THE REGULATION OF PONDEROSA PINE

A Problem in Forest Management

Richard F. Bickford

1937

TABLE OF CONTENTS

INTRODUCTION

The following few pages constitute a report on work done at the School of Forestry and Conservation of the University of Michigan in Management Problems under the guidance of Professor D. M. Matthews.

The use of the selection system of silvicultural management has advantages both in the protection offered the site and in the cheapness of cultural operations that no other system equals. The analysis of any stand to determine the possibilities of managing it under any method of silviculture is difficult without some method of comparison; in fact comparison with a standard is necessary before any method of management can be decided upon.

In the relative amounts of basal area in each diameter class and the distribution of the basal area between age classes, Professor Matthews has found a method of comparison that is not only easy of application and easy to understand but also goes a long way in the determination of cuts, thinnings and so forth.

In Part I of this report I have attempted to regulate ponderosa pine by this method and as is necessary in the presentation of any plan in Part II I have evaluated the results of part one in comparison with existing practice.

PART I

HOW TO REGULATE IT

THE PROBLEM

The data used in this problem represents a one percent cruise of an experimental forest on the west slope of the Sierra Nevada Mountains in central California. On the first eight pages of the Appendix a copy of the data as it was handed to me will be found.

In the analysis of a stand and stock table for a given area the first problem is to determine the age class distribution to find out if the stand is all aged or even aged. Then, when the stand is found to be all aged, various cutting cycles and rotations should be investigated both from the point of view of volume production and of value production. Due to the limitations of time only one cutting cycle with one rotation was investigated. The stand was divided into six fifty year age classes thus making an assumed cutting cycle of fifty years and a rotation of three hundred years. The plan is to cut the stand every twenty-five years and thus reduce the rotation to one hundred and fifty years when the stand has been completely cut over once and the cutting cycle will be twenty-five years. The first step in the analysis is the construction of the control table.

THE CONTROL TABLE

In the construction of my control table I used the figures of Dunning and Reineke(1). In order to use the rotation that I had assumed it was necessary to extend their figures to three hundred years. This extension was done by extrapolation. This extrapolation and the tabulation of the resulting figures appear in the appendix on pages nine and ten. The site was approximated by the ratio of the total volume to the total number of trees. By the above method the site was decided to be a medium site of 60 at fifty years. Then the following control table was constructed by the methods outlined on pages 138-142 of Matthews textbook(2).

Table I CONTROL TABLE

100% Ponderosa Pine 0-300 years Site 60

Age Class	Number of trees	Diameter Range	Average Diameter	Basal Area	% B. A.	Volume Bd.ft.
0-50	Advance Reproduction					
51-100	144	7.2-14.5	10.9	93	16.5	12,800
101-150	68	14.5-18.2	17.2	110	19.5	23,200
151-200	54	18.2-20.7	19.7	114	20.2	40,600
201-250	46	20.7-23.2	21.9	120	21.3	48,500
251-300	39	23.2-25.7	24.4	127	22.5	55,800
Total	351			564	100.0	180,900

THE CLASSIFIED STANDS

Then all the stands were classified according to this control table with the following tables showing the results of the classification.

'able II ACTUAL STAND BLOCK A

Age Class	Number of trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.	% Stocking
0-50	Advance Reproduction					
51-100	62.4	4-10	5.6	10.8	Nil	11.6
101-150	10.1	10-24	15.3	12.8	1798	11.6
151-200	2.8	24-34	29.4	13.2	3238	11.6
201-250	1.8	34-42	37.5	13.9	4069	11.6
251-300	1.3	42-	45.5	14.8	5103	11.6
Total	78.4			65.5	14,208	11.6

Table III BLOCK B

Age Class	Number of trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.	% Stocking
0-50		Advance Reproduction				
51-100	52.6	4-16	7.5	16.0	851	17.2
101-150	8.1	16-26	20.6	18.8	2987	17.1
151-200	4.5	26-30	28.2	19.5	4094	17.1
201-250	3.5	30-36	32.9	20.6	5071	17.1
251-300	2.6	36-	39.3	21.8	5873	17.1
Total	71.3			96.7	18876	17.1

Table IV BLOCK C

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50	Advance Reproduction				
51-100	52.0	4-18	7.8	17.0	1147
101-150	7.7	18-26	21.9	20.1	3233
151-200	4.5	26-32	28.7	20.8	4515
201-250	3.4	32-38	34.4	22.0	5497
251-300	2.4	38-	42.0	23.2	6548
Total	70.1			103.1	20940

Average Stocking -- 18.3

Table V BLOCK G

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50	Advance Reproduction				
51-100	54.3	4-16	6.4	12.2	443
101-150	5.7	16-26	21.6	14.5	1611
151-200	3.3	26-32	28.9	15.0	4317
201-250	2.5	32-38	34.3	16.0	4464
251-300	1.7	38-	42.7	16.7	5681
Total	67.5			74.4	16516

Average Stocking -- 13.2

Table VI BLOCK G -- COMPARTMENTS 3-4

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50	Advance Reproduction				
51-100	29.7	4-8	5.9	5.6	Nil
101-150	6.5	8-32	13.7	6.6	635
151-200	0.8	32-42	39.6	6.8	1988
201-250	0.6	42-48	47.0	7.2	2360
251-300	0.5	48-	52.7	7.5	2730
Total	38.1			33.7	7713

Average Stocking -- 5.98

Table VII BLOCK G -- COMPARTMENTS 6-7

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50	Advance Reproduction				
51-100	51.1	4-8	5.4	8.0	Nil
101-150	12.2	8-26	11.9	9.4	889
151-200	1.7	26-36	32.5	9.8	2520
201-250	1.3	36-44	38.0	10.3	3075
251-300	0.8	44-	50.0	10.9	3740
Total	67.1			48.4	10224

Average Stocking -- 8.6

Table VIII BLOCK P

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50		Advance Reproduction			
51-100	46.6	4-18	8.0	16.1	1161
101-150	6.9	18-26	22.4	18.9	3088
151-200	4.4	26-32	28.6	19.6	4432
201-250	3.4	32-36	33.4	20.7	5208
251-300	2.4	36-	40.9	21.9	5924
Total	63.7			97.2	19813

Average Stocking -- 17.2

Table IX BLOCK P -- COMPARTMENTS 23 - 26

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. ft.
0-50		Advance Reproduction			
51-100	28.5	4-22	11.7	21.2	2351
101-150	7.4	22-28	24.9	25.0	4377
151-200	5.6	28-32	29.2	26.0	5701
201-250	4.4	32-36	33.1	27.4	6423
251-300	3.3	36-	40.2	28.9	6501
Total	49.2			128.5	25353

Average Stocking -- 22.8

Table X BLOCK P -- COMPARTMENTS 31 - 21

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume bd. ft.
0-50		Advance Reproduction			
51-100	27.1	4-22	11.3	18.9	2285
101-150	6.5	22-28	25.1	22.3	4215
151-200	4.9	28-32	29.4	23.1	5255
201-250	4.0	32-36	33.4	24.4	6247
251-300	3.0	36-	39.7	25.8	6928
Total	45.5			114.5	24930

Average Stocking -- 20.3

The classification of the various stands reveals the significant characteristics of the various stands. Thus the conclusion is reached that Block A is the only one that is at present in an all aged condition. All of the other stands have an inconsistent difference between average diameters as witnessed by the 13.8 inch difference in the average diameters of the 51-100 and the 101-150 age classes. In this particular stand all other age classes have a difference of approximately 4 inches. This inconsistent difference is present in all the stands except Block A. The presence of this difference is good evidence that Ponderosa Pine does not naturally grow in an all aged forest and thus is not suitable to selection management. However the inconsistent difference noted above can be explained on other grounds. Ground fires, which are quite common, might easily have killed off the reproduction for the missing diameter classes. There is no bunching of the diameters in any of the stands as is common in the even aged stands of Lodgepole pine. Thus while the classified stands show evidence of being even aged there is nothing certain and final about their present condition. In the continuation of the study Block A will be used as typical of the all aged stands that might be produced by ponderosa pine.

