# DIFFERENTIAL STUMPAGE APPRAISAL AND ITS INFLUENCE ON MANAGEMENT.

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# INTRODUCTION

Through the years the logging industry has been forced to realize that the cost of logging increases with a decrease in the diameter of the tree logged. But, even today, many companies establish a minimum diameter as a matter of policy and not as a result of an appraisal and analysis of the specific cost controlling factors present in each and every logging operation and which vary from operation to operation. A flat policy designation of a minimum diameter limit is better than the complete absence of such a designation since it is a direct result of a realization that in "general" trees below the specified limit are uneconomic to log, however, the matter can be carried further. If it is possible to appraise a stand in view of the anticipated costs and to ascertain the differential between these costs for each diameter class, it is then feasible to determine the economic diameter limit for each and every logging operation. Such a method of appraisal is herein presented as applied to a SPRUCE-BALSAM stand two sections in area. The results of the appraisal are then analized in the light of a management plan which will create the greatest present worth per acre and the area as a whole.

In no way is the method of appraisal restricted to pulp wood stands such as used in this instance. It can readily be applied to any type of forest property irrespective of the product desired, provided one has the necessary differential cost data. Each year time and cost study data increases in abundance and it is a mark of poor business to disregard information so vital to the success of a logging venture.

The below stand table represents the average stand per acre in a mixed Spruce-Balsam forest on two sections. A company is interested in purchasing the cutting rights or in purchasing the area outright.

STAND TABLE

| DBH (inches) | No. of Trees | Volume per tree (cords) | Total Volume (cords) | BA per Tree (sq.ft) | Total BA (sq. ft.) |
|---|---|---|---|---|---|
| 6 | 10.0 | .047 | .47 | .20 | 2.00 |
| 7 | 12.5 | .072 | .90 | .27 | 3.38 |
| 8 | 20.0 | .100 | 2 .00 | .35 | 7.00 |
| 9 | 14.5 | .137 | 1 .99 | .44 | 6.38 |
| 10 | 17.0 | .177 | 3 .01 | .55 | 9.35 |
| 11 | 12.0 | .222 | 2 .66 | .66 | 7.92 |
| 12 | 6.2 | .270 | 1 .68 | .79 | 4.90 |
| 13 | 7.9 | .331 | 2.61 | .92 | 7.26 |
| 14 | 2.7 | .405 | 1 .09 | 1.07 | 2.89 |
| 15 | 2.7 | .481 | 1.330 | 1.23 | 3.32 |
| 16 | .9 | .562 | .51 | 1.40 | 1.26 |
| 17 | .9 | .657 | .59 | 1.58 | 1.42 |
| 18 | .9 | .756 | .68 | 1.77 | 1.59 |
| Total | 108.2 | | 19.49 | | 58.47 |

The following cost and production data regarding an operation of this nature has been collected.

Transportation Investment and Costs

Rail haul to mill - - - - - - - - - - - - $5 per cord
Access road from railroad to mill - - 10 miles(a)$2,000 per.mi.
Average speed on this road - - - - 15 mph.
Interior roads - - - - - - - - - - - - $10 per station of 100
Average speed on these roads - - 10 mph.
Truck machine rate
Fixed cost - - - - - - - - - - - - $1.85 per hour
Operating costs- - - - - - - - - - - - $1.65 per hour
Total - - - - - - - - - - $3.50 per hour
Average load- - - - - - - - - - - - - - -3 cords

Operating Costs

Felling and limbing
Four man crew and chain saw- - - - - 6¢ per min.
Skidding tree length logs
Tractor, sulky, driver, & choker man-7¢ per min.
Cross cutting with portable slasker
Forman - - - - - - - -$ 8.00 a day
Crew of 6 men - - - 43.50
Slasker 6.10
$57.60 a day- - 12¢ per min.
Slasker moving & set up- - - - - - - -$50.
(slasker set up will be treated as landings in calculation of road spacing and road and variable skidding costs.)

Loading

On trucks.
Loading will be done by slasker crew and truck driver, and is estimated at 15 minutes per cord. The operation is to be so timed that the 12¢ per minute cost of slasking will cover the cost of loading. Therefore, truck standby is the only loading cost incurred.
On railroad cars.
Jammer- - - - - - - - - - - - - - - - - - - -$ .45 per cord

Unloading

Farm trucks.
Time per cord - - - - - - - - - - - - 10 min.
Jammer - - - - - - - - - - - - - - - - - -$ .45 per cord

Supervision

---- - -$600. per mo.

Production rate

----- - -1000 cords per mo.

## Production Data

Stop watch studies for trees of various diameters have been made and standard times per cord have been determined. However, it is estimated that the efficiency which can be maintained on this operation will be 60% of standard with regard to all operations except variable skidding since this is a function of size of load and round trip tractor speed. This estimate of 60% efficiency also includes desired margin.

Schedule of production times (minutes)

Standard

| DBA (inches) | Felling & Limbing (per cordcrew) | Fixed Tractor (per cord) | Slasher (per cord crew) | Variable Skidding (per cord/100') |
|---|---|---|---|---|
| 6 | 43.0 | 127 | 18.6 | 2.9 |
| 7 | 29.0 | 79 | 12.9 | 2.1 |
| 8 | 22.0 | 52 | 10.5 | 1.6 |
| 9 | 19.1 | 36 | 9.1 | 1.1 |
| 10 | 16.6 | 28 | 8.0 | .9 |
| 11 | 15.3 | 22 | 7.7 | .8 |
| 12 | 14.1 | 17 | 7.2 | .7 |
| 13 | 13.5 | 15 | 7.2 | .6 |
| 14 | 12.6 | 12 | 7.2 | .5 |
| 15 | 12.1 | 11 | 7.2 | .5 |
| 16 | 12.0 | 9 | 7.2 | .5 |
| 17 | 12.0 | 8 | 7.2 | .5 |
| 18 | 12.0 | 7 | 7.2 | .5 |

60% efficiency

| DBA Inches | Felling & Limbing (per cord crew) | Fixed Tractor (per cord) | Slasker (per cord crew) |
|---|---|---|---|
| 6 | 71.5 | 211.5 | 31.0 |
| 7 | 48.3 | 131.8 | 21.5 |
| 8 | 36.6 | 86.7 | 17.5 |
| 9 | 31.8 | 60.0 | 15.2 |
| 10 | 27.7 | 46.6 | 13.3 |
| 11 | 25.5 | 36.6 | 12.8 |
| 12 | 23.5 | 28.3 | 12.0 |
| 13 | 22.5 | 25.0 | 12.0 |
| 14 | 21.0 | 20.0 | 12.0 |
| 15 | 20.2 | 18.3 | 12.0 |
| 16 | 20.0 | 15.0 | 12.0 |
| 17 | 20.0 | 13.3 | 12.0 |
| 18 | 20.0 | 11.7 | 12.0 |

