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DEVELOPMENT AND FINANCIAL MERIT OF THREE WORKING PLANS FOR A SOUTHERN PINE FOREST

In the early years of the profession of Forestry in the United States the emphasis was primarily on the growing of timber crops. Only recently has it been recognized that there is no need of growing trees unless there is an adequate market for the product. In other words, Forestry, in order to justify its existence must be practical.

A timber operator who has been able to remain in business for any length of time has had to think in terms of dollars and cents, of costs and returns. He cannot be expected to adopt forestry practices merely to insure the presence of a stand of timber on the area fifty years hence when he will no longer be in business, nor to keep from offending someone's aesthetic sense with an unsightly denuded area. He will practice forestry only if it can be shown him that by doing so he will realize a larger return from his operation now or a short time in the future.

Methods have been developed by which forestry can be practiced without financial sacrifice on the part of the operator. These methods have not been widely publicized nor promoted and are not in general use. The leader in the development of these methods is Professor D. M. Matthews of the University of Michigan. The following discussion is an attempt to describe step by step the application of some of Professor Matthews' methods to the investigation of desirable forest practices on a given area. This paper is not intended to be an exhaustive treatise but a sample procedure which must be modified and adapted to new conditions every time it is applied.

DEVELOPMENT OF THE MANAGEMENT PLANS

The area under consideration is a tract of loblolly pine timber 30,000 acres in extent located on the Atlantic Coastal Plain. The tract is in one piece consisting of one entire township and portions of the township adjoining on the east. The terrain is level to gently rolling and there is a moderate amount of brush and reproduction on the ground.

As a first step in the development of a plan of management for the area a 10% cruise has been made. The data of the cruise were taken by 1 inch diameter classes. The average age of the dominant timber indicates a natural rotation of 60 years. The average site condition of the area is judged to be site index 90.

To be useful in working out a management plan, a cruise must present more than a mere estimate of volume. The forester must know the size classes present and the portion of the stand each represents. The cruise data are therefore presented as in Table I. Column 2 is developed by determining the average number of trees in each diameter class per plot or per forty and this put on an acre basis. Table I then represents an acre of average conditions for the entire tract.

(Table I on the following page)

Table I

1 Diameter Inches	2 No. of Trees	3 Basal Area Sq. Feet	4 Volume in Bd. Ft. per Tree	5 Total Vol. Bd. Ft.
6	6.2	1.215	-	-
7	5.7	1.522	20	114
8	9.2	3.211	36	331
9	9.5	4.199	41	390
10	10.2	5.559	57	581
11	8.5	5.610	76	646
12	9.4	7.380	100	940
13	8.1	7.468	127	1029
14	8.2	8.765	159	1304
15	6.0	7.362	196	1176
16	3.6	5.025	236	850
17	3.1	4.886	280	868
18	4.0	7.068	325	1300
19	1.9	3.740	373	709
20	1.2	2.618	424	509
21	1.0	2.405	477	477
22	0.8	2.112	535	428
23	0.4	1.154	590	236
24	0.4	1.258	655	262
25	0.3	1.022	715	215
26	0.4	1.474	780	312
27	0.2	0.795	850	170
28	0.2	0.855	930	184
29	0.2	0.917	990	198
Total	98.7	87.620	8,962	13,229

It is assumed that conditions on this area are uniform enough to permit one table to be used for the whole tract. This is frequently not the case. If wide variation in the type of timber, site, or stocking occur on an area, it may be broken down into smaller units such as a forty and a stand and stock table such as the above prepared for each such unit.

Column 3 of Table I is calculated by the use of an ordinary basal area table. Column 4 is prepared from information on average heights taken during the cruise and by the use of a local volume table. Column 5 is merely the product of Columns 2 and 4.

The regulation of cut on a managed forest is on the basis of time. That is, timber which has grown a certain length of time under known conditions (and therefore attained a certain size within limits) is cut during a given period. It is therefore desirable to transfer the data of Table I from a size basis to a time basis. This is done by the use of a control table. The first 2 columns of Table II represent such a control table. The last 4 columns are the application of the control to data in Table I.

TABLE II

Age Class	Basal Area Sq. Ft.	% of B.A.	Diameter Range	No. of Trees	B.A. Sq. Ft.	Volume Bd.Ft.
0-10						
11-20						
21-30	11.7	8.3	6-9	26.4	7.27	663
31-40	13.0	9.3	9-11	15.6	8.15	837
41-50	13.8	9.8	11-12	12.1	8.58	1032
51-60	14.1	10.0	12-13	10.2	8.76	1170
61-70	14.3	10.2	13-14	7.8	8.94	1164
71-80	14.6	10.4	14-15	7.8	9.12	1422
81-90	14.7	10.5	15-17	6.4	9.20	1559
91-100	14.8	10.5	17-18	5.4	9.20	1673
101-110	14.8	10.5	18-22	4.3	9.20	1785
111-120	14.8	10.5	22-29	2.7	9.20	1924
Total	140.6	100.0		98.7	87.62	13,229

The following is an illustration of the application of a control table to actual data.

87.62	total basal area of actual data
.083	% of basal area in 21-30 class of control table
7.27	sq. ft. of basal area of actual data should fall in the 21-30 age class

1.215	B.A. in 6" diameter class
1.522	" " 7" " "
3.211	" " 8" " "
5.948	

7.27-5.948 = 1.322 of the 9" class which will fall in 21-30 class.

4.199-1.322 = 2.877 of the 9" class will fall in 31-40 age class.

	6.2	trees in	6"	class
	5.7	" "	7"	class
	9.2	" "	8"	class
$\frac{1.322}{4.199} \times 9.5 =$ →	3.0	" "	9"	class
	24.1	trees in	21-30	age class

The last calculation above is repeated using volume instead of number of trees.

With the stand and stock table classified as to age classes the rotation and cutting cycle may be set up and the cutting area, age classes and volume to be cut may be calculated. The natural rotation of the stand was determined to be 120 years. By natural rotation is meant the average length of time in which a tree will grow to maturity and pass from the stand due to natural causes. During this time the tree is subject to many adverse conditions such as crowding or drought which slows its growth. It also may remain in the stand many years after it matures without being killed by insects or decay or thrown by the wind. Therefore, natural rotation indicates neither the length of time necessary to mature a tree nor the shortest time needed to grow a tree of a given size.

Loblolly pine grows quite rapidly and on the Atlantic coastal Plain will receive adequate moisture and a long growing season. Therefore, with a minimum of treatment it should reach a merchantable size long before 120 years. It has been known to grow ~~the~~ to a size of 18" in 80 years on similar sites and a rotation for purposes of management may be safely set at 60 years.

The cutting cycle is the period between cuts on the same area. Thus if the cutting cycle is 20 years, any given area will be logged once every 20 years or three times during a rotation of 60 years. The advantage of a long cutting cycle is a relatively heavy cut per acre over a small annual cutting area. This fact usually attracts the operator as it concentrates the operation. However, more age classes are cut on a long cutting cycle and therefore a wider range of diameters. This lowers the average diameter cut which in turn has a tendency to raise operating and hauling costs and decrease the average sales value of the product.

A short cutting cycle has just the opposite effect. A small cut per acre is taken from a large annual cutting area. However, it is in the larger diameter classes (older age classes) and therefore produces a large amount of high quality lumber as well as reducing costs which vary inversely as the size of material handled. The specific effects of long and short cycleson costs and plan of operation will be brought out as the costs under each plan are developed. Cutting cycles are usually an even fraction of the rotation and in this case three plans will be considered all on a 60 year rotation but one with a 20 year cutting cycle, one with 10, and one with a 5 year cutting cycle. Table III shows the age classes cut on each acre, the volume cut per acre, the annual cutting area, and the total annual cut for each plan.

Table III

Plan	Age Classes Cut	Cut per Acre Bd. Ft.	Annual Cutting Area Acres	Total Amt. Cut Bd. Ft.
60-20	81-120	6,941	1500	10,412
60-10	101-120	3,709	3000	11,127
60-5	111-120	1,924	6000	11,544

Planning the Operation

In order to determine which of the three plans under consideration will yield the greatest profit, the cost of logging under each plan must be forecast and compared. There may be other factors which will influence the decision in favor of one of the plans such as a large amount of decadent material to be salvaged or the length of the working season, but cost is the primary factor and should be considered first.

The planning of any operation depends on a knowledge of the cost of various processes in the operation and the factors which control these costs. Such costs must be more than historical costs, for historical costs are useful only when the new conditions are exactly the same as those applying to the historical costs. Unit costs must be developed which can be fitted together for any set of conditions and the true total cost found. Professor Matthews has done considerable work in developing such unit costs. The unit costs and formulae used in developing the total costs for the three plans under consideration have been taken from this source.

The first step in planning a logging operation for maximum economy is to break the operation down into individual units or processes. Logging may be divided into felling, bucking, prehauling, loading and hauling. For a given region the labor supply and wage standard are relatively fixed so that little control can be exercised over the cost of the felling and bucking process. Of course, reasonable care must be taken in hiring men, keeping tools in good condition, and providing adequate supervision. Loading also, once the type of equipment is decided upon, is difficult to control.

Prehauling and hauling must be planned and planned together if maximum economy is to be obtained. Cost of prehauling or skidding is a function of the distance to be skidded and this in turn varies with the spacing of the roads. The cost of hauling depends on the distance and the speed at which the hauling can be done. The speed varies with the road standard and this in turn affects the cost of road construction.