GROWTH PREDICTION

To continue the study of ponderosa pine under selection management it is necessary to predict the growth of the stands and determine the possibility of future cuts. To carry out this prediction it is necessary to have the growth of ponderosa pine by diameter classes.

Duncan Dunning in a government bulletin(3) gives the periodic annual growth percent in basal area. From this basal area growth percent the diameter growth percent can be obtained by simply extracting the square root. That this relationship holds is demonstrated below.

BA_1 -- Present basal area

BA_2 -- Future basal area

d_1 -- Present diameter

d_2 -- Future diameter

p --- ratio of circumferance to radius

r --- basal area growth percent

s --- diameter growth percent

BA_2 equals r x BA_1

BA equals $(q \times d^2)/4$

Then:

$$(q \times d_2^2)/4 \text{ equals } (r)(q \times d_1^2)/4$$

the q/4 cancel out leaving

$$d_2^2 \text{ equals } r \times d_1^2$$

then take square root of both sides

$$d_2 \text{ equals (square root of r) } \times d_1$$

then s equals the square root of r

The figures for basal area growth as appearing in Duncan Dunning's publication were changed to diameter growth figures as indicated on the last page and then through a series of arithmetical manipulations that appear on pages eleven and twelve of the appendix the following diameter growth figures were obtained.

Table XI DIAMETER GROWTH

Diameter Breast High	Growth Next 25 years	Diameter Breast High	Growth Next 25 Years
4"	4.8"	24"	4.7"
6	5.6	26	4.4
8	5.9	28	4.2
10	6.1	30	4.0
12	6.1	32	3.9
14	6.0	34	3.8
16	5.9	36	3.7
18	5.7	38	3.6
20	5.4	40	3.5
22	5.0	42	3.3

Using these growth rates Block A after being cut was predicted forward tenty-five years then cut again and predicted forward again and so forth until all the trees that were in the original stand were cut.

STAND PREDICTION

In the prediction of the stand possible at the time of the next cut I used a method developed by Reynolds of the Crosset Lumber Company of Arkansas. As an example of this method of stand prediction I will consider the ten inch diameter class of Block A. This diameter class includes 4.08 trees. Ten-inch trees, from the table on the preceding page, will grow 6.1 inches in twenty-five years. In a large sample the trees in the ten inch class would be evenly divided throughout that is there would be just as many trees in a one tenth inch class at 9.6 as there would be at any other one tenth inch class up to 10.5. If a 9.6 inch tree grows 6.1 inches it will then fall in the 16 inch class with a diameter of 15.7. A ten inch tree would also fall in the 16 inch class with a diameter of 16.1. But a 10.5 inch tree would be 16.6 inches in diameter at the end of the period and thus would fall into the 17 inch diameter class. Thus it is seen that the units of a diameter growth rate indicate the number of diameter classes moved by the tree in the growth period and the decimal indicates the percent of the trees that will move one more class than is indicated by the units. Thus if the number of trees in each diameter class is broken up in this way and added diagonally the number of trees in the predicted stand in the diameter class indicated will result. On the next page the stand prediction of Block A is carried out exactly as outlined here. The diagonal lines indicate the direction of the addition.

Table XII

PREDICTION OF STAND FOR SECOND CYCLE

Block A

First 25 Years

Di. in in.	No. of Trees	Radial Growth in 25Y	No. Trees 25 yrs. Hence	Move one Class	Move Two Classes	Move Three Classes	No. Trees 25 yrs. Hence	Vol. Per Tree bd.ft.	Total Volume bd.ft.	B.A. Per Tree	Total B.A.
4	32.3	2.4			19.4	12.9					
6	19.6	2.8			3.9	15.7					
8	8.4	3.0	19.4			8.4	19.4			0.35	6.8
10	4.1	3.0	16.8			4.1	16.8			0.54	9.2
12	2.5	3.0	15.7			2.5	15.7	118	1850	0.78	12.3
14	1.5	3.0	8.4			1.5	8.4	147	1240	1.07	9.0
16	1.1	3.0	4.1			1.1	4.1	186	760	1.40	5.7
18	0.9	2.8	2.5		0.2	0.7	2.5	234	590	1.77	4.4
20	0.7	2.7	1.5		0.2	0.5	1.5	308	460	2.18	3.3
22	0.7	2.5	1.3		0.3	0.4	1.3	429	560	2.64	3.4
24	0.6	2.4	0.9		0.3	0.3	0.9	593	530	3.14	2.8
26	0.6	2.2	0.8		0.5	0.1	0.8	778	620	3.69	2.9
28	0.7	2.1	0.7		0.6	0.1	0.7	995	700	4.28	3.0
30	0.7	2.0	0.8		0.7		0.8	1230	980	4.91	3.9
32	0.7	2.0	0.7		0.7		0.7	1475	1030	5.59	3.9
34	0.6	1.9	0.8		0.6		0.8	1730	1380	6.31	5.0
36	0.5	1.8	0.7	0.1	0.4		0.7	2120	1480	7.07	5.0
38	0.5	1.8	0.7	0.1	0.4		0.7	2290	1600	7.88	5.5
40	0.4	1.8	0.5	0.1	0.3		0.5	2640	1320	8.73	4.4
42			0.5				0.5	2960	1480	9.62	4.8
44			0.3				0.3	3380	1010	10.56	3.2
Totals	77.1		77.1				77.1		17590		98.5

In connection with the stand prediction carried out on the preceding page as the diameter classes involved were of a magnitude of two inches it was necessary to use radial growth rather then diameter growth. The volume per tree was obtained by dividing the volumes as given in the original data by the number of trees at the corresponding diameter class.

A control table was then constructed for the new stand as predicted. This control table will be for a stand 0-275 years old and appears below.

Table XIII CONTROL TABLE

Ponderosa Pine 0 - 275 years

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Percent of B.A.
0-25	Advance Reproduction				
25-75		No Data			
75-125	85	11-16	14.9	104	22.6
125-175	59	16-19	18.8	114	24.8
175-225	50	19-22	20.8	119	25.9
225-275	42	22-	23.1	123	26.7
Total	236			460	100.0

Then the stand as predicted on the last page is classified according to this control table.

Table XIV ACTUAL STAND

Block A Second Cycle

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd. Ft.
0-25		Advance Reproduction			
25-75		No Data			
75-125	44.2	8-12	9.7	22.3	950
125-175	22.3	12-18	14.2	24.4	3400
175-225	7.4	18-34	25.2	25.5	5410
225-275	3.2	34-	38.0	26.3	7830
Total	77.1			98.5	17590

Average Stocking 21.4

It is to be noted from the above table in comparison with the original stand classification table for Block A that there is an increase both in basal area and in volume. The increase in basal area make the stocking much more than it was in the original stand. The maximum diameter of the stand has decreased as has the total number of trees that we have data about. The number of trees corresponding to the number of trees in the same diameter classes has increased. That is there are more trees in the oldest diameter class of the new stand than there was in the oldest diameter class of the original stand.

