8.6	4.6	2.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	A	7.6	5.8
2-NO ACP, CUT-LEAVE	10.2	6.8	5.2
3-ACP, CUT-SELL	A	7.6	5.8
4-ACP, CUT-LEAVE	10.2	6.8	5.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	22.6	12.6	9.4
B-NO ACP, CUT-LEAVE	13.8	9.4	7.8
C-ACP, CUT-SELL	22.6	12.6	9.4
D-ACP, CUT-LEAVE	13.8	9.4	7.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	A	6.0	3.8
2-NO ACP, CUT-LEAVE	9.8	5.4	3.4
3-ACP, CUT-SELL	A	6.0	3.8
4-ACP, CUT-LEAVE	9.8	5.4	3.4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	A	8.6	6.4
2-NO ACP, CUT-LEAVE	11.4	7.4	5.8
3-ACP, CUT-SELL	A	8.6	6.4
4-ACP, CUT-LEAVE	11.4	7.4	5.8

TABLE K. REFERRAL NO, 1L16, SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	A	10,2	7,2
(2) SELL STUMPAGE			
A, AVE, PRICE	A	6,4	2,4
B, CONV, SURPLUS	A	10,2	6,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	28,0	15,4	12,6
(2) SELL STUMPAGE			
A, AVE, PRICE	A	10,2	6,6
B, CONV, SURPLUS	37,8	13,4	10,4
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	13,8	11,2	9,6
B-NO ACP, CUT-LEAVE	15,2	11,4	9,4
C-ACP, CUT-SELL	13,8	11,2	9,6
D-ACP, CUT-LEAVE	15,2	11,4	9,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	11,4	6,4
2-NO ACP, CUT-LEAVE	11,8	7,0	4,4
3-ACP, CUT-SELL	A	11,4	6,4
4-ACP, CUT-LEAVE	11,8	7,0	4,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	18,2	11,8	9,2
2-NO ACP, CUT-LEAVE	14,6	10,4	8,4
3-ACP, CUT-SELL	18,2	11,8	9,2
4-ACP, CUT-LEAVE	14,6	10,4	8,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	15,2	13,2	11,8
B-NO ACP, CUT-LEAVE	17,2	13,8	12,2
C-ACP, CUT-SELL	15,2	13,2	11,8
D-ACP, CUT-LEAVE	17,2	13,8	12,2
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	14,4	9,2
2-NO ACP, CUT-LEAVE	13,4	9,0	6,6
3-ACP, CUT-SELL	A	14,4	9,2
4-ACP, CUT-LEAVE	13,4	9,0	6,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	19,6	13,6	11,2
2-NO ACP, CUT-LEAVE	16,0	12,2	10,2
3-ACP, CUT-SELL	19,6	13,6	11,2
4-ACP, CUT-LEAVE	16,0	12,2	10,2

TABLE I. REFERRAL NO, 1M20. SENSITIVITY ANALYSIS OF THE ANNUAL COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	17,4	5,2	3,8
(2) SELL STUMPAGE			
A, AVE, PRICE	15,2	2,2	0,2
B, CONV, SURPLUS	17,0	4,4	2,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	31,0	10,0	6,8
(2) SELL STUMPAGE			
A, AVE, PRICE	A	4,8	2,8
B, CONV, SURPLUS	A	5,4	3,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	27,6	18,8	5,6
B-NO ACP, CUT-LEAVE	7,8	5,4	4,4
C-ACP, CUT-SELL	27,6	18,8	5,6
D-ACP, CUT-LEAVE	7,8	5,4	4,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	3,2	1,0
2-NO ACP, CUT-LEAVE	5,6	2,6	0,8
3-ACP, CUT-SELL	A	3,2	1,0
4-ACP, CUT-LEAVE	5,6	2,6	0,8
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	A	6,2	4,0
2-NO ACP, CUT-LEAVE	7,0	4,6	3,4
3-ACP, CUT-SELL	A	6,2	4,0
4-ACP, CUT-LEAVE	7,0	4,6	3,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	27,8	21,0	14,2
B-NO ACP, CUT-LEAVE	12,4	8,0	5,8
C-ACP, CUT-SELL	27,8	21,0	14,2
D-ACP, CUT-LEAVE	12,4	8,0	5,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	A	3,2	0,2
2-NO ACP, CUT-LEAVE	6,8	2,4	0,2
3-ACP, CUT-SELL	A	3,2	0,2
4-ACP, CUT-LEAVE	6,8	2,4	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	A	A	3,6
2-NO ACP, CUT-LEAVE	8,6	4,6	2,8
3-ACP, CUT-SELL	A	A	3,6
4-ACP, CUT-LEAVE	8,6	4,6	2,8

TABLE M. REFERRAL NO, 1L06, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	3,6	3,2	2,6
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	2,2	2,2	2,0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	6,0	5,2	4,4
(2) SELL STUMPAGE			
A, AVE, PRICE	1,0	1,0	0,8
B, CONV, SURPLUS	3,2	3,2	3,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,8	4,2	3,6
B-NO ACP, CUT-LEAVE	3,8	3,4	3,2
C-ACP, CUT-SELL	A	A	6,6
D-ACP, CUT-LEAVE	4,8	4,4	4,2
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	1,0	0,8	0,8
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	3,2	3,2	3,2
2-NO ACP, CUT-LEAVE	2,4	2,4	2,2
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	3,2	3,2	3,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6,4	5,2	4,4
B-NO ACP, CUT-LEAVE	4,8	4,4	3,8
C-ACP, CUT-SELL	A	A	7,2
D-ACP, CUT-LEAVE	6,2	5,6	5,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	1,4	1,4	1,2
2-NO ACP, CUT-LEAVE	0,8	0,6	0,4
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	1,4	1,4	1,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	3,6	3,6	3,4
2-NO ACP, CUT-LEAVE	2,8	2,8	2,6
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	3,6	3,6	3,6

TABLE II. REFERRAL NO, 2W09, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	4,8	4,4	4,0
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	3,6	3,6	3,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	14,2	7,8	5,4
(2) SELL STUMPAGE			
A, AVE, PRICE	1,6	1,4	1,2
B, CONV, SURPLUS	3,0	2,8	2,8
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6,4	6,2	5,8
B-NO ACP, CUT-LEAVE	5,0	4,8	4,4
C-ACP, CUT-SELL	6,4	6,2	5,8
D-ACP, CUT-LEAVE	6,8	6,6	6,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	2,4	2,4	2,2
2-NO ACP, CUT-LEAVE	1,6	1,4	1,2
3-ACP, CUT-SELL	2,4	2,4	2,2
4-ACP, CUT-LEAVE	2,6	2,6	2,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	5,2	5,0	5,0
2-NO ACP, CUT-LEAVE	4,0	3,8	3,6
3-ACP, CUT-SELL	5,2	5,0	5,0
4-ACP, CUT-LEAVE	5,4	5,4	5,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	14,4	8,4	6,0
B-NO ACP, CUT-LEAVE	7,4	5,8	4,6
C-ACP, CUT-SELL	14,4	8,4	6,0
D-ACP, CUT-LEAVE	20,4	9,8	6,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	2,6	2,4	2,2
2-NO ACP, CUT-LEAVE	1,4	1,2	1,0
3-ACP, CUT-SELL	2,6	2,4	2,2
4-ACP, CUT-LEAVE	3,0	2,8	2,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	3,6	3,6	3,4
2-NO ACP, CUT-LEAVE	2,8	2,6	2,4
3-ACP, CUT-SELL	3,6	3,6	3,4
4-ACP, CUT-LEAVE	3,8	3,8	3,6

TABLE O. REFERRAL NO, 2G10, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	2,4	2,0	1,6
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	6,0	4,4	3,4
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,4	0,2	0,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3,6	3,0	2,6
B-NO ACP, CUT-LEAVE	2,4	2,2	2,0
C-ACP, CUT-SELL	A	5,2	3,6
D-ACP, CUT-LEAVE	3,0	2,6	2,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	0,2
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,6	0,4	0,4
4-ACP, CUT-LEAVE	0,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8,6	5,0	3,6
B-NO ACP, CUT-LEAVE	4,2	3,4	2,8
C-ACP, CUT-SELL	A	33,4	5,2
D-ACP, CUT-LEAVE	5,2	4,2	3,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	0,2
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	1,2	1,0	1,0
2-NO ACP, CUT-LEAVE	0,8	0,8	0,6
3-ACP, CUT-SELL	1,6	1,6	1,6
4-ACP, CUT-LEAVE	1,0	1,0	1,0