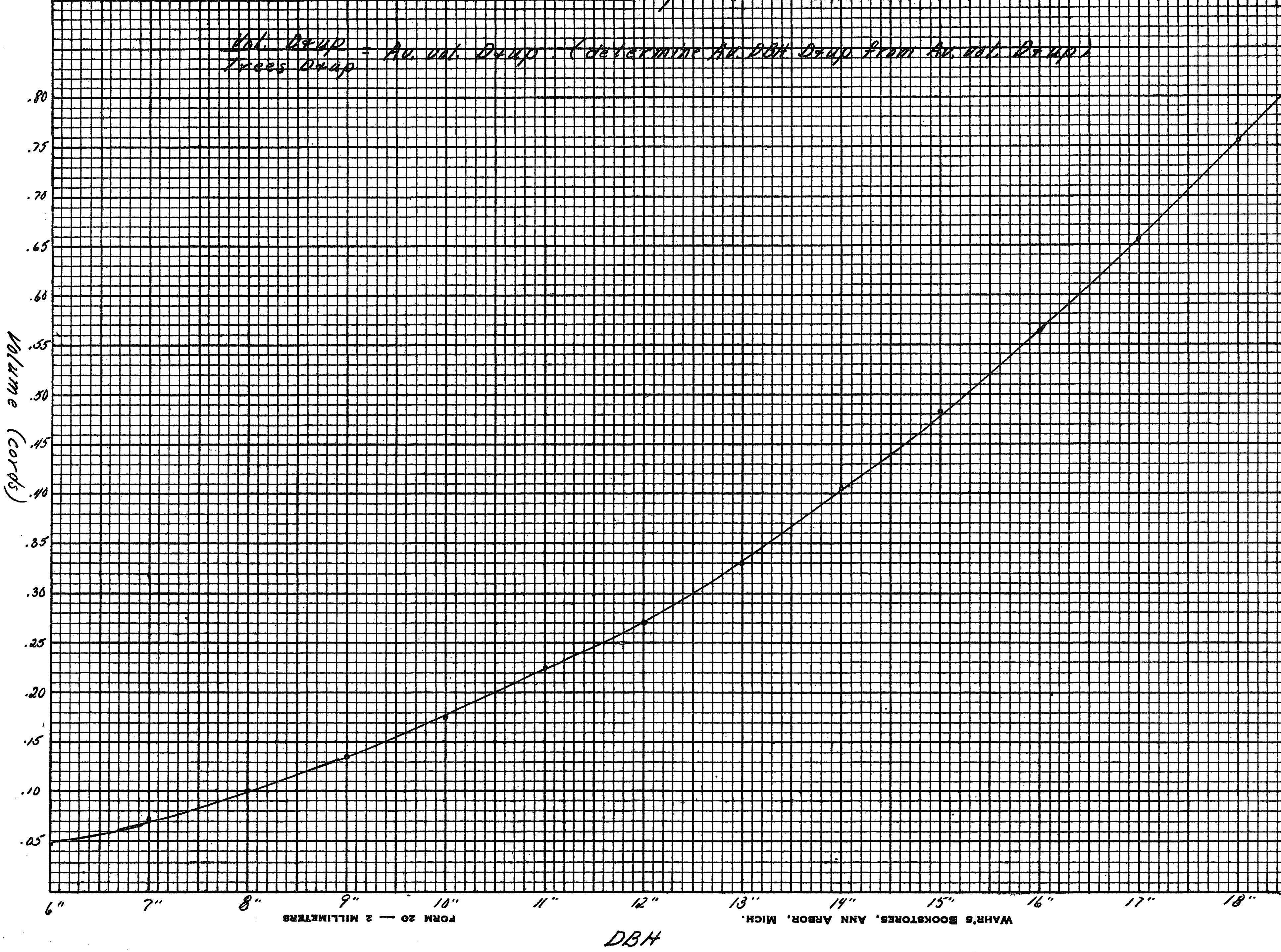
## Stumpage Appraisal

Classification of costs.

Class A costs: costs which vary with the size of the cut.
(machine rate x 60% of standard time)

| DBH (in.) | Felling & Limbing (per cord crew) | Fixed Tractor (per cord) | Slaskers (per cord crew) | Total |
|---|---|---|---|---|
| 6 | $4.30 | $14.80 | $3.72 | $22.82 |
| 7 | 2.90 | 9.22 | 2.58 | 14.70 |
| 8 | 2.20 | 6.07 | 2.10 | 10.37 |
| 9 | 1.91 | 4.20 | 1.82 | 7.93 |
| 10 | 1.66 | 3.26 | 1.60 | 6.52 |
| 11 | 1.53 | 2.56 | 1.54 | 5.63 |
| 12 | 1.41 | 1.98 | 1.44 | 4.83 |
| 13 | 1.35 | 1.75 | 1.44 | 4.54 |
| 14 | 1.26 | 1.40 | 1.44 | 4.10 |
| 15 | 1.20 | 1.28 | 1.44 | 3.92 |
| 16 | 1.20 | 1.05 | 1.44 | 3.69 |
| 17 | 1.20 | .93 | 1.44 | 3.57 |
| 18 | 1.20 | .83 | | 3.46 |

# Volume per DBH



Class B costs:

Costs which are constant irrespective of size of tree or volume logged.

| | | Cost per cord |
|---|---|---|
| Loading on trucks: ($\frac{1}{4}$hr. x 1.85 per hr) | | $ .463 |
| Truck hauls: Interior roads | $\frac{2 \times \$3.50 \times 1 \text{ mi.}}{10 \text{ mph.} \times 3 \text{ cds.}}$ | .234 |
| Exterior roads | $\frac{2 \times \$3.50 \times 10 \text{ mi.}}{15 \text{ mph.} \times 3 \text{ cds.}}$ | 1.555 |
| Unloading trucks--Jammer | | .450 |
| Truck ($\frac{1}{6}$ hr. x 1.85/hr) | | .308 |
| Loading on R. R. cars | | .450 |
| Rail haul | | 5.000 |
| Supervision | $\frac{\$600 \text{ per mo.}}{1000 \text{ cords per mo.}}$ | .600 |
| | Total | $ 9.06 |

Class C costs:

Costs which are fixed per acre.

To determine the costs of skidding and interior roads it is necessary to determine the variable skidding time and cost per cord per 100' for each diameter and up. Therefore, the average DBH of all trees at a diameter limit and up must be determined, these then being interpolated in the schedule of time for each diameter class and multiplied by the machine rate. The variable skidding cost per cord per 100' D and up is used to determine the most economic road spacing D and up, variable skidding cost per cord D and up, and interior road costs per cord D and up.

| DBH | Variable Skidding Time per cord per 100' | Average DBH D& up | Var. Skid. Time D & up | V.Skid. Cost per cord/100 D & up | Interior Road Spacing |
|---|---|---|---|---|---|
| 6 | 2.9 min. | 9.9" | .90 min. | 6.3¢ | 10.2 stat. |
| 7 | 2.1 | 10.4" | .85 min. | 5.8¢ | 10.8 " |
| 8 | 1.6 | 10.8" | .80 min. | 5.6¢ | 11.3 " |
| 9 | 1.1 | 11.5" | .75 min. | 5.2¢ | 12.5 " |
| 10 | .9 | 12.1" | .70 min. | 4.9¢ | 13.7 " |
| 11 | .8 | 12.9" | .60 min. | 4.2¢ | 16.7 " |
| 12 | .7 | 13.6" | .55 min. | 3.8¢ | 20.0 " |
| 13 | .6 | 14.2" | .50 min. | 3.5¢ | 23.9 " |
| 14 | .5 | 15.4" | .50 min. | 3.5¢ | 29.8 " |

| | Variable Skidding Cost D & up | Interior Road Cost D & up | Slasher Moving Cost D & up | Exterior Road Cost D & up | Total Class C Costs per Cord D & up |
|---|---|---|---|---|---|
| 6 | 21.6¢ | 21.6¢ | 13.4¢ | 80.2¢ | $1.368 |
| 7 | 21.4" | 21.4" | 12.4" | 82.2" | 1.374 |
| 8 | 21.2" | 21.2" | 11.8" | 86.2" | 1.404 |
| 9 | 21.8" | 21.8" | 11.1" | 97.0" | 1.517 |
| 10 | 22.6" | 22.6" | 10.2" | 110.5" | 1.659 |
| 11 | 23.5" | 23.5" | 8.9" | 141.0" | 1.969 |
| 12 | 27.8" | 27.8" | 8.0" | 180.0" | 2.336 |
| 13 | 30.6" | 30.6" | 7.7" | 230.5" | 2.994 |
| 14 | 38.1" | 38.1" | 7.4" | 374.0" | 4.575 |

