AN ANALYSIS OF SELECTIVE
TIMBER MANAGEMENT IN
PONDEROSA PINE
By
Glenn B. Parsons

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A Thesis

Presented to the Faculty

of the

School of Forestry

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Approved:

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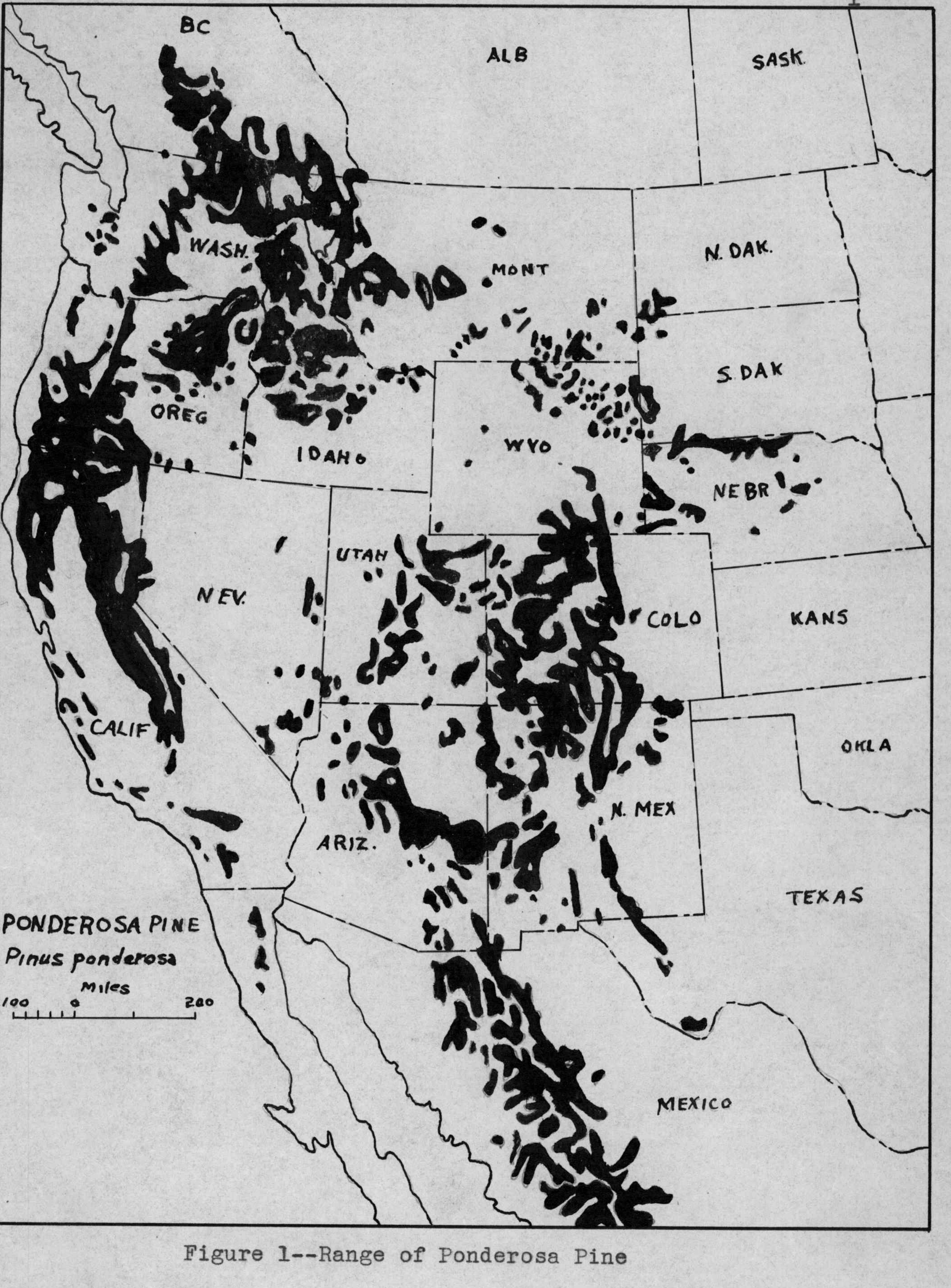


Figure 1--Range of Ponderosa Pine

INTRODUCTION

Ponderosa pine (Pinus ponderosa), until recently called Western Yellow Pine, is no doubt the most important commercial pine west of the Great Plains. Its geographic commercial range extends over a tremendous area (See Figure 1). It is found in commercial quantities over a greater area in western United States than any other species. It is the principal timber tree of the Black Hills Region of South Dakota, the lumbering centers of western Montana, south central British Columbia, Oregon and Washington east of the Cascade Mountains, California, Arizona and New Mexico. The total volume of ponderosa pine contained within its commercial range is estimated at 251 billion board feet--a tremendous volume of timber when compared with the volume of California sugar pine and Idaho white pine, its only two western competitors in pine lumber markets.

Just how long the supply of timber will last is difficult to predict, because of the various factors affecting the rate of cutting which constitute the greatest drain. During the past ten years the annual cut of ponderosa pine has averaged 2,655,441,000 board feet. This includes only that volume being manufactured into lumber.

It occurs at the lower altitudes which begin at approximately 3700 feet in the southern part of the region and 2500 feet in the north. It has a vertical range of about 2000 feet.

Fine specimens of Ponderosa Pine

Figure 2

A great variation exists in the volume of timber per acre. The largest timber and the most productive land is found in southern Oregon, where volumes of 20 to 30 M board feet per acre occur over limited areas. The virgin timber in the Blue Mountains of Oregon and Okanogan Mountains of Washington is smaller size--individual acres varying from 6 to 25 M per acre.

Lodgepole pine (Pinus contorta), Douglas fir (Pseudotsuga taxifolia), white fir (Abies concolor), and lowland white fir (Abies grandis) commonly occur in mixture on the cool situations. Sugar pine (Pinus lanbertiana) is confined to the southern part of the region while red fir (Abies magnifica), noble fir (Abies nobilis), incense cedar (Libocedrus decurrens), and western read cedar (Thuja plicata) occur in the higher Cascades. Western larch (Larix occidentalis) is a common associate in the Blue Mountains and in northern Cascades. Mountain mahogany (Cercocarpus ledifolius) frequently occur on the shallow rocky sites in the Blue Mountains, as do the Rocky Mountain red (Juniperus scopulorum) and western juniper (Juniperus occidentalis).

Lumbermen are selecting logs in the woods to the end that they may produce lumber which must not be shipped at a loss. This is essential for any operation which desires to retain its financial stability.

To clarify the conception that underlie this new system of ponderosa pine management, 18 basic considerations upon which this maturity selection system is founded are:

"1. The objective of forest management, both for the public and private owner, should be the attainment of the maximum sustained-value production of forest products, unless there be conflicting considerations of aesthetics, watershed protection, range or game management, etc.

"2. Hence the function of silviculture is to show the way to maximum quantity and quality production, using means that are economically feasible and justifiable. "Silvicultural" and "economic" considerations therefore are not antagonistic but are to a considerable degree parallel. Good silviculture is good economics and vice versa.

"3. The irregular virgin ponderosa pine forests in Oregon and Washington are silviculturally neglected and unmanaged. Partial cutting converts them to productive forest stands. Light and frequent cuttings are desirable since these help to maintain forest conditions, assist in building up the soil fertility, eliminate or retard the growth of shrubby vegetation, surplus reproduction and grass. The gradual removal of the timber helps to develop wind-firm trees and also permits corrections and modifications not possible under heavy cutting, and thus gives rather complete control over the composition and character of the forest.

"4. The volume of the virgin forest is in the long run stationary, with periods when losses exceed growth, as during insect epidemics or hurricanes, which are made up for later by periods of net growth.

"5. The removal of the overmature element of the stand (mostly the high mortality trees) converts the stationary forest to a growing forest. If only the trees likely to die before the next cutting were removed the gross growth of the stand would be realized as the net growth. Unfortunately these high-mortality trees cannot be accurately foretold.

"6. It is sound policy for both a public and private forest owner to liquidate the low-earning trees and to reserve for volume and/or value increment the high-earning trees.

"7. If a large percentage of the stand is cut the forest capital is so reduced that the net increment is small, even though mortality is nearly eliminated and the growth of all the reserve trees is good. Thus in one case it was calculated that after a 80-percent cut the net annual growth per acre will be 72 board feet, while after a 40-percent cut it will be 94 board feet, in a stand which in the virgin condition is making a <u>gross</u> growth of about 120 board feet per acre per year.

"8. In comparing the merits of one system of selection cutting with another, e.g., light versus heavy cutting, the effect upon the whole forest should be considered and not the effect upon the current cutting area alone. Thus, considering the whole working circle, it is more desirable to remove the most overripe half of the mature trees from the whole area in 30 years than to take twice that length of time to get over the whole area with a cutting that takes all the mature trees. In this way a 30-year cutting cycle converts the whole forest from the stagnant to the growing condition twice as quickly as does a 60-year cutting cycle.

"9. The shorter the cutting cycle the better the chances for salvaging before deterioration windfalls and insect-killed trees in the course of the regular periodic cutting.

"10. The shorter the cutting cycle the quicker will the whole working circle be put under control with roads, and hence the better will be the opportunities for special salvage cutting of timber killed by fire, insect epidemic or wind throw.

"11. The lighter the cut the lower will be the charges for slash disposal and cut-over land protection.

"12. The lighter the cut the greater will be the logging cost per M feet, but with modern tractor and truck logging the fixed per-acre costs are so small that the cost does not increase rapidly with lowering of the cut.

"13. If the light cut is composed largely of the financially (and physically) mature trees there average value will be enough higher than the value of a heavy cut to offset extra logging costs.

"14. It is not sound policy to cut a tree of no present value <u>merely</u> to make growing space for reproduction. The idleness of the small area of cheap land is immaterial in comparison to the economic loss of cutting minus value trees or in comparison to the idleness of the great areas of stagnant virgin forest that are getting no selective cutting treatment whatsoever.

"15. In a working circle with a prescribed cutting budget or contracts providing a fixed cut, it must be assumed that if a certain class of tree is reserved from cutting another class of tree will be cut somewhere else. Hence the reserving through a lighter cut of a moderately overripe tree here should result in the cutting of a very overripe tree somewhere else, with resultant silvicultural benefit to the forest as a whole.

"16. The enhancement, or depression, of stumpage value through changes in the prescribed system of cutting should all accrue to the forest owner.

"17. Assuming that a light cut should be made, for example 40 percent with an assumed return cut in 30 years (the exact percentage depending on circumstances and the character of the stand), the following considerations should control the selection of the trees to be cut:

a. Cut all positive value trees that will not survive until the next cut.

b. Cut the trees that show a positive conversion value above the average of the whole stand but a low value increment; these are ordinarily the oldest and largest diameter classes, of slow growth and high mortality probability.

c. Cut some of the low value increment trees whose conversion value is below the average of the whole stand as measure of stand betterment.

"18. The above principles will on the average result in removing the trees which for both financial and silvical reasons it is most desirable to cut now, but there are considerations which involve the individual tree which must be taken into account, particularly the relation of an individual tree to its neighbor. Consideration (c) will be used to remove a tree in order thereby to benefit the whole forest and conversely to leave trees of (b) and (c) description that are needed to maintain the percentage of reserve, for protection, seed, aesthetics, etc." (1)

These basic considerations will more clearly show the relative merits of the selective cutting system as applied to the ponderosa pine type, but this article is more concerned with the "why" for taking such actions, and how we determine the volume and trees to be cut.

The purpose of this study is to supply information (1) on the quantity, grade, and value of lumber produced of different sizes and grades; (2) the cost of producing the lumber; and (3) a comparison of lumber values and production costs when trees of the same size and grade are sawed.

Essentially, the goal of logging and milling studies is to determine conversion values of trees of different size, age, and grade, as they stand in the woods. They aim to show which trees are profitable to log and mill, and which involves a loss. They aim at better utilization of existing timber supplies and toward the shaping of better exploitation policies.

As there is no information available at this writing, the data used in the body of this article will be assumed. The main objective, as I see it, is to get the principle behind the study rather than a large accumulation of figures.

The quantity and grade of lumber produced by trees of different sizes and grades and the cost of producing the lumber can be obtained by observing the milling of trees from a selected tract of a representative logging operation and obtaining a lumber tally for each log and tree. Supplementary time studies of headsaw operations provided information on sawmill production costs. Time studies in the woods of the felling and bucking, skidding, loading and trucking operations provided data on production costs between the stump and sawmill. The study of lumber grades and yields end at the green chain and dry kiln.

FOREST INVENTORY*

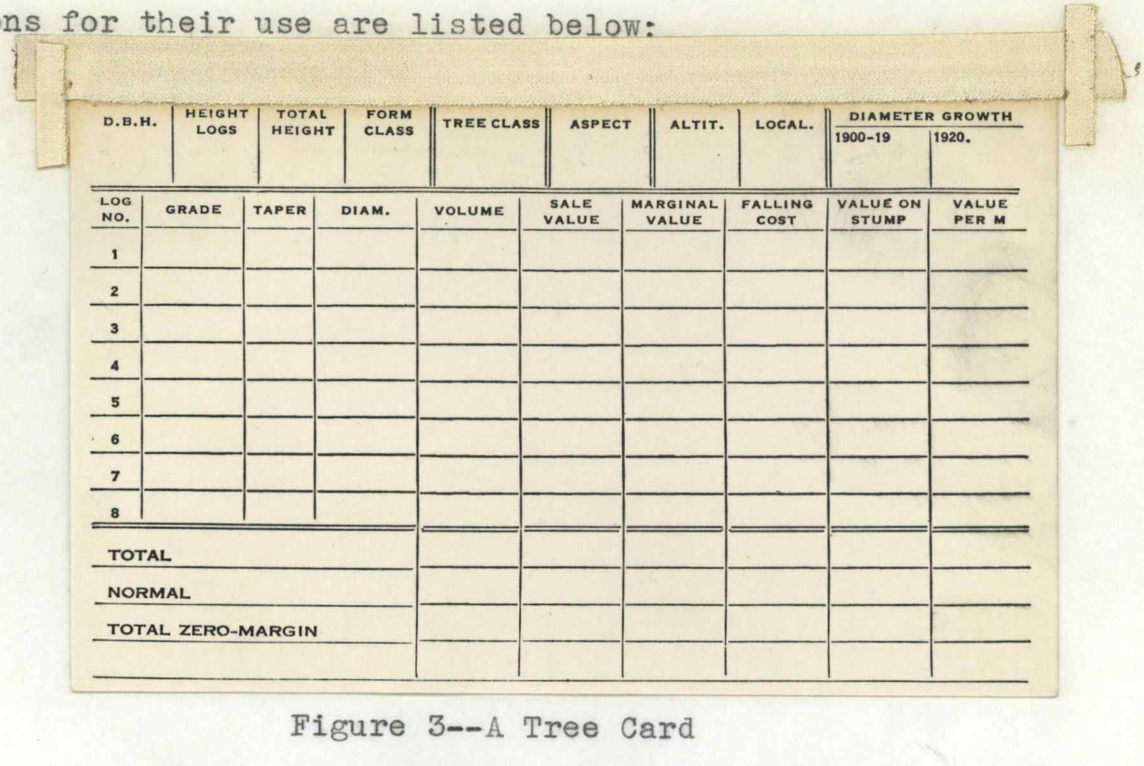
Prior to logging the tract, each living pine over 12 inches in diameter at breast height, was numbered consecutively commencing at one. At the same time, each tree was described in terms of attributes such as diameter breast high; location on plot; size, shape, and dominance of crown; suitability for seed production; size and frequency of limbs; and external evidence of decay or other damage.