TABLE P. REFERRAL NO, 1814, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	7,4	7,0	6,8
(2) SELL STUMPAGE			
A, AVE, PRICE	4,0	4,0	4,0
B, CONV, SURPLUS	6,4	6,4	6,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	11,4	10,4	9,2
(2) SELL STUMPAGE			
A, AVE, PRICE	5,6	5,4	5,4
B, CONV, SURPLUS	7,8	7,6	7,6
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	23,6	8,8	7,4
B-NO ACP, CUT-LEAVE	7,0	6,8	6,6
C-ACP, CUT-SELL	23,6	8,8	7,4
D-ACP, CUT-LEAVE	7,0	6,8	6,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	5,2	5,2	5,2
2-NO ACP, CUT-LEAVE	4,6	4,6	4,6
3-ACP, CUT-SELL	5,2	5,2	5,2
4-ACP, CUT-LEAVE	4,6	4,6	4,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	7,8	7,6	7,6
2-NO ACP, CUT-LEAVE	6,8	6,8	6,6
3-ACP, CUT-SELL	7,8	7,6	7,6
4-ACP, CUT-LEAVE	6,8	6,8	6,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	25,2	12,6	9,6
B-NO ACP, CUT-LEAVE	10,2	9,4	8,8
C-ACP, CUT-SELL	25,2	12,6	9,6
D-ACP, CUT-LEAVE	10,2	9,4	8,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	6,2	6,0	6,0
2-NO ACP, CUT-LEAVE	5,4	5,4	5,2
3-ACP, CUT-SELL	6,2	6,0	6,0
4-ACP, CUT-LEAVE	5,4	5,4	5,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	8,6	8,6	8,6
2-NO ACP, CUT-LEAVE	7,4	7,4	7,4
3-ACP, CUT-SELL	8,6	8,6	8,6
4-ACP, CUT-LEAVE	7,4	7,4	7,4

TABLE Q. REFERRAL NO, 1L16, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	11,4	10,2	8,8
(2) SELL STUMPAGE			
A, AVE, PRICE	6,6	6,4	6,2
B, CONV, SURPLUS	10,2	10,2	10,0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	16,6	15,4	14,0
(2) SELL STUMPAGE			
A, AVE, PRICE	10,4	10,2	10,2
B, CONV, SURPLUS	13,6	13,4	13,4
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	15,0	11,2	8,8
B-NO ACP, CUT-LEAVE	12,2	11,4	10,6
C-ACP, CUT-SELL	15,0	11,2	8,8
D-ACP, CUT-LEAVE	12,2	11,4	10,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	11,8	11,4	11,0
2-NO ACP, CUT-LEAVE	7,2	7,0	6,6
3-ACP, CUT-SELL	11,8	11,4	11,0
4-ACP, CUT-LEAVE	7,2	7,0	6,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	11,8	11,8	11,6
2-NO ACP, CUT-LEAVE	10,6	10,4	10,2
3-ACP, CUT-SELL	11,8	11,8	11,6
4-ACP, CUT-LEAVE	10,6	10,4	10,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	16,8	13,2	10,8
B-NO ACP, CUT-LEAVE	14,6	13,8	13,0
C-ACP, CUT-SELL	16,8	13,2	10,8
D-ACP, CUT-LEAVE	14,6	13,8	13,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	14,8	14,4	13,8
2-NO ACP, CUT-LEAVE	9,2	9,0	8,6
3-ACP, CUT-SELL	14,8	14,4	13,8
4-ACP, CUT-LEAVE	9,2	9,0	8,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	13,8	13,6	13,4
2-NO ACP, CUT-LEAVE	12,4	12,2	12,0
3-ACP, CUT-SELL	13,8	13,6	13,4
4-ACP, CUT-LEAVE	12,4	12,2	12,0

TABLE R. REFERRAL NO, 1M20, SENSITIVITY ANALYSIS OF THE PERIODIC COST ASSUMPTION, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5,4	5,2	5,0
(2) SELL STUMPAGE			
A, AVE, PRICE	2,2	2,2	2,0
B, CONV, SURPLUS	4,4	4,4	4,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	12,8	10,0	8,0
(2) SELL STUMPAGE			
A, AVE, PRICE	4,8	4,8	4,8
B, CONV, SURPLUS	5,4	5,4	5,4
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	36,0	18,8	6,8
B-NO ACP, CUT-LEAVE	5,6	5,4	5,4
C-ACP, CUT-SELL	36,0	18,8	6,8
D-ACP, CUT-LEAVE	5,6	5,4	5,4
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	3,2	3,2	3,0
2-NO ACP, CUT-LEAVE	2,6	2,6	2,6
3-ACP, CUT-SELL	3,2	3,2	3,0
4-ACP, CUT-LEAVE	2,6	2,6	2,6
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	6,2	6,2	6,2
2-NO ACP, CUT-LEAVE	4,8	4,6	4,6
3-ACP, CUT-SELL	6,2	6,2	6,2
4-ACP, CUT-LEAVE	4,8	4,6	4,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	36,4	21,0	10,0
B-NO ACP, CUT-LEAVE	9,6	8,0	6,6
C-ACP, CUT-SELL	36,4	21,0	10,0
D-ACP, CUT-LEAVE	9,6	8,0	6,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	3,2	3,2	3,0
2-NO ACP, CUT-LEAVE	2,6	2,4	2,4
3-ACP, CUT-SELL	3,2	3,2	3,0
4-ACP, CUT-LEAVE	2,6	2,4	2,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	A	A	8,6
2-NO ACP, CUT-LEAVE	4,8	4,6	4,6
3-ACP, CUT-SELL	A	A	8,6
4-ACP, CUT-LEAVE	4,8	4,6	4,6

TABLE S. REFERRAL NO. 1L06. SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	3,0	3,2	3,2
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	0,2
B. CONV. SURPLUS	1,8	2,2	2,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4,8	5,2	5,4
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	1,0	1,8
B. CONV. SURPLUS	2,8	3,2	3,6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,0	4,2	4,4
B-NO ACP, CUT-LEAVE	3,4	3,4	3,6
C-ACP, CUT-SELL	A	A	A
D-ACP, CUT-LEAVE	4,4	4,4	4,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,6
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,8	2,4
4-ACP, CUT-LEAVE	0,2	0,2	0,4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	3,0	3,2	3,4
2-NO ACP, CUT-LEAVE	2,2	2,4	2,6
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	3,2	3,2	3,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5,0	5,2	5,6
B-NO ACP, CUT-LEAVE	4,2	4,4	4,4
C-ACP, CUT-SELL	A	A	A
D-ACP, CUT-LEAVE	5,4	5,6	5,8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,4	1,4	2,2
2-NO ACP, CUT-LEAVE	0,2	0,6	1,2
3-ACP, CUT-SELL	1,8	A	A
4-ACP, CUT-LEAVE	0,4	1,4	2,0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	3,2	3,6	4,0
2-NO ACP, CUT-LEAVE	2,4	2,8	3,0
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	3,2	3,6	4,0

TABLE I. REFERRAL NO. 2W09. SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	4,2	4,4	4,6
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	0,8
B. CONV. SURPLUS	3,4	3,6	3,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	6,8	7,8	9,4
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	1,4	3,2
B. CONV. SURPLUS	2,2	2,8	3,6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A–NO ACP, CUT–SELL	6,0	6,2	6,2
B–NO ACP, CUT–LEAVE	4,8	4,8	4,8
C–ACP, CUT–SELL	6,0	6,2	6,2
D–ACP, CUT–LEAVE	6,6	6,6	6,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1–NO ACP, CUT–SELL	1,8	2,4	2,8
2–NO ACP, CUT–LEAVE	0,8	1,4	1,8
3–ACP, CUT–SELL	1,8	2,4	2,8
4–ACP, CUT–LEAVE	1,8	2,6	3,0
B. CONV. SURPLUS			
1–NO ACP, CUT–SELL	5,0	5,8	5,2
2–NO ACP, CUT–LEAVE	3,6	3,8	4,0
3–ACP, CUT–SELL	5,0	5,0	5,2
4–ACP, CUT–LEAVE	5,2	5,4	5,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A–NO ACP, CUT–SELL	7,4	8,4	10,0
B–NO ACP, CUT–LEAVE	5,2	5,8	6,2
C–ACP, CUT–SELL	7,4	8,4	10,0
D–ACP, CUT–LEAVE	8,2	9,8	12,2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1–NO ACP, CUT–SELL	0,8	2,4	4,6
2–NO ACP, CUT–LEAVE	0,2	1,2	2,2
3–ACP, CUT–SELL	0,8	2,4	4,6
4–ACP, CUT–LEAVE	1,0	2,6	7,0
B. CONV. SURPLUS			
1–NO ACP, CUT–SELL	2,8	3,6	4,4
2–NO ACP, CUT–LEAVE	2,2	2,6	3,2
3–ACP, CUT–SELL	2,8	3,6	4,4
4–ACP, CUT–LEAVE	3,0	3,8	4,6