Thsi stand prediction is continued on the next few pages until the data are exausted.

Table XV

PREDICTION OF STAND FOR THIRD CYCLE

Block A　　　　　　Second 25 Years

Di. in in.	No. of Trees	Radial Growth in 50Y	No. Trees 50 yrs. Hence	Move one Class	Move Two Classes	Move Three Classes	No. Trees 50 Yrs. Hence	Vol. Per Tree bd. ft	Total Volume bd. ft.	B.A. Per Tree	Total B.A.
8	19.4	3.0				19.4					
10	16.8	3.0				16.8					
12	15.7	3.0				15.7					
14	8.4	3.0	19.4			8.4	19.4	147	2850	1.07	20.7
16	4.1	3.0	16.8			4.1	16.8	186	3130	1.40	23.5
18	2.5	2.8	15.7		0.5	2.0	15.7	234	3680	1.77	27.8
20	1.5	2.7	8.4		0.5	1.0	8.4	308	2580	2.18	18.3
22	1.3	2.5	4.6		0.7	0.6	4.6	429	1930	2.64	12.1
24	0.9	2.4	2.5		0.5	0.4	2.5	593	1480	3.14	7.9
26	0.8	2.2	1.7		0.6	0.2	1.7	778	1320	3.69	6.3
28	0.7	2.1	1.1		0.6	0.1	1.1	995	1090	4.28	4.7
30	0.8	2.0	1.0		0.8		1.0	1230	1230	4.91	4.9
32	0.7	2.0	0.8		0.7		0.8	1475	1180	5.59	4.5
34	0.3	1.9	0.9		0.3		0.9	1730	1560	6.31	5.7
36			0.8				0.8	2120	1690	7.07	5.7
38			0.3				0.3	2290	690	7.88	2.4
Totals	74.0		74.0				74.0		24410		144.5

Table XVI CONTROL TABLE

Ponderosa Pine 0-250 Years

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Percent B.A.
0-25		Advance Reproduction			
25-50		No Data			
50-100		No Data			
100-150	68	15-18	17.2	110	32.0
150-200	54	18-21	19.7	114	33.2
200-250	46	21-23	21.9	120	34.8
Totals	168			344	100.0

Table XVII ACTUAL STAND

Block A Third Cycle

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume Bd.ft.
0-25		Advance Reproduction			
25-50		No Data			
50-100		No Data			
100-150	37.3	14-18	15.1	46.2	6150
150-200	24.5	18-22	19.0	48.0	6710
200-250	12.2	22-	27.5	50.3	11550
Totals	74.0			144.5	24410

Average Stocking -- 42.0%

Table XVIII PREDICTION OF STAND FOR THE FOURTH CYCLE

Block A Third 25 Years

Di. in in.	No. of Trees	Radial Growth in 25Y.	NO. Trees 75yrs. Hence	Move one Class	Move Two Classes	Move Three Classes	No. Trees 75 yrs. Hence	Vol. Per Tree bd.ft.	Total Volume bd.ft.	B.A. Per Tree	Total B.A.
14	19.4	3.0				19.4					
16	16.8	3.0				16.8					
18	15.7	2.8			3.2	12.5					
20	8.4	2.7	19.4		2.5	5.9	19.4	308	6000	2.18	42.3
22	3.9	2.5	20.0		1.9	2.0	20.0	429	8680	2.64	52.8
24			15.0				15.0	593	8900	3.14	47.2
26			7.8				7.8	778	6060	3.69	28.8
28			2.0				2.0	995	1990	4.28	8.6
Totals	64.2		64.2				64.2		31530		179.7

Table XIX CONTROL TABLE

Ponderosa Pine 0-225 Years

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Percent B.A.
0-25		Advance Reproduction			
25-50		No Data			
50-75		No Data			
75-125		No Data			
125-175	59	16-19	18.8	114	48.8
175-225	50	19-22	20.8	119	51.2
Total	109			233	100.0

Table XX ACTUAL STAND

Block A Fourth Cycle

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume bd.ft.
0-25		Advance Reproduction			
25-50		No Data			
50-75		No Data			
75-125		No Data			
125-175	36.6	20-22	20.9	87.7	13380
175-225	27.6	22-	24.7	92.0	18150
Total	64.2			179.7	31530

Average Stocking -- 77.2

Table XXI PREDICTION OF STAND FOR THE FIFTH CYCLE

Block A Fourth 25 Years

Di. in in.	No. of Trees	Radial Growth in 25Y	No. Trees 100 yrs. Hence	Move one Class	Move Two Classes	Move Two Classes	No. Trees 100 yrs. Hence	Vol. Per Tree bd.ft.	Total Volume bd.ft.	BA Per tree	Total BA
20	19.4	2.7			5.8	13.6					
22	17.2	2.5			8.6	8.6					
24			5.8				5.8	593	3440	3.14	18.2
26			22.2				22.2	778	17300	3.69	82.0
28			8.6				8.6	995	8550	4.28	36.8
Total	36.6		36.6				36.6		29390		137.0

Table XXII CONTROL TABLE

Ponderosa Pine 0-200 Years

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Percent B.A.
0-25		Advance Reproduction			
25-50		No Data			
50-75		No Data			
75-100		No Data			
100-150		No Data			
150-200	54	18-21	19.7	114	100
Total	54			114	100

Table XXIII ACTUAL STAND

Block A Fifth Cycle

Age Class	Number of Trees	Diameter Range	Average Diameter	Basal Area	Volume bd.ft.
0-25		Advance Reproduction			
25-50		No Data			
50-75		No Data			
75-100		No Data			
100-150		No Data			
150-200	36.6	24-28	26.2	137.0	29390
Total	36.6			137.0	29390

Average Stocking -- 111%

The points noted on page 14 concerning the first prediction of the stand continue in evidence as long as the data lasted. The average stocking increased from 11.6% to 111% in the final stand. The volume of the cut increased from 5103 board feet to 29390 board feet in the final stand. It is of course obvious that the actual stand on the ground will not do this. The actual stand will undoubtedly grow slower as well as have considerable nortality which is not considered. Both mortality and growth slower than is possible are indications of the necessity of thinnings to maintain the forest at its highest rate of possible production.

The question arises as to how many trees should be removed. The choice of the actual trees should be of course on the basis of good silvicultural practice in the field; however a guide to the actual number of trees that the area can successfully carry would be of great assistance to the silviculturalist in the field. When accurate data as to the stand and as to growth rates are available this number of trees can be very closely approximated by calculations similar to the ones that follow.

In order to be more general a mixed stand, Block C, was chosen for these calculations as most stands are mixed to some extent. First it is necessary to determine how close to normal the stand is capable of approaching in respect to normality. Then growth rates need to be determined and finally computations similar to those that were carried out on Block A are carried out. The chief difference is that the stand is not allowed to become of a higher stocking than it was previously decided the area could carry.