# DIFFERENTIAL STUMPAGE APPRAISAL SCHEDULE

| Line No. | Item of Cost or value | 6" | 7" | 8" | 9" | 10" | 11" | 12" | 13" | 14" | 15" | 16" | 17" | 18" |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Mill value per cord | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 | \$20.00 |
| B | Class B costs per cord | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 | \$9.06 |
| C | Surplus per cord to pay A & B costs | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 | \$10.94 |
| D | Class A costs per DBH class | \$22.82 | \$14.70 | \$10.37 | \$7.93 | \$6.52 | \$5.63 | \$4.83 | \$4.54 | \$4.10 | \$3.92 | \$3.69 | \$3.57 | \$3.46 |
| E | Net surplus per DBH per cord (D-E) | \$-11.88 | \$-3.76 | \$.57 | \$3.10 | \$4.42 | \$5.31 | \$6.11 | \$6.40 | \$6.84 | \$7.02 | \$7.25 | \$7.37 | \$7.48 |
| F | Volume per DBH class | .47 | .90 | 2.00 | 1.99 | 3.01 | 2.66 | 1.68 | 2.61 | 1.09 | 1.30 | .51 | .59 | .68 |
| G | Net surplus per DBH class (FxE) | \$-5.58 | \$-3.38 | \$1.14 | \$5.98 | \$13.30 | \$14.12 | \$10.27 | \$16.70 | \$7.45 | \$9.13 | \$3.70 | \$4.34 | \$5.08 |
| H | Volume D & up (cords) | 19.49 | 19.02 | 18.12 | 16.12 | 14.13 | 11.12 | 8.46 | 6.78 | 4.17 | 3.08 | 1.78 | 1.27 | .68 |
| I | Net surplus D & up | \$82.25 | \$87.83 | \$91.21 | \$91.07 | \$84.89 | \$70.79 | \$56.67 | \$46.40 | \$29.70 | \$22.25 | \$13.12 | \$9.42 | \$5.08 |
| J | Surplus per cord D & up (I÷H)* | \$4.22 | \$4.61 | \$5.04 | \$5.62 | \$5.95 | \$6.37 | \$6.70 | \$6.84 | \$7.12 | | | | |
| K | Class C costs D & up | \$1.37 | \$1.37 | \$1.40 | \$1.52 | \$1.66 | \$1.97 | \$2.34 | \$2.99 | \$4.58 | | | | |
| L | Stumpage per cord D & up (J-H) | \$2.85 | \$3.24 | \$3.64 | \$4.10 | \$4.29 | \$4.40 | \$4.36 | \$3.85 | \$2.52 | | | | |
| M | Stumpage recovery per acre D & up | \$55.50 | \$61.60 | \$65.90 | \$66.10 | \$60.60 | \$48.90 | \$36.90 | \$26.10 | \$10.59 | | | | |

In the above schedule it will be noted that the first positive surplus after deducting class A and B costs occurs in the 8" diameter class. Theoretically it follows that the greatest per acre stumpage recovery should occur at that diameter limit. The slight rise in the total stumpage recovery per acre from the 8" to the 9" diameter limit is due to the necessity of using the variable skidding cost as a C class cost. The fact that it is impossible to determine a variable skidding cost for each diameter class since it is a direct function of volume cut and road spacing necessitates this classification of an A cost as a C cost. However, only a very slight error is incurred since this cost varies only slightly and none of the usefulness of the schedule is lost.

Interpretation of Appraisal Schedule

On purchasing the cutting rights on such an area certain stipulations will be made by the seller. A schedule of this nature presents a clear picture of values, indespensible in making such a purchase.

If the seller stipulated the production of or payment for all merchantable wood on the tract the maximum price which could be bid for the cutting rights is:

$ 2.85 per cord
55.50 per acre or $71,000 for the total area.

However, should the seller contract to sell the cutting rights on scale the purchaser would find it more economic to cut only the trees 8" in DBH and up. The schedule indicates a stumpage recovery per acre of approximately \$66. per acre at 8" and up in contrast to a recovery of \$56.50 per acre at 6" and up. To illustrate the economics let us assume a purchase price of \$2. per cord with cutting rights on scale.

Profit per acre if cut 6" and up.

| | | |
|---|---|---|
| Surplus per cord | | \$4.22 |
| FPA costs | \$1.37 | |
| Stumpage | 2.00 | 3.37 |
| | Profit | \$ .85 per cord |

Profit per acre- \$ .85 x 19.49 cords -- \$16.52

Profit per acre if cut 8" and up

| | | |
|---|---|---|
| Surplus per cord | | \$5.04 |
| FPA costs | \$1.37 | |
| Stumpage | 2.00 | 3.37 |
| | Profit - | 1.67 per cord |

Profit per acre- \$1.67 x 19.02 cords - \$31.70

Similarly the schedule indicates the point at which the greatest profit per cord can be anticipated, this point being where the stumpage recovery per cord is greatest, or at 11" and up.

| | | |
|---|---|---|
| Surplus per cord | | \$6.37 |
| FPA costs | \$1.97 | |
| Stumpage | 2.00 | 3.97 |
| | Profit | \$2.40 per cord |

Profit per acre- \$2.40 x 11.12 cords - \$26.70

It has been assumed that the company would consider the purchase of the property out right with a \$3. per acre value placed on the land.

Unless the seller has prepared a differential stumpage appraisal schedule as above he may be induced to relinquish the stumpage at $2.85 per cord, its value if an ordinary appraisal be made for the removal of all merchantable timber.

This would result in the ~~below~~ following value for the property.

| | | | | |
|---|---|---|---|---|
| Stumpage - - | $55.50 | per acre x 1280 acres- | | $71,000 |
| Land - - - | 3.00 | " " " " " | | 3,840 |
| | | | Property value | $74,840 |

In actuality the property has a value of:

| | | | | |
|---|---|---|---|---|
| Stumpage- - | $66.00 | per acre x 1280 acres- | | $84,500 |
| Land - - - | 3.00 | " " " " " | | 3,840 |
| | | | Property value | $88,340 |

It can readily be appreciated that a variation of $13,500 in recovery value on an area of 1280 acres dependant on the decision as to whether 6" or 8" trees should be cut is of extreme importance. It may often mean the success or failure of the operation.

Thus the schedule illustrates four distinct uses;

1) the point at which a negative surplus is incurred. (Economic cutting limit)
2) the stumpage value at each DBH limit and the procedure to be followed when purchasing on cruise or scale.
3) the point at which the greatest return per acre is attained.
4) the point at which the greatest return per cord is attained.