TABLE U. REFERRAL NO, 2G10. SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	1,8	2,0	2,2
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,2	0,2	0,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4,0	4,4	5,0
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	0,2	0,2
B, CONV, SURPLUS	0,2	0,2	0,8
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2,8	3,0	3,2
B-NO ACP, CUT-LEAVE	2,2	2,2	2,4
C-ACP, CUT-SELL	4,2	5,2	39,0
D-ACP, CUT-LEAVE	2,6	2,6	2,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	0,2
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	0,2	0,2	0,6
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,4	1,0
4-ACP, CUT-LEAVE	0,2	0,2	0,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,6	5,0	5,6
B-NO ACP, CUT-LEAVE	3,2	3,4	3,6
C-ACP, CUT-SELL	27,0	33,4	38,8
D-ACP, CUT-LEAVE	4,0	4,2	4,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,4
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	1,8
4-ACP, CUT-LEAVE	0,2	0,2	0,2
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	0,6	1,0	1,6
2-NO ACP, CUT-LEAVE	0,4	0,8	1,0
3-ACP, CUT-SELL	1,0	1,6	2,4
4-ACP, CUT-LEAVE	0,6	1,0	1,4

TABLE V. REFERRAL NO, 1814, SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION,

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	7,0	7,0	7,2
(2) SELL STUMPAGE			
A, AVE, PRICE	3,8	4,0	4,2
B, CONV, SURPLUS	6,2	6,4	6,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	10,0	10,4	10,8
(2) SELL STUMPAGE			
A, AVE, PRICE	4,8	5,4	6,2
B, CONV, SURPLUS	7,2	7,6	8,2
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8,2	8,0	10,0
B-NO ACP, CUT-LEAVE	6,8	6,8	7,0
C-ACP, CUT-SELL	8,2	8,8	10,0
D-ACP, CUT-LEAVE	6,8	6,0	7,0
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	4,8	5,2	5,6
2-NO ACP, CUT-LEAVE	4,4	4,6	4,8
3-ACP, CUT-SELL	4,8	5,2	5,6
4-ACP, CUT-LEAVE	4,4	4,6	4,8
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	7,2	7,6	8,2
2-NO ACP, CUT-LEAVE	6,6	6,8	6,8
3-ACP, CUT-SELL	7,2	7,6	8,2
4-ACP, CUT-LEAVE	6,6	6,8	6,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	11,2	12,6	15,0
B-NO ACP, CUT-LEAVE	9,2	9,4	9,6
C-ACP, CUT-SELL	11,2	12,6	15,0
D-ACP, CUT-LEAVE	9,2	9,4	9,6
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	5,2	6,0	7,2
2-NO ACP, CUT-LEAVE	4,0	5,4	5,8
3-ACP, CUT-SELL	5,2	6,0	7,2
4-ACP, CUT-LEAVE	4,8	5,4	5,8
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	7,8	8,6	10,0
2-NO ACP, CUT-LEAVE	7,0	7,4	7,8
3-ACP, CUT-SELL	7,8	8,6	10,0
4-ACP, CUT-LEAVE	7,0	7,4	7,8

TABLE W. REFERRAL NO. IL16. SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	10,0	10,2	10,6
(2) SELL STUMPAGE			
A. AVE. PRICE	5,8	6,4	7,0
B. CONV. SURPLUS	9,8	10,2	10,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	15,0	15,4	15,8
(2) SELL STUMPAGE			
A. AVE. PRICE	9,4	10,2	11,0
B. CONV. SURPLUS	13,0	13,4	14,0
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	10,4	11,2	12,2
B-NO ACP, CUT-LEAVE	11,2	11,4	11,6
C-ACP, CUT-SELL	10,4	11,2	12,2
D-ACP, CUT-LEAVE	11,2	11,4	11,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	8,8	11,4	A
2-NO ACP, CUT-LEAVE	6,6	7,0	7,2
3-ACP, CUT-SELL	8,8	11,4	A
4-ACP, CUT-LEAVE	6,6	7,0	7,2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	10,4	11,8	13,6
2-NO ACP, CUT-LEAVE	10,2	10,4	10,6
3-ACP, CUT-SELL	10,4	11,8	13,6
4-ACP, CUT-LEAVE	10,2	10,4	10,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	12,4	13,2	14,0
B-NO ACP, CUT-LEAVE	13,6	13,8	14,0
C-ACP, CUT-SELL	12,4	13,2	14,0
D-ACP, CUT-LEAVE	13,6	13,8	14,0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	11,0	14,4	A
2-NO ACP, CUT-LEAVE	8,4	9,0	9,4
3-ACP, CUT-SELL	11,0	14,4	A
4-ACP, CUT-LEAVE	8,4	9,0	9,4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	12,0	13,6	15,6
2-NO ACP, CUT-LEAVE	12,0	12,2	12,4
3-ACP, CUT-SELL	12,0	13,6	15,6
4-ACP, CUT-LEAVE	12,0	12,2	12,4

TABLE X. REFERRAL NO. 1M20. SENSITIVITY ANALYSIS RESULTING FROM A 5 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5,2	5,2	5,2
(2) SELL STUMPAGE			
A. AVE. PRICE	1,8	2,2	2,4
B. CONV. SURPLUS	4,4	4,4	4,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	9,2	10,8	11,2
(2) SELL STUMPAGE			
A. AVE. PRICE	4,2	4,8	5,6
B. CONV. SURPLUS	4,6	5,4	6,4
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9,2	18,8	24,6
B-NO ACP, CUT-LEAVE	5,4	5,4	5,6
C-ACP, CUT-SELL	9,2	18,8	24,6
D-ACP, CUT-LEAVE	5,4	5,4	5,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	2,8	3,2	3,6
2-NO ACP, CUT-LEAVE	2,4	2,6	2,8
3-ACP, CUT-SELL	2,8	3,2	3,6
4-ACP, CUT-LEAVE	2,4	2,6	2,8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	5,6	6,2	7,4
2-NO ACP, CUT-LEAVE	4,6	4,6	4,8
3-ACP, CUT-SELL	5,6	6,2	7,4
4-ACP, CUT-LEAVE	4,6	4,6	4,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	16,4	21,0	25,6
B-NO ACP, CUT-LEAVE	7,4	8,0	8,4
C-ACP, CUT-SELL	16,4	21,0	25,6
D-ACP, CUT-LEAVE	7,4	8,0	8,4
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	2,0	3,2	5,2
2-NO ACP, CUT-LEAVE	1,6	2,4	3,2
3-ACP, CUT-SELL	2,0	3,2	5,2
4-ACP, CUT-LEAVE	1,6	2,4	3,2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	5,4	A	A
2-NO ACP, CUT-LEAVE	4,2	4,6	5,2
3-ACP, CUT-SELL	5,4	A	A
4-ACP, CUT-LEAVE	4,2	4,6	5,2

TABLE Y. REFERRAL NO. 1L06. SENSITIVITY ANALYSIS RESULTING FROM A 10 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	3,0	3,2	3,4
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	0,2
B. CONV. SURPLUS	1,6	2,2	2,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4,6	5,2	5,8
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	1,8	2,6
B. CONV. SURPLUS	2,4	3,2	4,0
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3,8	4,2	4,6
B-NO ACP, CUT-LEAVE	3,2	3,4	3,6
C-ACP, CUT-SELL	7,2	A	A
D-ACP, CUT-LEAVE	4,2	4,4	4,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	1,2
2-NO ACP, CUT-LEAVE	0,2	0,2	0,4
3-ACP, CUT-SELL	0,2	0,8	A
4-ACP, CUT-LEAVE	0,2	0,2	1,0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2,8	3,2	3,8
2-NO ACP, CUT-LEAVE	2,0	2,4	2,6
3-ACP, CUT-SELL	A	A	A
4-ACP, CUT-LEAVE	3,0	3,2	3,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,6	5,2	5,8
B-NO ACP, CUT-LEAVE	4,0	4,4	4,6
C-ACP, CUT-SELL	37,8	A	A
D-ACP, CUT-LEAVE	5,2	5,6	6,0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	1,4	3,2
2-NO ACP, CUT-LEAVE	0,2	0,6	1,8
3-ACP, CUT-SELL	0,2	A	A
4-ACP, CUT-LEAVE	0,2	1,4	2,8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2,8	3,6	4,4
2-NO ACP, CUT-LEAVE	2,2	2,8	3,2
3-ACP, CUT-SELL	4,4	A	A
4-ACP, CUT-LEAVE	3,0	3,6	4,2

TABLE Z. REFERRAL NO, 2W09, SENSITIVITY ANALYSIS RESULTING FROM A 10 PERCENT CHANGE IN THE QUALITY INDEX, VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION;