In this case the natural order of the processes is reversed and first consideration is given to hauling costs. The hauling costs used were developed in Northern Michigan and while they may not apply directly to this case they are the most accurate available and will serve to illustrate the procedure. The costs were developed on the following road classification.

Class I — Strip Roads - Bushed out, stumps cut low, little or no grading, rough, no alignment, creeper gear.

Class II — Poor Haul Roads - Brushed out, stumps cut low, hand graded with shovel and grubhoe, not smooth, more or less contour alignment, creeper and first gear.

Class III — Fair Haul Roads - Hand or machine graded, more or less contour alignment, gradient changing frequently but more favorable, fairly smooth if properly maintained, considerable first and second gear.

Class IV Good Haul Roads - Machine graded, drainage provided for, dirt surface, fair alignment and gradient, fairly smooth.

Class V Dirt and Poor Gravel - Fair alignment and gradients, about 20% second and first gear, surface smooth or rough depending on maintenance.

Class VI Good gravel - Good alignment and gradients, surface more or less even, nearly equal to hard surface roads.

Truck Operating Costs

$1\frac{1}{2}$ ton truck - Operating Year 2500 hours

Investment	
Chassis and Cab	$710.00
Freight	45.00
Tax	23.00
Rack	25.00
Overload springs	12.50
Oilbath aircleaner	3.25
Oil filter	3.75
Dual wheels and heavy duty tires	127.00
Gross Investment	$949.50
Less Tires (charged off on mileage)	237.00
Net Investment	$712.50
Trade in value after 2 years	150.00
Amount to be depreciated	$502.50
Fixed Cost Per Hour	
Driver's Wages	$ 0.40
Helper's Wages	0.30
Interest, license and insurance $210	0.042
Depreciation $\frac{562.50}{5000}$ hours	0.1125
Total	$ 0.8545

The cost of hauling per M.b.f. varies with the load carried. The average D.B.H. of the timber to be cut under each plan and the average load in board feet Doyle scale for $1\frac{1}{2}$ ton trucks is presented in Table IV. The loads used here are very conversative and introduce a margin of safety in the hauling cost calculations.

Table IV

Plan	Ave. D.B.H. of Timber Cut (inches)	Ave. Load of $1\frac{1}{2}$ ton Truck - bd. ft. Doyle Scale
60-20	19	1080
60-10	22	1250
60-5	26	1435

The calculation below demonstrates the determination of the operating cost for trucks operating on each class of road. The cost thus found is divided by the load in M.b.f. to find the hauling cost per M.b.f.

Operating Cost on Class VI Roads - average condition
(Loaded speed 24.1 m.p.h.; empty speed 31.15 m.p.h.)

	per hour (cents)	loaded per mile (cents)	empty per mile (cents)
Gas @ 20.7¢ L 9 mi. / gal; E 12.5 mi./gal		2.18	1.66
Oil @ 30¢ per qt. 9 qts. every 50 miles	5.40	0.22	0.17
Tires	25.00	1.04	0.80
Repairs $400	8.00	0.33	0.26
Greasing and Maintenance	1.17	0.05	0.04
Total Direct Operating Cost		3.82	2.93
Prorated fixed cost	85.45	3.54	2.74
Total fixed and operating cost		7.36	5.67

Average round trip speed 27 m.ph .

Cost per mile of round trip distance 13.034

Cost per 100' of round trip distance 0.25¢

Table V

Cost of Construction and Hauling Cost

Class of Road	Cost of Constr. per mi.$	60-20 Cost of Hauling Mi.-100' (cents)		60-10 Cost of Hauling Mi.-100' (cents)		60-5 Cost of Hauling Mi.-100' (cents)	
I	$50	131.16	2.5	105.3	2.0	94.7	1.8
II	150	73.69	1.4	59.0	1.17	53.1	1.01
III	300	43.06	0.82	34.4	0.66	31.0	0.59
IV	450	33.74	0.64	27.0	0.51	24.3	0.46
V	750	17.80	0.34	14.2	0.27	12.9	0.24
VI	1500	13.03	0.25	10.4	0.20	9.4	0.18

The construction costs were set after consultation with Mr. Frank Murray, superintendent of the University of Michigan, School of Forestry and Conservation forest properties, and Professor Matthews. They are believed to be reasonable and conservative.

With the data now available the proper standard for the primary or interior main logging road may be determined. Since the amount of timber hauled over such a road decreases as the road penetrates the timber tract, there is a tendency on the part of operators to decrease the standard also. In reality the decrease in the amount of timber hauled has little effect on the proper standard of road except very near the end of the road and thus, reducing the standard steadily from the start results in inefficiency and increased cost of hauling.

Any increase in cost of construction due to rise in road standard must be offset by at least an equal saving in hauling cost on the volume of timber to be moved. A definite amount of timber is tributary to each unit of road. The problem is to find the length of road necessary to bring sufficient timber over this road, the total saving on which will offset the increased cost of construction. The saving for any one unit of road will be the volume in M.b.f. on the area tributary to that unit of road; i.e., an area, one dimension of which is the unit distance of the road and the other the width of the timber tract, whether it extends on one or both sides of the road; times the reduction in hauling cost per M.b.f. obtained by the higher standard.

Each M.b.f. from the area tributary to the first unit of road will be hauled a distance of one unit, and each M.b.f. from the area tributary to the second unit of road will be hauled two units, and so on to the end of the timber tract. This constitutes an arithmetic progression and the formula for the sum of such a progression (which will give the total saving on the full length of the road) is $\frac{n}{2}$ (a plus na). Using S as the saving per unit and n as the number of units the formula becomes $\frac{n}{2}$ (S plus nS). For the same n units then will be an increase R in construction cost per unit and the total increase will be nR. If the total saving is to balance the total increase in cost the two may be equated and the formula becomes

$$nR = \frac{n}{2} (S \text{ plus } nS)$$

The quantity to be solved for is n or the number of units of road necessary to justify the added expenditure for road construction. The formula may be simplified as follows:

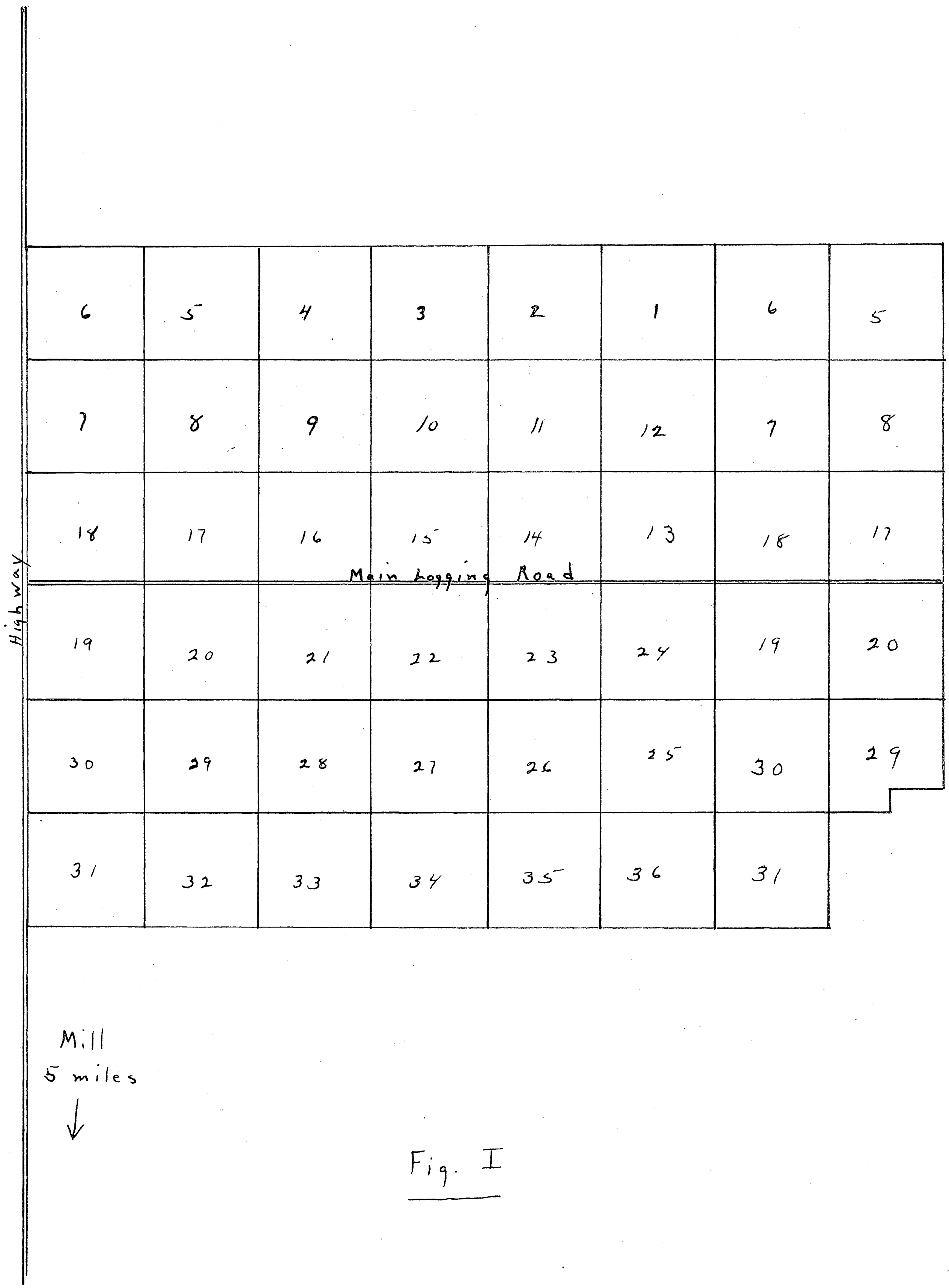

6
5
4
3
2
1
6
5
7
8
9
10
11
12
7
8
18
17
16
15
14
13
18
17
Main Logging Road
Highway
19
20
21
22
23
24
19
20
30
29
28
27
26
25
30
29
31
32
33
34
35
36
31
Mill
5 miles