"When sawyers felled the study trees, more data was obtained and included in the description for each tree. These data included stump height and stump diameter inside bark; volume of long-butts, breakage, and cull material left in woods; merchantable length; used length; length

*This procedure was taken from Univ. Idaho Bu. No. 16 of a W.W.P. study but changed so that it would apply to Ponderosa pine.

and diameter of utilized logs; and, often, total height of the tree. At the same time, logs from each tree were marked on each end with the tree number and log position so they could be identified at the landing when they were scaled or when they came into the sawmill. Thus, for example, the logs in tree 96, which was a 5-log tree, were numbered consecutively 96-1, 96-2, and so on to the top log which carried the number 96-5." (2:10)

This study resulted in a large accumulation of data which necessitated some scheme of keeping the material in some usable order. This scheme was the use of tree cards and the instructions for their use are listed below:



D.B.H.	HEIGHT LOGS	TOTAL HEIGHT	FORM CLASS	TREE CLASS	ASPECT	ALTIT.	LOCAL.	DIAMETER GROWTH 1900-19	1920.

LOG NO.	GRADE	TAPER	DIAM.	VOLUME	SALE VALUE	MARGINAL VALUE	FALLING COST	VALUE ON STUMP	VALUE PER M
1									
2									
3									
4									
5									
6									
7									
8									
TOTAL									
NORMAL									
TOTAL ZERO-MARGIN									

Figure 3--A Tree Card

"As each one-quarter acre circular sample plot (58.9 feet radius) is located at five chain intervals along the strip line, a temporary stake is set in the center of the plot.

"The merchantable ponderosa pine (12 inches D.B.H. and over) nearest the center of the plot will be considered the sample tree.

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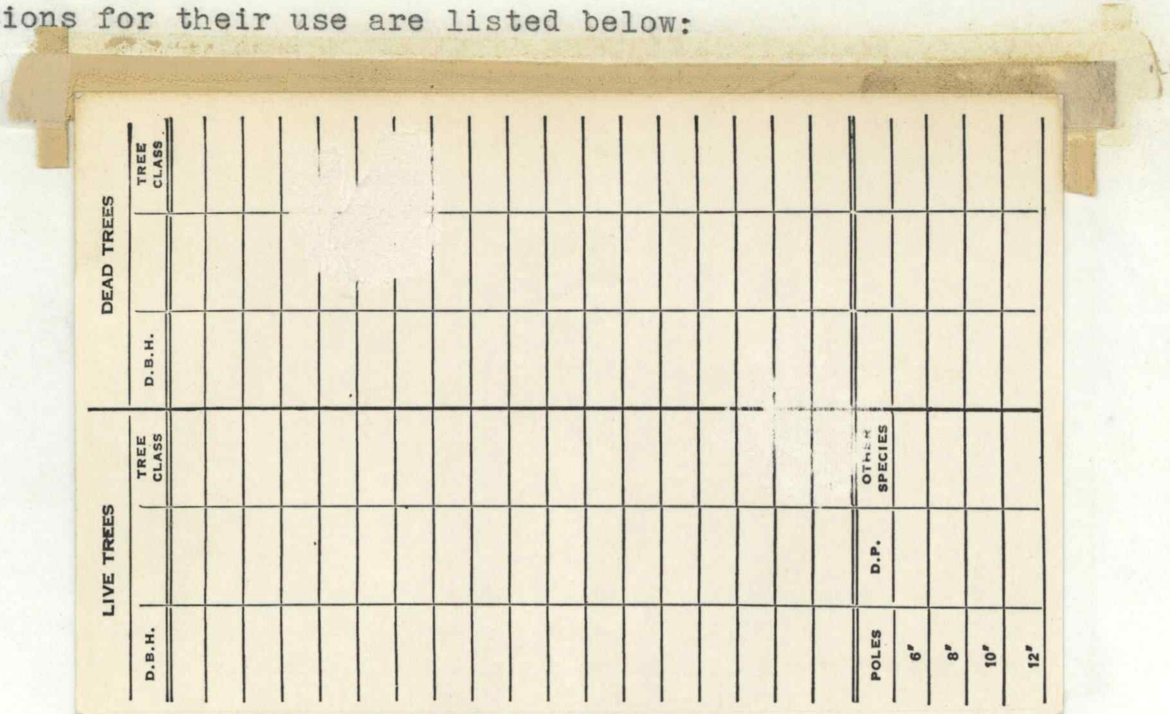

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"The merchantable ponderosa pine (12 inches D.B.H. and over) nearest the center of the plot will be considered the sample tree.

"This tree along with the other merchantable trees standing on the plot is taped and classified according to Keen's tree classification and recorded on a tree card. It is important to measure from the center of the circular plot the radial distance of 58.9 feet to the boundary line. In such line cases one-half the trees will be included in the plot and the other half excluded from the plot.

"Each tree card represents a sample plot. Under the heading "locat." on the card the township, range, section and plot number is recorded. The first plot sampled each day may be entered as plot number one and the others numbered consecutively thereafter. The aspect or direction of slope is posted on the card for each plot.

"On the back of each tree card an inventory of the sample plot is recorded under the headings of live trees and dead trees. The species and their diameter which will be taped and read by 2-inch classes are entered on the cards for both live and dead trees (12 inches D.B.H. and over) on the plot. The live and beetle-killed ponderosa pine will also be classified according to Keen's classification.

"The items on the face of the tree card pertain to the sample tree. As only one tree on a plot is sampled for log sizes and grades, it is highly important that precision and accuracy accompany the measurements and estimations of the sample.

"The diameter of the tree is taped at four and one-half feet from the ground and is recorded on the card to the nearest one-tenth of an inch. The sample tree is classified according to Keen's classification.

"By use of an Abney the total height of the tree is determined and entered on the card. The number and size of each 16' log in the tree is estimated on the basis of utilizing all merchantable logs in the tree.

"As a reliable means of determining the diameter inside the bark at the small end of the first 16' log in the standing tree, the form class based on the estimation of the cylindrical form of the butt log is used. The form class expresses the relation in percent of the DIB at the small end of the first or butt log to the DBH of 40.5 inches and a form class of 75 percent would scale 30" in diameter. In estimating the form class it is essential that a check on the eye estimate be made from time to time by following the fallers in the woods. Before the tree is felled the form class, number, and sizes of logs in the standing tree should be estimated and then after falling an actual check on the estimation should be made by scaling the logs in the felled tree. The form class for most trees will fall within a range of 70 percent to 87 percent of a tree diameter.

"The taper for the remaining logs is recorded in the taper column on the cards. The diameter of the first log can be calculated (convenient to use small slide rule) at the time the form class is estimated and the diameters of the remaining logs determined. For example, the DIB at the small end of the second log would then be found by subtracting the taper of the second log from the calculated diameter of the first log.

"Log grades are based on the surface appearance of the log. Once the size and number of logs in the standing tree is determined, grades may be judged by observing all faces of the log and applying the log grade rule. (See page number 13)

"Diameter growth for all sample trees of Keen's classes one, two, and three will be obtained by boring each tree and counting the core in the field. This can be done conveniently and accurately in the field provided an increment borer with a sharp cutting edge is used along with a razor or knife for cutting a clean surface on the core and a hand lens to magnify the annual rings for counting. The signs on the core are counted back to 1920 (growth from 1920-1937 considered abnormal on account of drought period); each division being marked with an indelible pencil. Reading the "20" scale on a six-inch ruler, the growth for the two periods is converted directly into diameter growth in inches.

"At the end of each day's work a tally of all trees recorded on the cards will be made by segregating the species by tree diameters and for ponderosa pine by Keen's tree classes. One tally sheet will be used for "live" trees and another for "dead" trees. The locality and number of plots for each day's work will be recorded on the tally sheet as will as the total number of trees by species and classes.

"The tree cards should then be indexed and filed away in boxes."

LOG GRADES

It may be appropriate to list the ponderosa pine log grades while the logging study is still fresh in our mind. Below is the log grade descriptions as reworded by the Pacific Northwest Forest and Range Experiment Station:

Grade 1

"Shall be smooth and surface clear without indications of knots near the surface, providing, however, that 1 pin knot is permissible any place on the log.

Grade 2

"Shall be smooth and surface clear on three faces but with knots permissible on the fourth face; or shall be smooth and surface clear on the lower three-fourths of the length, above which a few knots are permissible; or shall be smooth and surface clear to within 2 feet of the upper end, above which any number of knots are permissible. In any case 1 pin knot is permissible on the clear portion of the log.

Grade 3

"Shall display knots which may vary from small black knots to large sound or unsound knots but which are spaced at least 3 feet apart (longitudinally) when the knots are staggered or 6 feet apart when they are in solid whorls. The surface clear areas must aggregate at least 50 percent of the total surface of the log, provided that each clear area must be at least 4 feet long by one-fourth the circummerence in width.

Grade 4

"Shall display numerous small and medium-sized red (live) knots, provided, however, that black (dead) knots which in the grader's judgment will cut out sound beneath the surface (usually on black barked logs) are permissible. The size of the knots shall be proportionate to the size of the log. For a 12-inch log 2-inch live or 1-inch dead knots are for a 24-inch log 4-inch live or 2-inch dead knots are permissible. An average longitudinal spacing of not less than 2 feet shall be required for logs with maximum knot sizes.

Grade 5

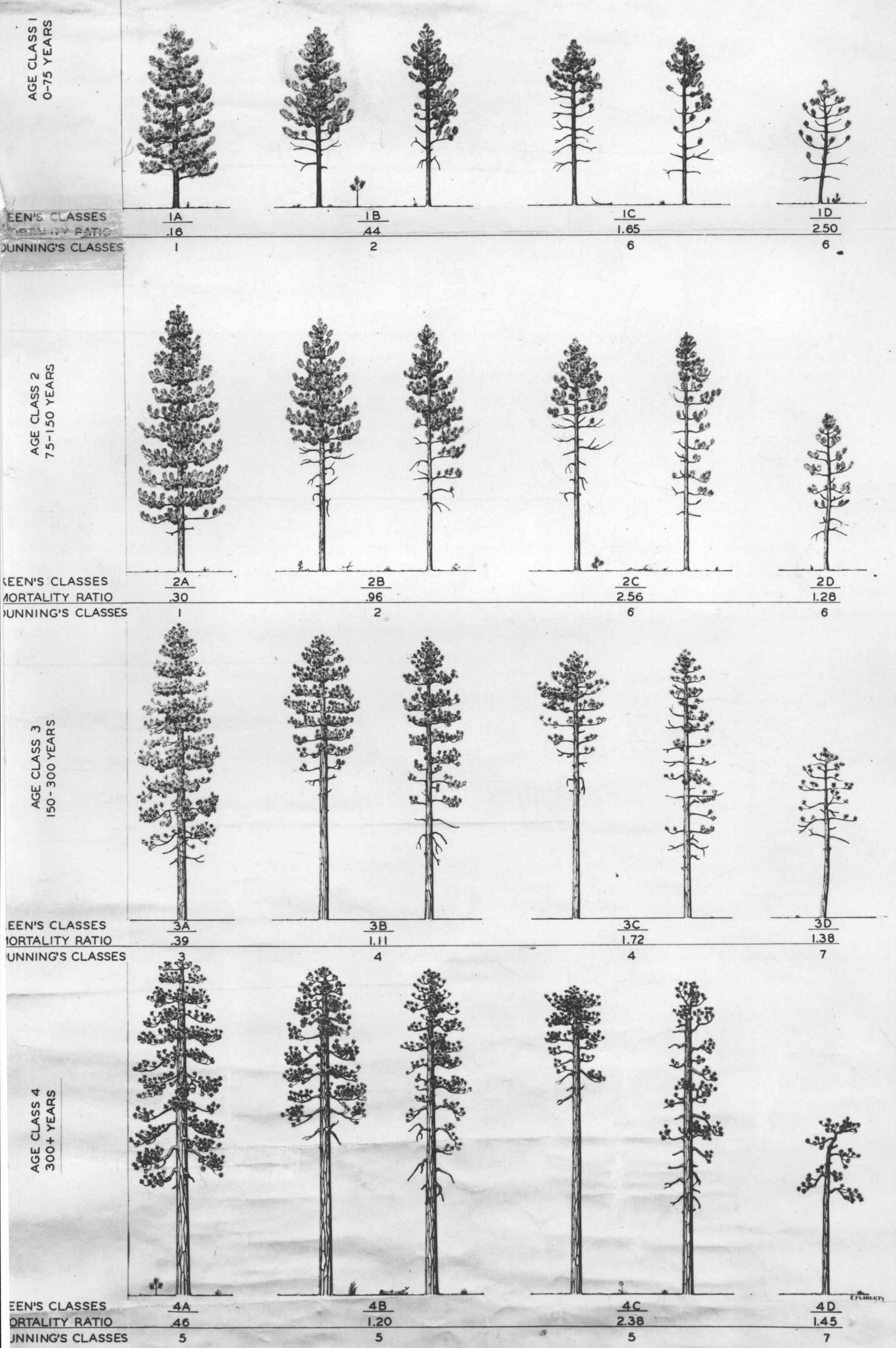
"Shall display numerous live and/or dead knots, the maximum size of which shall be proportionate to the size of the log. For a 12-inch log, 4-inch live and 2-inch dead knots, and for a 24-inch log, 5-inch live and 3-inch dead knots, and for a 36-inch log, 6-inch live and 4-inch dead knots are permissible. An average longitudinal spacing of not less than 2 feet shall be required for logs with maximum knot sizes.