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	4,2	4,4	4,6
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	8,2	1,4
B, CONV, SURPLUS	3,2	3,6	3,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	5,8	7,0	11,4
(2) SELL STUMPAGE			
A, AVE, PRICE	0,2	1,4	8,0
B, CONV, SURPLUS	1,6	2,8	4,6
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6,0	6,2	6,4
B-NO ACP, CUT-LEAVE	4,6	4,8	5,0
C-ACP, CUT-SELL	6,0	6,2	6,4
D-ACP, CUT-LEAVE	6,4	6,6	6,8
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,8	2,4	3,2
2-NO ACP, CUT-LEAVE	0,2	1,4	2,2
3-ACP, CUT-SELL	0,8	2,4	3,2
4-ACP, CUT-LEAVE	1,0	2,6	3,4
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	4,8	5,0	5,4
2-NO ACP, CUT-LEAVE	3,6	3,8	4,0
3-ACP, CUT-SELL	4,8	5,0	5,4
4-ACP, CUT-LEAVE	5,2	5,4	5,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6,6	8,4	11,
B-NO ACP, CUT-LEAVE	4,8	5,8	8 6,
C-ACP, CUT-SELL	6,6	8,4	811,
D-ACP, CUT-LEAVE	7,0	9,8	815,
(2) SELL STUMPAGE			
A, AVE, PRICE			
1-NO ACP, CUT-SELL	0,2	2,4	611,
2-NO ACP, CUT-LEAVE	0,2	1,2	4 3,
3-ACP, CUT-SELL	0,2	2,4	211,
4-ACP, CUT-LEAVE	0,2	2,8	4 A
B, CONV, SURPLUS			
1-NO ACP, CUT-SELL	2,2	3,6	5,
2-NO ACP, CUT-LEAVE	1,6	2,4	4 3,
3-ACP, CUT-SELL	2,2	3,6	6 58
4-ACP, CUT-LEAVE	2,4	3,8	4 68

TABLE AA. REFERRAL NO. 2G10. SENSITIVITY ANALYSIS RESULTING FROM A 19 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	1.8	2.0	2.2
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	0.2
B. CONV. SURPLUS	0.2	0.2	0.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	3.6	4.8	5.6
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	0.8
B. CONV. SURPLUS	0.2	0.2	1.4
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2.6	3.0	3.4
B-NO ACP, CUT-LEAVE	2.0	2.2	2.4
C-ACP, CUT-SELL	3.6	5.2	A
D-ACP, CUT-LEAVE	2.6	2.6	2.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	0.2
2-NO ACP, CUT-LEAVE	0.2	0.2	0.2
3-ACP, CUT-SELL	0.2	0.2	0.4
4-ACP, CUT-LEAVE	0.2	0.2	0.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0.2	0.2	0.8
2-NO ACP, CUT-LEAVE	0.2	0.2	0.4
3-ACP, CUT-SELL	0.2	0.4	1.6
4-ACP, CUT-LEAVE	0.2	0.2	0.8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3.8	5.0	6.8
B-NO ACP, CUT-LEAVE	3.0	3.4	3.8
C-ACP, CUT-SELL	6.2	33.4	A
D-ACP, CUT-LEAVE	3.6	4.2	5.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	1.6
2-NO ACP, CUT-LEAVE	0.2	0.2	0.4
3-ACP, CUT-SELL	0.2	0.2	A
4-ACP, CUT-LEAVE	0.2	0.2	1.0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0.2	1.0	2.2
2-NO ACP, CUT-LEAVE	0.2	0.8	1.4
3-ACP, CUT-SELL	0.4	1.6	A
4-ACP, CUT-LEAVE	0.2	1.0	1.8

TABLE BB. REFERRAL NO. 1814. SENSITIVITY ANALYSIS RESULTING FROM A 10 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	7,0	7,0	7,2
(2) SELL STUMPAGE			
A. AVE. PRICE	3,6	4,0	4,4
B. CONV. SURPLUS	6,2	6,4	6,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	9,6	10,4	11,2
(2) SELL STUMPAGE			
A. AVE. PRICE	4,0	5,4	6,8
B. CONV. SURPLUS	6,8	7,6	8,6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7,6	8,8	12,8
B-NO ACP, CUT-LEAVE	6,8	6,8	7,0
C-ACP, CUT-SELL	7,6	8,8	12,8
D-ACP, CUT-LEAVE	6,8	6,8	7,0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	4,4	5,2	6,2
2-NO ACP, CUT-LEAVE	4,2	4,6	5,0
3-ACP, CUT-SELL	4,4	5,2	6,2
4-ACP, CUT-LEAVE	4,2	4,6	5,0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	6,8	7,6	9,0
2-NO ACP, CUT-LEAVE	6,6	6,8	6,8
3-ACP, CUT-SELL	6,8	7,6	9,0
4-ACP, CUT-LEAVE	6,6	6,8	6,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8	12,6	19,0
B-NO ACP, CUT-LEAVE	9,0	9,4	10,0
C-ACP, CUT-SELL	0,2	12,6	19,0
D-ACP, CUT-LEAVE	9,0	9,4	10,0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	4,4	6,0	9,2
2-NO ACP, CUT-LEAVE	4,2	5,4	6,4
3-ACP, CUT-SELL	4,4	6,0	9,2
4-ACP, CUT-LEAVE	4,2	5,4	6,4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	7,0	8,6	A
2-NO ACP, CUT-LEAVE	6,8	7,4	8,0
3-ACP, CUT-SELL	7,0	8,6	A
4-ACP, CUT-LEAVE	6,8	7,4	8,0

TABLE CC. REFERRAL NO. 1L16. SENSITIVITY ANALYSIS RESULTING FROM A 10 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	9,6	10,2	10,8
(2) SELL STUMPAGE			
A. AVE. PRICE	5,0	6,4	7,6
B. CONV. SURPLUS	9,4	10,2	10,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	14,6	15,4	16,2
(2) SELL STUMPAGE			
A. AVE. PRICE	8,6	10,2	11,8
B. CONV. SURPLUS	12,4	13,4	14,6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9,8	11,2	13,2
B-NO ACP, CUT-LEAVE	11,0	11,6	11,6
C-ACP, CUT-SELL	9,8	11,2	13,2
D-ACP, CUT-LEAVE	11,0	11,4	11,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	7,0	11,4	A
2-NO ACP, CUT-LEAVE	6,0	7,0	7,6
3-ACP, CUT-SELL	7,0	11,4	A
4-ACP, CUT-LEAVE	6,0	7,0	7,6
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	9,2	11,8	17,4
2-NO ACP, CUT-LEAVE	10,0	10,4	10,8
3-ACP, CUT-SELL	9,2	11,8	17,4
4-ACP, CUT-LEAVE	10,0	10,4	10,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	11,6	13,2	15,0
B-NO ACP, CUT-LEAVE	13,4	13,8	14,2
C-ACP, CUT-SELL	11,6	13,2	15,0
D-ACP, CUT-LEAVE	13,4	13,8	14,2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	9,0	14,4	A
2-NO ACP, CUT-LEAVE	8,0	9,0	9,8
3-ACP, CUT-SELL	9,0	14,4	A
4-ACP, CUT-LEAVE	8,0	9,0	9,8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	10,8	13,6	20,2
2-NO ACP, CUT-LEAVE	11,6	12,2	12,6
3-ACP, CUT-SELL	10,8	13,6	20,2
4-ACP, CUT-LEAVE	11,6	12,2	12,6

TABLE DD. REFERRAL NO, 1M20. SENSITIVITY ANALYSIS RESULTING FROM A 10 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5.2	5.2	5.2
(2) SELL STUMPAGE			
A. AVE. PRICE	1.6	2.2	2.6
B. CONV. SURPLUS	4.2	4.4	4.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	8.2	10.0	12.2
(2) SELL STUMPAGE			
A. AVE. PRICE	3.6	4.8	6.4
B. CONV. SURPLUS	4.0	5.4	7.4
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7.4	18.8	29.6
B-NO ACP, CUT-LEAVE	5.4	5.4	5.6
C-ACP, CUT-SELL	7.4	18.8	29.6
D-ACP, CUT-LEAVE	5.4	5.4	5.6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	2.4	3.2	4.2
2-NO ACP, CUT-LEAVE	2.2	2.6	3.0
3-ACP, CUT-SELL	2.4	3.2	4.2
4-ACP, CUT-LEAVE	2.2	2.6	3.0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	5.2	6.2	A
2-NO ACP, CUT-LEAVE	4.6	4.6	4.8
3-ACP, CUT-SELL	5.2	6.2	A
4-ACP, CUT-LEAVE	4.6	4.6	4.8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	12.2	21.0	30.2
B-NO ACP, CUT-LEAVE	6.8	8.0	9.0
C-ACP, CUT-SELL	12.2	21.0	30.2
D-ACP, CUT-LEAVE	6.8	8.0	9.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	1.0	3.2	A
2-NO ACP, CUT-LEAVE	1.0	2.4	4.0
3-ACP, CUT-SELL	1.0	3.2	A
4-ACP, CUT-LEAVE	1.0	2.4	4.0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	4.2	A	A
2-NO ACP, CUT-LEAVE	3.6	4.6	5.8
3-ACP, CUT-SELL	4.2	A	A
4-ACP, CUT-LEAVE	3.6	4.6	5.8