Fig. I

dividing by n $R = \frac{1}{2}(S \text{ plus } ns)$

$$R = \frac{S}{2} \text{ plus } \frac{ns}{2}$$

$$n\frac{S}{2} = R - \frac{S}{2}$$

multiplying by 2 $ns = 2R - S$

$$n = \frac{2R - S}{S}$$

For the 60-20 plan with a cut of 7M per acre, Class V and VI road with construction costs of $750 and $1500 respectively and hauling costs per 100' unit of road of .34¢ and .25¢ respectively, may be compared as follows:

$\frac{100 \times 3 \times 5280 \times 2}{43560} \times 7 = 508.2$ M volume tributary to 100' of road.

Saving per unit $= 508\,(.34 - .25) = 45.72¢ = S$

Increase in cost of construction $= \frac{1500}{52.8} - \frac{750}{52.8} = 1420¢ = R$

$$n = \frac{2R - S}{S} = \frac{(2 \times 1420) - 45.72}{45.72} = 61.2;\ 100' \text{ units}$$

Therefore if the road is to be 6120' or longer CLass VI road is justified. A glance at the plat of the property (Fig. I) shows that the road will be 8 miles long which easily justifies CLass VI road.

Before the standard and the spacing of the secondary and tertiary logging road can be determined the equipment to be used for prehauling must be selected. With any type of equipment the cost of skidding a given distance is made up of a fixed and a variable cost. The fixed cost is set by the time necessary to accomplish certain acts such as unhooking the present load bringing the equipment into position for a new load and hooking it on, which must be done each round trip. Ordinary delays are also included in this fixed element. The variable cost varies with the distances the load must be skidded and the speed at which the skidding device moves. These cost elements for four types of skidding equipment are presented in Table VI. The first two and last columns are the result of direct field observation. The third column is the product of fixed time and the machine rate per minute. This machine rate is developed exactly the same as the machine rate for the truck previously described. Fixed cost per M.b.f. is found by dividing the fixed cost per turn by the load per turn in M.b.f.

Table VI

Device	Load per Turn M.b.f.	Fixed time per turn minutes	Cost of time per turn (cents)	Fixed Cost per M.b.f. (cents)	Variable Cost per 100' of hauling distance (cents)
			60-20 Plan		
Team	.235	7.75	9.3	39.6	12.0
D2 Tractor	.308	5.25	14.7	47.8	8.0
D4 Tractor	.434	7.25	24.4	56.2	6.7
D4 Sulky	.846	10.9	41.4	48.9	3.4
			60-10 Plan		
Team	.297	8.25	9.9	33.3	11.4
D2 Tractor	.366	4.5	12.6	34.5	6.5
D4 Tractor	.525	6.5	34.1	65.0	5.5
D4 Sulky	1.06	9.1	34.6	32.6	2.7

60-5 Plan

Team	.352	8.75	10.5	29.9	12.0
D2 Tractor	.422	4.0	11.2	26.6	5.6
D4 Tractor	.610	5.5	18.5	30.3	4.7
D4 and Sulky	1.27	7.7	29.3	23.1	2.3

It is clear from Table VI that in the 60-10 and 60-5 plans the D4 and Sulky unit is the cheapest both as to fixed cost and to variable cost. Of the equipment considered the D4 and Sulky is the logical choice for these two plans. However, in the 60-20 plan there are two pieces of equipment with lower fixed costs than the D4 and Sulky. Obviously as the skidding distance increases the larger the variable element becomes proportionally and the less effect a lower fixed cost will have on total skidding cost. In considering any two pieces of equipment, one with a high fixed and low variable cost and the other with a low fixed but high variable cost, there will be an output, or distance in this case, at which the total cost for that output will be the same for both pieces of equipment. Below this point the low fixed cost machine will be more economical and above the high fixed cost will be more efficient. This point is called the break-even point or distance.

If C = total cost at a given output, F = fixed cost. D-number of variable units (distance), and V = variable cost per unit (distance) then C = F plus D V .

Now if F' and V' represent the fixed and variable costs for a machine with a higher fixed cost but lower variable cost, the point at which the two will give the same total cost may be found by the equation F plus D V = F' plus D V' in which all elements are known except D. Then

$$D = \frac{F' - F}{V - V'}$$

Using this formula in choosing between teams and D4 and Sulkies or D2's and D4 plus Sulkies in the 60-20 plan, the break-even distance is found to be $\frac{48.9 - 39.6}{12 - 3.4} = 108$ feet for the first combination and $\frac{48.9 - 47.8}{8 - 3.4} = 24$ feet for the second. As the average skidding distance is practically certain to exceed 108 feet, it is safe to choose the D4 and Sulky for the 60 - 20 plan.

The construction of secondary and tertiary logging roads is mainly for the purpose of reducing the cost of the prehaul or skidding operation. This is desirable since skidding generally costs much more per unit distance than hauling. However, transportation is one of the major items in logging costs and the cost of prehaul and the transportation system frequently make up 50% of the total logging costs exclusive of supervision; therefore, costs of skidding should not be reduced at the expense of increasing total transportation costs. In order to prevent such an occurrence, three factors must be brought into balance, the cost of hauling on the roads, cost of constructing these roads, and the cost of skidding to the roads. The cost of hauling depends on the length of the haul and the standard of the road over which the haul is made. Cost of construction and skidding (when the standard of road and the skidding devise have been selected) vary with the spacing of the roads, the first inversely and the second directly.

If these latter two factors were to be considered by themselves, the formula for their combined cost would be $X' = C\frac{S}{4}$ plus $\frac{R/12.1}{VS}$ where X = total cost, C = Cost of skidding per volume unit per unit of distance, R = cost of road construction per mile, S = spacing of roads in the same unit distance as C, and V = volume per acre in the same unit as C. These distance and volume units are customarily 100' and M feet board measure respectively. The factors of this equation are logically derived since when roads are spaced a given distance apart, the maximum skidding distance is one-half the spacing and the average skidding distance one-half the maximum or one-fourth the spacing. If C = skidding cost per unit distance, then $C\frac{S}{4}$ = cost of the average turn. And again if R = cost of constructing one mile of road and roads are placed 100' apart, each road will serve $\frac{100 \times 5280}{43560} = 12.1$ acres. Then $\frac{R}{12.1}$ = cost of construction per acre. But if roads are placed 200' apart the area served will be just twice as great and the cost just half as much. Then $\frac{R/12.1}{S}$ = cost of construction per acre on any spacing S and the cost per M.b.f., when V = volume per acre, will be $\frac{R/12.1}{VS}$.

Since the cost of skidding varies directly as the spacing and the cost of road construction varies inversely as the spacing, there is some spacing at which these factors will be equal and this spacing will give the minimum total cost. If the ~~time~~ two factors are equal then $C\frac{S}{4} = \frac{R/12.1}{VS}$ and solving for S:

$$CS^2 = \frac{4\ R/12.1}{V} \quad \text{multiplying by 4 S}$$

$$S^2 = \frac{4\ R/12.1}{VC} \quad \text{dividing by C}$$

$$S = \sqrt{\frac{.33\ R}{VC}}$$

As was stated previously three factors, cost of road construction, cost of hauling, and cost of skidding must be kept in balance. The above formula for road spacing balances the first and third, but the second depends on the proper selection of road standards. In this case it is necessary to set a standard for both secondary and tertiary roads. Since it is difficult to handle two variables in one set of calculations, the standard of tertiary roads will first be considered fixed while the proper standard of secondary roads is determined. The operation of hauling on tertiary roads to secondary roads is comparable to skidding to tertiary roads, and if C is set equal to cost of hauling on tertiary roads, then the same formula $S = \sqrt{\frac{.33R}{VC}}$ may be used to determine the spacing of secondary roads.

The standard of tertiary roads is first considered fixed at Class I and the spacing for various classes of secondary roads calculated. The total cost of road construction, skidding, and hauling is then found by the formula $X = 2C\frac{S}{4}$ plus $H\frac{D}{2}$. Since $C\frac{S}{4} = \frac{R/12.1}{VS}$ then $2\,C\frac{S}{4} =$ ~~plus~~ $C\frac{S}{4} + \frac{R.12.1}{VS}$ (C in this being the cost of hauling on tertiary roads). $H =$ cost of hauling on secondary roads and $\frac{D}{2} =$ average haul for the depth of timber, D, which in this case is 3 miles. This process was repeated for class II and Class III tertiary road and the spacing and costs set forth in Table VII.