"Logs with larger knots shall also be admitted to this grade if their surface clear areas aggregate at least one-third of the total surface of the log, provided that each clear area must be at least 3 feet long by one-fourth the circumference in width.

FIG. 4

A PONDEROSA PINE TREE CLASSIFICATION

FOR COMPARISON OF BARKBEETLE SUSCEPTIBILITY CLASSES BASED ON AGE AND VIGOR



EEN'S CLASSES	1A	1B	1C	1D
ORTALITY RATIO	.16	.44	1.65	2.50
UNNING'S CLASSES	1	2	6	6
EEN'S CLASSES	2A	2B	2C	2D
ORTALITY RATIO	.30	.96	2.56	1.28
UNNING'S CLASSES	1	2	6	6
EEN'S CLASSES	3A	3B	3C	3D
ORTALITY RATIO	.39	1.11	1.72	1.38
UNNING'S CLASSES	3	4	4	7
EEN'S CLASSES	4A	4B	4C	4D
ORTALITY RATIO	.46	1.20	2.38	1.45
UNNING'S CLASSES	5	5	5	7

Grade 6

"Shall be rough, coarse or densely knotted logs unsuited to any of the previous grades.

General Considerations

"Foregoing specifications as to spacing between knots refer to distance between knot or limb edges rather than from center to center.

"Defects for which deductions are made in scaling shall not be considered in determining log grades.

"Standing trees shall be graded on the basis of 16-foot logs and each log shall be graded solely on the basis of its own grade characteristics, i.e., the grade characteristics of adjoining logs shall not be allowed to influence the grader's judgment." (4)

TREE CLASSIFICATION

"This tree classification, illustrated by the accompanying chart, is applicable to the ponderosa pine forest of the Pacific Northwest. It is based upon the two major factors of age and vigor. Four age groups are recognized and numbered one to four; and four degrees of crown vigor are lettered A to D. Combining these two factors gives 16 possible groups into which any ponderosa pine in the stand may be classified.

Age groups

1. Young trees--less than 75 years old, commonly referred to as "bull pines" or "black jacks"; with dark brown to black, deeply ridged bark, top usually pointed and branches upturned and in whorls.

2. Immature trees--75 to 150 years; trees still making height growth and with pointed tops; bark reddish brown, fissured; branches in whorls, mostly upturned.

3. Mature trees--150 to 300 years; usually with rounded or pointed tops; bark light reddish brown with moderately large plates between the fissures; incomplete whorls or branches with nodes indistinct; nearly all branches horizontal and the lower ones drooping.

4. Overmature trees--over 300 years with flat tops and making no further height growth; branches mostly drooping, gnarled or crooked; bark light yellow in color, the plates usually very wide, long and smooth.

Vigor groups

A. Full vigorous crowns with a length of 55% or more of the total height and of average width or wider; foliage usually dense, long and green; position of tree isolated or dominant (rarely cod.).

B. Fair to moderately vigorous crowns with average width or narrower and length less than 55% of the total height; either short wide crown or long narrow ones but not sparse nor ragged; position, usually codominant but sometimes isolated or dominant.

C. Fair to poor crowns, very narrow and sparse or represented by only a tuft of foliage at the top; foliage usually short and thin; position usually intermediate, sometimes codominant, rarely isolated.

D. Crowns of very poor vigor; foliage sparse and scattered or only partially developed; diameters decidedly subnormal considering age; position suppressed or intermediate."

TIME STUDIES

Time studies should be made of the log-making, skidding and yarding, loading, and transportation operations. Felling time studies are determined by tree size relations while the other operations are on a log size basis. When these data are compiled with the wages paid, cost of teams, trucks, etc., it is possible to compute the costs for logs and trees of different diameters.

The time study of log-making is started by observing the felling and bucking crews in the woods. For trees of various stump diameters, inside bark, will be recorded the time necessary for felling, limbing and marking of logs, and bucking time. It is necessary to observe the felling, bucking, and limbing of several trees so that a better average will be maintained.

The time study will show that the time for making the felling cut varies with the stump diameter and for making the bucking cut, with the log diameter; other items such as gathering tools, walking from tree to tree, and swamping tend to be constant per tree; still others such as limbing, marking log lengths, and walking from log to log in bucking varies as the number of logs in a tree but were more or less constant per log. The remaining time, rests and delays, belongs to the "non-productive category."

All time studies of activities performed by different crews working independently of each other, as felling, bucking, limbing, skidding, etc., involve variations arising from differences in personal efficiency entirely aside from effect of the tree or log size or rate of output. Provisions should be made to distribute the observations so each crew will be represented by approximately equal proportions of the time study. The combined data will then be a cross-section of the average efficiency of the crews.

Figure V represents hand felling in the pine region by crews who do no limbing or bucking after the trees are cut. In large timber, both members of a crew work on the same tree at the same time but in small timber they usually work singly when swamping and undercutting. Since the direct purpose of making the study is the determination of the total working time required to fell each tree, the observer may have to account for man-minute part of the time and crew-minutes part of the time.

Section AB is for recording crew-minutes and sections A and B when the members of the crew perform different tasks.

FELLING

Tree No. 94 Spec. P Location Landing #5
D.B.H. 48.1 in's. Crew #4 Date 10/7/34

(AB)			(A)			(B)		
Item	Time	Net	Item	Time	Net	Item	Time	Net
FWD	9:03.2							
M	3.9	0.7	(Dist. 75 ft.)					
SW	5.4	1.5						
U	9.3	3.9						
B	10.2	0.9		10.2			10.2	
	10.6	---	U	10.6	.0.4	Oil Saw	10.6	0.4
S	16.8	6.2		16.8			16.8	
	17.3	---	Oil Saw	17.3	0.5	W	17.3	0.5
S	17.8	0.5		17.8			17.8	
	18.7	---	R	18.7	0.9	W	18.7	0.9
S	21.9	3.2						
T	9:23.9	2.0						

	Man-min	Crew-min.	Height
Plan			Low Side 0.9'
Move	1.4	0.7	
Swamp	3.0	1.5	High Side 1.3'
Undercut	8.2	4.1	
Bark	1.8	0.9	
Saw	20.7	10.35	
Wedge	1.4	0.7	
Tools	4.0	2.0	
Rest	0.9	0.45	
Misc.			
Total	41.4	20.7	

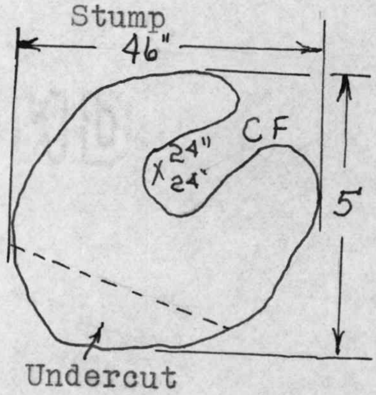


Figure 5

If faller A had undercut tree 94 alone while faller B was undercutting tree 95, the entry for B should still be made on the form for tree 94, with a notation just above the entry "Tree No. 95". The net time is transferred to tree-95 form and deducted from tree-94 time in the office.

The space in the lower right-hand corner is filled with a sketch of the stump to show its irregularities. A sound stump need not be sketched, but height and diameter should be noted.

The "Oil Saw" enteries are added in with "Sawing" in the summary, since oiling the saw is an essential part of the sawing job. It is not itemized when both men are sawing together. The capital letters denoting the activity items are the first letters of the items at the bottom of the form. Miscellaneous minor items not to be seperately computed should be designated "Misc" under "Item".

Limbing Studies

From one standpoint, limbing is a charge against each log limbed. A grade-1 log with no limbs will bear no limbing cost. To arrive at the true cost log by log, it is necessary to make the timing study log by log. A log by log limbing study should be preceded by marking each tree in mill-log lengths, since an accurate estimate of length and position during the timing study is practically impossible.

Considered from another angle, limbing is a charge against the whole tree as a unit, including lopping of the unutilized top. Figure 6 shows a limbing study form for timing by logs only. Starting time on this form is the time when the first chopping begins on each tree---finishing time when the last limb is chopped. Moving time is obtained by deducting "finish" entry from the next succeeding "start" entry.

LIMBING TIME BY LOGS

Location L #5 Limber #2 Timer MH
Tree No. 125 Species P DBH 62.5"
Date 4/28/35 M= move; C= chop; S= saw
T= tools; R= rest

Log No.	L'gth.	Grade	Diam.	Watch Time 10:24.5 fwd. from 124	Net Time
(Move 60 ft from # 124)				M 25.0	
1	16	1			
2	16	2A		C 26.5	
3	14	2B		C 29.4 S 47.8 to 50.5 R	51.5
Brk	6			Not limbed	
4	16	2B		C 32.7	
5	16	4		C 37.3 T 38.3	
6	16	4		C 41.5	
7	16	4		C 43.0	
8	16	3		C 45.1	
9	18	3		C 46.8	

Figure 6--Limbing study form for enteries by logs. Diameters are entered later from records of tree measurement crews.

(8:65)

LIMBING TIME BY TREES

Location______________Limber__________Timer_______Date_____

Tree No.	Spec.	Start	Finish	Net: Time	Remarks
125	p	10:25.0	C* 46.8		*Sharpened T37.3-38.3
		*47.8	Sl 50.5		*Go for saw T46.8- 47.8
126	p	*51.9	C11:05.4		*R 50.5-51.5 M= 0.4 Min

Figure 7--Limbing study form for enteries by trees. Symbols used are the same as those in figure 6. Sl denotes 1 man sawing. If another limber had helped him, the entry would have been S2. (8:66)

BUCKING TIME STUDIES

Bucking time studies recorded by species and cut diameter are applicable to logs of any length. It is necessary to time the bucker on all trees in a felling study unless the direct method is to be used in obtaining costs by trees. Under the reconstruction method, time per tree by d.b.h. classes can be readily calculated for all trees by application of curved time per cut to the scaled diameter.

A form for detailed timing by cuts is illustrated in figure 8. Enteries are made in the same manner as with the previous forms.

BUCKING---WOODS

Location__________Bucker__________Timer_______Date_______

Tree No.	Cut No.	Start to: Swamp	Start to: Buck	Finish	Miscellaneous

(8:67)

Figure 8

Felling, Limbing, Bucking and Tree Measurements

Tree No. 150 Spec. P Class 5 DBH 59.8" Stump 61.4"-1.6' Location L.#34

M = Move; SW = Swamp; PL = Plan; E = Effective direct time; R = Rest; T = Tools

FELLING TIME	
Date 10/7/34	Timer MH Lv. last tree 9:03.2 M 03.9 (75 feet) SW 08.4 E 53.4*
	Crew #6 *R 5.4 min. T 2.1 min.

Log	Woods	1		2		3	Brk	4		5			Brk Tip		Util.	To 10"	Brk	Stump	To
Number	Mill	1B	1T	2B	2T	3	—	4B	4T	5B	5M	5T	10" Top						
Diam.	O.B	55.1	53.5																
Inches	I.B	51.5	50.3	(etc)															
Log grade		1	2A																
Scale Bd-ft	Gross	195	187																
	Cull	32	10																
Dec-C	Net	163	177	(etc)															
Length	Woods	32.7		32.8		16.7	4.8	28.9		39.0			5.6	3.5	150.1	160.5	10.4	1.6	175.6
feet	Mill	16.4	16.3	16.4	16.4	16.7		14.5	14.4	14.4	12.3	12.3			150.1				

		1B	1T	2B	2T	3
	FWd	8:52.1				
Limbing		M53.2	E59.6	9:03.1		
Date	10/8/34			T05.1	(etc)	
Timer	JB					
Limber	#2					
	FWd	10:38.2		M11:31.3		
Bucking		SW 42.9		SW 32.7		
Date	10/10	T 44.3		E 59.3		(etc)
Timer	WSP	E* 11:30.5		R12:00.0		
Bucker	#5	*(Saw		Noon		
		pinched)		hour		

Summary	M	SW	PL	T	R	E	Total
Felling							
Limbing							
Bucking							

(8:71)

Figure 9 — Form Including all Log-Making

Felling, limbing, and bucking studies combined in Figure 9. A form for recording felling, limbing, and bucking time on a single sheet for each tree, together with full tree measurements, is shown.

This form is used when the felling crew also does the limbing and bucking as soon as each tree is down, or when the limbing and bucking can be scheduled to follow within short time intervals.

ELEMENTS OF LOG-MAKING TIME*AS A
BASIS FOR COMPUTING COSTS OF LOG-MAKING

Stump diam. inside bark	Felling Time*	Log Diam inside Bark	Bucking time	Tree diameter breast high	Limbing and marking time per log for trees of limb size- 1 & 2	: 3 & 4
Inches	crew minutes	inches	crew minutes	inches	crew minutes	crew minutes
10	3.71	6	0.59	10	0.90	0.93
11	3.72	7	0.61	11	0.90	0.98
12	4.38	8	0.73	12	0.91	1.02
13	5.08	9	0.80	13	0.93	1.07
14	5.06	10	0.95	14	0.95	1.11
15	5.43	11	1.15	15	0.98	1.16
16	5.33	12	1.23	16	1.02	1.21
17	5.94	13	1.39	17	1.06	1.26
18	6.31	14	1.58	18	1.10	1.31
19	6.78	15	2.01	19	1.15	1.37
20	6.95	16	2.18	20	1.20	1.42
21	7.66	17	2.30	21	1.25	1.47
22	7.71	18	2.53	22	1.31	1.53
23	9.59	19	3.39	23	1.37	1.58
24	10.37	20	3.89	24	1.42	1.63
25	10.39	21	3.82	25	1.48	1.69
26	9.29	22	4.59	26	1.55	1.74
27	12.85	23	4.75	27	1.61	1.80
28	12.76	24	5.49	28	1.67	1.85
29	13.56	25	5.76	29	1.73	1.91
30	14.41	26	5.82	30	1.80	1.97
30	15.31	27	7.20			
32	16.16	28	8.00			

Figure 10-shows felling time by stump diameter, bucking time by log diameter, and other items of log-making costs. From this basic table the time and cost per M feet for making logs from trees of different sizes can be computed.