TABLE EE. REFERRAL NO. 1L06. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	2.8	3.2	3.4
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	0.2
B. CONV. SURPLUS	1.4	2.2	2.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4.4	5.2	6.0
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	1.0	3.2
B. CONV. SURPLUS	2.0	3.2	4.4
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3.8	4.2	4.8
B-NO ACP, CUT-LEAVE	3.2	3.4	3.6
C-ACP, CUT-SELL	6.0	A	A
D-ACP, CUT-LEAVE	4.2	4.4	4.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	1.8
2-NO ACP, CUT-LEAVE	0.2	0.2	0.8
3-ACP, CUT-SELL	0.2	0.8	A
4-ACP, CUT-LEAVE	0.2	0.2	1.4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2.4	3.2	4.0
2-NO ACP, CUT-LEAVE	2.0	2.4	2.8
3-ACP, CUT-SELL	4.4	A	A
4-ACP, CUT-LEAVE	2.8	3.2	3.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4.4	5.2	6.2
B-NO ACP, CUT-LEAVE	3.8	4.4	4.8
C-ACP, CUT-SELL	6.6	A	A
D-ACP, CUT-LEAVE	4.8	5.6	6.2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	1.4	4.2
2-NO ACP, CUT-LEAVE	0.2	0.6	2.2
3-ACP, CUT-SELL	0.2	A	A
4-ACP, CUT-LEAVE	0.2	1.4	3.4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2.4	3.6	5.0
2-NO ACP, CUT-LEAVE	2.0	2.8	3.4
3-ACP, CUT-SELL	3.4	A	A
4-ACP, CUT-LEAVE	2.6	3.6	4.6

TABLE FF. REFERRAL NO. 2W09. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	4.0	4.4	4.8
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	1.8
B. CONV. SURPLUS	2.8	3.6	4.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	5.2	7.8	13.8
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	1.4	26.6
B. CONV. SURPLUS	1.0	2.8	6.2
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5.8	6.2	6.4
B-NO ACP, CUT-LEAVE	4.6	4.8	5.0
C-ACP, CUT-SELL	5.8	6.2	6.4
D-ACP, CUT-LEAVE	6.4	6.6	6.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	2.4	3.6
2-NO ACP, CUT-LEAVE	0.2	1.4	2.4
3-ACP, CUT-SELL	0.2	2.4	3.6
4-ACP, CUT-LEAVE	0.2	2.6	3.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	4.6	5.0	5.4
2-NO ACP, CUT-LEAVE	3.4	3.8	4.2
3-ACP, CUT-SELL	4.6	5.0	5.4
4-ACP, CUT-LEAVE	5.0	5.4	5.8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5.8	8.4	14.2
B-NO ACP, CUT-LEAVE	4.4	5.8	7.2
C-ACP, CUT-SELL	5.8	8.4	14.2
D-ACP, CUT-LEAVE	6.2	9.8	19.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	2.4	26.8
2-NO ACP, CUT-LEAVE	0.2	1.2	4.2
3-ACP, CUT-SELL	0.2	2.4	26.8
4-ACP, CUT-LEAVE	0.2	2.8	A
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	1.6	3.6	7.2
2-NO ACP, CUT-LEAVE	1.2	2.6	4.2
3-ACP, CUT-SELL	1.6	3.6	7.2
4-ACP, CUT-LEAVE	1.8	3.8	A

TABLE GG. REFERRAL NO. 2G10. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	1.6	2.0	2.4
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	0.2
B. CONV. SURPLUS	0.2	0.2	0.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	3.2	4.6	6.2
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	1.8
B. CONV. SURPLUS	0.2	0.2	2.0
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2.4	3.0	3.8
B-NO ACP, CUT-LEAVE	2.0	2.2	2.4
C-ACP, CUT-SELL	3.4	5.2	A
D-ACP, CUT-LEAVE	2.4	2.6	3.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	0.4
2-NO ACP, CUT-LEAVE	0.2	0.2	0.2
3-ACP, CUT-SELL	0.2	0.2	1.0
4-ACP, CUT-LEAVE	0.2	0.2	0.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0.2	0.2	1.2
2-NO ACP, CUT-LEAVE	0.2	0.2	0.6
3-ACP, CUT-SELL	0.2	0.4	2.0
4-ACP, CUT-LEAVE	0.2	0.2	1.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3.4	5.0	8.4
B-NO ACP, CUT-LEAVE	2.8	3.4	4.2
C-ACP, CUT-SELL	4.8	33.4	A
D-ACP, CUT-LEAVE	3.4	4.2	5.2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	0.2	3.8
2-NO ACP, CUT-LEAVE	0.2	0.2	1.0
3-ACP, CUT-SELL	0.2	0.2	A
4-ACP, CUT-LEAVE	0.2	0.2	1.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0.2	1.0	3.0
2-NO ACP, CUT-LEAVE	0.2	0.0	1.8
3-ACP, CUT-SELL	0.2	1.6	A
4-ACP, CUT-LEAVE	0.2	1.0	2.4

TABLE HH. REFERRAL NO. 1814. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	7.0	7.0	7.2
(2) SELL STUMPAGE			
A. AVE. PRICE	3.2	4.0	4.6
B. CONV. SURPLUS	6.2	6.4	6.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	9.2	10.4	11.6
(2) SELL STUMPAGE			
A. AVE. PRICE	3.4	5.4	7.6
B. CONV. SURPLUS	6.4	7.6	9.2
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7.2	8.8	22.0
B-NO ACP, CUT-LEAVE	6.6	6.8	7.0
C-ACP, CUT-SELL	7.2	8.8	22.0
D-ACP, CUT-LEAVE	6.6	6.8	7.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	3.8	5.2	7.2
2-NO ACP, CUT-LEAVE	4.0	4.6	5.0
3-ACP, CUT-SELL	3.8	5.2	7.2
4-ACP, CUT-LEAVE	4.0	4.6	5.0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	6.6	7.6	A
2-NO ACP, CUT-LEAVE	6.6	6.8	7.0
3-ACP, CUT-SELL	6.6	7.6	A
4-ACP, CUT-LEAVE	6.6	6.8	7.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9.4	12.6	23.8
B-NO ACP, CUT-LEAVE	8.6	9.4	10.2
C-ACP, CUT-SELL	9.4	12.6	23.8
D-ACP, CUT-LEAVE	8.6	9.4	10.2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	3.6	6.0	A
2-NO ACP, CUT-LEAVE	3.8	5.4	6.8
3-ACP, CUT-SELL	3.6	6.0	A
4-ACP, CUT-LEAVE	3.8	5.4	6.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	6.4	8.6	A
2-NO ACP, CUT-LEAVE	6.4	7.4	8.4
3-ACP, CUT-SELL	6.4	8.6	A
4-ACP, CUT-LEAVE	6.4	7.4	8.4

TABLE II. REFERRAL NO. 1L16. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	9.2	10.2	11.2
(2) SELL STUMPAGE			
A. AVE. PRICE	4.0	6.4	8.2
B. CONV. SURPLUS	9.0	10.2	11.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	14.2	15.4	16.6
(2) SELL STUMPAGE			
A. AVE. PRICE	7.6	10.2	12.6
B. CONV. SURPLUS	11.8	13.4	15.0
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9.0	11.2	14.4
B-NO ACP, CUT-LEAVE	10.8	11.4	11.8
C-ACP, CUT-SELL	9.0	11.2	14.4
D-ACP, CUT-LEAVE	10.8	11.4	11.8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	5.6	11.4	A
2-NO ACP, CUT-LEAVE	5.6	7.0	8.0
3-ACP, CUT-SELL	5.6	11.4	A
4-ACP, CUT-LEAVE	5.6	7.0	8.0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	8.4	11.8	A
2-NO ACP, CUT-LEAVE	9.8	10.4	11.0
3-ACP, CUT-SELL	8.4	11.8	A
4-ACP, CUT-LEAVE	9.8	10.4	11.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	11.0	13.2	16.2
B-NO ACP, CUT-LEAVE	13.2	13.8	14.4
C-ACP, CUT-SELL	11.0	13.2	16.2
D-ACP, CUT-LEAVE	13.2	13.8	14.4
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	7.4	14.4	A
2-NO ACP, CUT-LEAVE	7.4	9.0	10.2
3-ACP, CUT-SELL	7.4	14.4	A
4-ACP, CUT-LEAVE	7.4	9.0	10.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	9.8	13.6	A
2-NO ACP, CUT-LEAVE	11.4	12.2	13.0
3-ACP, CUT-SELL	9.8	13.6	A
4-ACP, CUT-LEAVE	11.4	12.2	13.0

TABLE JJ. REFERRAL NO. 1M20. SENSITIVITY ANALYSIS RESULTING FROM A 15 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5.0	5.2	5.4
(2) SELL STUMPAGE			
A. AVE. PRICE	1.2	2.2	2.8
B. CONV. SURPLUS	4.2	4.4	4.6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	7.6	10.8	13.2
(2) SELL STUMPAGE			
A. AVE. PRICE	3.2	4.8	7.6
B. CONV. SURPLUS	3.6	5.4	8.6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6.6	18.8	34.2
B-NO ACP, CUT-LEAVE	5.4	5.4	5.6
C-ACP, CUT-SELL	6.6	18.8	34.2
D-ACP, CUT-LEAVE	5.4	5.4	5.6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	2.0	3.2	5.0
2-NO ACP, CUT-LEAVE	2.0	2.6	3.2
3-ACP, CUT-SELL	2.0	3.2	5.0
4-ACP, CUT-LEAVE	2.0	2.6	3.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	4.8	6.2	A
2-NO ACP, CUT-LEAVE	4.4	4.6	4.8
3-ACP, CUT-SELL	4.8	6.2	A
4-ACP, CUT-LEAVE	4.4	4.6	4.8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	9.0	21.8	34.6
B-NO ACP, CUT-LEAVE	6.4	8.8	9.6
C-ACP, CUT-SELL	9.0	21.8	34.6
D-ACP, CUT-LEAVE	6.4	8.8	9.6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	3.2	A
2-NO ACP, CUT-LEAVE	0.2	2.4	4.8
3-ACP, CUT-SELL	0.2	3.2	A
4-ACP, CUT-LEAVE	0.2	2.4	4.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	3.4	A	A
2-NO ACP, CUT-LEAVE	3.2	4.6	6.4
3-ACP, CUT-SELL	3.4	A	A
4-ACP, CUT-LEAVE	3.2	4.6	6.4