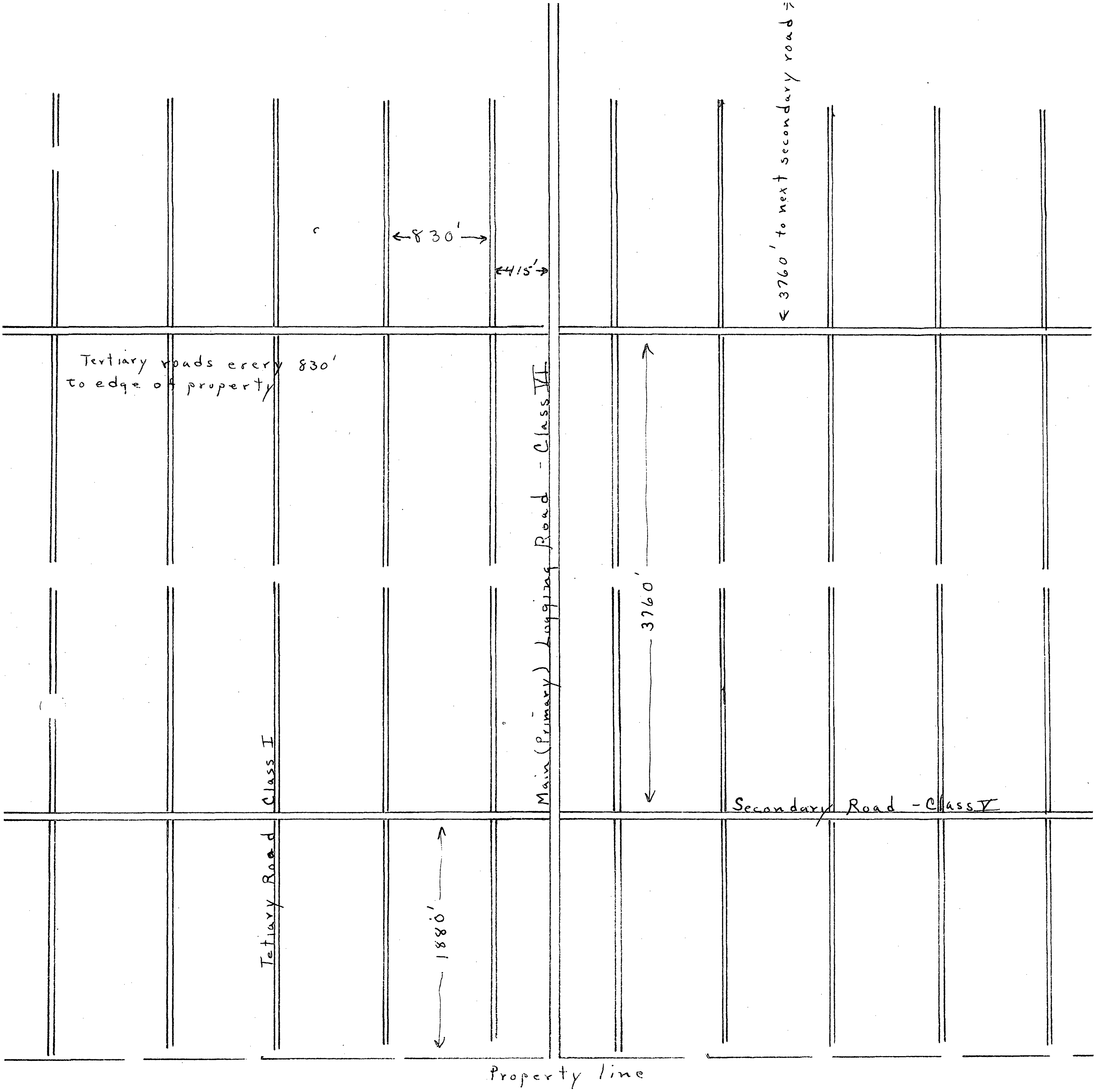
(Table VII on following page)

Table VII

Class of Secondary Roads		III Spac. (100' Units)	III Cost (cents)	IV Spac.	IV Cost	V Spac.	V Cost	VI Spac.	VI Cost
Plan 60-20	I	23.8	94.7	29.1	87.0	37.6	73.9	53.1	86.2
	II	32.0	87.4	38.5	77.6	50.3	62.1	71.0	69.5
	III	41.6	82.1	50.9	71.4	65.7	53.9	92.9	57.9
	IV	47.1	80.1	57.6	69.1	74.4	50.7	105.1	53.5
Class of Tertiary Roads — Plan 60-10	I	36.6	88.8	44.8	85.2	57.8	79.2	81.8	97.6
	II	47.8	80.1	58.6	74.7	75.6	65.6	106.8	78.3
	III	63.6	73.2	77.9	66.2	100.5	54.4	142.3	62.9
	IV	72.4	70.6	88.5	63.0	114.2	50.6	161.5	57.0
Plan 60-5	I	53.8	95.2	65.8	95.6	85.0	95.5	120.3	122.3
	II	71.7	82.9	87.9	80.8	113.3	71.2	160.5	95.0
	III	93.9	74.5	115.0	70.3	148.5	62.8	210.0	76.3
	IV	106.1	71.1	130.2	66.3	168.1	57.6	237.9	68.9

It is apparent that in each case a secondary road of Class V designation gives the lowest total cost except in the 60-5 plan where Class III is lower. However, as costs are so close, either class III or V could be used. This is then the economic standard for secondary roads.

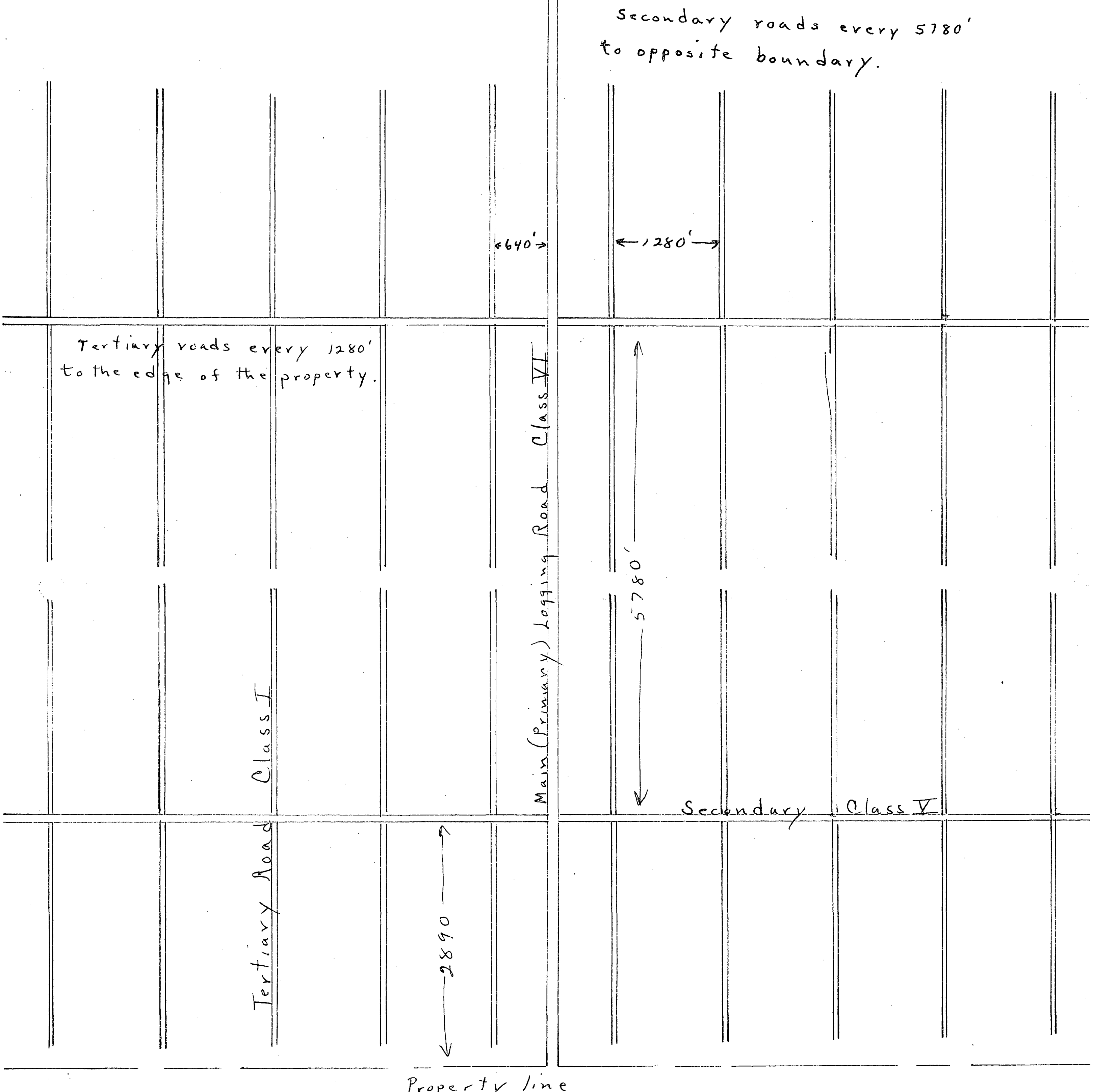
The spacing and total cost for various standards of tertiary roads are calculated. In this case H in the expression $H \frac{D}{2}$ is the hauling cost on tertiary roads and D is the spacing of Class V secondary roads for the class of tertiary road under consideration. The spacings and costs from these calculations are presented in Table VIII.