"How to use the table: Example, Tree 11 inches d.b.h. of limb size 1, with 10-inch stump, yielding 3 logs, 9,7, and 6 inches in diameter. Felling time is 3.71; bucking time, 0.80 minutes plus 0.61 plus 0.59 minutes; limbing and marking time, 3 times 0.90; or a total log-making time of 8.41 crew-minutes. Assuming a cost of 2½ cents per effective crew-minute, the cost for the tree becomes 21 cents. If the tree has a volume of 80 feet, net scale, the cost per M feet is $2.63. (2:47)

SKIDDING

In making a time study of the skidding operation, the results will vary with the motive power--horse or cat logging. This study is to be made on the ground by taking the necessary data while the operation is in progress. The following correlations must be recognized; time in, with distance, size and number of logs carried; time out, with distances; hooking and unhooking, with size and number of logs carried.

Figure 11 is an all purpose skidding form. One form is used for each turn by a "chasing timer", or by the observer stationed in the woods with the hook-up crew when the "landing observer-woods observer" system of study is followed.

In knowing the skidding time required for logs of different sizes, corresponding costs per minute can readily be determined by multiplying the minutes by the cost per minute. Figure 12 shows the skidding time by log diameter (this table is just an example as it is used in different timber type with horse skidding).

SKIDDING

Equipment #1 Trail 4-C Date 9/10/34
Turn No. 3 Observer MH
Distance 2900' Slope Ave. 2% Stump 456 ≠ 50

ITEM	WATCH	NET	STA. DIST.	SLOPE	REMARKS
FWD	8:22.7				
TL	23.1				
0	27.1		3		
0	32.2				
WC	32.4				
TW	33.8				
HK	34.1				#456-1
Spot	34.7		(50)		
HK	35.1				#456-2
Spot	35.7		(30)		
HK	36.9				#456-3
Y	37.2		(30)		Brk. line
D	48.3				Fix line
In	51.4		4	Drop 453:2	
--	54.5		3		
--	9:00.6		2		
--	2.9		1		
--	3.1		1-40'		Stop to
MK	4.4				mk logs.
In	5.3				
Unkh	5.6				

Log No.	Diameter Inches Sm.	Diameter Inches Lg.	Length feet	Gross Scale bd. ft.	Cull bd. ft.	Gross cubic feet
456-1	34	42.3	32J		60	
-2	19	34	32J			
453-2	28	31	32P	(Dropped after hk)		

Figure 11--All purpose yarding form.
Symbols---TL-Turn at landing; 0-out time; TW-turn in woods; HK-hookup time; y-yarding to tractor with line and drum; D-delay: MK-marking logs; Unhk-unhooking; In-Time from end of hookup to arrival at landing.

Elements of Skidding Time as Used as a Basis
For Computing Cost of Skidding

Log Diam. inside Bark	Hauling Time	Haulback Time	Hookup Time	Unhook Time	Total
INCHES	Crew Minutes	Crew Minutes	Crew Minutes	Crew Minutes	Crew Minutes
6	1.10	1.05	0.16	0.69	3.00
7	0.87	1.05	0.25	0.59	2.76
8	0.87	1.05	0.25	0.59	2.76
9	0.83	1.05	0.22	0.46	2.56
10	1.01	1.05	0.25	0.61	2.92
11	0.84	1.05	0.22	0.65	2.76
12	0.96	1.05	0.22	0.52	2.75
13	0.92	1.05	0.23	0.58	2.78
14	0.88	1.05	0.20	0.64	2.77
15	0.93	1.05	0.27	0.71	2.96
16	0.97	1.05	0.27	0.80	3.09
17	0.84	1.05	0.26	0.91	3.06
18	0.99	1.05	0.40	0.90	3.34
19	0.99	1.05	0.30	0.82	3.16
20	1.13	1.05	0.37	0.88	3.43
21	1.07	1.05	0.38	1.20	3.70
22	1.37	1.05	0.36	1.08	3.86
23	1.23	1.05	0.56	1.00	3.84
24	1.39	1.05	0.39	1.44	4.27
25					
26	2.27	1.05	0.49	0.62	4.43

(Figures do not include rests and delays which amount to 42.6%) (2:48)

Figure 12

This table was constructed by using only one skidding distance and it would not be representative if skidding distances were longer than used here. When making this study, all distances up to the maximum used on the operation should be considered.

In using this table, a log 20 inches, d.i.b., 16 feet long requires 1.13 crew minutes hauling time, 0.37 hooking up, 0.88 unhooking, and 1.05 haulback or a total crew time of 3.43 minutes. Assuming a cost of 3 cents per effective crew minute, the cost for the log becomes 10.3 cents. The log has a volume of 280 bd. ft., Scribner rule, net scale, the cost per M is $ .36.

The following form is used in making a loading time study. One form is used for each car load and the data on log sizes serves as the basis for anhalysis of the relation between log sizes and transportation costs as shown in figure 15.

TRUCK LOADING & TRIP TIME

Truck ____________ Landing ____________ Date ____________

Trip No. ____________ Distance ____________ Observer ____________

Log No.	Sp	Diam Sm	Diam Lg	L	Def.	Scale Gr.	Scale C	Scale Net	Cu. ft.	Time I	Time Watch	Net
										FWD	8:29.32	
										D	39.10	
1	P	32	35	32						E	40.48	
										BBlk	40.95	
										D	41.15	
2	P	9	17	30						E	41.42	
										D	42.55	
3	P	18	23	32	Rot		5			E	42.75	
4	P	22	26	20	Brk					E	43.32	
5	P	27	33	32						E	43.88	
					(ETC.)							

TRIP TIME

	Watch	Delays and Notes	Net
Arr. W.			
Spot			
Start			
Arr. M.			
Unl.			
Arr. W.			

Figure 13--Form A for recording truck-loading time.

Form A is used for recording truck-loading time, log by log, and round trip travel time. It is used in conjunction with Form B, Figure 14. Symbols used are--Arr. M-time of arrival at mill or other unloading point and the time of unloading Unl.; Arr. W.-arrival in woods; Spot-time truck is spotted at the landing ready for landing. Start--time driver starts away after the load is bound.

TRUCK LOGGING STUDY
Driver's Record
Truck________ Driver________ Date________

Trip No.	Arrive Mill	Unloaded	Delays & Notes	Gas & Oil

Figure 14. Form B used by truck-driver; used for noting time of arrival at unloading point, time load is removed, time lost enroute, and fuel and oil added during the day. (8:90)

Comparative costs of transporting logs of different sizes by truck are determined by methods of study essentially similar to those used in skidding. One observer stationed at the loading point in the woods will be able to obtain loading and round-trip time for as many trucks as the operator is running from that landing. With a little cooperation from the truck-driver he will be able also to segregate unloading and return- time from load-trip time. The cost of loading then can be obtained by multiplying the total time by the cost per effective crew-minute. This cost can then be converted to a thousand basis as demonstrated figure 12.

Figure 15 gives the average loading time by log diameters using various lengths. This data was assembled after the time study was made, or in other words, summarized from the data obtained from Figures 13 and 14.

Figure 15--Loading time by Log Diameter

Log DIB	Loading time for 16-foot logs	Loading time for Other lengths
Inches	Minutes	Minutes
6	0.58	0.42
7	0.52	0.48
8	0.55	0.54
9	0.65	0.59
10	0.71	0.65
11	0.77	0.75
12	0.87	0.76
13	0.96	0.89
14	1.06	0.99
15	1.18	1.01
16	1.27	1.09
17	1.34	1.17
18	1.49	1.30
19	1.62	1.33
20	1.79	1.46
21	1.95	1.65
22	2.14	1.70
23	2.15	1.76
24	2.48	1.73
25	2.52	1.80

The final analysis in determining the cost of log-making, skidding, etc., is the cost involved in getting the log from the stump to the mill pond. A large number of truck or train loads should be observed to ascertain the effect of log diameters. The cost of trucking from the woods to the mill will be higher for small logs than large ones. An important reason is that small logs contain less board feet per cubic foot and also a larger proportion of the heavier sapwood.

The results of a study made for trucking is given in the following table which shows the volume per load for a few representative log diameters. This study is based on the performance of 6-wheeled light trucks.

Figure 16--Relation of Log Diameter to Load Capacity of Motor Trucks

Log Diam. Inside Bark	Number of Logs hauled per load	Volume Per Load--Scrib. Dec. C
Inches	Number	Board feet
6	59.5	1190
10	40.0	2400
14	25.5	2805
18	14.0	2940
22	9.0	2970
Weighted ave.	26.5	2647

From these time studies, the felling studies, limbing studies, bucking studies, skidding studies, loading and hauling studies, the cost per thousand for logs and trees of various diameters can be determined for log-making or the cost per thousand board feet for the various log sizes involved between the stump and mill pond.

THE MILLING STUDY

In order to provide figures on lumber yields, values, and production costs for the operation, a milling study must be made. The study trees from which we have determined the cost of log-making and transporting them to the mill pond are observed in the lumber-making operation in order that we may find the amount and grade of lumber which can be secured from the various log sizes and grades as well as the production cost of converting rough logs into log products.

In the sawmill a record is kept for each log of the amount and grade of lumber it produces, and also the time required at the headsaw to break the logs down into cants. As a log comes into the mill, its woods number is recorded by a study crew member who then renumbers it according to the order in which it is to be sawed. The record kept is such that it ties the mill number and sawmill data into the individual logs and trees on the study tract. At this point in the mill there may be one or two men involved in the study--one to scale and grade the logs and the other to number the logs as they come up on to the log deck, keep the time necessary to saw up the various logs, and record the data on working sheet. Working behind the log-carriage is another member of the study crew who marks the cants as they are sawed off the study trees. This mans main function is to place a mark on every piece of lumber sawed from a study tree so that the other members of the crew can distinguish the boards sawed from the proper logs. Usually about every second or third log sawed is a study log. The reason for not sending one log in after the other is that it gives the tallyman and grader more time in which to record their data. In alternating the logs in this order the marker behind the carriage may mark the first log red, the second green, the next blue, and so on for possibly five colors and then he starts over again. The object in this procedure is to enable the grader to keep the cants of the different logs separate. Every cant should have a wavy mark from edge to edge so that each piece can be recognized after it passes through the edger and trimmer.

The time, in minutes and hundredths, required to saw each log at the headsaw is to be recorded by the second crewman on the log deck. The time recorded for each log included sawing and loading, or the time required to load the log, to saw it up into cants, and move the carriage back into position for the next log.

Time lost in changing saws, oiling, removing bark, and in stops and delays must be recorded separately, and later prorated to each log on a percentage basis.

HEADSAW TIME

Headrig__________Observer__________Date__________

Log No.	Watch Time: Sawing Completed	Net		Delay	Remarks
501	7:03.45*	3.40			*Started Sawing 7:00.05
502	7.40	3.95			
503	9.95	2.55			
504	14.65	4.70			
505	22.55	5.15	P	2.75	*15.70-18.45 fixed air
506	24.75	2.20		*	Skip 6 logs *Change saw 26.6-32.8
507	44.80*	5.30			*Start 39.50
	(etc.)				

Figure 17--Simple form for recording sawing time by consecutive watch readings. Letter P, Log 505, denotes 2.75 minutes prorated delay time.

The fourth man, in a successful study crew, is located near the end of the live rolls after the gang saw, or depending upon how the mill is laid out, at a point just before the lumber goes on the green chain. On every board he places the log and tree number or more simple yet, on the first and last piece sawed from a log.

The lumber in the Ponderosa pine region should be graded on the green chain by an accepted grader of the Western Pine Association. The reason for this is to get some uniformity in the grading used. The grader is assisted by a tallyman who records the necessary information. The actual rough-green grade is marked on each board and recorded on a tally sheet. The record for each board also includes its volume, length, width, thickness and the mill number of the log from whence it came. All boards from the same logs must be recorded on the same tally sheet; sheets will have to be changed when lumber from the next log passes before the grader. All lumber going into the dry kiln should be regraded as it comes out on the dry chain as a piece may drop from A- select, as graded on the green chain, to B-select, etc.

When the mill study is complete an analysis can be made to determine the total milling cost, grade recovery and volume of each log of various size classes. Then by grouping together the logs according to tree numbers, the total volume, grade, and cost for each tree can be obtained.

Figure 18 is an overall cost chart which might be expected to represent any logging operation in the ponderosa pine region. It gives the total cost from stump to pond, pond to car, and stump to car for each of the various steps in converting trees into boards; it gives the total cost of logging and milling at a glance and the operator can tell which phase of the business is being run at a loss, if any.

When knowing the lumber grade recovery for logs of given grade and size you can determine the sales value of each by applying average regional lumber prices. Log values are obtained by securing the average selling price of the various

Figure 18
Costs of a Representative Logging Operation
All on Shipping Tally Basis

	Costs Varying with Log Size	Annl Prod.	Stand Acre	Costs M	Dep.	Total
Felling & Bucking	$ .85	$ .04	$.-	$ -	-	$ .89
Brush Disposal	-	-	.07	-	-	.07
Tractor Skidding	2.04	-	-	-	-	2.04
Deck logs	.03	-	-	-	-	.03
Load cars or trucks	.30	-	.05	-	-	.35
Rail transportation	-	.12	.45	.60	-	1.17
Truck Roads	-	-	.08	.23	-	.31
Truck operation	.60	-	-	-	-	.60
Logging overhead	-	.33	-	.22	-	.55
Stump to Pond	3.82	.49	.65	1.05	-	6.01
Pond	.07	-	-	.06	-	.13
Sawmill labor	1.32	-	-	-	-	1.32
Resaw labor	.19	-	-	-	-	.19
Sawmill supp. & repl.	.42	-	-	-	-	.42
Power house	-	.51	-	-	-	.51
Green chain	-	-	-	.85	-	.85
Dry Kilns	-	.31	-	-	-	.31
Lumber transportation	-	-	-	.13	-	.13
Dry sorter	-	-	-	.54	-	.54
Piling & unstack'g	-	-	-	.07	-	.07
Crane shed	-	-	-	.22	-	.22
Overhead-supt.	-	.17	-	-	-	.17
misc. labor	-	.15	-	-	-	.15
repairs, etc.	-	.11	-	-	-	.11
Compensation	-	-	-	.12	-	.12
Boiler ins.	-	.17	-	-	-	.17
General	-	1.20	-	.12	-	1.32
Taxes, ex factory	-	.25	-	-	-	.25
Plant dep. ex. factory	-	-	-	-	1.32	1.32
Planers	-	-	-	.65	-	.65
Shipping	-	.17	-	1.83	-	2.00
Selling	3.10	-	-	-	-	3.10
Pond to car (incl. sell)	5.10	3.04	-	4.59	1.32	14.05
(excl. ")	2.00	3.04	-	4.59	1.32	10.95
Stump to car (exc. stump.)	8.92	3.53	.65	5.64	1.32	20.06
Stumpage, s.t. basis	----	----	---	3.90	----	3.90
(incl. stumpage)	8.92	3.53	.65	9.54	1.32	23.96

grades which can be obtained from the logs. The average selling price is the average millrun value of the product of an operation per thousand board feet or other unit. The average selling price is computed by averaging together the average market values for each grade of final product produced. A separate average selling price should be computed for each major product of the stand.