TABLE XX. REFERRAL NO, 1L06. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	2,6	3,2	3,6
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	0,6
B. CONV. SURPLUS	1,0	2,2	2,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4,2	5,2	6,4
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	1,0	4,0
B. CONV. SURPLUS	1,6	3,2	4,8
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3,6	4,2	5,0
B-NO ACP, CUT-LEAVE	3,2	3,4	3,8
C-ACP, CUT-SELL	5,4	A	A
D-ACP, CUT-LEAVE	4,0	4,4	4,8
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	2,2
2-NO ACP, CUT-LEAVE	0,2	0,2	1,0
3-ACP, CUT-SELL	0,2	0,8	A
4-ACP, CUT-LEAVE	0,2	0,2	1,8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2,2	3,2	4,2
2-NO ACP, CUT-LEAVE	1,8	2,4	2,8
3-ACP, CUT-SELL	3,6	A	A
4-ACP, CUT-LEAVE	2,6	3,2	3,8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	4,2	5,2	6,6
B-NO ACP, CUT-LEAVE	3,8	4,4	4,8
C-ACP, CUT-SELL	5,8	A	A
D-ACP, CUT-LEAVE	4,6	5,6	6,4
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	1,4	5,4
2-NO ACP, CUT-LEAVE	0,2	0,6	2,6
3-ACP, CUT-SELL	0,2	A	A
4-ACP, CUT-LEAVE	0,2	1,4	4,0
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2,0	3,6	5,6
2-NO ACP, CUT-LEAVE	1,6	2,8	3,6
3-ACP, CUT-SELL	2,8	A	A
4-ACP, CUT-LEAVE	2,2	3,6	5,0

TABLE LL. REFERRAL NO. 2W09. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	3.8	4.6	4.8
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	0.2	2.2
B. CONV. SURPLUS	2.6	3.6	4.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	4.6	7.8	16.6
(2) SELL STUMPAGE			
A. AVE. PRICE	0.2	1.4	36.2
B. CONV. SURPLUS	0.6	2.8	10.6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5.8	6.2	6.4
B-NO ACP, CUT-LEAVE	4.4	4.8	5.0
C-ACP, CUT-SELL	5.8	6.2	6.4
D-ACP, CUT-LEAVE	6.2	6.6	7.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	2.4	3.8
2-NO ACP, CUT-LEAVE	0.2	1.4	2.8
3-ACP, CUT-SELL	0.2	2.4	3.8
4-ACP, CUT-LEAVE	0.2	2.6	4.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	4.4	5.8	5.6
2-NO ACP, CUT-LEAVE	3.2	3.8	4.2
3-ACP, CUT-SELL	4.4	5.8	5.6
4-ACP, CUT-LEAVE	4.8	5.4	6.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	5.2	8.4	16.8
B-NO ACP, CUT-LEAVE	4.2	5.8	7.8
C-ACP, CUT-SELL	5.2	8.4	16.8
D-ACP, CUT-LEAVE	5.4	9.8	25.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	2.4	36.2
2-NO ACP, CUT-LEAVE	0.2	1.2	5.2
3-ACP, CUT-SELL	0.2	2.4	36.2
4-ACP, CUT-LEAVE	0.2	2.8	A
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	1.2	3.6	13.0
2-NO ACP, CUT-LEAVE	0.8	2.6	4.8
3-ACP, CUT-SELL	1.2	3.6	13.0
4-ACP, CUT-LEAVE	1.2	3.8	A

TABLE MM. REFERRAL NO. 2G10. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	1,4	2,0	2,4
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	0,2
B. CONV. SURPLUS	0,2	0,2	0,4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	2,8	4,4	6,8
(2) SELL STUMPAGE			
A. AVE. PRICE	0,2	0,2	3,0
B. CONV. SURPLUS	0,2	0,2	2,6
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	2,2	3,0	4,0
B-NO ACP, CUT-LEAVE	1,8	2,2	2,6
C-ACP, CUT-SELL	3,0	5,2	A
D-ACP, CUT-LEAVE	2,4	2,6	3,0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	0,8
2-NO ACP, CUT-LEAVE	0,2	0,2	0,2
3-ACP, CUT-SELL	0,2	0,2	2,0
4-ACP, CUT-LEAVE	0,2	0,2	0,4
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0,2	0,2	1,6
2-NO ACP, CUT-LEAVE	0,2	0,2	0,8
3-ACP, CUT-SELL	0,2	0,4	2,8
4-ACP, CUT-LEAVE	0,2	0,2	1,2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	3,0	5,0	11,2
B-NO ACP, CUT-LEAVE	2,6	3,4	4,4
C-ACP, CUT-SELL	3,8	33,4	A
D-ACP, CUT-LEAVE	3,8	4,2	5,6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0,2	0,2	A
2-NO ACP, CUT-LEAVE	0,2	0,2	1,6
3-ACP, CUT-SELL	0,2	0,2	A
4-ACP, CUT-LEAVE	0,2	0,2	2,6
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	0,2	1,0	4,0
2-NO ACP, CUT-LEAVE	0,2	0,6	2,2
3-ACP, CUT-SELL	0,2	1,6	A
4-ACP, CUT-LEAVE	0,2	1,0	2,8

TABLE NN. REFERRAL NO. 1814. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I, NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	6,8	7,0	7,4
(2) SELL STUMPAGE			
A. AVE. PRICE	3,0	4,0	4,8
B. CONV. SURPLUS	6,0	6,4	6,6
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	8,8	10,4	12,0
(2) SELL STUMPAGE			
A. AVE. PRICE	2,6	5,4	8,4
B. CONV. SURPLUS	6,0	7,6	9,6
II, TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7,0	8,8	27,8
B-NO ACP, CUT-LEAVE	6,6	6,8	7,2
C-ACP, CUT-SELL	7,0	8,8	27,8
D-ACP, CUT-LEAVE	6,6	6,8	7,2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	3,4	5,2	9,0
2-NO ACP, CUT-LEAVE	3,6	4,6	5,2
3-ACP, CUT-SELL	3,4	5,2	9,0
4-ACP, CUT-LEAVE	3,6	4,6	5,2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	6,2	7,6	A
2-NO ACP, CUT-LEAVE	6,4	6,8	7,0
3-ACP, CUT-SELL	6,2	7,6	A
4-ACP, CUT-LEAVE	6,4	6,8	7,0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8,8	12,6	28,6
B-NO ACP, CUT-LEAVE	8,4	9,4	10,4
C-ACP, CUT-SELL	8,8	12,6	28,6
D-ACP, CUT-LEAVE	8,4	9,4	10,4
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	3,0	6,0	A
2-NO ACP, CUT-LEAVE	3,2	5,4	7,2
3-ACP, CUT-SELL	3,0	6,0	A
4-ACP, CUT-LEAVE	3,2	5,4	7,2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	6,0	8,6	A
2-NO ACP, CUT-LEAVE	6,2	7,4	8,8
3-ACP, CUT-SELL	6,0	8,6	A
4-ACP, CUT-LEAVE	6,2	7,4	8,8

TABLE OO. REFERRAL NO. 1L16. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION.