Road Layout - 60-20 Plan

Scale 1" = 1000'

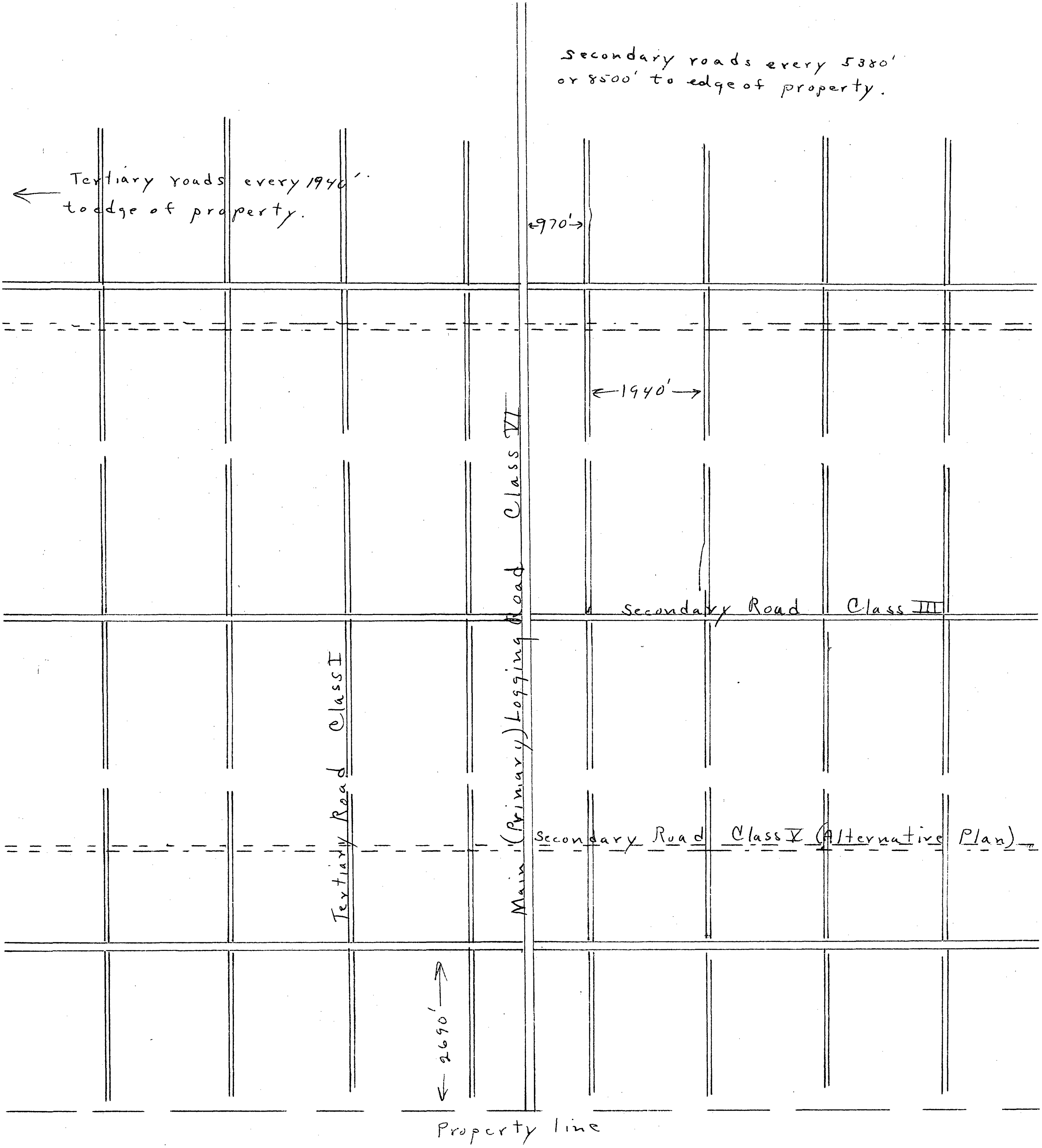
Fig. II



Road Layout 60-10 Plan

scale 1" = 1500'

Fig. III



Road Layout 60-5 Plan
Scale 1" = 2000'

Fig. IV

Table VIII

Plan	I Spac.	I Cost	II Spac.	II Cost	III Spac.	III Cost	IV Spac.	IV Cost
60-20	8.3	37.6	14.4	42.1	20.4	48.1	-	-
60-10	12.8	46.1	22.2	52.1	31.5	59.1	-	-
60-5	19.4	60.8	33.6	67.2	47.6	76.7	58.2	86.2
60-5	-	46.7	-	56.7	-	68.6	-	79.3

The results of these road standard determinations for each plan are:

	60-20 Plan	60-10 Plan	60-5 Plan
Class of Tertiary Rd.	I	I	I
Spacing of Tertiary Roads 100' units	8.3	12.8	19.4
Class of Secondary Rds.	V	V	III
Spacing of Secondary Roads (100' Units)	37.6	57.8	53.8

A schematic diagram of the road systems for each plan is presented in Figs. II, III, and IV.

With the logging equipment selected and the road system planned, total logging costs per M.b.f. at the edge of the timber tract may be calculated. These costs are tabulated in Table IX.

Table IX

Costs at Edge of Timber Tract

60-20		Cents
Felling and Bucking		62.0
Skidding Cost		
Fixed		48.9
Variable	$C\frac{S}{4}$ $\quad 3.4 \times \frac{8.3}{4}$	7.1
Loading	30 x (1.125 plus 1.423	76.5
Road Construction (Tertiary)	$\frac{R/12.1}{VS}$ $\quad \frac{5000/12.1}{6.94 \times 8.3}$	7.2
Hauling on Tertiary Roads	$H\frac{S'}{4}$ $\quad 2.5 \quad \frac{37.6}{4}$	23.5

Road Construction (Secondary)	$\frac{R'/12.1}{VS}$	$\frac{75000/12.1}{6.94 \times 37.6}$	23.7
Hauling on Secondary Roads	$H' \frac{D}{2}$	$.34 \times \frac{158.5}{2}$	26.9
Road Construction Primary	$\frac{R''}{V}$	$\frac{150000 \times 8}{208500}$	5.7
Hauling on Primary	$H' \frac{D'}{2}$	$13.03 \times \frac{S}{2}$	52.1
			333.6

60-10 Plan

Felling and Bucking			56.0
Skidding Cost			
Fixed			32.6
Variable	$C \frac{S}{4}$	$2.7 \times \frac{12.8}{4}$	8.6
Loading			76.5
Construction Tertiary Roads	$\frac{R/12.1}{VS}$	$\frac{500/12.1}{3.7 \times 12.8}$	8.7
Hauling on Tertiary Roads	$H \frac{S'}{4}$	$2.0 \quad \frac{57.8}{4}$	28.9
Construction Secondary Roads	$\frac{R'/12.1}{VS'}$	$\frac{75000/12.1}{3.7 \times 57.8}$	29.0
Hauling on Secondary Roads	$H' \frac{D}{2}$	$.27 \times \frac{158.5}{2}$	21.4
Construction Primary Road	$\frac{R''}{V}$	$\frac{150000 \times 5}{111000}$	10.8
Hauling on Primary Road	$H'' \frac{D'}{2}$	$10.4 \times \frac{8}{4}$	41.6
			314.1

60-5 Plan

Felling and Bucking			55.0
Skidding			
Fixed			23.1
Variable	$C \frac{S}{4}$	$2/3 \quad \frac{19/4}{4}$	11.2
Loading			76.5
Construction Tertiary Roads	$\frac{R/12.1}{VS}$	$\frac{5000/12.1}{1.9 \times 19.4}$	11.2

Hauling on Tertiary Roads	$H \frac{S'}{4}$	$1.8 \times \frac{53.8}{4}$	24.2
Construction Secondary Roads	$\frac{R'/12.1}{VS'}$	$\frac{30000/12.1}{1.7 \times 53.8}$	24.3
Hauling on Secondary Roads	$H' \frac{D}{2}$	$.59 \; \frac{158.5}{2}$	46.7
Construction Primary Road	$\frac{R''}{V}$	$\frac{150000 \times 8}{57000}$	21.1
Hauling on Primary Road	$H'' \frac{D'}{2}$	$9.4 \; \frac{8}{2}$	37.6
			310.9

Felling and bucking costs were taken from Professor Matthews text, P. 316. Loading cost was calculated from loading time data found in Principles of Forest Industry Economy by Professor Matthews. Fixed time was charged for the truck and a machine rate for the team, driver, and tackle used in loading. The method in this case was assumed to be cross haul where logs could be loaded at any point along the tertiary roads. The methods used to calculate skidding, road construction and hauling cost were those previously discussed.

In the case of the 60-5 plan of ~~8500', the cost of~~ class V secondary roads were used on a sparing of 8500', the cost of hauling on tertiary roads, construction of secondary roads, and hauling on secondary roads would have been 95.5¢ instead of 95.2¢ using Class III secondaries on a spacing of 5380'. While the cost of hauling on tertiary roads and constructing secondary roads is increased by using Class V, the hauling cost on secondary roads is enough less to offset this increase.

It is interesting to note that reducing the cutting cycle from 20 to 10 years brings about a decrease of 9.5¢ per M in logging cost and that again splitting the cutting cycle in half brings about an additional saving of 3 cents. The reason for this reduction in total cost may be found by examining each item which makes up the total with reference to what change brought about by the change in management plan affected that item.