Market values must be secured at active markets for the products of the stand. In the Douglas Fir region, the market value of logs may be used, but in the pine belt no such market exists, consequently, it is necessary to obtain the figures from the lumber market. Market values over a period of at least three years preceding should be averaged and care should be taken not to include values which are abnormally high or low, for such values are the result of exceptional conditions. Protracted periods of abnormal market values caused by wars, depressions, and the like, necessitate a very careful consideration in order to eliminate all abnormal values.

By applying the percentage of the various grades recovered from logs of different sizes and grades to the average price per thousand obtained from the average market value, the sales realization of the log can be computed. Figure 19 gives a good example of determining the sales value.

"The average selling price per M must be weighted in proportion to the various grades of the product in accordance with the results of the quality cruise. The first step is to determine the percentage of the total volume found in each

Figure--19

COMPUTATION OF AVERAGE SELLING PRICE

Item	Per cent	Market values	Weighted prices	
V. G. Flooring #3 Cl.	2.5	$49.60	$1.24	
F. G. " "	2.5	34.00	.85	
Finish "	4.5	51.70	2.33	
Siding & Rustic "	10.1	25.30	3.53	
Sel. Com. Dimension	4.5	24.10	1.08	
" " Timbers	6.0	29.40	1.76	
No. 1 Com. Timbers	8.0	23.80	1.90	
No. 1 Com. Plank	13.0	21.50	2.80	
No. 1 Com. Boards	14.0	19.80	2.77	
No. 1 Com. Dimension	20.0	19.10	3.82	
No. 2 Com. & poorer	15.0	13.80	2.07	
Overrun value - 12%			$24.15	
Underweights			2.90	27.05
Slabs and lath				.50
Total on log scale basis				.25
				$27.80

grade class. Each percentage is then multiplied by the average market value for the grade class concerned, and the products for all grade classes are totaled. If lumber grades are used, it is necessary to consider any effect the weight of the lumber will have upon the actual freight paid. Savings in freight, resulting from the lumber being lighter than the weight used in freight computations, are called underweights, and should be added to the average selling price. Overweights, if any, should be subtracted from the average selling price. Likewise, discounts should be deducted and profits from any by-products added." (9:83-86)

From the milling study we obtain the grades and volumes that can be obtained from logs of various sizes. Likewise, in the illustration above, the value of the various diameter classes can be computed. The marginal tree, or log, can then be found by camparing the cost data represented in Figure 18 with the sales value as found in Figure 19. The operator can see at a glance what he may expect to make from a run of logs and he can tell what trees in the woods to cut so that he may increase his profits.

Profitableness of Leaving Small Trees in Any Case

Regardless of the amount of young growth on the area, whether it is seedling, sapling, or poles, it will always be desirable to leave the small trees which are on the border line of merchantability. It won't only be desirable but it will also be profitable to the operator to leave the small trees he now logs. The reason for this is that the small trees yield less profitable lumber grades and are converted into lumber at a higher cost, that is, logging and milling costs are higher than the sales realization for the smaller trees.

The diameter limit of the most profitable cutting, the economic diameter limit, will vary with the extent of the timber holdings, the distribution of trees by diameter classes, the accessibility of the timber, logging and milling costs, value of lumber grades, and the character of the logging and manufacturing facilities.

"An actual comparison of lumber values and production costs for trees of different sizes, such as given in figure 20, shows that the logging and milling costs per thousand feet are highest for the small trees and rapidly become less as the tree increases in size. It shows that the values, on the other hand, are lower for the small trees and gradually increase as the trees become larger. In the case illustrated, the costs and values balance each other when the trees become about 19 inches in dia-

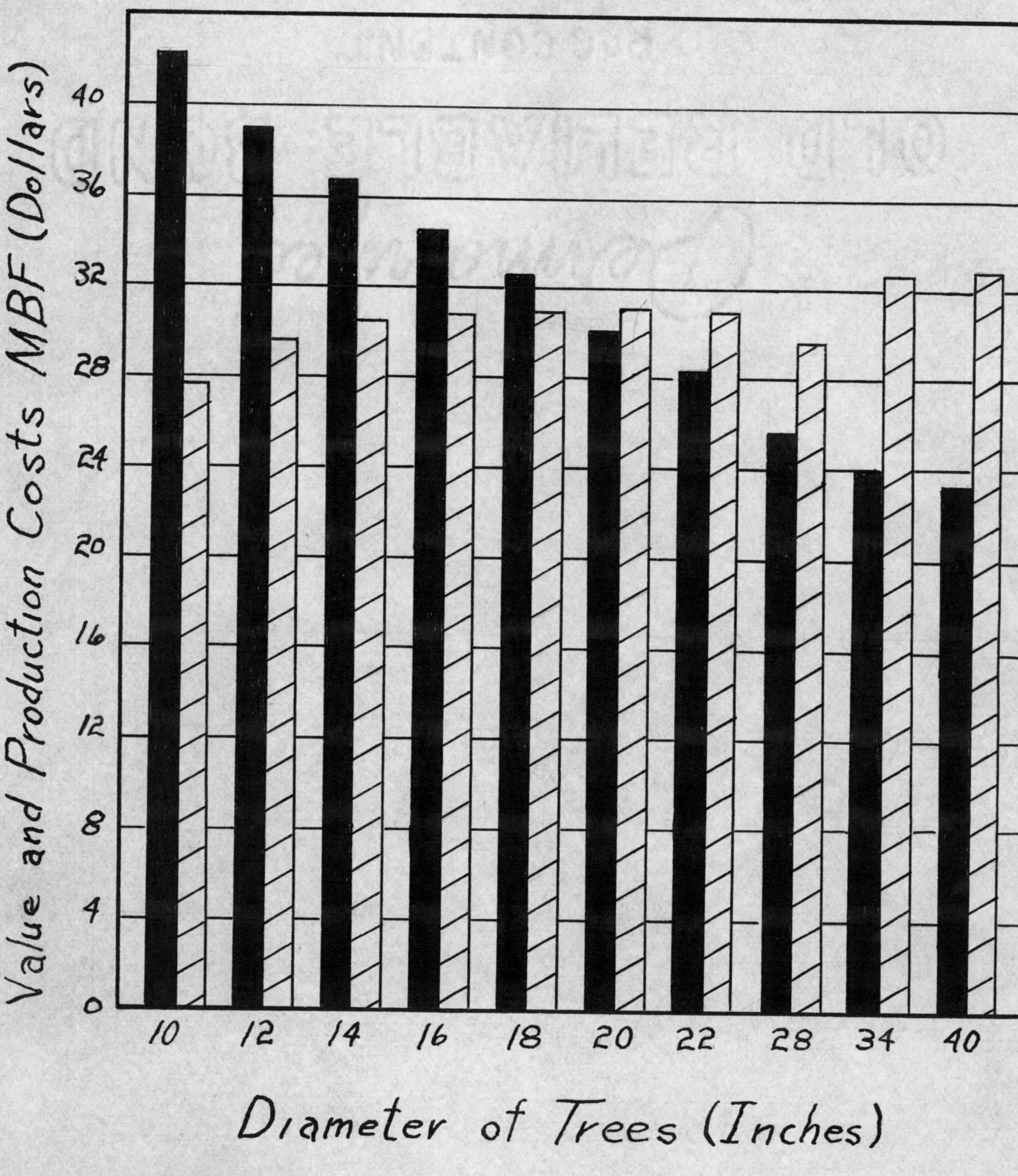


Figure 20--Comparison of Lumber Values (7:42)
and Production Costs.

meter. Below that size, the costs of production are greater than the lumber values contained in the trees, the excess of cost over value being $1.70 a thousand feet in 18-inch trees, $4 in 16-inch trees, and as much as $15 in 10-inch trees." (7:42)

The costs and values will vary somewhat with wages and market conditions but the general relationships shown in the graph will remain much the same. The size at which costs and values balance will be smaller than shown here in some operations and, under other conditions, it might even be higher. Types of logging, skidding, distances, and all such factors carry a great deal of weight in the resultant figures.

The reason for the difference between the lumber values for small and large logs is readily apparent from the table of percentages of lumber grades in ponderosa pine. This shows that the Select grades sawed from 16-inch trees are less than 12 percent of its total volume, and that Selects do not reach 20% of the volume of a tree until it attains a diameter of 20 inches. Shop lumber is practically absent in the smaller trees and barely reaches 5% of the volume of those 20 inches in diameter. The large remainder of the contents of small trees goes into Common lumber. The rather desirable No. 2 Common contains 53% of the volume of 12-inch trees and only 34% of the 20-inch trees.

"It will readily be appreciated, however, that the smaller percentage in the 20-inch trees contain as much

Lumber Grades in Sound Ponderosa Pine Trees of Different DBH

DBH	SELECT			SHOP				COMMON					Total
In.	B&Btr	C	D	No 1	No 2	No. 3	4/4 Com	No. 1	No. 2	No. 3	No. 4	No 5	
10	0.50	4.10	10.0	0	0	0	0	4.00	58.60	19.40	3.40	0	100%
12	0.70	4.70	12.0	0	0	0	0	2.90	52.90	22.90	3.50	.40	
14	1.00	4.30	9.9	.60	.60	0	1.30	2.30	51.80	21.60	5.50	1.10	
16	0.80	3.30	7.5	.50	0	.3	0	1.60	42.60	36.90	5.20	1.30	
18	2.80	4.20	11.7	.30	.40	.6	.60	.50	35.70	32.40	8.80	2.00	
20	4.80	5.88	10.9	.20	.75	1.95	1.30	.92	34.10	32.60	5.70	.90	
22	4.23	6.20	12.23	.40	1.60	1.9	2.20	.66	26.68	36.30	6.90	1.10	
24	6.48	5.08	12.96	2.04	4.20	2.60	2.40	.60	29.50	28.60	4.90	.60	
26	8.30	5.40	10.5	1.40	6.20	5.10	2.10	.10	20.80	29.20	9.20	1.70	
28	9.68	5.89	13.31	3.72	6.60	4.43	2.70	.18	18.45	25.65	8.63	.76	
34	5.73	4.07	12.11	6.17	11.30	6.86	3.10	.18	14.24	25.31	9.43	1.50	
40	7.80	6.60	13.1	8.90	10.50	8.00	4.50	.10	8.10	20.60	10.70	1.60	

Figure 21--Lumber Grades in Sound Logs (7:43)

as three times as the high percentage in the 12-inch trees. This difference in favor of the middle-sized trees is only slightly reduced by the higher overrun of the small classes. Overrun is sometimes as high as 35% in the 12-inch trees and 30 and 20 percent, respectfully, in 20-inch and 26-inch classes. These facts would indicate that there is little justification for belief sometimes expressed by operators that the smallest trees are the chief source of No.2 Common."

In the exhaustive time studies conducted by the Forest Service in ponderosa pine operations in Montana and Idaho, it was found that the cost of felling and bucking a thousand board feet, log scale, from 2-log trees 10 inch in diameter was $2.21 as compared with $1.18 for cutting the same footage from 5 log trees 20 inches in diameter. Horse skidding required an outlay of $7.40 a thousand for 10 inch trees and only $2.88 a thousand for 20 inch trees. The cost of chuting was $3.16 a thousand for 10 inch trees as against $1.77 for an equal amount of logs in the 20 inch class. It cost $1.24 a thousand to load 10 inch trees and only 64 cents a thousand to load 20 inch logs. In the sawmill, it was found that the pond-to green-chain costs for 10 inch trees amounted to $5.92 per thousand and $2.99 for trees in the 20 inch diameter class. The total logging and manufacturing costs were 41% greater for smaller as compared to larger logs.

Figure 22

EFFECT OF DIFFERENT CUTTING LIMITS ON RETURNS
TO DETERMINE COST OF LEAVING SMALL TREES *1.

Diameter Inches	Amount cut per Acre *2	Trees*3 Left per Acre 12" DBH & up	Value of lumber M/ft.	Production cost per M/ft *4.	*5 Total Returns Per M/ft.	Per Acre
9	17,728	0	26.35	19.99	6.36	127.95
10	17,716	0	26.35	19.98	6.37	128.05
11	17,679	0	26.36	19.97	6.39	128.15
12	17,613	1.22	26.37	19.95	6.42	128.20
13	17,509	2.63	26.39	19.92	6.47	128.29
14	17,355	4.12	26.41	19.87	6.54	128.39
15	17,214	5.27	26.44	19.83	6.61	128.54
16	17,009	6.49	26.47	19.82	6.65	127.62
17	16,614	8.25	26.54	19.80	6.74	126.03
18	16,333	9.43	26.60	19.80	6.80	124.77
19	15,693	11.49	26.71	19.79	6.92	121.60
20	15,324	12.56	26.78	19.81	6.97	119.33
21	14,845	13.71	26.90	19.83	7.07	116.94
22	14,022	15.39	27.00	19.92	7.08	110.16
23	13,401	16.54	27.14	19.99	7.15	106.00
24	12,611	17.76	27.21	20.13	7.08	98.32
25	11,490	19.20	27.43	20.36	7.07	89.16
26	10,596	20.23	27.56	20.60	6.96	80.74
27	9,404	21.45	27.87	21.01	6.86	70.35

*1 Based on studies conducted in 1928 near Bend, Oregon.
*2 Volume of cut is given in log scale.
*3 Values, costs and returns per M are based on lumber tally.
*4 Logging cost cover log making, skidding, loading, railroading and unloading, and include also charges for improvement, depreciation, administration, railroad construction and maintenance, taxes, slash disposal, fire protection, and interest at 6%. Manufacturing cost cover all steps from pond to car and include charges for depreciation, general expense, taxes, interest, and cash discount.
*5 Represents the amount available for stumpage and profit and interest on stumpage

Figure 22 is the results of a study carried on near Bend, Oregon. The stand was practically pure and averaged 17,728 board feet per acre. The ground was mostly level and the skidding was done with the lidgerwood skyline method.