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	9.0	10.2	11.4
(2) SELL STUMPAGE			
A. AVE. PRICE	3.0	6.4	8.6
B. CONV. SURPLUS	8.4	10.2	11.4
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	13.8	15.4	16.8
(2) SELL STUMPAGE			
A. AVE. PRICE	6.6	10.2	13.2
B. CONV. SURPLUS	11.4	13.4	15.6
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	8.6	11.2	15.8
B-NO ACP, CUT-LEAVE	10.8	11.4	12.0
C-ACP, CUT-SELL	8.6	11.2	15.8
D-ACP, CUT-LEAVE	10.8	11.4	12.0
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	4.4	11.4	A
2-NO ACP, CUT-LEAVE	5.0	7.0	8.2
3-ACP, CUT-SELL	4.4	11.4	A
4-ACP, CUT-LEAVE	5.0	7.0	8.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	7.6	11.8	A
2-NO ACP, CUT-LEAVE	9.6	10.4	11.2
3-ACP, CUT-SELL	7.6	11.8	A
4-ACP, CUT-LEAVE	9.6	10.4	11.2
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	10.4	13.2	17.6
B-NO ACP, CUT-LEAVE	13.0	13.8	14.6
C-ACP, CUT-SELL	10.4	13.2	17.6
D-ACP, CUT-LEAVE	13.0	13.8	14.6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	6.0	14.4	A
2-NO ACP, CUT-LEAVE	6.8	9.0	10.6
3-ACP, CUT-SELL	6.0	14.4	A
4-ACP, CUT-LEAVE	6.8	9.0	10.6
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	9.0	13.6	A
2-NO ACP, CUT-LEAVE	11.0	12.2	13.2
3-ACP, CUT-SELL	9.0	13.6	A
4-ACP, CUT-LEAVE	11.0	12.2	13.2

TABLE PP. REFERRAL NO. 1M20. SENSITIVITY ANALYSIS RESULTING FROM A 20 PERCENT CHANGE IN THE QUALITY INDEX. VALUES ARE INTERNAL RATES OF RETURN FOR EACH OPTION

	LOW	MEDIUM	HIGH
I. NO TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS	5.0	5.2	5.4
(2) SELL STUMPAGE			
A. AVE. PRICE	0.8	2.2	3.0
B. CONV. SURPLUS	4.2	4.4	4.8
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS	6.8	10.8	14.4
(2) SELL STUMPAGE			
A. AVE. PRICE	2.6	4.8	8.8
B. CONV. SURPLUS	3.0	5.4	10.2
II. TSI IN 1962			
(A) NO FUTURE THINNING			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	6.2	18.8	38.6
B-NO ACP, CUT-LEAVE	5.4	5.4	5.6
C-ACP, CUT-SELL	6.2	18.8	38.6
D-ACP, CUT-LEAVE	5.4	5.4	5.6
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	1.6	3.2	A
2-NO ACP, CUT-LEAVE	1.6	2.6	3.2
3-ACP, CUT-SELL	1.6	3.2	A
4-ACP, CUT-LEAVE	1.6	2.6	3.2
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	4.6	6.2	A
2-NO ACP, CUT-LEAVE	4.4	4.6	5.0
3-ACP, CUT-SELL	4.6	6.2	A
4-ACP, CUT-LEAVE	4.4	4.6	5.0
(B) FUTURE THINNINGS			
(1) MARKET PRODUCTS			
A-NO ACP, CUT-SELL	7.4	21.0	38.8
B-NO ACP, CUT-LEAVE	6.0	8.0	10.2
C-ACP, CUT-SELL	7.4	21.0	38.8
D-ACP, CUT-LEAVE	6.0	8.0	10.2
(2) SELL STUMPAGE			
A. AVE. PRICE			
1-NO ACP, CUT-SELL	0.2	3.2	A
2-NO ACP, CUT-LEAVE	0.2	2.4	5.8
3-ACP, CUT-SELL	0.2	3.2	A
4-ACP, CUT-LEAVE	0.2	2.4	5.8
B. CONV. SURPLUS			
1-NO ACP, CUT-SELL	2.8	A	A
2-NO ACP, CUT-LEAVE	2.8	4.6	7.2
3-ACP, CUT-SELL	2.8	A	A
4-ACP, CUT-LEAVE	2.8	4.6	7.2