## DEVELOPEMENT OF MANAGEMENT PLAN

It is assumed that a company has acquired title to this tract through outright purchase and is desirous of putting the area under the plan of management which will result in the greatest present worth of the property. It is further assumed that a Spruce-Balsam stand of an even aged composition such as this is best harvested through a two or three cut liquidation plan. Such a decision must be based on an actual examination of the area and a study of the silvicultural treatment which will favor the greatest future production. Much has been written concerning the proper silvicultural treatment of Spruce-Balsam stands, and, the methods recommended are as varied as the sites on which these stands may be found. No general plan of action may reasonably be recommended since each stand and site merits individual study and attention. If it is evident that satisfactory reproduction can be attained under a selective logging plan of management then such a plan will probably produce the highest present worth. If clear cutting is necessary to attain satisfactory future reproduction, then that plan will probably produce the maximum present worth.

In the past a clear cutting plan has been looked upon with disfavor in many localities since, in many instances the area reproduced a pure Balsam Fir stand, which was undesirable from the economic standpoint. However, at present the preference for Spruce as a pulp wood is no longer as great.

The method here in used to determine the best cycle of operation may be applied irrespective of the harvesting plan selected. In this instance a two cut plan of liquidation is considered best in view of the limited available information. This decision is based on the even aged condition indicated by the DBH distribution; the lack of information regarding reproduction present; and the obvious understocked condition of the stand. Obviously this doesnot mean each and every acre of the area is understocked as is indicated by the stand table. In all probability patchiness is prevelant wherein some areas are over-stocked while others may be virtually bare. However, the stand table in its present form is an adequate management tool. It is assumed that the two cut liquidation of the present stand will lead to a future reproduction and full stocking of the area. However, since this too is a conjecture no attempt will be made toward ascertaining an Se (sail expectation) value based on future production. Instead, for purposes of valuation the land will be given a value of $3. per acre as was done previously. The average rate of growth anticipated under management is approximately .2" in DBH per year, and the land will be taxed at the rate of $200. per year.

Prediction of Surpluses per Acre

Curve of Surpluses

For ease in predicting future surpluses a curve of surpluses per tree has been constructed ~~per tree~~. This is obtained from the differential appraisal schedule by dividing surplus per class by the trees per class. A curve of this nature permits the ready determination of surpluses attainable in the future when applied to growth prediction data.

This is illustrated below for a plan of management requiring a cut at present and a second and final cut in ten years. The calculations for a second cut in 15, 20, 25, 30, and 35 years may be found in the appendix, the results of which have been put in tabular form.

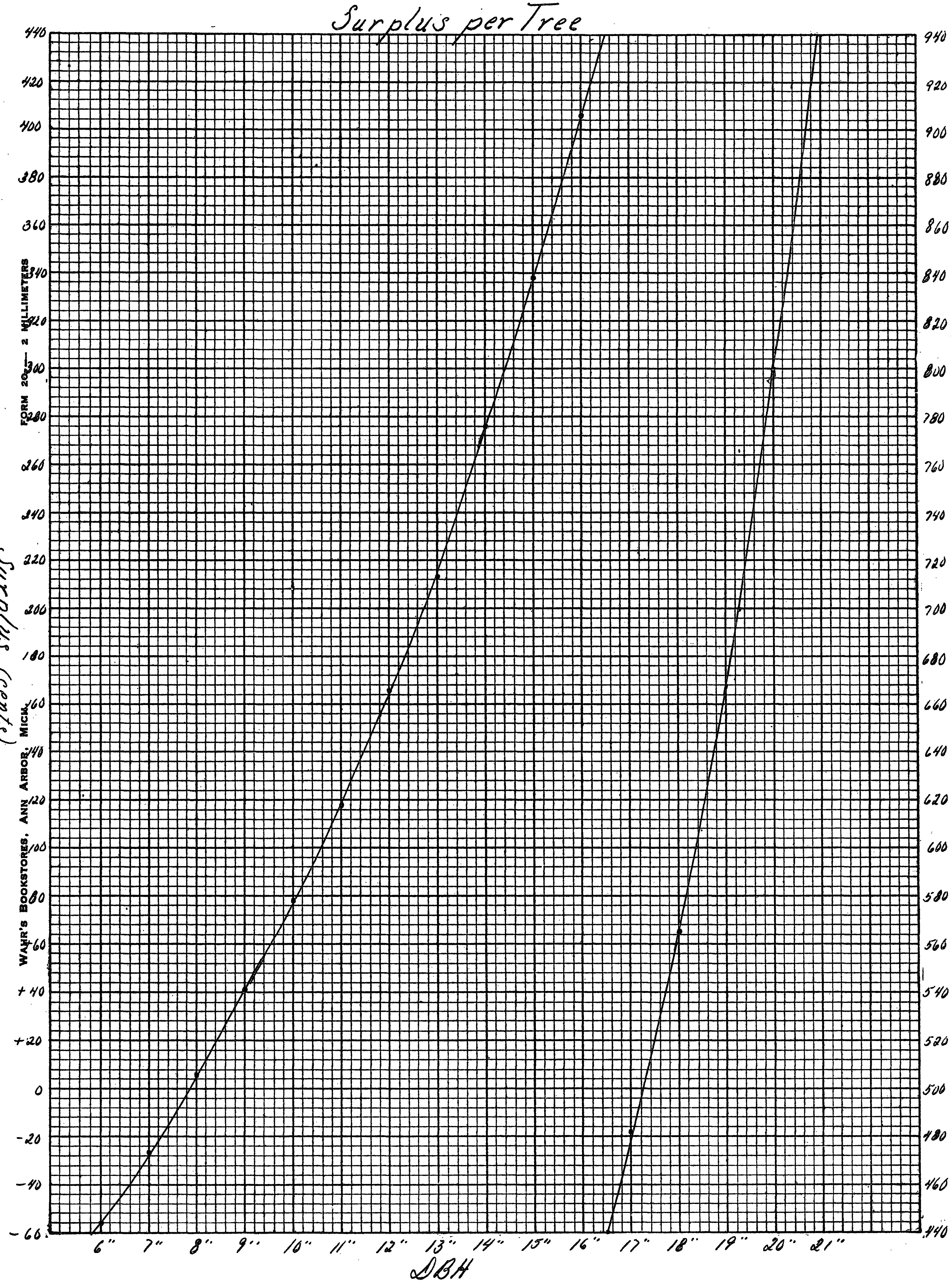
## Calculation of present and future surpluses with final cut in 10 years

| DBH | 7/0. trees | Surplus per class | Surplus per tree | Present Surplus D & up | Surplus per class in 10 years | Surplus D&up of cut to below limit now. 9" | 10" | 11" | 12" | 13" | 14" | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 10.0 | -$5.58 | -$.558 | $82.25 | | | | | | | | |
| 7 | 12.5 | - 3.38 | -.271 | 87.83 | | | | | | | | |
| 8 | 20.0 | + 1.14 | +.057 | 91.21 | $ .57 | | | | | | | |
| 9 | 14.5 | 5.98 | .412 | 90.07 | 5.12 | $16.25 | | | | | | |
| 10 | 17.0 | 13.30 | .782 | 84.09 | 10.56 | | $33.30 | | | | | |
| 11 | 12.0 | 14.12 | 1.175 | 70.79 | 17.05 | | | $61.50 | | | | |
| 12 | 6.2 | 10.27 | 1.660 | 56.67 | 28.20 | | | | $86.80 | | | |
| 13 | 7.9 | 16.70 | 2.110 | 46.40 | 17.14 | | | | | $103.74 | | |
| 14 | 2.7 | 7.45 | 2.760 | 29.70 | 26.80 | | | | | | $130.74 | |
| 15 | 2.7 | 9.13 | 3.390 | 22.25 | 11.10 | | | | | | | $141.84 |
| 16 | .9 | 3.70 | 4.110 | 13.12 | | | | | | | | |
| 17 | .9 | 4.34 | 4.820 | 9.42 | | | | | | | | |
| 18 | .9 | 5.08 | 5.650 | 5.08 | | | | | | | | |