For each diameter class, the table shows the amount cut per acre, trees left per acre 12" and up, value per M feet, production cost per M Feet, and total returns per M feet and per acre. The value per M gradually increases from 2 inch trees due to the increasing percentage of the higher grade lumber.

By increasing the cutting diameter limit the amount cut per acre is reduced. The production costs per M feet gradually decreased from $19.99 per M for 9 inch trees to $19.79 per M for 19 inch trees where the cost begins to increase. The total return per acre and per M feet reach the point of culmination at different diameter limits. The greatest return per M feet is $7.15 for 23 inch trees and $128.54 per acre for 15 inch trees.

"In one of the logging economics studies made last summer in the ponderosa pine region (1936) of Oregon and Washington a detailed analysis was made of the spread in value among not only diameter classes but also within individual diameter classes. Records for more than 2,000 sample trees, showing among other things volume and grade of each log and net stumpage return, were placed on individual cards. The cards were sorted first by diameter classes and then by value. Finally, each diameter class was divided into value classes, of equal volume, the highest value class being designated 1 and the lowest 10. The average value for each value class was then determined. In the table below the results are shown for the highest, lowest and two intermediate value classes.

"Strikingly wide variations in values are shown. On the basis of diameter classification alone tree values rise from minus $4.65 per M (for 12-inch trees) to plus $6.30 (for 56-inch trees). A strikingly wide variation occurs also within each diameter class, particularly in the higher diameter range; for example, in the 56-inch class the stumpage value per M of class 1 trees is $9.00 higher than that of class 10 trees.

"From the standpoint of selective logging this wide spread within diameter classes is obviously of great importance."

Figure 23--Value of Ponderosa Pine before falling by Diameter and value classes.

Breast-height diameter (inches)	Value per M for value class				Average value per M
	1	4	7	10	
12	-$3.80	-$4.30	-$4.65	-$5.80	-$4.65
16	- 1.40	- 2.55	- 2.90	- 3.70	- 2.75
20	0.40	- 1.00	- 1.55	- 2.10	- 1.15
24	2.25	0.35	- 0.40	- 0.95	0.25
28	3.85	1.70	0.60	0.00	1.40
32	5.40	2.90	1.55	0.60	2.45
36	6.80	4.10	2.40	1.05	3.45
40	7.95	5.05	3.15	1.45	4.30
44	8.90	5.70	3.70	1.70	5.05
48	9.75	6.30	4.15	1.95	5.60
52	10.55	6.85	4.55	2.10	6.00
56	11.30	7.35	4.90	2.25	6.30

(6)

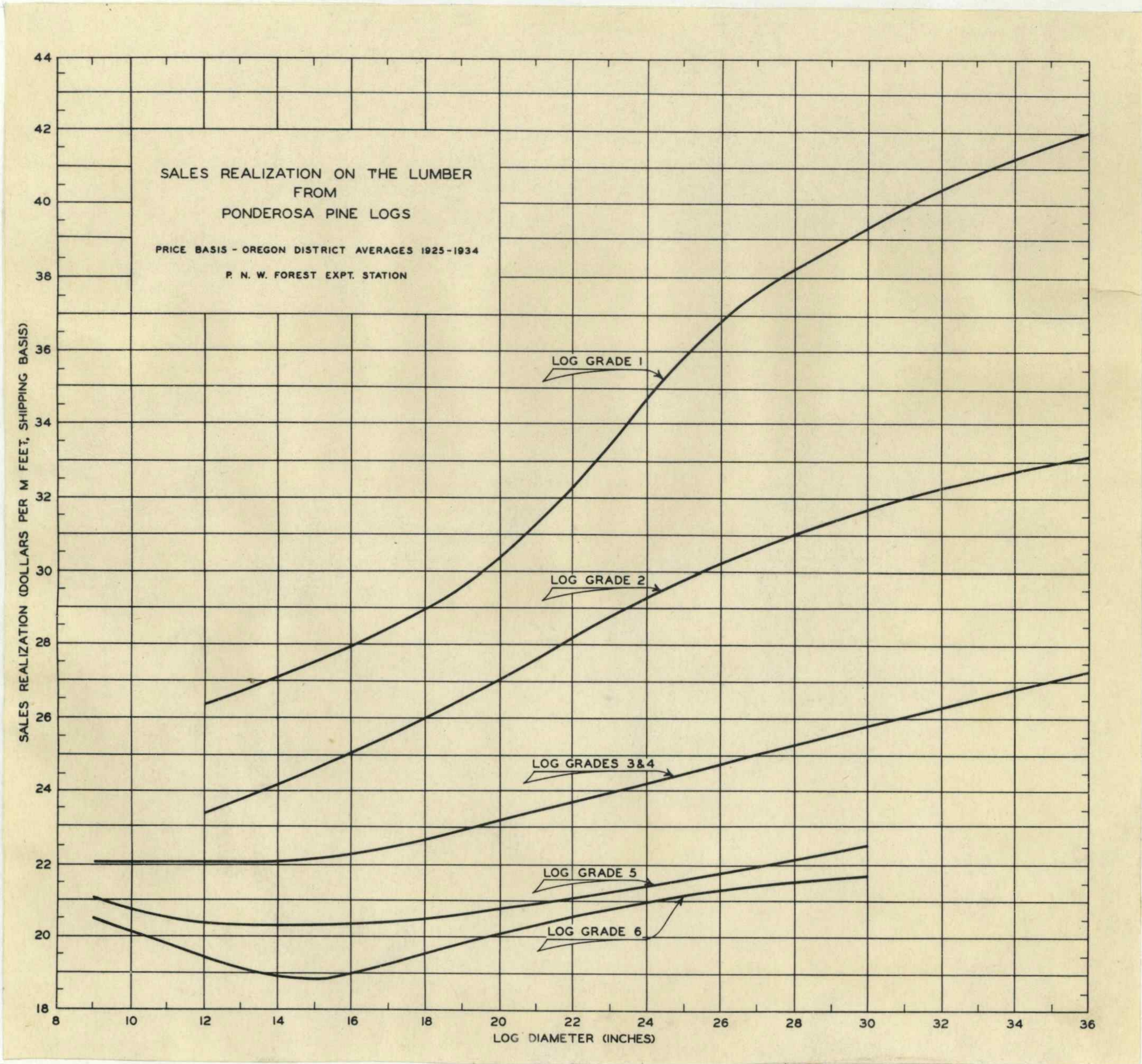

SALES REALIZATION ON THE LUMBER
FROM
PONDEROSA PINE LOGS
PRICE BASIS - OREGON DISTRICT AVERAGES 1925-1934
P. N. W. FOREST EXPT. STATION
LOG GRADE 1
LOG GRADE 2
LOG GRADES 3&4
LOG GRADE 5
LOG GRADE 6
SALES REALIZATION (DOLLARS PER M FEET, SHIPPING BASIS)
LOG DIAMETER (INCHES)
18
20
22
24
26
28
30
32
34
36
38
40
42
44
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36

Figure 24

ECONOMIC OR SILVICULTURAL SELECTION

In times such as these it may seem too optimistic to talk about increasing profits by selective logging. It is all too true that under present conditions the problem has become in many cases of reducing losses.

On any old growth forest there are high grade trees and low grade trees, trees of good species and trees of inferior species. Sometimes the valueless trees are scattered among the valuable trees; sometimes the good species are in patches, strips, or interspersed with inferior species. Conversion values may be as much as $10 per M for the best trees on the easiest ground to minus $5 for the rough trees of the inferior species on the most inaccessible part of the section.

The bull team logger of 30 years ago picked out patches of good timber which was fairly accessible, and proceeded to fall the good trees. His investment was small; his bookkeeping simple, and he could tell just about what each log cost him and what he could get for it.

With the advent of the donkey, highlead and skidder came larger investments in equipment and the necessity of quantity production at high speed which meant clear cutting. This meant logging the entire stand of good, medium, and poor timber. This pretty much ignores quality and goes after quantity production.

It is evident, then, that the crying need for intelligent selection of timber value is not just a passing phenomenon that has come in and will go out with the business depression.

What form, then, should selection take in order to meet the demands of this complex structure of different values and different earning which confronts us in intensive appraisals from log to log, tree to tree, and area to area?

In answer to this question is a comparison of the economic and silvicultural study which was made on a representative logging operation in the Ponderosa pine country. This study was made as outlined in this thesis and the final data from the tree cards are summarized in Figure 25.

The study area included 749 trees with a total volume of 792,933 board feet. The total area of the $\frac{1}{4}$ acre sample plots is 44 acres.

In analysing the cut which is most feasible from the economic and silvicultural standpoint we must take into account the objective of the owner and the size of operation. Other factors will have some affect but I am considering these two points from the standpoint of the field inventory data as was presented to me.

In choosing the economic rotation the operator will want to know the volume to cut at each rotation which will give him the greatest return per acre or per M.

In my analysis of the economic and silvicultural rotation I have encountered a few errors in the data given me which cannot be corrected without considerable time and delay. But as previously stated, this thesis is not a study of a logging operation but is merely an example showing how such a study is made.

From a study conducted on the operation in question, or some other representative operation, a growth study should be made for each of Keen's tree classes. Then to get the growth percent for each of the sample trees in the study the growth percent is taken from the curve and applied to the appropriate size and tree class.

The second step, after finding the growth percent for each of the study trees, is to determine the sales value for the study trees and indicate it on the tree card. When all trees have been given their sales value the sorting of the trees into value classes begins. Tree cards are sorted differently in economic and silvicultural selection so they will have to be dealt with seperately.

Economic selection is made by sorting the trees on the basis of value. The study trees are sorted into 10 value classes--class 1 having the low value and class 10 having the high value trees. For each value class the number of trees are placed upon the summary sheet. The total diameter is found by adding the diameter of all the trees in the value classes. The average diameter is found by dividing the total diameter by the number of trees represented. The total tree value is found by totaling the sales value for each of the study trees, and the value per M is determined by dividing the volume in the value class into the total sales value. The total gross and net growth is sec-

Summary Sheet of Tree Cards — as used in Economic Selection

Total volume divided into 10 Value Classes — #1 being low and #10 being high

Value Class (1)	Volume (2)	Percent of Total (3)	# Trees (4)	Total Diam. (5)	Ave. Diam (6)	Total Tree Value (7)	Value per M (8)	Total Sale Value (9)	Average Sale Value (10)	Total Gross Growth (11)	Total Net Growth (12)
1	76,832	9.68	272	5016	18	$57.22	$ .74	$1,645.29	$21.41	737.90	127.42
2	79,674	10.05	82	2302	28	82.28	1.03	1,728.25	21.69	565.14	-17.56
3	80,109	10.10	70	2016	30	118.46	1.48	1769.29	22.09	504.91	-55.22
4	79,438	10.02	62	1878	30	151.56	1.91	1765.53	22.23	513.55	4386
5	79,716	10.05	52	1692	32	180.91	2.27	1786.68	22.41	460.26	14.13
6	78,848	9.96	51	1654	32	203.40	2.58	1806.74	22.91	448.43	2.27
7	78,998	9.96	44	1548	34	250.92	3.18	1828.19	23.14	367.23	-160.80
8	79,256	9.99	46	1572	34	293.57	3.70	1907.10	24.06	385.65	-156.87
9	80,907	10.20	36	1378	38	371.25	4.59	2005.93	24.79	329.28	-228.21
10	79,215	9.99	34	1306	38	468.77	5.92	2078.99	26.24	280.28	-266.70
Total	792,993		749								

Figure 25

ured by totaling the growth as determined by multiplying each tree class by the corresponding growth percent.

Figure 26, a chart showing the relationship of road construction to value per M, is constructed from Figure 25. When an operator makes a cut of 10 percent of the total volume he will take the highest valued trees or take value class 10. In a 20 percent cut the two highest value classes are taken, and so on to a 100 percent cut. The total tree values and the values per M are accumulated--for a 10 percent cut the average value per M is $5.92 while a 100 percent cut is $2.60. These values are the gross per acre returns which must pay for the per acre costs. Road construction is not a logging cost so it is deducted from the gross value after the logging and milling costs have been paid.

Road construction in the Ponderosa pine type costs, approximately, $.30 per acre when a 100 percent cut is used. In using this figure, the cost for the various cuts can be determined. For example, it costs $ .30 an acre for a 100 percent cut so with a 50 percent cut two acres must be logged to get the same volume, giving a road construction cost of $ .60. The road construction costs are taken from the gross value per M giving the net realization for each type of cutting practice. These values are all plotted on the graph, Figure 27, value per M over Percent cut.