APPENDIX IV

The Modified Version of Clark Row's Computer Program (1963) Which Was Used in the Present Study.

```
      PROGRAM INVEST
      DIMENSION ANC(10),CANC(10),NC(6,200),PECO(6,200),N1(6,200),YLD1(6,
     1200),QUAL1(6,200),N2(6,200),QUAL2(6,200),N3(6,200),YLD3(6,200),QUA
     2L3(6,200),PR(3,20),CPR(3,20),FVAL(25),RATE(200),RTLOG(200),VALIN(
     35,200),LY(6),KCX(6),K1X(6),K2X(6),K3X(6),A(26),LI(6),YLD2(6,200)
      DIMENSION RINT(3),KIRR(6)
      DISC(X)=RTLOI**X
      PRINT 75
   75 FORMAT(1H1,10X,*SENSITIVITY ANALYSIS OF THE PRICE ASSUMPTION*,//)
142   READ 17000,(RINT(I),I=1,3),IOUT
17000 FORMAT (3F4.3,I2)
      RATE(1)=RINT(1)
      DO 17001 I=2,200
      IF(RATE(I-1)-RINT(3)) 17002,17003,17003
17002 RATE(I)=RATE(I-1)+RINT(2)
      GO TO 17001
17003 LENGTH=I-1
      IF(MOD(LENGTH,2)) 17004,17005,17004
17004 LENGTH=(LENGTH+1)/2
      GO TO 137
17005 LENGTH=LENGTH/2
      GO TO 137
17001 CONTINUE
137   DO 138 I=1,LENGTH
138   RTLOG(I)=1.+RATE(I)
      READ 11, NO,LZ,LX,(LI(L),L=1,6),(LY(L),L=1,6),KX,KCXX,
     1(KCX(L),L=1,6),K1XX,(K1X(L),L=1,6),K2XX,(K2X(L),L=1,6),
     2K3XX,(K3X(L),L=1,6),JX,MX,NZ,NX
11    FORMAT(3I2,6A4,6I3,I2/21I3/7I3,4I2)
      PRINT 76,NO,(LI(L),L=1,6)
   76 FORMAT(1H0,5X,I2,10X,6(6X,A4))
      PRINT 77
   77 FORMAT(1H )
      READ 15,(A(I),I=1,14)
   15 FORMAT  (14A5)
      READ 15,(A(I),I=15,26)
      IF (KCXX) 160,160,152
  152 DO 155 KC=1,KCXX
      READ 13,(NC(L,KC),PECO(L,KC),L=1,6)
13    FORMAT(6(I3,F9.2))
  155 CONTINUE
  160 IF (K1XX)170,170,162
  162 DO 165 K1=1,K1XX
      READ 14,(N1(L,K1),YLD1(L,K1),QUAL1(L,K1),L=1,6)
14    FORMAT(6(I3,F5.3,F4.2))
  165 CONTINUE
  170 IF(K2XX) 180,180,172
  172 DO 175 K2=1,K2XX
      READ 14,(N2(L,K2),YLD2(L,K2),QUAL2(L,K2),L=1,6)
  175 CONTINUE
  180 IF (K3XX) 190,190,182
  182 DO 185 K3=1,K3XX
      READ 14,(N3(L,K3),YLD3(L,K3),QUAL3(L,K3),L=1,6)
  185 CONTINUE
12    FORMAT (8F9.3)
  190 READ 12,(ANC(J),CANC(J),J=1,JX)

       DO 191 M=1,MX
 1200  FORMAT(6F9.3)
 191   READ 1200,(PR(K,M),CPR(K,M),K=1,KX)
   192 IF(NZ-1)195,195,193
   193 READ 12,(FVAL(N),N=1,NX)
   195 DO 390 J=1,JX
       DO 390 M=1,MX
       LLLX=NX
       IF(NX.EQ.0)LLLX=1
   198 DO 390 N=1,LLLX
   210 DO 345 L=1,LX
       KCXA=KCX(L)
       K1XA=K1X(L)
       K2XA=K2X(L)
       K3XA=K3X(L)
       XLY=FLOAT(LY(L))
       ASSIGN 220 TO NZERO
       DO 340 I=1,LENGTH
       GO TO NZERO,(220,330)
```

```
220   DANC=0.0
      DCANC=0.0
      DKC=0.0
      DK1=0.0
      DK2=0.0
      DK3=0.0
      DFVAL=0.0
      RTLOI=RTLOG(I)
      DISCO=RTLOG(I)**XLY
      IF(ANC(J)) 225,230,225
  225 DANC=(ANC(J)*(DISCO-1.))/(RATE(I)*DISCO)
  230 IF (CANC(J)) 235,240,235
  235 DCANC=(CANC(J)+ANC(J)*(DISCO-XLY*RATE(I)-1.))/(RATE(I)**2*DISCO)
  240 IF(KCXA) 250,250,241
  241 DO 246 KC=1,KCXA
      XNC=FLOAT(NC(L,KC))
      IF(XNC-1.0) 244,244,245
  244 DKC=DKC+PECO(L,KC)
      GO TO 246
  245 DKC=DKC+PECO(L,KC)/DISC(XNC-1.0)
  246 CONTINUE
  250 IF (K1XA) 260,260,251
  251 DO 255 K1=1,K1XA
      XN1=FLOAT(N1(L,K1))
  255 DK1=DK1+(YLD1(L,K1)*PR(1,M)*QUAL1(L,K1)*(1.+CPR(1,M)
     1*XN1))/DISC(XN1)
  260 IF (K2XA)270,270,261
  261 DO 265 K2=1,K2XA
      XN2=FLOAT(N2(L,K2))
  265 DK2=DK2+(YLD2(L,K2)*PR(2,M)*QUAL2(L,K2)*(1.+CPR(2,M)*XN2))/
     1DISC(XN2)
  270 IF(K3XA)280,280,271
  271 DO 275 K3=1,K3XA
      XN3=FLOAT(N3(L,K3))
  275 DK3=DK3+(YLD3(L,K3)*PR(3,M)*QUAL3(L,K3)*(1.+CPR(3,M)*XN3))
     1/DISC(XN3)
  280 TDVAL=DK1+DK2+DK3-DANC-DCANC-DKC
      IF(NZ-1)290,290,295
  290 VALIN(L,I)=TDVAL*(1.+1./(DISCO-1.))
      GO TO 340
  295 DFVAL=FVAL(N)/DISCO
      VALIN(L,I)=TDVAL+DFVAL
      IF(VALIN(L,I))330,340,340
330   VALIN(L,I)=0.0
      ASSIGN 330 TO NZERO
  340 CONTINUE
  345 CONTINUE
      DO 1308 I=1,LENGTH
      RATE(I)=RATE(I)*100.0
 1308 CONTINUE
      DO 800 L=1,LX
      DO 801 I=1,LENGTH
      IF(VALIN(L,I).GT.0.0) GO TO 801
      IF(VALIN(L,I).EQ.0.0) GO TO 802
      IF(I.EQ.1) GO TO 803
      XIRR(L)=(RATE(I-1)+RATE(I))/2.0
      GO TO 800
  802 XIRR(L)=RATE(I)
      GO TO 800
  801 CONTINUE
  803 XIRR(L)=-0.0
  800 CONTINUE
      IF(M-2) 80,81,82
   80 PRINT 768,(XIRR(L),L=1,6)
  768 FORMAT(1H ,18X,*LOW*,F6.1,5F10.1)
      GO TO 4665
   81 PRINT 778,(XIRR(L),L=1,6)
  778 FORMAT(1H ,15X,*MEDIUM*,F6.1,5F10.1)
      GO TO 4665
   82 PRINT 788,(XIRR(L),L=1,6)
  788 FORMAT(1H ,17X,*HIGH*,F6.1,5F10.1)
 4665 DO 4667 I=1,LENGTH
 4667 RATE(I)=RATE(I)/100.0
  390 CONTINUE
      READ 11, IEND
      IF(IEND-98)400,142,410
  400 PRINT 42
   42 FORMAT (23H0  ERROR IN INPUT CARDS)
  410 STOP
      END
```

```
C
C DATA INPUT INSTRUCTIONS
C   CARD     COLUMNS                      ITEM                               FIELD
C --------  -------   --------------------------------------------   ---------
C CONTROL-1  1-4      MINIMUM RATE OF INTEREST                           .XXX
C            5-8      INTEREST RATE INCREMENT                            .XXX
C            9-12     MAXIMUM RATE OF INTEREST                           .XXX
C           13-14     (00 FOR INT. RATE ONLY, 01 FOR P.W. AND
C                     INTEREST RATE, 02 FOR PRESENT WORTHS ONLY)           XX
C
C CONTROL-2  1-2      PROBLEM NUMBER (1 TO 99) FOR IDENTIFICATION          XX
C            3-4      ALTERNATIVE TYPE (01-ROTATION, 02-SITE INDEX,
C                     03-PRODUCTION SYSTEM)                                XX
C            5-6      NUMBER OF ALTERNATIVES (01 TO 06)                    XX
C            7-30     4 DIGIT NO. IDENTIFYING EACH ALTERNATIVE           XXXX
C           31-48     LENGHT OF EACH ALTERNATIVE (1-999 YEARS)            XXX
C           49-50     MAX. NO. OF DIFFERENT PRODUCTS (0-3)                 XX
C
C CONTROL-3  1-3      MAX. NO. PERIODIC COSTS                             XXX
C            4-21     NO. PERIODIC COSTS, EACH ALTERNATIVE                XXX
C           22-24     MAX. NO. RETURNS FOR PRODUCT ONE                    XXX
C           25-42     NO. RETURNS FOR EACH ALTERNATIVE-PRODUCT ONE        XXX
C           43-45     MAX. NO. RETURNS FOR PRODUCT TWO                    XXX
C           46-63     NO. RETURNS FOR EACH ALTERNATIVE-PRODUCT TWO        XXX
C
C CONTROL-4  1-3      MAX. NO. RETURNS FOR PRODUCT THREE                  XXX
C            4-21     NO. RETURNS - EACH ALTERNATIVE-PRODUCT THREE        XXX
C           22-23     NO. SETS OF ANNUAL COSTS (0-10)                      XX
C           24-25     NO. SETS OF PRODUCT PRICES (0-20)                    XX
C           26-27     TYPE OF TERMINAL CALCULATION (01-IF PERPETUAL
C                     SERIES, 02-IF FINAL VALUE)                           XX
C           28-29     NO. OF FINAL VALUES (0-25)                           XX
C
C PROB. NAME 1-72     NAME OF PROBLEM
C
C PROD.NAMES 1-20     NAME OF PRODUCT ONE
C           21-40     NAME OF PRODUCT TWO
C           41-60     NAME OF PRODUCT THREE
C
C PERIODIC   1-3      YEAR OF ITH COST FOR ALT. 1                         XXX
C  COSTS     4-12     ITH COST FOR ALT. 1                           XXXXXX.XX
C           13-15     YEAR OF ITH COST FOR ALT. 2                         XXX
C           16-24     ITH COST FOR ALT. 2                           XXXXXX.XX
C           25-27     YEAR OF ITH COST FOR ALT. 3                         XXX
C           28-36     ITH COST FOR ALT. 3                           XXXXXX.XX
C           37-39     YEAR OF ITH COST FOR ALT. 4                         XXX
C           40-48     ITH COST FOR ALT. 4                           XXXXXX.XX
C           49-51     YEAR OF ITH COST FOR ALT. 5                         XXX
C           52-60     ITH COST FOR ALT. 5                           XXXXXX.XX
C           61-63     YEAR OF ITH COST FOR ALT. 6                         XXX
C           64-72     ITH COST FOR ALT. 6                           XXXXXX.XX
C   (NO. OF CARDS = MAX. NO. OF PERIODIC COSTS IN ANY ALT.)
C
C PRODUCT    1-3      YEAR OF JTH RETURN FOR THE KTH PRODUCT-ALT. 1 XXX
C RETURNS    4-8      VOLUME OF JTH YIELD -OR KTH PRODUCT-ALT. 1  XXX.X
C            9-12     QUALITY INDEX,JTH RETURN FOR KTH PROD.-ALT.1 X.XX
C            ----       AND SO FORTH FOR ALL SIX ALTERNATIVES
C   (NO. OF CARDS IN A SET = MAX. NO. OF RETURNS FROM THE PRODUCT IN ANY
C    ALTERNATIVE - NO. OF SETS = NO. OF PRODUCTS (1 TO 3))
C
C ANNUAL     1-9      ITH ANNUAL COST ASSUMPTION                   XXXXX.XXX
C COST      10-18     ITH CHANGE IN ANNUAL COST ASSUMPTION         XXXXX.XXX
C            ----       AND SO FORTH, FOR UP TO 10 SETS
C
C PRICES     1-9      ITH UNIT PRICE ASSUMPTION-PRODUCT ONE        XXXXX.XXX
C           10-18     ITH ANNUAL CHANGE IN UNIT PRICE
C                     ASSUMED FOR PRODUCT ONE                      XXXXX.XXX
C           -----       AND SO FORTH FOR ALL THREE PRODUCTS (ADDITIONAL
C                       CARDS OF OTHER SETS OF PRICE ASSUMPTIONS TO A
C                       MAXIMUM OF 20)
C
C FINAL      1-9      ITH FINAL VALUE ASSUMPTIONS                  XXXXX.XXX
C  VALUES   -----       AND SO FORTH FOR A MAXIMUM OF 25 (DO
C                       NOT USE IF TERM. CALC. IS PERPETUAL SERIES)
C
C TERMINAL   1-2      TERMINAL CODE (98-ANOTHER PROB. FOLLOWS
C                       99- AFTER THE FINAL PROBLEM)                       XX
C
```

VITA

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Final Exam: May 6, 1969

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MS in Forest Management from Michigan State University in 1966.

Biographical Sketch:

Born, March 29, 1943 in Elsie Michigan; Attended Elsie High School and graduated in 1961. Enrolled at Michigan State University in the fall of 1961, majoring in Forestry. Married in 1965.

Graduate Studies:

Economics, 36 credits
Statistics, 26 credits
Computer Science, 10 credits
Operations Research, 18 credits

Experience:

Forestry Aid - U. S. Forest Service, Wyoming, summer of 1962.
Forestry Aid - U. S. Forest Service, California, Summer of 1963.
Salesman at a retail lumber yard, summer of 1965.
Graduate Research Assistant with the Department of Forestry, Michigan State University, from 1965 to 1968.
Instructor in the Department of Forestry, Michigan State University during the fall of 1968 and the spring of 1969; teaching a 5-credit course in forest biometrics, and a 3-credit course in woodland forestry.

Member of:

Society of American Foresters, Sigma Xi, and Xi Sigma Pi.