## Present Worth of total surpluses

| Limit of Present Cut | | |
|---|---|---|
| 9" | $= \$90.07 + \frac{16.25}{1.04^{10}}$ | $= \$90.07 + \$11.00 = \$101.07$/acre |
| 10" | $= \$84.09 + \frac{33.30}{1.04^{10}}$ (1.48) | $= \$84.09 + \$22.50 = \$106.59$/acre |
| 11" | $= \$70.79 + \frac{61.50}{1.04^{10}}$ | $= \$70.79 + \$41.60 = \$112.39$/acre |
| 12" | $= \$56.67 + \frac{86.80}{1.04^{10}}$ | $= \$56.67 + \$58.60 = \$115.27$/acre |
| 13" | $= \$46.40 + \frac{103.94}{1.04^{10}}$ | $= \$46.40 + \$70.20 = \$116.60$/acre |
| 14" | $= \$29.70 + \frac{130.74}{1.04^{10}}$ | $= \$29.70 + \$88.40 = \$118.10$/acre |
| 15" | $= \$22.25 + \frac{141.84}{1.04^{10}}$ | $= \$22.25 + \$95.75 = \$118.00$/acre |

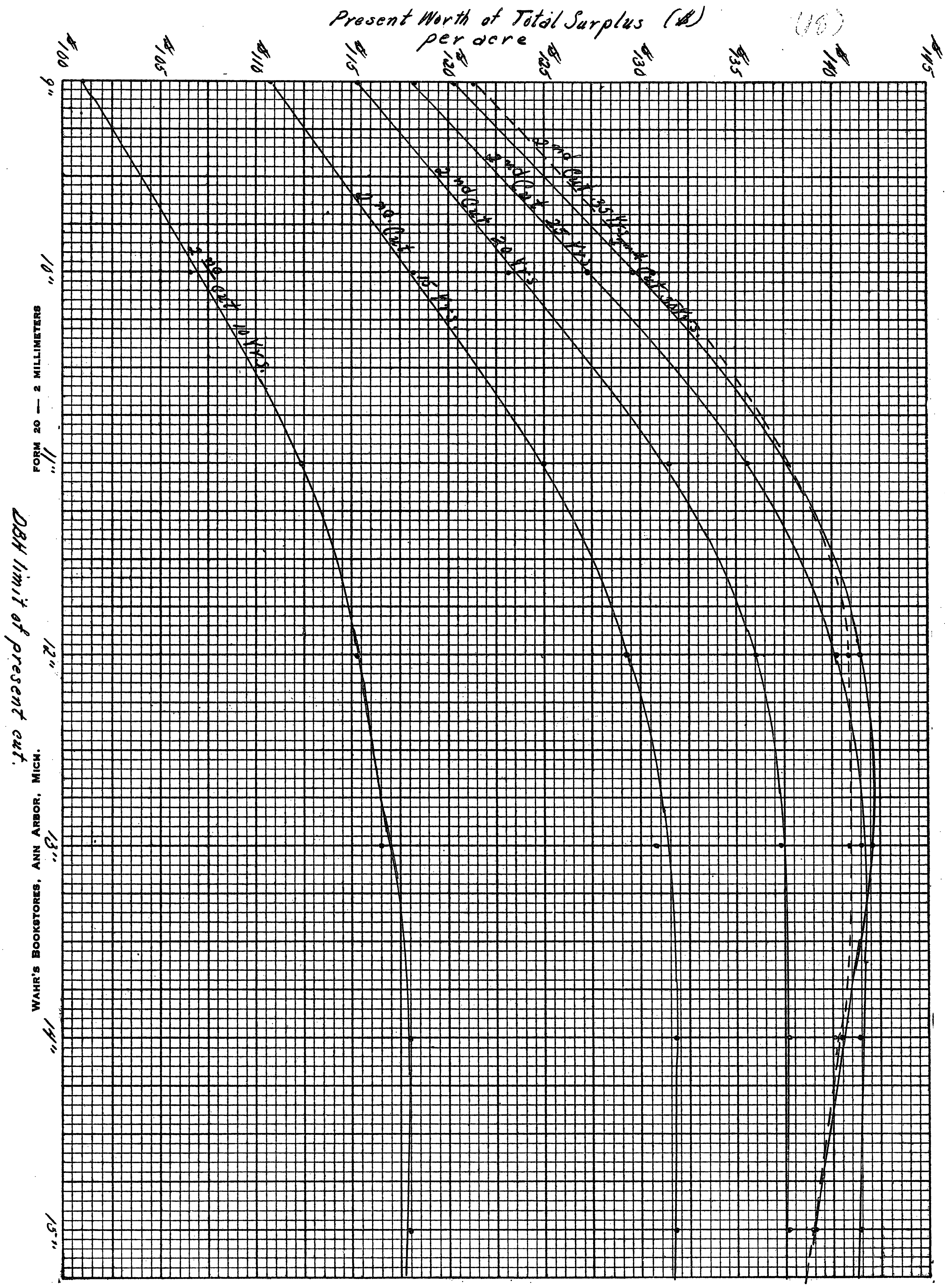
(16)



Surplus per Tree
Surplus (cents)
DBH
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
+40
+20
0
-20
-40
-60
940
920
900
880
860
840
820
800
780
760
740
720
700
680
660
640
620
600
580
560
540
520
500
480
460
440
6"
7"
8"
9"
10"
11"
12"
13"
14"
15"
16"
17"
18"
19"
20"
21"
FORM 20 — 2 MILLIMETERS
WAHR'S BOOKSTORES, ANN ARBOR, MICH.

Tabulation of present, future, total,
and present worth of surpluses under various plans.