In the case of Block C it was decided that the greatest possible stocking and still maintain growth at a satisfactory rate was 50 percent. For ease of computation a growth rate of three inches per twenty-five year period was assumed. Then a control table was constructed on the basis of 50 percent stocking and the actual data for Block C was made to fit this table. The oldest age group was removed and the stand was predicted forward as in Block A as discussed on page 11. In addition to cutting of the oldest age class, if at any time the predicted stand contained more basal area than the 50% of normal control stand, then the original stand was thinned to reduce the number of trees to such an extent that the predicted stand would not have more basal area then the 50% of normal control stand.

Below is the control table that was used.

Table XXIV CONTROL TABLE

Age Class	Number of Trees	Average Diameter	Basal Area
0-50	Advance Reproduction		
50-100	72	11	48
100-150	34	17	54
150-200	27	20	59
200-250	23	22	60
250-300	19	24	60
Total	175		282

50% Stocked

Table XXV DEMONSTRATION OF THINNING

Block C 50 % stocked

Age Class	No. Trees	B.A.	Dia.	Dia.	P.P.* No. Trees	P.P.* B.A.	W.F.** No. Trees	W.F.** B.A.	I.C.*** No. Trees	I.C.*** B.A.
Control				Actual Stand						
Original Stand										
50-100#	72	48	11	8	31.1	10.8	19.6	5.8	1.3	0.4
100-150	34	54	17	22	6.1	16.3	1.3	3.1	0.3	0.7
150-200	27	59	20	29	3.6	16.8	0.7	2.8	0.3	1.2
200-250	23	60	22	34	2.8	17.6	0.4	2.8	0.2	1.6
250-300	19	60	24	42	1.6	16.2	0.4	3.5	0.4	3.5
Cut all trees 42 inches and up										
Stand 25 Years Hence										
75-125#	43	53	15	11	31.1	20.5	19.6	12.9	1.3	0.8
125-175	29	57	19	25	6.1	20.8	1.3	4.4	0.3	1.0
175-225	25	60	21	32	3.6	20.1	0.7	3.9	0.3	1.7
225-275	21	60	23	37	2.8	20.9	0.4	3.0	0.2	1.5
Cut all trees 37 inches and up Thin 1.3 11 inch Incense Cedar Trees										
Stand 50 Years Hence										
100-150	34	54	17	14	31.1	33.1	19.6	21.0		
150-200	27	59	20	28	6.1	25.7	1.3	5.6	0.3	1.3
200-250	23	60	22	35	3.6	24.1	0.7	4.7	0.3	2.0
Cut all trees 35 inches and up Thin 14.7 14 inch White Fir										
Stand 75 Years Hence										
125-175	29	57	19	17	31.1	49.2	4.9	7.8		
175-225	25	60	21	31	6.1	31.9	1.3	6.8	0.3	1.6
Cut all trees 31 inches and up Thin in the 17" class 4.9 White Fir and 4.1 P.P.										
Final Stand										
150-200	27	59	20	20	27.0	59.0				

*- Ponderosa Pine, **-White Fir, ***-Incense Cedar
#- No data available for the younger age classes.

Any caluclation such as has been carried out on the preceding pages is of course highly theoretical, however, to any timber marker to have an idea of the exact number of trees to be removed in the thinning would be of great assistance.

In the first part of this report the possibilities of applying all aged regulation to Ponderosa Pine in the California Pine Region has been investigated. Before any definite conclusions can be drawn the basic data that are available must be elaborated upon so that these methods can be applied more accurately. There is a genuine need for growth data for stands after release.

The data that were available indicated that Ponderosa Pine does not generally grow in all aged stands . In fact out of five stands considered only one was definitely in an all aged condition. The remainder of the stands being in various stages of evenness that is there was doubt as to their actual state. They were neither definitely even aged nor were they definitely all aged but more or less of a combination of both for example Block G is all aged in the four older age classes but the youngest age class is out of line as regards the age of the rest of the stand. These differences can be explained on the basis of fire if one wants to believe it, but nothing can be proven either way. If one thinks that ponderosa pine does grow in all aged stands similar to Block A then it is logical to assume that the methods here demonstrated will operate very satisfactrolly.

On the assumption that the stands will respond to all aged management the second part of this report considers the financial problems involved.

PART II

WILL IT PAY DIVIDENDS

THE PROBLEM

In the practice of any business the ultimate criteron of any plan is: will it pay? Then if it will pay it must pay better than any other plan that is in use or might be advanced. In the practice of forestry in the California Pine region in the past all operators have been liquidating their timber holdings as fast as market conditions would allow. The Forest Service has advocated partial cutting with long cutting cycles. Since the publication as to the cost of logging small and large size timber many private operators have been cutting to an arbritrary diameter limit simply because it has been shown that that is more profitable because the smaller diameters cost more to produce as lumber than can be realized from the lumber. This has in effect made for the longer cycle advocated by the Forest Service.

If any other plan is to be adopted by the owners it will have to be shown to their satisfaction that the plan is more profitable not only in the long run but in many instances more profitable as regards immediate income. In order to compare the plan of management advocated with various other operating methods this paln will be evaluated and a liquidating plan will be evaluated for comparison.

STUMPAGE VALUES

In order to evaluate the cuts under different plans of management it is necessary to obtain the value of trees of different diameters. W. H. Gibbons, H. M. Johnson, and H. R. Spelman have published in The Timberman(4) complete figures on the cost of production of lumber. This article is excellent in that the cost are broken down into the various items that make up the total cost. The following table is the result of combining certain of their figures, the combinations are indicated, with the depreciation on logging equipment eliminated as this depreciation is a per acre charge and is included later.

Table XXVI Stumpage Value Determination

D. B. H.	Total Logging Costs $/M	Total Manuf. Cost $/M	Total Prod. $/M	Int.* $/M	Total Costs $/M	Value per M $/M	Surplus for Stumpage $/M	Smoothed Stumpage Surplus $/M
12	18.90	14.35	33.25	3.46	36.71	29.93	-6.78	-4.80
14	15.94	12.58	27.52	3.11	30.63	30.18	-0.45	-1.40
16	15.03	11.14	26.17	2.82	28.99	30.03	1.04	0.90
18	14.52	10.01	24.53	2.72	27.25	28.89	1.64	2.50
20	14.03	9.29	23.32	2.58	25.90	29.17	3.27	3.95
22	13.07	8.69	21.76	2.47	24.23	30.07	5.84	5.20
24	12.88	8.29	21.17	2.41	23.58	31.03	6.45	6.40
26	11.94	7.91	19.85	2.20	22.05	29.44	7.39	7.42
28	11.58	7.59	19.17	2.09	21.26	32.93	11.67	8.25
30	11.53	7.35	18.88	2.10	20.98	30.15	9.17	9.12
32	11.13	7.16	18.29	2.02	20.31	30.77	10.46	9.80
34	11.42	7.15	18.57	2.02	20.59	30.96	9.37	10.24
36	10.89	7.05	17.94	1.98	19.92	30.60	10.68	10.50
38	10.86	6.90	17.76	1.95	19.71	32.14	12.43	10.65
40+	11.45	7.21	18.66	2.09	20.75	27.34	6.59	10.70**

*Interest on invested capital
**All higher diameters are assumed to have this surplus.