The volume to cut in the economic rotation is taken

Relationship of Road Construction to Gross Value
for Different Cuttings

Percent Reserve	Percent Cut	Total Volume	Percent Yield	Total Tree Value	Value Per M	Road Construction/M	Net Realization/M
90	10	79,215	9.99	$ 468.17	$ 5.92	$3.00	2.92
80	20	160,122	20.19	840.02	5.25	1.50	3.75
70	30	239,378	30.18	1133.53	4.74	.99	3.75
60	40	318,376	40.14	1384.45	4.35	.75	3.60
50	50	397,224	50.10	1587.85	4.00	.60	3.40
40	60	476,940	60.15	1768.76	3.71	.50	3.21
30	70	556,378	70.17	1920.32	3.45	.43	3.02
20	80	636,487	80.27	2038.78	3.20	.37	2.83
10	90	716,161	90.32	2121.06	2.76	.33	2.43
0	100	792,993	100	2063.84	2.60	.30	2.30

FIGURE – 26

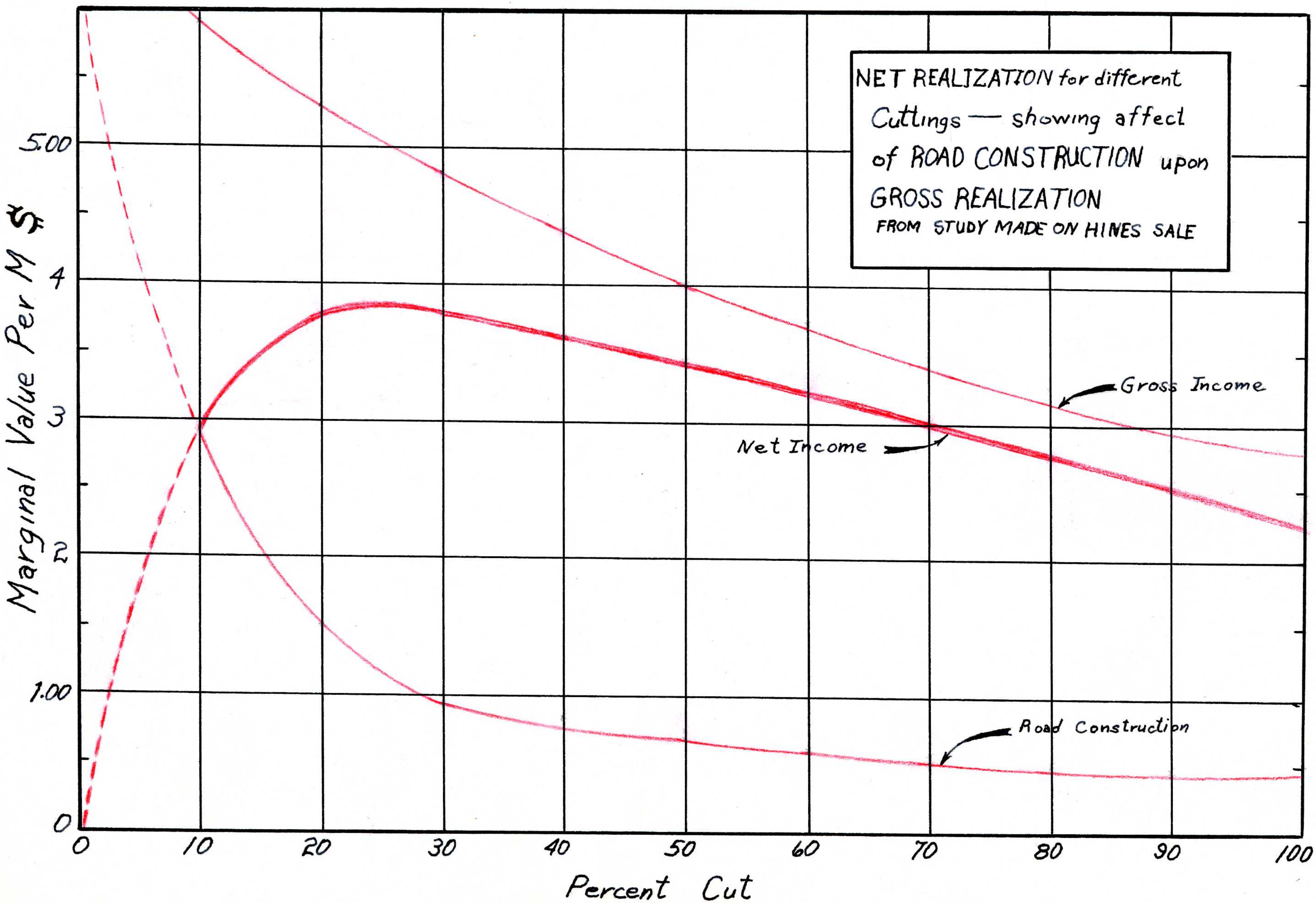

NET REALIZATION for different Cuttings — showing affect of ROAD CONSTRUCTION upon GROSS REALIZATION
FROM STUDY MADE ON HINES SALE
Gross Income
Net Income
Road Construction
Marginal Value Per M $
5.00
4
3
2
1.00
0
0
10
20
30
40
50
60
70
80
90
100
Percent Cut

FIGURE 27

Relationship of Reserve Stand to Growth Per Acre for Different Cutting Practices

Percent Cut	Reserve Stand	Total Volume	Gross Growth	Gross Growth %	Net Growth %	Net Growth	Volume Per Acre	Gross Growth / A.	Net Growth / A
90	10	76,832	737.90	.96%	.16%	127.42	1746	16.76	2.79
80	20	156,506	1303.04	.83%	.07%	109.86	3557	29.52	2.49
70	30	236,615	1807.95	.76%	.023%	54.64	5377.6	40.87	1.24
60	40	316,053	2312.50	.73%	.031%	98.50	7185	52.45	2.23
50	50	395,769	2781.76	.70%	.029%	112.63	8995	62.96	2.81
40	60	474,617	3230.19	.69%	.024%	114.90	10,788	74.44	2.59
30	70	553,615	3597.42	.65%	-.008%	-45.90	12,582	81.78	-1.01
20	80	632,871	3983.07	.63%	-.03%	-202.77	14,383	90.61	-4.31
10	90	713,778	4312.35	.60%	-.06%	-431.08	16,222	97.33	-9.73
0	100	792,993	4592.63	.58%	-.088%	-697.78	18,022.86	104.53	-15.86

FIGURE 28

from the curve. The highest return per M comes at the culmination of the curve--between 20 and 30 percent.

In analysing the affect each cut has upon the reserve stand I have prepared another set of data, Figures 28 and 29, to get a graphic picture of the result. For a 90 percent cut, a reserve volume of 10 percent is left--especially in the lowest valued trees; an 80 percent cut leaves a reserve of 20 percent of the stand of value classes 1 and 2. The net and gross growth is taken from Figure 25 for each cutting practice and entered on the table. The net and gross growth percent is computed by dividing the gross and net growth by the total volume. To get the volume per acre, the total reserve volume is divided by 44, the number of acres in the sampled area. The net and gross growth percent is applied to the volume per acre to give the gross and net growth per acre. These values are plotted on the following graph, Figure 29, to show the relationship of growth to percent of cut.

From this curve it can readily be seen that a 30 percent cut is necessary or the mortality will be greater than the growth. The curve is relatively flat as the trees are selected on the basis of value rather than growth. All large, high valued trees are taken which includes some of the large thrifty trees while the reserve stand will be made up of the lower value classes and slower growing trees.

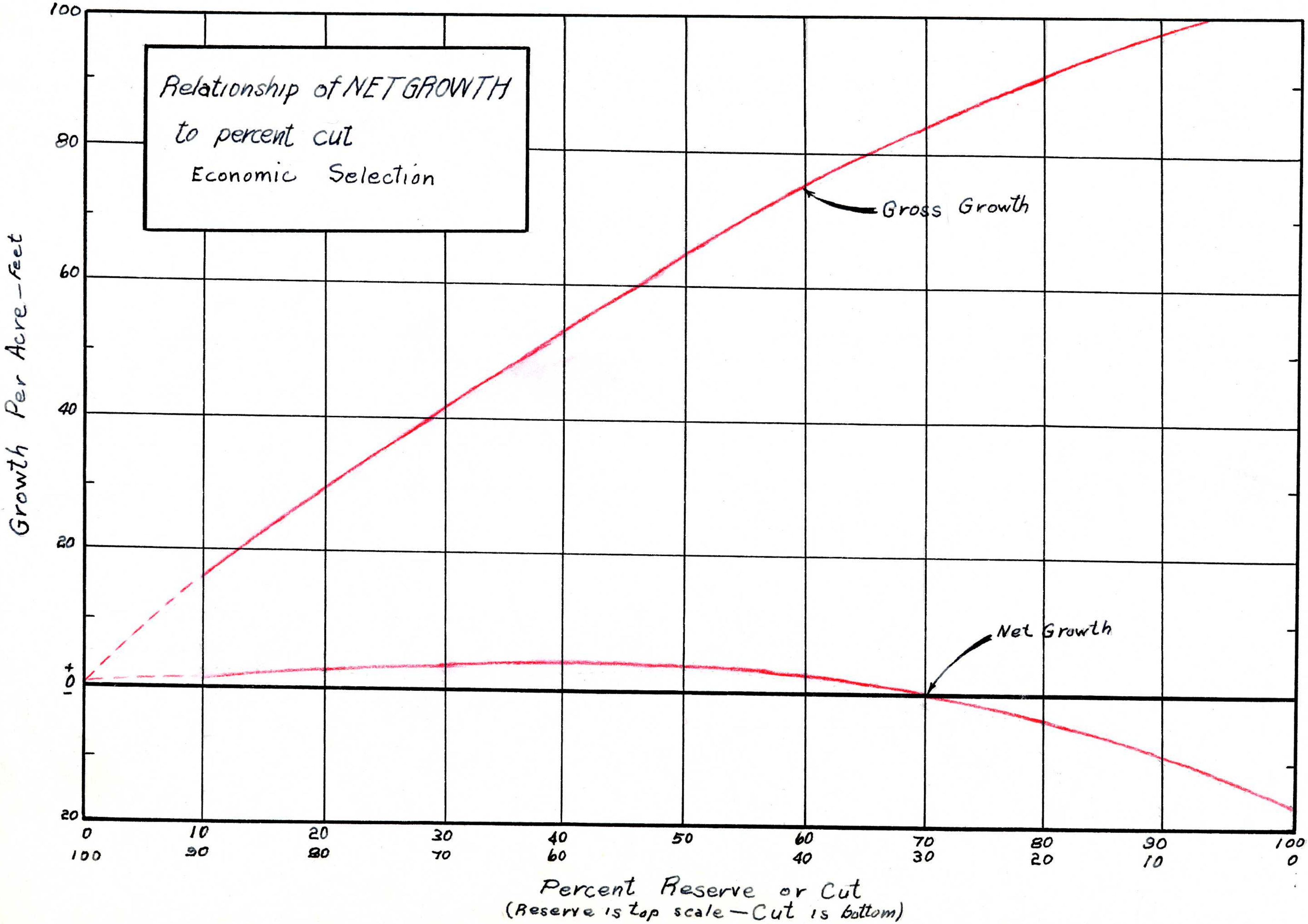

Relationship of NET GROWTH
to percent cut
Economic Selection
Gross Growth
Net Growth
Growth Per Acre—Feet
100
80
60
40
20
+
0
−
20
0 10 20 30 40 50 60 70 80 90 100
100 90 80 70 60 40 30 20 10 0
Percent Reserve or Cut
(Reserve is top scale—Cut is bottom)

FIGURE 29

THE ECONOMIC BASIS FOR SILVICULTURAL PRACTICE

Cutting should have as its objective the silvicultural improvement of the stand. This implies leaving a thrifty reserve stand and making provision for satisfactory regeneration. Cutting should be concentrated among the overmature and mature age classes, but occasional trees of the latter age group must be retained for seed in the absence of adequate reproduction. The retention of thrifty mature trees not needed for seed is justified because these trees increase the volume increment per acre after cutting, and they are not so susceptible to mortality as many poorer trees in virgin stands. It is often advantageous to cut as lightly as possible, depending on the thriftiness of the stand, thereby cutting over more virgin timber per year and reducing the annual mortality on all lands to a minimum.

In the application of the standards set up for cutting the ponderosa pine type, mature and overmature trees should be cut, except where in the absence of younger and better seed trees they are necessary as seed trees or to afford protection for the establishment of reproduction. In general, black-jacks and intermediate trees should not be cut except when a thinning will improve the stand or where a disease or otherwise defective condition of the stand will improve sanitary conditions.

In applying the principle of selective cutting to different types of stands, consideration must be given to the amount, distribution, and size of reproduction, the quantity of immature trees, and the extent of insect, disease, and mechanical defect. When immature trees predominate, cutting should be on an improvement basis--in other words, only those trees should be cut which are in some way defective or which are impeding the growth rate of the stand. Defective trees should be removed in proportion to the seriousness of the defect and the abundance of the sound trees. When defect is so bad as to indicate the death of the tree in a few years, it should be cut. Defective trees which will survive until the second cut can be left if needed for seed or protective purposes.

The selection method of cutting fits in most advantageously with the economic as well as the silvicultural requirements of the forest. It provides for a sufficient nucleus of trees for seed and for a reasonably early second crop, and avoids loss which would be incurred in handling the smaller trees.

The silvicultural requirements of the stand can thus be met by designating trees for cutting on the basis of Keen's or Dunning's tree classification. Actual diameter limits for cutting must be determined for each operation. Trees smaller than the marginal tree, determined by logging and milling studies, should be cut for stand improvement or thinning. Considerable valuable growth is lost when trees occur in dense groups, especially in clumps of immature timber.

Recently Dunning analyzed the growth of ponderosa pine by tree classes. Trees in class one are by far the most rapidly growing, especially in the smaller diameter classes. Average annual growth per cent by tree classes is as follows: Class 1, 3.05 per cent; Class 2, 1.53 per cent; Class 3, .98 per cent; Class 6, 2.34 per cent; Class 4, .59 per cent; Class 7, .65 per cent; and, Class 5, .35 per cent. There is little difference in the growth of Class 2 and Class 3 trees above 18 inches d.b.h. Satisfactory growth of class 6 trees is entirely dependent upon release by cutting. In addition to having a rapid growth, Class 1 trees are a low risk from the standpoint of mortality. On the basis of mortality the seven tree classes rated in the following order, arranged from the lowest to the highest risk: Class 1, Class 3, Class 2, Class 4, Class 5, Class 7, and Class 6. (See Figure 4)

As a general rule, Classes 4, 5, and 7 should always be cut. An exception may have to be made in situations where trees must be left for seed, but where there are no trees among the faster growing classes. Under such circumstances, one of the better trees among class 4 or 5 can be selected for this purpose. Class 1 trees should always be left because of their high capacity for growth and seed production. Class 2 trees should ordinarily be left but they should be cut in preference to Class 1. Care should be exercised in the retention of Class 3 trees. Where the cutting cycle is short, these can be retained to build up the volume of the reserve stand. Where the cutting cycle is to be 50 or 60 years they should not often be left. Class 6 trees have a good capacity for increased growth if they can be released by cutting so they should be retained.

Various factors must be weighed in arriving at a decision as to how heavy a first cut must be made. Some of the economic drawbacks to a light cut per acre that formerly existed in fact or theory have been removed by the recent developments in logging methods. The fewer spur railroads and the longer skidding distances have cheapened logging considerably. A light cut per acre is no longer economically objectionable. It is also recognized that the logging and manufacturing into lumber of trees under 20 inches d.b.h. do not leave a margin for stumpage and profit. Consequently there is little economic justification for cutting small trees.