Felling and bucking was reduced because a crew can fell and buck a large volume of large timber in a given time than they can small timber. This effect is, in a measure, offset by increased lost time in walking from the tree just finished to the next tree to be felled. In the 60-5 plan this latter effect so nearly offsets the first that the reduction is only one cent per M.b.f.

Fixed cost of skidding is again a function of the size of the timber. Within the power limit of the equipment a greater amount of large timber can be skidded per load than small timber. This reduction continues through all three plans reducing the cost one third in the 60-10 plan and one half in the 60-5 plan. The variable skidding cost, as has been stated before, is a function of the distance to be skidded and its rise may be explained in this manner. As the cutting cycle is shortened the number of age classes taken is reduced. This reduces the volume cut per unit area. From the road spacing formula $S = \sqrt{\frac{.33R}{VS}}$ it is evident that road spacing varies inversely with volume. A reduction in volume will therefore drive roads further apart. Finally as roads are placed further apart, variable skidding cost is increased.

Cost of constructing tertiary roads determined by the formula $\frac{R/12.1}{VS}$ also varies inversely as volume and since it was set equal to the variable skidding cost, $C\frac{S}{4} = \frac{R/12.1}{VS}$, it increases at the same rate as this cost. As has been explained before hauling on tertiary roads and construction of secondary roads have the same relationships as skidding and construction of tertiary roads and their costs are subject to variation by the same factors. These costs, therefore, rise for the same reason as variable skidding and tertiary road construction costs. However, in the case of hauling on tertiary roads the hauling cost is reduced because more board feet of large logs can be carried in one load than if the logs are small.

This same effect unopposed by any increase in distance to be hauled is responsible for the reduction in cost of hauling on secondary roads and on the primary or main logging road. Since the total cost of constructing the main logging road remains the same for all three management plans, but the total cut from the area which must carry this cost is reduced, the cost per M.b.f. for constructing the primary logging road increases as the cutting cycle is reduced.

Inasmuch as the total logging cost per M.b.f. is reduced as the cutting cycle is shortened, it is obvious that the decreases in cost of felling and bucking, fixed skidding, and hauling on primary and secondary roads must be greater than the increases in variable cost of skidding, and cost of all road construction and hauling on tertiary roads. It is logical to assume, therefore, that the effect on cost of size of material handled is greater than that of area covered in operation.

From the costs thus far determined it appears that the 60-5 plan is slightly more economical than the 60-10 plan and considerably more so than the 60-20 plan. These costs are only direct logging costs necessary to get the logs to the edge of the property. The cost of hauling to a mill and certain indirect costs have yet to be taken into account. In addition to this, the fixed investment and depreciation on that investment will add to the expense of doing business and, if the mill is under the same ownership, these calculations must be extended to include it.

In figuring the amount of the fixed investment it is necessary to know the amount of equipment needed. For the tractor and sulky unit this was done by dividing the time per turn as it was found it developed a machine rate for this equipment into the working time per day which gives the number of turns per day. This figure times the load per turn gives the daily output for one unit. Since the annual cut is known the daily cut can be determined by dividing the annual cut by the number of working days per year. In this case 250 was chosen as a reasonable figure. This makes some allowance for shut-downs. The ~~faily~~ average cut per day divided by the daily output per unit determines the number of units needed. In no case should this be less than 2, as all equipment must be repaired and maintained and this cannot be accomplished without interrupting the whole operation unless extra equipment is available. This extra equipment will in a measure increase the life of the machine it relieves and provide a certain amount of flexibility in the operation, thus justifying its added cost.

A similar method is used for determining the number of trucks needed. In order to calculate hauling costs on various classes of roads it was necessary to find the average speed of trucks traveling in each class. From the road layouts (Figs. II, III, and IV) the average hauling distance over each class of road can be determined. Average speed times the average round trip distance gives the average time to traverse each class of road; these added together plus the loading and unloading time give the time per trip. In this case, a 5 mile haul to the mill over a Class VII highway was assumed. Trips per day, and output per day are calculated as for the tractor and sulky. And from the daily output and daily cut the units required is determined. The calculations of equipment needed follow:

60-20 Plan

Tractors:

Fixed per turn time	11 Min.
Ave. Haul $\frac{8.3}{4}$ = 2 plus min. times speed (100' per min.)	2 "
Total per turn time	13 Min.

$\frac{8 \times 60}{13}$ minutes per day = 36 plus trips per day

36 x .846 M per turn = 31 M. per day

$\frac{\text{Annual cust } 10500 \text{ M}}{\text{Working days } 250}$ = 42 M. per day

$\frac{42}{31}$ = 2 tractor and sulky units needed.

Trucks:

3760' on Class I roads @ 184' per minute =	20.5 Min.
$\frac{2(4.15 \text{ plus } 158.4)}{2}$ = 16260' on Class V roads @ 1630' per min. =	10.0 "
$\frac{2(18.8 \text{ plus } 422.4)}{2}$ = 44120' on Class VI roads @ 2380' per min. =	18.5 "
10 miles on Class VII highway at .51 mi. per min. =	19.6 "
Loading time	30.0 "
Unloading time	15.0 "
Time per trip	113.6 "

$\frac{8 \times 60}{114}$ - 4. plus trips per day x 1.08 M. per trip - 4.5 M. per day

$\frac{42\ M}{4.5\ M}$ - 10 trucks allowing 2 for "extras", 12 trucks are needed.

60-10 Plan

Tractor and Sulky: Cut per day - $\frac{11127}{250}$ - 44.5 M.

Fixed time per turn - 9.1 min. $\frac{480}{12.3}$ - 39 turns
Variable time $\frac{12.8}{4}$ x 1 - 3.2 "
Per turn time - 12.3 "

$\frac{44.5M}{41.4M}$ - 1 plus 1" extra" - 2 Tractor & Sulky Units.

39 x 1.06 M. per turn -- 41.4 M. daily output

Trucks:

5780' on class I roads @ 184' per min.	-	31.5 Min.
2($\frac{6.4 \text{ plus } 158.4}{2}$) - 16480' on Class V roads @ 1630' per min.	-	10.1 "
2($\frac{28.9 \text{ plus } 422.4}{2}$) - 25120' on Class VI roads @ 2380' per min	-	19.0 "
10 miles on Class VII highway @ .51 Mi. per min.	-	19.6 "
Loading time	-	30.0 "
Unloading time	-	15.0 "
Per trip time		125.2 "

$\frac{480}{125}$ - 4 trips per day x 1.25 M. per trip - 5M daily output

$\frac{44.5}{5}$ - 10 plus 2 "extras" -- 12 trucks needed.

60-5 Plan

Tractors & Sulkies: $\frac{11,544\ M}{250}$ - 46.2 M. daily production

Fixed time per turn - 7.7 Min.
Variable time - $\frac{19.4}{4}$ x 1 - 4.9 " $\frac{480}{12.6}$ - 38 turns per day
Per turn time - 12.6 "

38 x 1.27 M. per turn - 48.3 M. per day

$\frac{46.2\ M.}{48.3\ M.}$ - 1 plus 1 "extra" - 2 Tractor and Sulky units needed.

Trucks:

5380' on Class I roads @ 184' per min.	=	29.3 Min.
$\frac{2(9.7 \text{ plus } 158.4)}{2}$ = 12800' on Class III roads @ 670' per min.	=	19.1 "
$\frac{2(26.9 \text{ plus } 422.4)}{2}$ = 44920' on Class VI roads @ 2380' per min.	=	18.9 "
10 miles on class VII highway @ .51 Mi. per Min.	=	19.6 "
Loading	=	30.0 "
Unloading	=	15.0 "
Trip time	=	131.9 "

$\frac{480}{132}$ = 3 trips per day x 1.435 M. per trip = 4.3 M per day

$\frac{46.2}{4.3}$ - 11 plus 1 "extra" = 12 trucks needed.

Other fixed Investments besides tractors, sulkies, and trucks are other logging equipment such as teams, tackles, etc., logging camps, the sawmill, planing mill, drying yards, kilns, etc. and the working capital. In this case an arbitrary figure of $2500 was set as the cost of a logging camp and it is expected to serve about 8000 acres. The figure for sawmill plant and equipment is also arbitrary. Working capital is the money needed to run the business until an income is realized. In a going concern this is largely inventory. In the case under consideration it should be figured on the average yard inventory times the cost of production per M. This would be about 1/3 of the annual cut times the production costs under each plan but $50,000 was taken as an average figure.

Investment Schedule

Camps - life $\frac{8040}{1500}$ = 5 years			$2,500
Logging equipment			
2 D4 and sulky units @ $4000		$8000	
12-1½ ton trucks @ $700	8400 -		
Salvage value @ 150	-1800	6600	
Other equipments		6500	21,100
Plant and Equipment			200,000
Working Capital			50,000
			$273,600

The annual burden which this investment places on the business may now be calculated. The formula used is:

$$\text{Annual Burden} = \frac{I}{M} \text{ plus } I \left(\frac{.oP}{2}\right) \frac{n \text{ plus } 1}{n}$$

I = initial investment
n = life of the investment
.op = interest rate desired on the investment usually the rate the business as a whole is expected to earn.