Four plans were chosen as a basis of comparison, namely: destructive logging taking everything on the ground, destructive logging to a zero margin diameter limit, twenty-five year periodic sustained yield, and annual sustained yield. The depreciation on the logging equipment was determined by multiplication of the volume per diameter class by the depreciation as given in the article in the Timberman and summation and then dividing by the volume per acre and thus obtaining a constant depreciation figure. Then the values were reduced by this figure which in the order of listing above was \$0.31, 0.30, 0.24, and 0.24. The stumpage values were then multiplied by the volume per diameter class in each case with the following incomes resulting.

Incomes Under the Various Plans

Complete Destruction	\$129,200
Zero Margin Destruction	131,000
Periodic Sustained Yield	49,300
Annual Sustained Yield	19,740

Then these incomes were evaluated on the basis of their present value as a capital sum at four, three, and two percent. The formulas involved are indicated below.

Complete Destruction:

$$Co = \frac{a(1.0p^n - 1)}{(0.0p)(1.0p^n)}$$

When:
Co - Present Value
a - Annual income
p - Interest rate
n - Number of Years in this case 10

Cut to the diameter of zero margin and return for a second cut of one third the original cut in sixty years:

$$Co = \frac{a(1.0p^n-)}{(0.0p)(1.0pn)} \text{ plus } \frac{a/3(1.0p^n-1)}{(0.0p)(1.0p^n)(1.0p^r)}$$

r - Period before second cut starts
Other symbols are the same as before

Periodic Sustained Yield:

Cut area over selectively in ten years and then wait fifteen years before starting a second cut.

The formulas are the same as in the preceding case.

Annual Sustained Yield:

$$Co = \frac{\text{Income minus expenses}}{o.op}$$

By use of the above formulas the resulting values tabulated below were obtained.

Table XXVII Values of Different Plans

Plan	Interest at 4%	Interest at 3%	Interest at 2%
Complete Destruction	$1,048,000	$1,091,000	$1,120,000
Zero Margin Destruction	1,096,400	1,180,000	1,252,000
Periodic Sustained Yield	640,000	796,000	1,095,000
Annual Sustained Yield	493,500	658,000	987,000

From the point of view of the forester these results as tabulated on the preceding page as far from satisfactory andcosts were further investigated to see if it was possible to improve the relative position of sustained yield. The publication of M. Brundage, M. Krueger, and D. Dunning on the economic significance of tree size(5) was used for value data for the same calculations as was some unpublished cost data of the Hines Lumber Company. The difference gained by this manipulation is not worth mentioning so that the results given on the last page can be considered representative of what the available cost data will produce in the way of value under the different plans.

In order to demonstrate the situation met by an operating timber company when it meets falling market prices a chart showing the results of curtailing the cut horozontally and vertically is included on the last page of the appendix. By curtailing the cut ~~horozontally~~ vertically is meant the raising of the diameter limit as contrasted with a ~~vertical~~ horizontal curtailment entirely on the area basis.

CONCLUSIONS

The following conclusions drawn from the analysis of the data are worthy of note:

1. Ponderosa Pine probably does not grow naturally in all aged stands.

2. Where Ponderosa Pine is found growing in an all aged condition the method of basal area control management applies easily and with perfect fit.

3. Under selection management the present stand can be maintained and a cut of between five and six thousand board feet taken every twenty-five years.

4. The most profitable method of management for the private operator is a liquidation plan to a zero margin diameter limit.

5. When periods of low prices are encountered it is more profitable to curtail the cut ~~horizontally~~ vertically then vertically.

APPENDIX

Block A -- Summary by Diameters

Total Area of Block -------------------------- 1108.3 A.
Total Area of Timber Types in Block --------- 788.1 A.

Diameter Breast High	Number of Trees per Acre	Volume per Acre
4	32.31	Pure Ponderosa Pine
6	19.63	
8	8.44	
10	4.08	
12	2.51	296
14	1.48	218
16	1.14	212
18	0.93	217
20	0.67	206
22	0.67	287
24	0.65	385
26	0.59	459
28	0.67	667
30	0.68	833
32	0.67	989
34	0.62	1072
36	0.52	1101
38	0.49	1122
40	0.39	1028
42	0.39	1153
44	0.24	813
46	0.19	734
48	0.14	609
50	0.09	447
52	0.09	470
54	0.06	327
56	0.03	188
58	0.02	166
60	0.01	92
62	0.01	68
64		1
66		34
Total	78.40	14208

Block B -- Summary by Diameters

Total Area in Block ---------------- 1144.2 A.
Total Area of Timber Types in Block 1142.4 A.

D. B. H.	PP* Trees /A	PP* Vol. /A	WF** Trees /A	WF** Vol. /A	IC*** Trees /A	IC*** Vol. /A	Total Trees /A	Total Vol. /A
4	15.38		5.89		2.44		23.7	
6	8.81		3.19		1.18		13.2	
8	3.94		1.34		0.29		5.6	
10	2.89		0.65		0.12		3.7	
12	2.43	287	0.47	48	0.09	2	3.0	337
14	1.84	264	0.25	34	0.07	3	2.2	301
16	1.62	303	0.20	35	0.07	4	1.9	342
18	1.55	361	0.18	40	0.12	7	1.8	408
20	1.39	414	0.14	41	0.16	13	1.7	467
22	1.49	638	0.12	45	0.09	18	1.7	701
24	1.72	1008	0.10	46	0.10	25	1.9	1079
26	1.70	1309	0.09	56	0.14	43	1.9	1408
28	1.62	1580	0.09	69	0.14	53	1.8	1702
30	1.45	1761	0.09	76	0.12	55	1.7	1891
32	1.33	1942	0.07	79	0.14	76	1.5	2096
34	0.99	1698	0.07	87	0.13	87	1.2	1871
36	0.72	1444	0.06	95	0.09	71	0.9	1610
38	0.50	1144	0.05	92	0.09	74	0.6	1310
40	0.32	853	0.04	75	0.07	69	0.4	997
42	0.22	670	0.03	62	0.08	88	0.3	820
44	0.13	430	0.02	54	0.06	70	0.2	554
46	0.07	255	0.01	35	0.05	65	0.1	354
48	0.04	161	0.01	21	0.03	50	0.1	232
50	0.03	119		17	0.02	41	0.1	176
52	0.01	44		10	0.02	32		87
54		22		4	0.01	17		42
56		13			0.01	31		44
58						10		10
60		11				8		19
62						4		4
64						8		8
66						3		3
68-						3		3
Total	52.2	16731	13.2	1121	6.0	1030	71.3	18876

*Ponderosa Pine, ** White Fir, *** Incense Cedar

Block C -- Summary by Diameters

Total Area of Block -------------------- 2354.0
Total Area of Timber Types in Block ---- 2354.0