| Time of second cut | Surpluses | DBH limit of present cut. 9" | 10" | 11" | 12" | 13" | 14" | 15" |
|---|---|---|---|---|---|---|---|---|
| 10 years | Present | $ 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 16.25 | 33.30 | 61.50 | 86.80 | 103.99 | 130.74 | 141.84 |
| | Total | 106.95 | 117.39 | 132.29 | 143.47 | 150.34 | 160.44 | 164.34 |
| Present worth of total | | 101.07 | 106.59 | 112.39 | 115.27 | 116.60 | 118.10 | 118.00 |
| 15 years | Present | 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 37.47 | 61.47 | 97.67 | 130.77 | 151.72 | 184.22 | 199.22 |
| | Total | 128.87 | 146.56 | 168.46 | 187.44 | 198.12 | 213.92 | 229.72 |
| Present worth of total | | 110.87 | 118.29 | 124.99 | 129.27 | 130.70 | 131.90 | 131.75 |
| 20 years | Present | 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 55.63 | 86.53 | 133.43 | 174.03 | 199.53 | 237.63 | 252.88 |
| | Total | 156.33 | 107.62 | 204.22 | 230.70 | 245.93 | 267.33 | 275.38 |
| Present worth of total | | 115.47 | 123.09 | 131.59 | 136.17 | 137.40 | 137.70 | 137.75 |
| 25 years | Present | 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 75.07 | 115.07 | 172.57 | 222.82 | 252.72 | 297.32 | 318.17 |
| | Total | 165.77 | 199.16 | 243.36 | 279.49 | 299.12 | 327.02 | 340.67 |
| Present worth of total | | 118.27 | 127.29 | 135.59 | 140.27 | 141.40 | 141.20 | 141.25 |
| 30 years | Present | 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 98.37 | 147.37 | 217.37 | 275.17 | 310.17 | 352.42 | 378.02 |
| | Total | 189.07 | 231.46 | 288.16 | 331.84 | 356.57 | 382.12 | 400.52 |
| Present worth of total | | 120.37 | 129.59 | 137.79 | 141.47 | 142.00 | 139.70 | 139.00 |
| 35 years | Present | 90.70 | 84.09 | 70.79 | 56.67 | 46.40 | 29.70 | 22.50 |
| | Future | 123.40 | 183.00 | 264.90 | 332.65 | 373.55 | 436.75 | 462.15 |
| | Total | 214.10 | 267.09 | 335.69 | 389.32 | 419.95 | 466.45 | 484.65 |
| Present worth of total | | 121.37 | 130.49 | 137.79 | 140.87 | 140.90 | 140.20 | 139.20 |


Present Worth of Total Surplus ($)
per acre
$100
$105
$110
$115
$120
$125
$130
$135
$140
$145
9"
10"
11"
12"
13"
14"
15"
DBH limit of present cut.
2nd Cut 10 Yrs.
2nd Cut 15 Yrs.
2nd Cut 20 Yrs.
2nd Cut 25 Yrs.
2nd Cut 35 Yrs.
2nd Cut 30 Yrs.
FORM 20 — 2 MILLIMETERS
WAHR'S BOOKSTORES, ANN ARBOR, MICH.

Interpretations of Present Worth of Surpluses.

The plotting of the present worth of total surpluses per acre illustrates a distinct pattern in cost trends with the increase in diameter limit cut at present. For each time interval it is evident that each curve flattens distinctly at the 12" diameter limit. In general the highest present worth of surpluses for any one time interval is reached at the 14" diameter limit, however, the cutting of trees 14" and up will result in a present stumpage recovery of $10.59 per acre in contrast to a ~~present~~ recovery of $36.90 per acre attained when trees 12" and up are harvested. This investment of $26.31 per acre results in an approximate increase in the total present worth up to $3. per acre which difference also decreases with the increase in time interval. Therefore, cutting to the 12" limit is highly preferable especially when the element of risk is introduced. Since risk is largely a matter of personal opinion based on personal observations there is reasonable probability that the risk factor may be increased with the length of time between incomes. If this view is taken the last possibility of adopting the plan of cutting to the 14" limit at present is eliminated.

Similarly, it is evident that the present worth of surpluses increases with the increase in time interval at a decreasing rate with the rate becoming negative at 35 years. The occurance of this negative rate of value increase is due to the fact that the 4% capitaliaation of surpluses increases at a faster rate than the compounding effect of growth. Were a higher percent rate used for capitalization the point of negative increase would be reached in a shorter period of time. Also, at 35 years the rate of surplus increase would slow due to the slowing of growth rate. At that time the stand would be stocked to 128 square feet of basal area whereas 130 square feet is considered full stocking.

## Recommended Management Plan

The present cutting limit of 12" and up has been established as best due to the higher present stumpage recovery; the unconsidered element of risk in the above capitalization; and the minor increase in present worth resulting from cutting at a higher limit.

The time at which the second cut should be made to attain the highest present worth of the property is 30 years following the first. However, the plan is very flexible at this point. The increase in value from the 10 to 15 years period is greater than the combined value increases from the 15 to 30 year period. This illustrates the advisability of waiting at least 15 years prior to the second cut, and also illustrates the relatively negligible effect on present worth if the plan of cutting in 30 years is varied. The differential between the present worth of the surpluses at 15 years and those at 30 years is approximately $12. per acre, whereas the differential in present worths after deduction of fixed per acre costs and taxes, and the addition of land value is approximately $10 per acre. Necessarily these differentials decrease if cuts are made at 20 or 25 years.

The recommended program is therefore a present cut of 8.46 cords at 12" and up with a final cut of 39.17 cords in 30 years. Also, the alternate proposal, that the final cut may be made in 15, 20, or 25 years with approximate value decreases of 9, 3.5, and .7 percent respectively.

Under the thirty year plan the present worth per acre is $114.33 with a total property value of $146,000.

# APPENDIX

Calculations of economic interior road spacing, and skidding, landing, and road costs.

Landings are spaced at 80% of road spacing.

When present cut:-6" and up

Road spacing $= \sqrt{\frac{13.0 \times r}{vc}} = \sqrt{\frac{13.0 \times 1000}{19.49 \times 6.3}} = \sqrt{105} = 10.2$ stations

Skidding cost: $= .pcs = .336 \times 6.3 \times 10.2 =$ 21.6¢

Interior rd." $= \frac{4.356}{19.49 \times 10.2} =$ 21.6¢

Landings $= \frac{5000}{.183 \times 105 \times 19.40} =$ 13.4¢

When present cut: 7" and up

Road spacing $= \sqrt{\frac{130000}{19.02 \times 5.9}} = \sqrt{116} =$ 10.8 stations

Skidding cost $= .pcs = .336 \times 5.9 \times 10.8 =$ 21.4¢
Road costs $=$ 21.4
Landings $= \frac{5000}{.183 \times 116 \times 19.02}$ 12.4¢

When present cut: 8" and up

Road spacing $= \sqrt{\frac{13000}{18.12 \times 5.6}} = \sqrt{128} =$ 11.3 stations

Skidding cost:- $.336 \times 5.6 \times 11.3 =$ 21.2¢
Road cost $=$ 21.2¢
Landings $= \frac{5000}{.183 \times 128 \times 18.12} =$ 11.8¢

When present cut 9" and up

Road spacing $= \sqrt{\frac{13000}{16.12 \times 5.2}} = \sqrt{155} =$ 12.5
Skidding costs $= .336 \times 5.2 \times 12.5 =$ 21.8¢
Road costs $=$ 21.8¢
Landings $= \frac{5000}{.183 \times 155 \times 16.12}$ 11.0¢

When present cut: 10" and up

Road spacing $= \sqrt{\dfrac{13000}{14.13 \times 4.9}} = \sqrt{188} =$ 13.7 stations

Skidding costs $= .336 \times 4.9 \times 13.7 =$ 22.6¢
Road costs $=$ 22.6¢
Landings $= \dfrac{5000}{.183 \times 188 \times 14.3}$ 10.2¢

When present cut: 11" and up

Road spacing $= \sqrt{\dfrac{13000}{11.12 \times 4.2}} = \sqrt{278} =$ 16.7 stations

Skidding costs $= .336 \times 4.2 \times 16.7 =$ 23.5¢
Road costs $=$ 23.5¢
Landings $= \dfrac{5000}{.183 \times 278 \times 11.12}$ 8.9¢

When present cut 12" and up

Road spacing $= \sqrt{\dfrac{13000}{8.46 \times 3.8}} = \sqrt{404} =$ 20.0 stations