The annual burden thus calculated consists of $\frac{1}{n}$ part of the original investment which over n years will return the investment, plus interest on the average investment. This last factor is developed logically from the formula for the average investment on an investment which has no residual value, A.I. $= \frac{I\,(n \text{ plus } 1)}{2\,n}$, which multiplied by the interest rate .op is rearranged in the form $I \left(\frac{.op}{2}\right) \frac{n \text{ plus } 1}{n}$. If the investment has a residual value the amount to be depreciated becomes I - R (the residual value) and the whole formula

$$\frac{I - R}{n} \text{ plus } I\text{-}R \left(\frac{.op}{2}\right) \frac{n \text{ plus } 1}{n} \text{ plus } .opR$$

The last factor is added since while the residual value is returned at the end of the life of the investment, it is tied up during that period and should return interest.

Since capital recovery has been taken into account in developing the machine rate for the trucks and tractor and sulky units, these need not be considered further. Working capital is recovered at the end of operations hence only interest need be charged on it. Calculations of the annual burden under each of the three plans is as follows:

60-20 Plan

Camps $\frac{2500}{5}$ plus $2500 \left(\frac{.08}{2}\right) \frac{6}{5}$ =	\$ 620
Logging Equipment $\frac{6500}{5}$ plus $6500 \left(\frac{.08}{2}\right) \frac{6}{5}$	1,612
Plant and Equipment $\frac{200,000}{30}$ plus $200,000 \left(\frac{.08}{2}\right) \frac{31}{30}$	14,927
Working Capital 50,000 x .06	3,000
	\$20,159

$\frac{20159}{10500\text{ M}}$ = \$1.92 per M.

60-10 Plan

Camps $\frac{2500}{3}$ plus $2500 \left(\frac{.08}{2}\right) \frac{4}{3}$ =	\$ 967
Logging Equipment	1,612
Plant and Equipment	14,927
Working Capital	3,000
	\$20,506

$\frac{20506}{11,127\text{ M}}$ = \$1.85 per M

60-5 Plan

Camps $\frac{2500}{1.5}$ plus $.2500 \left(\frac{.08}{2}\right) \frac{2.5}{1.5}$ =	\$ 1,834
Logging Equipment	1,612
Plant and Equipment	14,927
Working Capital	3,000
	\$21,373

$\frac{21373}{11544\text{M}}$ = \$1.85 per M

The 8% interest rate used consists of 6% expected return from the business and 2% allowance for taxes and insurance.

It is now possible to make a complete cost estimate, including hauling cost from property to mill; depreciation (annual burden); camp and logging supplies; scaling, supervision, etc.; road maintenance (the last three are grouped as other woods costs); sawmill operation, general expense (main office, selling force, etc.); and lumber taxes, insurance and selling expense. All these items except hauling cost, depreciation, and road maintenance were taken from Matthews, "Management of American Forests" page 316. Hauling cost was determined similarly to that for interior logging roads, and road maintance was figured as 10% of the cost of construction for primary and secondary roads. It is believed that tertiary roads would hold for their own period of use and then have to be rebuilt at the time of the second cut.

Cost Estimate

	60-20	60-10	60-5
Direct Logging Costs	$3.34	$3.14	$3.11
Other Woods Costs	2.04	1.88	1.74
Hauling from property to Mill	.54	.47	.41
Sawmill operation	4.14	3.80	3.58
General Expense	1.80	1.70	1.64
Lumber taxes, insurance & selling exp.	1.51	1.51	1.51
Depreciation	1.92	1.85	1.85
	$15.29	$14.35	$13.84

When all costs are taken into account the economy of the short rotation is somewhat more striking, but there is still another factor to be considered in getting a true picture of the relative merits of the plans, that is average value of the product obtained under each plan. These values were obtained by finding a weighted average using volumes by diameter class in Table I and values of lumber cut from trees of various sizes (1931 prices) from Matthews, "Management of American Forests" page 369.

(table on following page)

Calculation of Average Value Per M

Diameter Class (in DBH)	Volume f.b.m.		Value $ per M	Weighted Average 60-20	60-10	60-5
15	223		$20.50	$4.57		
16	850		20.73	17.60		
17	868		21.11	18.30		
18	1300	.9	21.53	28.00	$0.19	
19	709		22.14	15.68	15.68	
20	509		22.77	11.59	11.59	
21	477		23.46	11.40	11.40	
22	428	347	24.10	10.30	10.30	8.36
23	236		24.70	5.83	5.83	5.83
24	262		25.21	6.61	6.61	6.61
25	215		25.71	5.53	5.53	5.53
26	312		26.12	8.15	8.15	8.15
27	170		26.43	4.49	4.49	4.49
28	184		26.78	4.92	4.92	4.92
29	198		27.02	5.35	5.35	5.35
	6941	3709	1924	$158.32	$90.04	$49.24
				÷ 6.941	÷ 3.709	÷ 1.924
				$22.82	$24.23	$25.60

Since as the cutting cycle is shortened, large logs are taken and more high grade lumber can be cut from these logs, the average value of the lumber cut increases. This, together with decreasing costs, increases greatly the advantage of the short cutting cycle.

Plan	60-20	60-10	60-5
Value of Product	$22.82	$24.23	$25.60
Cost of Production	15.29	14.35	13.84
Net to carry taxes, interest on indebtedness and profit	$ 7.53	$ 9.88	$11.76

With an advantage of more than $4 over the 60-20 plan and more than $2 over the 60-10 plan, the 60-5 plan appears to be by far the most economically desirable. However, any operator considering the working of this tract of timber would want to know how much money he would have to have available to start operations. This also is important since it determines the amount of capital which must be borrowed and therefore the amount of interest which must be paid on this capital.

In determining the initial investment the amount of road which would have to be built annually was calculated by the formula $\frac{\text{annual cutting area}}{12.1S}$. As has already been shown, one mile of road on a spacing of 100' would serve 12.1 acres. The area served increases directly with spacing. Therefore 12.1S gives the area served by one mile of road on any spacing S, and this divided into the annual cutting area equals the number of miles of road needed annually.

Initial Investment

Plan		60-20		60-10		60-5
Roads-Primary	0.4 Mi.	$ 600	0.8 Mi.	$ 1,200	1.6 Mi.	$2,400
Secondary	3.3 "	2,470	4.3 "	3,230	9.2 "	2,760
Tertiary	14.9 "	745	19.4 "	970	25.6 "	1,280
Camps		2,500		2,500		2,500
Logging Equipment		21,100		21,100		21,100
Plant & Equipment		200,000		200,000		200,000
Working Capital		50,000		50,000		50,000
		$ 277,415		$279,000		$280,040

It is apparent that the initial investment does not vary materially for the three plans and even an individual with no great source of capital would not have to borrow over $275,000. The methods by which this sum might be procured will not be considered here. It could be done by an ordinary mortgage loan, thru a bond issue, or by interesting some individual or group with sufficient capital in becoming part owners of the operation for use of the capital. In subsequent calculations it has been decided that no matter how the sum is procured an allowance for 6% interest on it will have to be made.

It is a recognized principle in economics that capital value depends on income. As a final step in considering this property and the three methods of managing it, the prospective income should be calculated and the capital value of the property under each plan determined. In doing this two additional items of expense have been included - taxes at the rate of 50¢ per acre per year and interest on borrowed capital. These are two necessary expenses of doing business which have not been allowed for previously.

In finding the present worth of the income for the first cutting cycle, the net annual income has been multiplied by the number of years in the cutting cycle and a valuation factor derived from the compound interest formula for the future value of series of equal annual incomes discounted back to the present has been applied. This gives the value at 4% which is taken to be the risk free interest rate.

The cut for the second cycle is determined by projecting the stand as presented in the stand and stock table (Table I) through one cutting cycle of growth by Reynolds' method of growth prediction. The average diameter of the material to be cut during the second cutting cycle is calculated and the cost estimate and the average value of the product produced are revised slightly according to the change in diameter. It is assumed that annual income during the second cutting cycle can be maintained indefinitely. Therefore this income may be capitalized by dividing by the risk free interest rate and this capitalized value discounted back to the present using this same interest rate. The present value of the first cutting is added to this value and a factor of safety applied. The purpose of this factor of safety is to reduce the value of the property by an amount equitable for the risk of loss of capital involved. The risk in this case is assumed to be equal to a 30% reduction in the appraised value or a safety factor of .7.

The method just outlined assumes that the $275,000 indebtedness is continually refinanced. If, however, it is desired to retire this indebtedness over a 10 year period during the second cycle for example, a certain sum can be set aside each year and be reinvested in the business so that earning at the same rate as the business it will equal $275,000 at the end of the 10 years. This sum which must be set aside annually is equal to the principle times the compount interest factor $\frac{.op}{1.op^{n}-1}$ in this case $\frac{.06}{1.06^{10}-1}$. During this time, however, interest still must be paid on the principle. Thus, for the 10 years during which the debt is to be retired the annual income will be reduced by $275,000 \times \frac{.06}{1.06^{10}-1}$ in addition to the regular interest payment. The income during this period must be capitalized in the same manner as that of the first cutting cycle. After the debt is retired the annual income will increase by the amount formerly set aside for amortization and this income may be treated as a permanent income.

Income Sheet

The 60--20 Plan - 1st Cutting Cycle

Gross Income 10,500M @ $22.82 -		$240,000
Operating Expenses (including depreciation)		
10,500M @ $15.29 -	$160,000	
Taxes @ 50¢ per acre	15,000	
Interest on indebtedness 275,000 x .06	16,500	192,100
Net Annual Income		$47,900
		20
Total Income 1st C.C.		$958,000
Valuation Factor @ 4%		.6795
Present worth at 4%		$658,000

Stand 2nd C.C.