D.B.H.	PP* Trees /A	PP* Vol. /A	WF*** Trees /A	WF*** Vol. /A	IC** Trees /A	IC** Vol. /A	Total Trees /A	Total Vol. /A
4	12.21		8.62		0.53		21.4	
6	7.25		4.76		0.31		12.3	
8	3.64		2.25		0.17		6.0	
10	2.52		1.51		0.10		4.1	
12	2.21	260	1.20	120	0.08	2	3.5	382
14	1.65	243	0.75	102	0.06	2	2.5	347
16	1.41	262	0.55	96	0.06	4	2.0	362
18	1.32	307	0.44	100	0.07	7	1.8	414
20	1.30	400	0.31	90	0.06	9	1.7	499
22	1.31	560	0.29	107	0.08	16	1.7	683
24	1.45	853	0.28	132	0.08	19	1.8	1004
26	1.39	1070	0.26	152	0.10	29	1.7	1251
28	1.35	1332	0.22	160	0.10	37	1.7	1529
30	1.27	1554	0.19	169	0.10	44	1.6	1767
32	1.19	1714	0.18	189	0.10	55	1.5	1958
34	0.98	1703	0.14	179	0.08	49	1.2	1931
36	0.82	1649	0.12	175	0.08	58	1.0	1882
38	0.63	1454	0.09	156	0.07	58	0.8	1668
40	0.43	1137	0.08	158	0.06	55	0.6	1350
42	0.32	975	0.06	136	0.05	56	0.4	1167
44	0.19	665	0.04	118	0.04	56	0.3	839
46	0.13	483	0.03	103	0.04	54	0.2	640
48	0.08	334	0.02	67	0.03	50	0.1	451
50	0.04	184	0.01	48	0.02	41	0.1	273
52	0.03	147	0.01	42	0.02	32	0.1	221
54	0.01	85	0.01	37	0.01	18		140
56	0.01	36		23	0.01	18		77
58		18		13		6		37
60		18		5		8		31
62		3				8		11
64		4		3		5		12
66						4		4
68-		5				5		10
Total	45.1	17455	22.4	2680	2.5	805		20940

*Ponderosa Pine, **Incense Cedar, ***White Fir

Block G -- Summary by Diameters

Total Area of Block --------------------- 3158.0
Total Area of Timber Types in Block ----- 2799.2

D. B. H.	PP* Trees /A	PP* Vol. /A	WF** Trees /A	WF** Vol. /A	IC*** Trees /A	IC*** Vol. /A	Total Trees /A	Total Vol. /A
4	26.82		0.53		0.11		27.5	
6	13.33		0.33		0.07		13.7	
8	6.33		0.14		0.03		6.5	
10	3.21		0.07		0.02		3.3	
12	1.76	213	0.04	4	0.01		1.8	216
14	1.16	170	0.03	4	0.01		1.2	175
16	0.96	179	0.02	3	0.01		1.0	182
18	0.94	213	0.02	4	0.01	1	1.0	217
20	0.92	283	0.02	5		1	0.9	289
22	1.05	454	0.02	6	0.01	2	1.1	462
24	1.16	683	0.02	8	0.01	3	1.2	693
26	1.18	922	0.01	8	0.01	4	1.2	935
28	1.26	1210	0.01	9	0.01	4	1.3	1223
30	1.15	1407	0.01	12	0.01	6	1.2	1425
32	1.03	1505	0.01	11	0.01	8	1.1	1524
34	0.91	1581	0.01	16	0.01	8	0.9	1605
36	0.73	1470	0.01	15	0.01	9	0.7	1494
38	0.56	1304	0.01	11	0.01	10	0.6	1325
40	0.41	1090	0.01	19	0.01	7	0.4	1116
42	0.30	891	0.01	17		5	0.3	912
44	0.20	676	0.01	19	0.01	6	0.2	701
46	0.16	545		15	0.01	13	0.2	572
48	0.12	448		9		4	0.1	461
50	0.07	303		8		5	0.1	317
52	0.04	215		6		3		223
54	0.03	147				5		152
56	0.02	113		2		5		120
58	0.01	74		2		1		77
60		33				3		37
62		28				1		29
64		9				1		10
66		3						3
68-		24						24
Total	65.8	16190	1.3	213	0.4	115	67.5	16516

*Ponderosa Pine, **White Fir, ***Incense Cedar

Summary by Diameters

Block G Compartment 4 - 3

Total Area of Compartment -------------- 494.9
Total Area of Timber Types in Compartment - 159.2

Diameter Breast High	Number of Trees per Acre	Volume per Acre
4	16.06	Pure
6	10.62	Ponderosa
8	4.80	Pine
10	2.68	
12	1.01	121
14	0.32	47
16	0.10	19
18	0.05	11
20	0.04	12
22	0.08	36
24	0.05	32
26	0.10	79
28	0.09	85
30	0.11	136
32	0.09	137
34	0.15	252
36	0.13	251
38	0.13	295
40	0.20	526
42	0.20	614
44	0.25	830
46	0.22	838
48	0.21	902
50	0.13	592
52	0.09	496
54	0.07	413
56	0.05	324
58	0.05	310
60	0.02	168
62	0.02	154
64		19
66		
68-		14
Total	38.1	7713

Summary by Diameters

Block G Compartment 7 - 6

Total Area of Compartment --------------- 182.6 A.
Total Area of Timber Types in Compartment 173.6 A.

Diameter Breast High	Number of Trees per Acre	Volume per Acre
4	26.44	Pure
6	18.92	Ponderosa
8	9.22	Pine
10	4.70	
12	1.74	207
14	0.67	99
16	0.32	59
18	0.25	60
20	0.22	67
22	0.24	101
24	0.30	170
26	0.32	246
28	0.33	324
30	0.38	459
32	0.37	547
34	0.40	688
36	0.44	892
38	0.33	765
40	0.32	833
42	0.29	857
44	0.23	770
46	0.16	614
48	0.19	797
50	0.12	580
52	0.06	323
54	0.05	306
56	0.04	251
58	0.02	119
60	0.01	59
62		4
64		27
Total	67.1	10224

Block P -- Summary by Diameters

Total Area of Block ---------------------- 1994.4 A.
Total Area of Timber Types in Block ------ 1994.4 A.

D. B. H.	PP* Trees /A	PP* Vol. /A	WF** Trees /A	WF** Vol. /A	IC*** Trees /A	IC*** Vol. /A	Total Trees /A	Total Vol. /A
4	14.21		5.53		0.84		20.6	
6	7.07		2.68		0.37		10.1	
8	3.33		1.23		0.15		4.7	
10	2.42		0.90		0.11		3.4	
12	2.04	241	0.80	80	0.08	2	2.9	322
14	1.44	207	0.55	74	0.05	2	2.0	283
16	1.32	246	0.52	90	0.05	4	1.9	339
18	1.25	291	0.38	87	0.05	6	1.7	383
20	1.24	380	0.26	75	0.06	8	1.6	463
22	1.48	631	0.25	89	0.08	15	1.8	735
24	1.54	905	0.19	87	0.08	20	1.8	1013
26	1.59	1227	0.15	88	0.11	28	1.9	1343
28	1.61	1575	0.12	89	0.09	35	1.8	1699
30	1.45	1766	0.10	88	0.09	40	1.6	1894
32	1.39	2028	0.09	91	0.10	58	1.6	2177
34	1.06	1820	0.08	95	0.09	60	1.2	1974
36	0.83	1657	0.05	75	0.08	62	1.0	1794
38	0.57	1303	0.04	69	0.07	61	0.7	1434
40	0.38	1004	0.03	57	0.06	60	0.5	1120
42	0.25	765	0.02	43	0.05	56	0.3	864
44	0.15	517	0.01	36	0.04	51	0.2	603
46	0.11	392	0.01	22	0.04	55	0.2	469
48	0.06	247		12	0.04	57	0.1	316
50	0.04	177		13	0.02	39	0.1	229
52	0.02	82		10	0.02	36		128
54	0.01	56		1	0.01	27		83
56	0.01	43			0.01	19		62
58		18		3	0.01	6		27
60		14				8		22
62		8		4		4		16
64		8		1		3		12
66		5				3		8
68						1		1
Total	46.9	17613	14.0	1379	2.8	826	63.7	19813

*Ponderosa Pine, **White Fir, ***Incense Cedar

Summary by Diameters

Block P Compartment 23-26

Total Area of Compartment -------------------- 90.8 A.
Total Area of Timber Types in Compartment ---- 90.8 A.