Skidding costs $= .366 \times 3.5 \times 23.9 =$ 27.8¢
Road costs $=$ 27.8¢
Landings $= \dfrac{5000}{.183 \times 404 \times 8.46} =$ 8.0¢

When present cut: 13" and up

Road spacing $= \sqrt{\dfrac{13000}{6.78 \times 3.5}} = \sqrt{570} =$ 23.9 stations

Skidding costs $= .366 \times 3.5 \times 23.9 =$ 30.6¢
Road costs $=$ 30.6¢
Landings $= \dfrac{5000}{.183 \times 570 \times 6.78}$ 7.7¢

When present cut: 14" and up

Road spacing $= \sqrt{\dfrac{13000}{4.17 \times 3.5}} = \sqrt{890} =$ 29.8 stations

Skidding costs $= .366 \times 3.5 \times 29.8 =$ 38.1¢
Road costs $=$ 38.1¢
Landings $= \dfrac{5000}{.183 \times 890 \times 4.17}$ 7.4¢

## Calculations for exterior road costs

Limit of Cut

$$6'' \text{ and up} = \frac{\$20{,}000}{19.49 \text{ cords} \times 1280 \text{ acres}} = \frac{20{,}000}{2495} = 80.2¢$$

$$7'' \text{ and up} = \frac{\$20{,}000}{19.02 \times 1280} = \frac{20{,}000}{2435} = 82.2¢$$

$$8'' \text{ and up} = \frac{\$20{,}000}{18.12 \times 1280} = \frac{20{,}000}{2320} = 86.2¢$$

$$9'' \text{ and up} = \frac{\$20{,}000}{16.12 \times 1280} = \frac{20{,}000}{2060} = 97.0¢$$

$$10'' \text{ and up} = \frac{\$20{,}000}{14.13 \times 1280} = \frac{20{,}000}{1810} = 110.5¢$$

$$11'' \text{ and up} = \frac{\$20{,}000}{11.12 \times 1280} = \frac{20{,}000}{1425} = 141.0¢$$

$$12'' \text{ and up} = \frac{\$20{,}000}{8.46 \times 1280} = \frac{20{,}000}{1082} = 180.0¢$$

$$13'' \text{ and up} = \frac{\$20{,}000}{6.78 \times 1280} = \frac{20{,}000}{868} = 230.5¢$$

$$14'' \text{ and up} = \frac{\$20{,}000}{4.17 \times 1280} = \frac{20{,}000}{534} = 374.0¢$$

## Calculation of future surpluses when second cut in 15 years

| DBH | No. Trees | Surplus per Tree | Future Surplus per Class | 9" | 10" | 11" | 12" | 13" | 14" | 15" |
|---|---|---|---|---|---|---|---|---|---|---|
| 9" | 10.0 | $ .412 | $ 4.12 | $37.47 | | | | | | |
| 10" | 12.5 | .783 | 9.80 | | $61.47 | | | | | |
| 11" | 20.0 | 1.177 | 23.55 | | | $97.67 | | | | |
| 12" | 14.5 | 1.657 | 24.00 | | | | $130.77 | | | |
| 13" | 17.0 | 2.130 | 36.20 | | | | | $151.72 | | |
| 14" | 12.0 | 2.760 | 33.10 | | | | | | $184.22 | |
| 15" | 6.2 | 3.380 | 20.95 | | | | | | | $197.22 |
| 16" | 7.9 | 4.110 | 32.50 | | | | | | | |
| 17" | 2.7 | 4.820 | 13.00 | | | | | | | |
| 18" | 2.7 | 5.650 | 15.25 | | | | | | | |

## Present Worth of pressnt and future surpluses

**Limit of present cut**

9" and up- $\$90.07 + \frac{37.47}{1.04^{15}} = \$90.07 + 20.80 = \$110.87$

10" and up- $\$84.09 + \frac{61.47}{1.04^{15}} = \$84.09 + 34.20 = 118.29$

11" and up- $\$70.79 + \frac{97.67}{1.04^{15}} = \$70.79 + 54.20 = 124.99$

12" and up- $\$56.67 + \frac{130.77}{1.04^{15}} = \$56.67 + 72.60 = 129.27$

13" and up- $\$46.40 + \frac{151.72}{1.04^{15}} = \$46.40 + 84.30 = 130.70$

14" and up- $\$29.70 + \frac{184.22}{1.04^{15}} = \$29.70 + 102.20 = 131.90$

15" and up- $\$22.25 + \frac{197.22}{1.04^{15}} = \$22.25 + 109.50 = 131.75$

Calculation of future surpluses when second cut in 20 years.

| DBH | No. Trees | Surplus per Tree | Future Surplusper Class | Future Surpluses D and up DBH limit of present cut 9" | 10" | 11" | 12" | 13" | 14" | 15" |
|---|---|---|---|---|---|---|---|---|---|---|
| 10" | 10.0 | $ .783 | $ 7.83 | $55.63 | | | | | | |
| 11" | 12.5 | 1.177 | 14.70 | | $86.53 | | | | | |
| 12" | 20.0 | 1.657 | 33.10 | | | $133.43 | | | | |
| 13" | 14.5 | 2.130 | 30.90 | | | | $174.03 | | | |
| 14" | 17.0 | 2.760 | 46.90 | | | | | $199.53 | | |
| 15" | 12.0 | 3.380 | 40.60 | | | | | | $237.63 | |
| 16" | 6.2 | 4.110 | 25.50 | | | | | | | $252.88 |
| 17" | 7.9 | 4.820 | 38.10 | | | | | | | |
| 18" | 2.7 | 5.650 | 15.25 | | | | | | | |

Present worth of present and future surpluses.

Limit of present cut

9" and up- $\$90.07 + \frac{\$55.63}{1.04^{20}} = \$115.47$

10" and up- $\$84.09 + \frac{\$86.53}{1.04^{20}} = \$123.09$

11" and up- $\$70.79 + \frac{\$133.43}{1.04^{20}} = \$131.59$

12" and up $\$56.67 + \frac{\$174.03}{1.04^{20}} = \$136.17$

13" and up $\$46.40 + \frac{\$199.53}{1.04^{20}} = \$137.40$

14" and up $\$29.70 + \frac{\$237.63}{1.04^{20}} = \$137.70$

15" and up $\$22.25 + \frac{\$252.88}{1.04^{20}} = \$137.75$

## Calculation of future surpluses when second cut in 25 years

| DBH | No. Trees | Surplus per Tree | Future Surplus per class | Future surpluses D and up DBH limit of present cut 9" | 10" | 11" | 12" | 13" | 14" | 15" |
|---|---|---|---|---|---|---|---|---|---|---|
| 11" | 10.0 | $1.177 | $11.77 | $75.07 | | | | | | |
| 12" | 12.5 | 1.657 | 20.70 | | $115.07 | | | | | |
| 13" | 20.0 | 2.130 | 42.60 | | | $172.57 | | | | |
| 14" | 14.5 | 2.760 | 40.00 | | | | $222.82 | | | |
| 15" | 17.0 | 3.380 | 57.50 | | | | | $252.72 | | |
| 16" | 12.0 | 4.110 | 49.25 | | | | | | $297.32 | |
| 17" | 6.2 | 4.820 | 29.90 | | | | | | | $318.17 |
| 18" | 7.9 | 5.650 | 44.60 | | | | | | | |
| 19" | 2.7 | 6.600 | 17.85 | | | | | | | |