To give a more significant relationship between the economic and silvicultural selection I have worked up the tree cards by using the same method as was applied to the economic study. The original tree cards were sorted into 10 value classes, <u>on the basis of growth instead of value</u>, with value class 1 being the fast growing and value class 10 being the slow growing trees.

The method of deriving these graphs and tables is same as was done in the economic study so to simplify matters I have eliminated instructions to their use.

A correlation of these two methods would give the ideal system of management. The silvicultural system gives a smaller net realization per acre but leaves a more rapidly grow-

Summary Sheet of Tree Cards as used in Silvicultural Selection

Value class	Total Volume	Percent Volume	Number Trees	Total Diameter	Average Diam.	Total Tree Value	Value Per M	Total Sales Value	Ave. Sales Value	Total Gross Growth	Total Net Growth
1	79,078	9.97	52	1,634	32	$214.66	$2.71	$1,816.32	$22.97	680.52	486.06
2	80,559	10.15	63	1,898	30	193.04	2.40	1,831.46	22.73	554.47	389.52
3	80,278	10.12	48	1,574	32	257.31	3.21	1,883.73	23.47	398.81	155.02
4	79,403	10.01	98	2,444	24	153.90	1.94	1,799.54	22.66	598.67	175.69
5	78,708	9.92	195	3,768	20	71.53	.91	1,742.04	22.18	659.81	135.36
6	78,931	9.95	97	2,464	26	168.81	2.14	1,808.35	22.91	485.10	-128.93
7	78,628	9.92	71	1,978	28	151.26	1.92	1,750.84	22.27	395.15	-298.25
8	79,475	10.02	51	1,678	32	265.85	3.35	1,872.72	23.56	332.08	-402.03
9	79,258	9.99	41	1,486	36	263.21	3.32	1,854.91	23.40	283.00	-503.50
10	78,885	9.95	34	1,354	40	333.76	4.23	1,922.02	24.36	354.03	-777.01
Total	793,203	100.00	750	20,278		$2,073.33		$18,281.93		4741.64	-768.07

FIGURE 30

Relationship of ROAD CONSTRUCTION to GROSS VALUE for Different Cuttings

Percent Reserve	Percent cut	Total Volume	Percent Volume	Total Tree Value	Value Per M	Road construction	Net Realization / M
90	10	78,885	9.95	$ 333.76	$ 4.23	$ 3.00	$ 1.23
80	20	158,143	19.94	596.97	3.77	1.50	2.27
70	30	237,618	29.96	862.82	3.63	1.00	2.63
60	40	316,246	39.88	1,014.08	3.21	.75	2.46
50	50	395,177	49.83	1,187.89	2.99	.60	2.39
40	60	473,885	59.75	1,254.42	2.65	.50	2.15
30	70	553,208	69.76	1,408.32	2.55	.43	2.12
20	80	633,566	79.88	1,665.63	2.63	.37	2.26
10	90	714,125	90.03	1,858.67	2.60	.33	2.27
0	100	793,203	100.00	2,073.33	2.61	.30	2.31

FIGURE 31

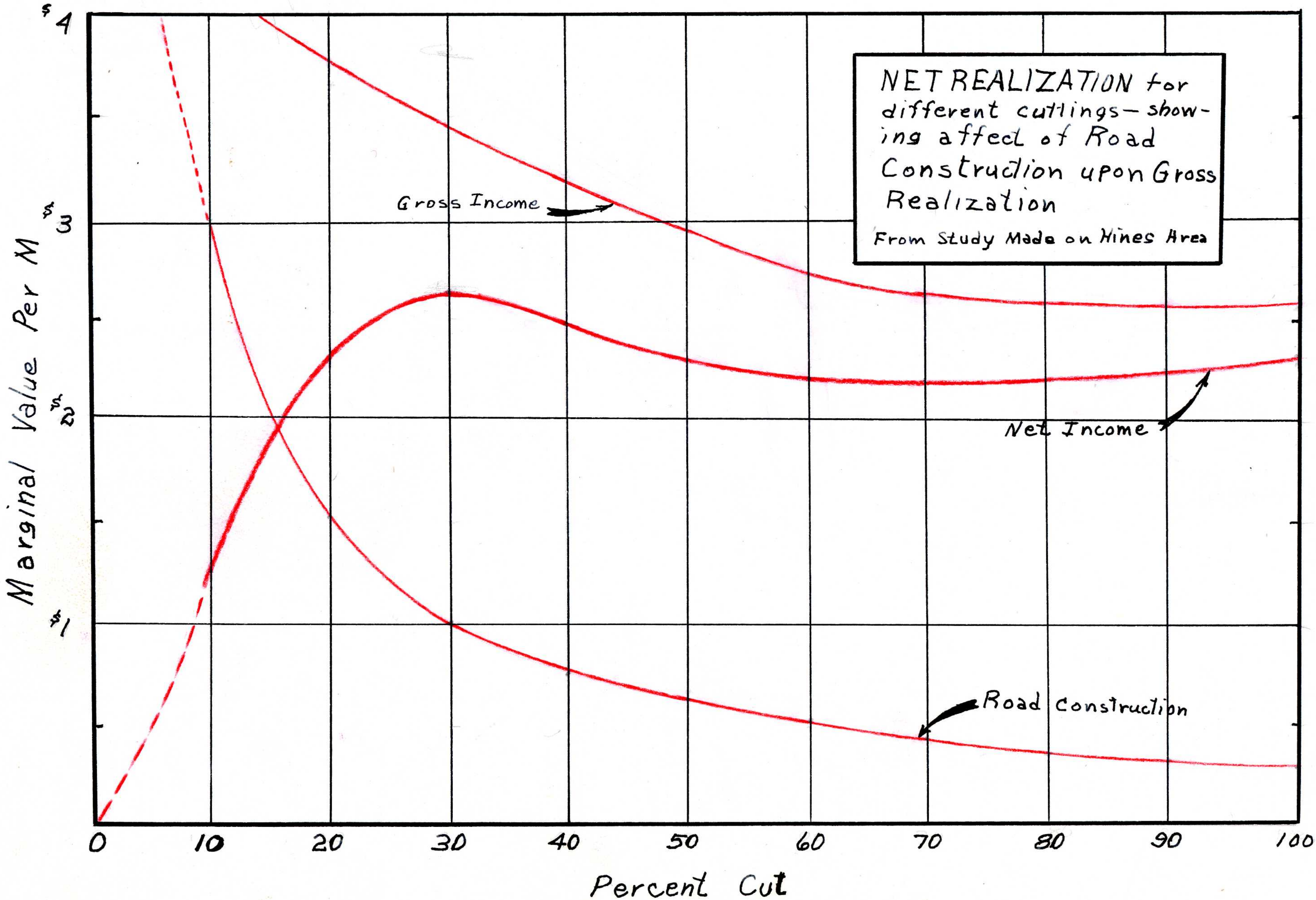
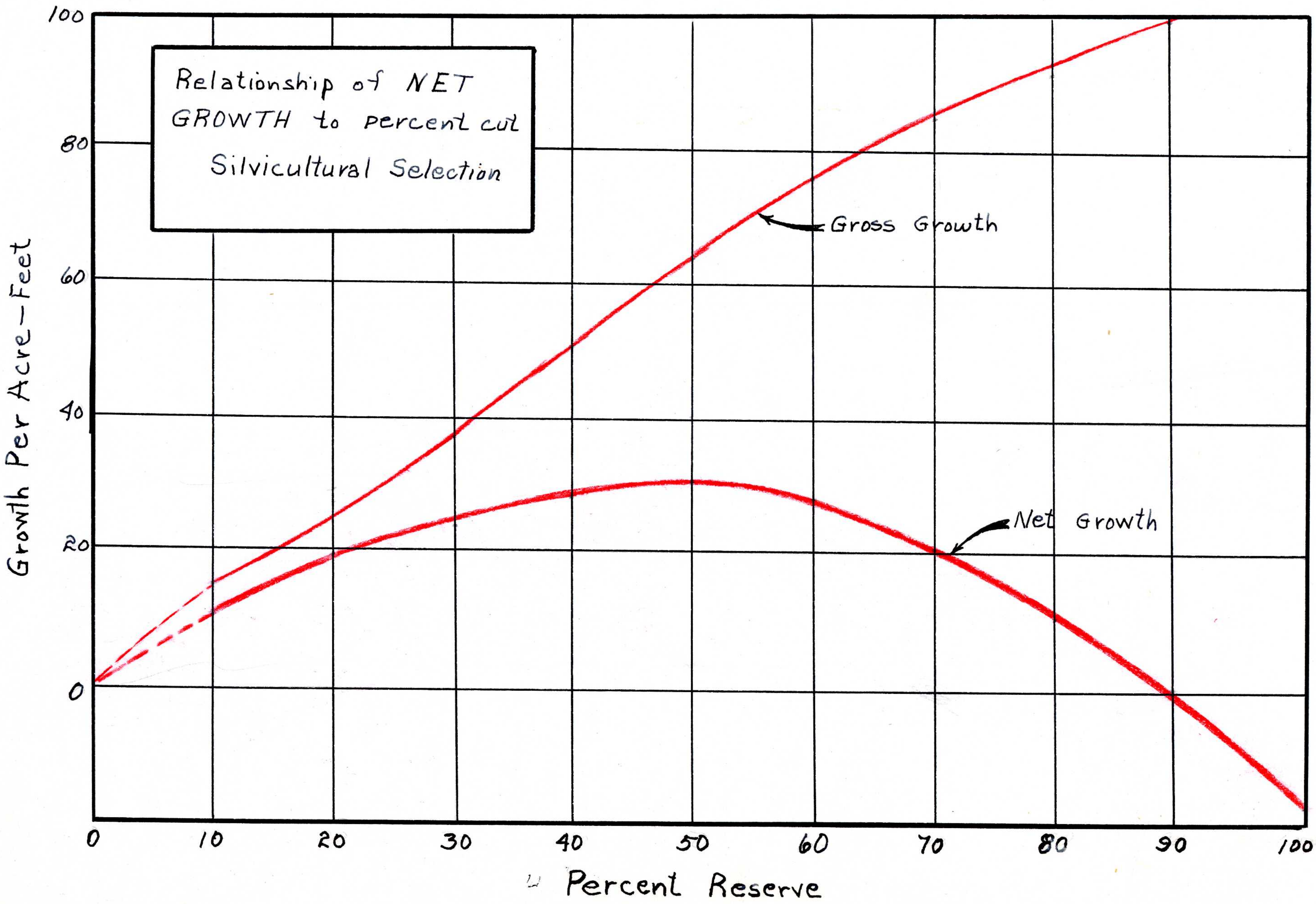

NET REALIZATION for different cuttings — showing affect of Road Construction upon Gross Realization
From Study Made on Hines Area
Gross Income
Net Income
Road Construction
$4
$3
$2
$1
Marginal Value Per M
0
10
20
30
40
50
60
70
80
90
100
Percent Cut

FIGURE 32

Relationship of Reserve Stand to Growth Per Acre for Different Cutting Practices									
Percent Cut	Percent Reserve	Total Volume	Gross Growth	Gross Growth Percent	Net Growth Percent	Net Growth	Volume Per A	Gross Growth Per A	Net Growth Per A
90	10	79,078	680.52	.860	.615	486.06	1,797	15.3	11.1
80	20	159,639	1,23499	.773	.548	875.58	3,628	28.0	19.9
70	30	239,915	1,633.80	.681	.430	1,030.60	5,453	37.1	23.5
60	40	319,318	2,232.47	.699	.378	1,206.29	7,275	50.8	27.5
50	50	398,026	2,892.28	.701	.337	1,341.65	9,046	63.4	30.5
40	60	476,957	3,377.38	.707	.254	1,212.72	10,840	76.6	27.5
30	70	555,585	3,772.53	.679	.164	914.47	12,621	85.7	20.7
20	80	635,060	4,104.61	.646	.080	512.44	14,433	92.2	11.6
10	90	714,318	4,387.61	.614	.001	8.94	16,235	99.7	.20
0	100	793,203	4,741.64	.597	-.097	-768.07	18,027	107.6	-17.5

FIGURE 33



Relationship of NET GROWTH to percent cut
Silvicultural Selection
Gross Growth
Net Growth
Growth Per Acre-Feet
100
80
60
40
20
0
0
10
20
30
40
50
60
70
80
90
100
Percent Reserve

FIGURE 24

ing reserve stand.

In comparison, the culmination of the net realization curve in the economic selection study is $3.75 per acre for a 30 percent cut while the silvicultural selection study is only $2.63 per acre. As to the growth of the reserve stand, the two methods give opposite results--the economic selection system has a net growth of 2.81 board feet for a 50 percent cut as compared to 30.5 board feet per acre for the silvicultural selection system.

The reason for this variation in the two cutting systems can readily be seen when considering the trees that are cut. The economic selection system is based upon the greatest return per acre in monetary or dollars value while the basic idea behind the silvicultural system is return in volume per acre. In the economic selection all high valued trees are taken without consideration to growth therefore some of the fast growing trees are left in the reserve stand. The cut is composed of Keen's 3A, 3B, 4A, 4B, and a few of the 4C's. A few of the 4C trees and all of the 4D, 3C, and 3D's are slow growing trees with high mortality make up part of the residual stand with the young thrifty trees (Fig. 4). The silvicultural method takes out the unthrifty trees without consideration of dollars return so the residual stand is composed of the 1A and B, 2A, 2B, 2C, and 3A trees. The cut is made in the slow growing, unthrifty trees that have a high rate of mortality. This leaves a very thrifty stand as shown by Figure 34 but the returns per acre is decreased because of taking out the submarginal trees in the vigor group D of Keen's tree classification.

Is the ideal situation determined by the volume return per acre or by dollars return? That is the question which the logger must try to decide for himself before going into the project. Possibly as I have mentioned, a correlation of the two methods would be more desirable or possibly some other combination may be developed which would give higher returns to the land and the operation--who knows?

That is the idea behind this thesis--formulation of some method by which the operator can decide for himself what trees should be cut and which ones he is to leave in the woods. Any operation which wishes to retain its financial stability cannot afford to go into the task of logging blindly and bring out logs which is costing them money.

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