D. B. H.	PP*		WF**		IC***		Total	
	Trees /A	Vol. /A	Trees /A	Vol. /A	Trees /A	Vol. /A	Trees /A	Vol. /A
4	4.82		2.74		1.30		8.9	
6	2.31		1.29		0.74		4.3	
8	1.64		0.44		0.22		2.3	
10	1.49		0.37		0.22		2.1	
12	1.41	167	0.53	53	0.22	5	2.2	225
14	1.27	188	0.20	37	0.05	2	1.5	227
16	1.35	253	0.28	48	0.16	10	1.8	311
18	1.34	313	0.15	34	0.18	19	1.7	366
20	1.71	524	0.18	51	0.20	29	2.1	605
22	2.22	935	0.12	42	0.33	63	2.7	1040
24	2.37	1375	0.19	89	0.39	91	3.0	1554
26	2.30	1748	0.08	49	0.40	122	2.8	1919
28	2.50	2406	0.07	46	0.45	169	3.0	2621
30	1.96	2484	0.09	79	0.32	147	2.4	2711
32	2.01	2948	0.07	70	0.51	282	2.6	3300
34	1.31	2233	0.10	125	0.32	208	1.7	2567
36	1.05	2081	0.04	63	0.30	222	1.4	2366
38	0.75	1714	0.02	29	0.30	252	1.1	1995
40	0.35	872	0.02	33	0.23	227	0.6	1132
42	0.23	668	0.01	16	0.16	179	0.4	863
44	0.12	402		11	0.11	137	0.2	551
46	0.02	88	0.01	34	0.11	151	0.1	273
48	0.05	213		3	0.12	182	0.2	397
50	0.01	49			0.06	97	0.1	146
52					0.03	66		66
54					0.05	96		96
56								
58						6		6
60								
62					0.01	16		16
Total	34.6	21661	7.0	912	7.5	2778	49.2	25353

*Ponderosa Pine, **White Fir, ***Incense Cedar

Summary by Diameters

Block P | Compartment 31-21

Total Area of Compartment ------------------ 39.0 A.
Total Area of Timber Types in Compartment -- 39.0 A.

D. B. H.	PP* Trees /A	PP* Vol. /A	WF** Trees /A	WF** Vol. /A	IC*** Trees /A	IC*** Vol. /A	Total Trees /A	Total Vol. /A
4	5.92		3.12		0.67		9.7	
6	2.82		1.08		0.23		4.1	
8	1.28		0.33		0.08		1.7	
10	1.03		0.38		0.15		1.6	
12	1.23	145	0.63	62	0.05	1	1.9	208
14	1.36	201	0.22	29	0.02	1	1.6	231
16	1.25	234	0.30	47	0.05	3	1.6	285
18	1.37	318	0.20	45	0.03	3	1.6	367
20	1.57	482	0.14	40	0.05	7	1.8	530
22	2.08	879	0.17	63	0.06	12	2.3	954
24	2.25	1296	0.27	126	0.11	27	2.6	1449
26	2.38	1818	0.12	69	0.09	27	2.6	1914
28	2.50	2403	0.23	177	0.09	32	2.8	2612
30	1.77	2055	0.16	143	0.04	19	2.0	2218
32	2.13	3093	0.10	106	0.05	27	2.3	3226
34	1.53	2597	0.09	107	0.12	79	1.7	2782
36	0.96	1911	0.12	191	0.10	74	1.2	2176
38	0.85	1941	0.03	43	0.03	21	0.9	2005
40	0.54	1400	0.05	101	0.11	112	0.7	1613
42	0.29	846	0.01	18	0.05	54	0.3	918
44	0.06	192	0.04	124	0.03	30	0.1	346
46	0.02	61	0.05	158	0.10	142	0.2	362
48	0.03	137			0.03	37	0.1	174
50	0.03	129	0.03	89	0.05	87	0.1	305
52	0.01	39						39
54	0.03	142						142
56	0.01	47			0.01	27		74
Total	35.3	22366	7.8	1738	2.4	822	45.5	24930

*Ponderosa Pine, **White Fir, ***Incense Cedar

Application of Regression Formula to Yield Table(1):