## Present worth of present and future surpluses

Limit of present cut

9" and up - $\$90.07 + \frac{\$75.07}{1.04^{25}} = \$118.27$

10" and up - $\$84.09 + \frac{\$115.07}{1.04^{25}} = \$127.29$

11" and up - $\$70.79 + \frac{\$172.57}{1.04^{25}} = \$135.59$

12" and up - $\$56.67 + \frac{\$222.84}{1.04^{25}} = \$140.27$

13" and up - $\$46.40 + \frac{\$252.72}{1.04^{25}} = \$141.40$

14" and up - $\$29.70 + \frac{\$297.32}{1.04^{25}} = \$141.20$

15" and up - $\$22.25 + \frac{\$318.17}{1.04^{25}} = \$141.25$

## Calculation of future surpluses when second cut in 30 years

| DBH | No. Trees | Surplus per Tree | Future Surplus per class | Future surpluses D and up DBH limit of present cut 9" | 10" | 11" | 12" | 13" | 14" | 15" |
|---|---|---|---|---|---|---|---|---|---|---|
| 12" | 10.0 | $1.657 | $16.57 | $98.37 | | | | | | |
| 13" | 12.5 | 2.130 | 26.60 | | $147.37 | | | | | |
| 14" | 20.0 | 2.760 | 55.20 | | | $217.37 | | | | |
| 15" | 14.5 | 3.380 | 49.00 | | | | $275.17 | | | |
| 16" | 17.0 | 4.110 | 70.00 | | | | | $310.17 | | |
| 17" | 12.0 | 4.820 | 57.80 | | | | | | $356.42 | |
| 18" | 6.2 | 5.650 | 35.00 | | | | | | | $378.02 |
| 19" | 7.9 | 6.600 | 46.25 | | | | | | | |
| 20" | 2.7 | 8.000 | 21.60 | | | | | | | |

## Present worth of present and future surpluses.

Limit of present cut

9" and up- $\$90.07 + \frac{\$98.37}{1.04^{30}} = \$120.37$

10" and up- $\$84;09 + \frac{\$147.37}{1.04^{30}} = \$129.59$

11" and up- $\$70.79 + \frac{\$217.37}{1004^{30}} = \$137.79$

12" and up- $\$56.67 + \frac{\$275.17}{1.04^{30}} = \$141.47$

13" and up- $\$46.40 + \frac{\$310.17}{1.04^{30}} = \$142.00$

14" and up- $\$29.70 + \frac{\$356.42}{1.04^{30}} = \$139.70$

15" and up- $\$22.25 + \frac{\$378.02}{1.04^{30}} = \$139.00$

Calculation of future surpluses when second cut in 35 years.

| DBH | No. Trees | Surplus per Tree | Future Surplus per class | Future surpluses D and up DBH limit of present cut |
|---|---|---|---|---|
| 13" | 10.0 | $2.13 | $21.30 | $123.40 |
| 14" | 12.5 | 2.76 | 34.50 | $183.00 |
| 15" | 20.0 | 3.38 | 67.60 | $264.90 |
| 16" | 14.5 | 4.11 | 59.60 | $332.65 |
| 17" | 17.0 | 4.82 | 81.90 | $373.55 |
| 18" | 12.0 | 5.65 | 67.75 | $436.75 |
| 19" | 6.2 | 6.60 | 40.90 | $462.15 |
| 20" | 7.9 | 8.00 | 63.20 | |
| 21" | 2.7 | 9.40 | 25.40 | |

Present worth of present and future surpluses

Limit of present cut

9" and up- $\$90.07 + \frac{\$123.40}{1.04^{35}} = \$121.27$

1

10" and up- $\$84.09 + \frac{\$183.00}{1.04^{35}} = \$130.49$

11" and up- $\$70.79 + \frac{\$264.90}{1.04^{35}} = \$137.79$

12" and up- $\$56.67 + \frac{\$332.65}{1.04^{35}} = \$140.87$

13" and up- $\$46.40 + \frac{\$373.55}{1.04^{35}} = \$140.90$

14" and up- $\$29.70 + \frac{\$436.75}{1.04^{35}} = \$140.20$

15" and up- $\$22.25 + \frac{\$462.15}{1.04^{35}} = \$139.25$

Calculation of present worth per acre

Present cut 12" and up.
Future cut in 15 years.

| | | |
|---|---|---|
| Income-first cut - | | \$36.90 per acre |
| Income-second cut- | | |
| Surplus per acre- | \$130.77 | |
| FPA costs: | | |
| Exterior road/acre- | \$.097 | |
| Interior roads/cd.- | .173 | |
| Landings/cd.- | .070 | |
| 22.55 cds. x \$.34 = | &.65 9.21 | |
| | Income/acre= \$121.56 | |

$$PW = 36.90 + \frac{\$121.56}{1.04^{15}} - \$.156\left(\frac{1.04^{15}-1}{.04 \times 1.04^{15}}\right) + \frac{\$3}{1.04^{15}} = \underline{\$104.34/\text{acre}}$$

Calculation of present worth per acre.

Present cut 12" and up
Future cut in 30 years.

| | | |
|---|---|---|
| Income first cut- | | \$36.90/acre |
| Income second cut | | |
| Surplus per acre | \$275.17 | |
| FPA costs: | | |
| EXterior roads/acre | \$1.56 | |
| Interior rds/cd- | \$.212 | |
| Skidding/cd.- | .115 | |
| Landings/cd.- | .091 | |
| 39 cds. x \$..418 = | 16.30 17.86 | |
| | Income/acre= \$257.31 | |

$$PW = 36.90 + \frac{257.31}{1.04.^{30}} - .156\left(\frac{1.04^{30}-1}{.04 \times 1.04^{30}}\right) + \frac{\$3}{1.04^{30}} = \$114.33/\text{acre}$$

Volumes cut at second cut if first cut is made at 12" and up:

| DBH | Vol. per Tree | In 15 yrs. No. Trees | Vol. | 20 yrs. Trees | Vol. | 25 yrs. Trees | Vol. | 30 yrs. Trees | Vol. | 35 yrs. Trees | Vol. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9" | .100cds. | 10.0 | 1.37 | | | | | | | | |
| 10" | .137 | 12.5 | 2.21 | 10.0 | 1.77 | | | | | | |
| 11" | .177 | 20.0 | 4.44 | 12.5 | 2.65 | 10.0 | 2.22 | | | | |
| 12" | .222 | 14.5 | 3.91 | 20.0 | 5.40 | 12.5 | 3.38 | 10.0 | 2.70 | | |
| 13" | .270 | 17.0 | 5.66 | 14.5 | 4.80 | 20.0 | 6.62 | 12.5 | 4.13 | 10.0 | 3.31 |
| 14" | .331 | 12.0 | 4.96 | 17.0 | 6.89 | 14.5 | 5.87 | 20.0 | 8.10 | 12.5 | 5.06 |
| 15" | .405 | | | 12.0 | 5.77 | 17.0 | 8.17 | 14.5 | 6.98 | 20.0 | 9.62 |
| 16" | .481 | | | | | 12.0 | 6.74 | 17.0 | 9.38 | 14.5 | 8.00 |
| 17" | .562 | | | | | | | 12.0 | 7.88 | 17.0 | 11.16 |
| 18" | .657 | | | | | | | | | 12.0 | 9.06 |
| | | 86.0 | 22.55 cords | | 28.28 cords | | 33.00 cords | | 39.17 cords | | 46.21 cords |