Age Class	Volume	Range	Ave.D.B.H.	Value	Ave. Value
81-90	1648	17"	33.15	$21.11	$41.20
91-100	1700	17"-18"	33.95	21.53	40.40
101-110	1743	18"-19"	36.90	22.14	42.90
111-120	1786	19"-20"	22.10	22.77	25.10
			126.10		149.60
		÷	6.877	÷	6.877
			18" Ave. D.B.H.		$21.75 Ave.Value

Cost Estimate

Direct Woods Costs	$3.40
Other Woods Costs	2.11
Hauling from Property to mill	.56
Sawmill operation	4.24
General Expense	1.83
Lumber Taxes, insurance, selling expense	1.51
Depreciation	1.92
	$15.57

STAND 2nd C.C.

Age Class	Volume	Range	Ave. D.B.H.	Value	Ave. Value
81-90	1648	17"	33.15	$21.11	41.20
91-100	1700	17"-18"	33.95	21.53	40.40
101-110	1743	18"-19"	36.90	22.14	42.90
111-120	1786	19"-20"	22.10	22.77	25.10
			126.10		149.60
		÷	6.877	÷	6.877
			18" Ave. DBH		$21.75 Ave.Value

Cost estimate

Direct Woods Costs	$3.40
Other Woods Costs	2.11
Hauling from Property to Mill	.56
Sawmill operations	4.24
General Expense	1.83
Lumber, taxes, insurance, selling expenses	1.51
Depreciation	1.92
	$15.57

Income sheet
60-20 Plan - 2nd Cutting Cycle

Gross Income 10,300 M @ $21.75		$224,100
Operating Expenses (including depreciation)		
10,300 M @ $15.57	$160,200	
Taxes	15,000	
Interest on indebtedness	16,500	191,700
Net annual income		$ 32,400

Capitalized @ 4% $\frac{32400}{.04}$ = $810,000

Discounted to present $\frac{810,000}{1.04^{20}}$ = $370,000

Value 1st C.C. income	658,000
Total safe rate value	$1,028,000
Safety factor	.7
Present Worth of the property	$ 719,600

If Indebtedness is Retired in 1st 10 years of 2nd Cutting Cycle

Gross Income 10,300 M @ $21.75		$224,100
Operating Expenses	$160,200	
Taxes	15,000	
Interest on Indebtedness	16,500	
Amortization of Indebtedness $275,000 \times \frac{.06}{1.06^{10} - 1} =$	20,900	212,600
		$11,500
		10
Total income 1st 10 years 2nd C.C.		$116,000
Valuation factor		.811
Value at beginning of 2nd C.C.		$ 93,250

Discounted to present $\frac{93250}{1.04^{20}} = \$42,500$

Gross Income		$224,100
Operating Expenses	$160,200	
Taxes	15,000	175,200
Net annual income 2nd 10 years, 2nd C.C.		$ 48,900

Capitalized @ 4% $\frac{48900}{.04} = \$1,222,500$

Discounted to present $\frac{1222500}{1.04^{30}} =$	$377,000
Value of 1st 10 years 2nd C.C.	42,500
Value of 1st C.C.	658,000
Total safe rate value	$1,077,500
Factor of Safety	7
	$ 764,250

Income Sheet
The 60-10 Plan - 1st Cutting Cycle

Gross Income 11,127 M @ $24.23		$270,000
Operating Expenses (including depreciation) 11,127 M @ $14.35	$159,600	
Taxes @ 50¢ per acre	15,000	
Interest on indebtedness $275,000 x .06	16,500	191,100
Net annual income		$ 78,900
		10
Total income 1st C.C.		$789,000
Valuation Factor		.811
Present Worth at 4%		$640,000

Stand 2nd C.C.

Age Class	Volume	Range D.B.H.		Value	
91-100	2220 b.f.	18"-19"	59.4	21.53	69.50
101-110	2310 "	19"-21"	58.8	22.14	68.60
			74.0	22.77	84.30
			29.4	23.46	32.80
			221.6		254.20
			÷ 11.5		÷ 11.5
			19" Ave.D.B.H.		$22.13 Ave. Value

Cost Estimate:

Same as for 60-20 plan since Ave. D.B.H. is same.

Income Sheet

The 60-10 Plan - 2nd Cutting Cycle

Gross Income 13,600 M @ $22.13 =		$301,000
Operating Expenses (including depreciation)		
13,600 M @ $15.29 =	$207,800	
Taxes @ 50¢ per acre	15,000	
Interest on indebtedness	16,500	239,300
Net annual income		$ 61,700

Capitalized @ 4% $\frac{61700}{.04}$ = $1542500

Discounted to present $\frac{1542500}{1.04^{10}}$ = $1,042,000

Value of 1st C.C. income	640,000
Total safe rate value	$1,682,000
Factor of safety	.7
Present worth of property	$1,177,400

If Indebtedness is Retired During 2nd Cutting Cycle

Gross Income		$301,000
Operating Expenses	$207,800	
Taxes	15,000	
Interest on indebtedness	16,500	
Amortization of indebtedness $275,000 x $\frac{.06}{1.06^{10}-1}$ =	20,900	260,200
Net annual income during 2nd C.C.		$40,800
Total income 2nd C.C.		408,000
Valuation factor		.811
Value at beginning of 2nd C.C.		$330,600

Discounted to present $\frac{330,600}{1.04^{10}}$ = $223,500

Gross Income 3rd C.C.		$301,000
Operating Expenses	$207,800	
Taxes	15,000	222,800
Net annual income 3rd C.C.		$ 78,200

Capitalized at 4% $\frac{78200}{.04}$ = $1,955,000

Discounted to present $\frac{1955000}{1.04^{20}}$ = $893,000

Value of 2nd C.C. income	223,500
Value of 1st C.C. income	640,000
Total safe rate value	$1,756,500
Factor of Safety	.7
Present worth of property	$1,229,550

Income Sheet
60-5 Plan - 1st Cutting Cycle

Gross Income 11,544 M @ $25,600		$295,600
Operating Expenses (including depreciation 11544M A $13.84 =	$159,800	
Taxes	15,000	
Interest on indebtedness	16,500	192,300
Net annual income		$103,300
		5
Total income 1st C.C.		516,500
Valuation factor		.8905
Present worth at 4%		$459,000

Stand - 2nd Cutting Cycle

Age Class	Bd.Ft. Volume	Range D.B.H.		Value	
106-115	2,345	20'-23'	7.24	$22.77	$8.24
			6.71	23.46	7.49
			5.54	24.10	6.09
			1.54	24.70	1.65
		Ave. D.B.H.	21.03"	Ave. Value	$23.47

Cost Estimate:

Direct Woods Costs	$3.20
Other Woods Costs	1.94
Hauling - property to mill	.47
Sawmill operation	3.89
General expense	1.73
Lumber, taxes, insurance & selling exp.	1.51
Depreciation	1.85
	$14.59

Income Sheet
60-5 Plan - 2nd Cutting Cycle

Gross Income 14,070 M @ $23.47 -		$330,000
Operating Expenses (including depreciation) 14,070 M @ $14.59 -	$205,200	
Taxes	15,000	
Interest on indebtedness	16,500	236,700
Net annual income 2nd C.C.		$ 93,300

Capitalized @ 4% $\frac{93,300}{.04}$ = $2,332,500

Discounted to present $\frac{2332500}{1.04^5}$ = $1,918,000

Value of 1st C.C. income	459,000
Total safe rate value	$2,377,000
Factor on Safety	.7
Present worth of property	$1,663,900

If Indebtedness is Retired During 2nd and 3rd Cutting Cycles

Gross Incomes		$330,000
Operating Expenses	$205,200	
Taxes	15,000	
Interest on Indebtedness	16,500	
Amortization of Indebtedness	20,900	257,600
Net annual income for 2nd & 3rd C.C.		$ 72,400
Total income for 2nd & 3rd C.C.		724,000
Valuation factor		.811
Value at beginning of 2nd C.C.		$580,000

Discounted to present $\frac{580000}{1.04^5}$ = $477,000

Gross Income 4th C.C.		$330,000
Operating Expenses	$205,200	
Taxes	15,000	220,200
Net annual income		$109,800

Capitalized at 4% $\frac{109800}{.04}$ = $2,745,000

Discounted to present $\frac{2745000}{1.04^{15}}$ =	$1,522,000
Value of 2nd & 3rd C.C. income	477,000
Value of 1st C.C. income	459,000
Total safe rate value	$2,458,000
Factor of Safety	.7
Present worth of property	$1,720,600

Present Worth of Property

	60-20	60-10	60-5
Continual Refinancing	$719,600	$1,177,400	$1,663,900
Retiring Indebtedness	764,250	1,229,550	1,720,600

From the standpoint of highest value of product, lowest cost of production, and largest capital value at no greater initial expense it is clear that financially the 60-5 plan is best.

Obviously, if the mill is not owned by the timber operator, mill cost and depreciation, sawmill operating, and lumber taxes, insurance and selling will drop out of the picture. General expense and working capital will be reduced and price of logs at the mill will take the place of the sale value of the lumber produced. However, fundamentally, the procedure would be the same.