Basal Area

B.A. = 2.03(100) plus 0.149(100) - 8.15

= 209.8% of Composite Table

Number of Trees

No. Trees = 2.06(100) plus 0.32(100) plus 19.36

= 188.3% of Composite Table

Volume in Cubic Feet

Volume = 1.53(100) plus 0.72(100) plus 128.78

= 209.5% of Composite Table

Yield Data after Application of

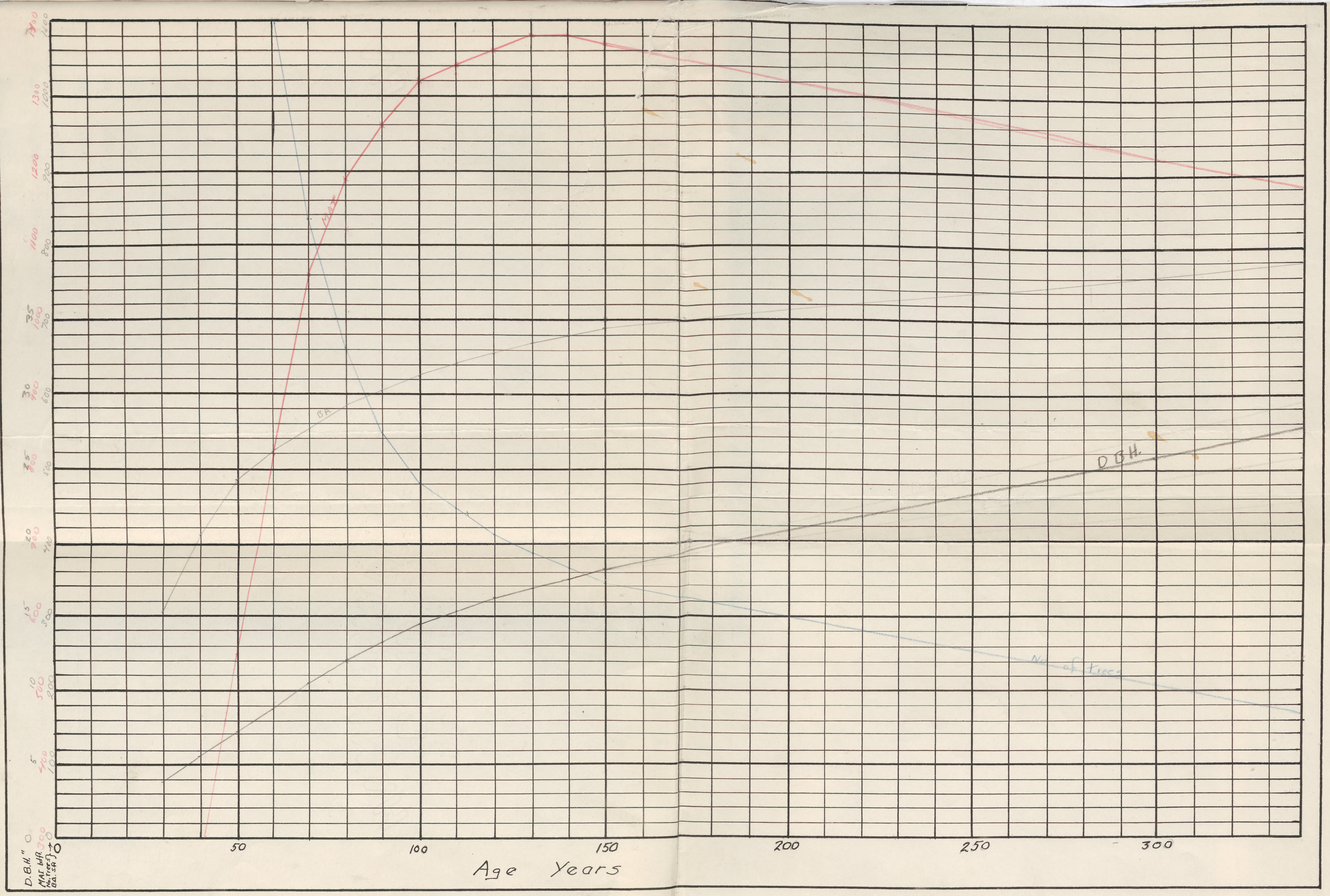
Regression Coefficients

Age	Basal area	Number of Trees	D.B.H.	Volume Cu.ft.	Volume Bd.ft.	M.A.I. Bd.ft.
30	306	3330	3.9	4600	2300	77
40	412	2150	5.6	7900	11600	290
50	483	1530	7.2	11300	27600	552
60	521	1120	8.8	14700	49200	820
70	554	836	10.5	17700	74200	1060
80	583	661	12.0	19900	94900	1190
90	604	550	13.3	22000	113900	1260
100	625	491	14.5	24100	132100	1320
110	640	446	15.4	25700	147800	1340
120	655	412	16.2	27600	163800	1360
130	670	385	16.9	29300	179100	1380
140	680	364	17.5	30900	192900	1380
150	690	343	18.2	32300	205500	1370

Extrapolated Yield Data*

Age	Number of Trees	Diameter Breast High	Basal area	M.A.I. Bd.ft.	Volume Bd.ft.
30	3330	3.9	306	77	2300
40	2150	5.6	412	290	11600
50	1530	7.2	483	552	27600
60	1120	8.8	521	820	49200
70	836	10.5	554	1060	74200
80	661	12.0	583	1190	94900
90	550	13.3	604	1260	113900
100	491	14.5	625	1320	132100
110	446	15.4	640	1340	147800
120	412	16.2	655	1360	163800
130	385	16.9	670	1380	179100
140	364	17.5	680	1380	192100
150	343	18.2	690	1370	205500
160	335	18.7	694	1360	217500
170	328	19.2	698	1350	229200
180	319	19.7	702	1340	241000
190	310	20.2	706	1330	253000
200	300	20.7	712	1320	264000
210	291	21.2	718	1310	275000
220	281	21.7	722	1300	286000
230	272	22.2	726	1290	296000
240	263	22.7	731	1280	307000
250	254	23.2	736	1270	318000
260	245	23.7	741	1260	328000
270	236	24.2	746	1250	337000
280	228	24.7	751	1240	347000
290	219	25.2	756	1230	356000
300	209	25.7	761	1220	366000

*See graph that follows for actual extrapolation



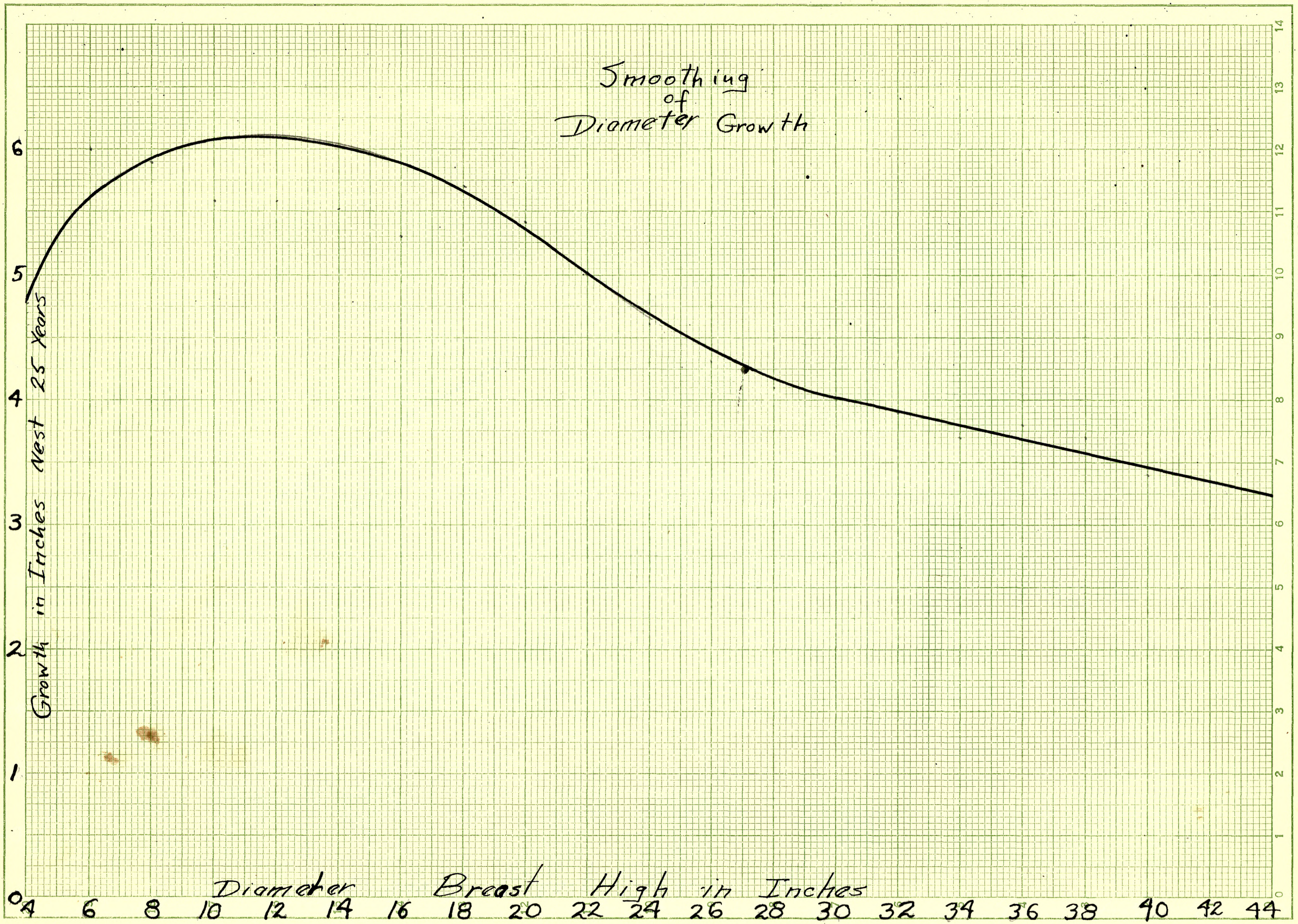
Extrapolation of Yield Table

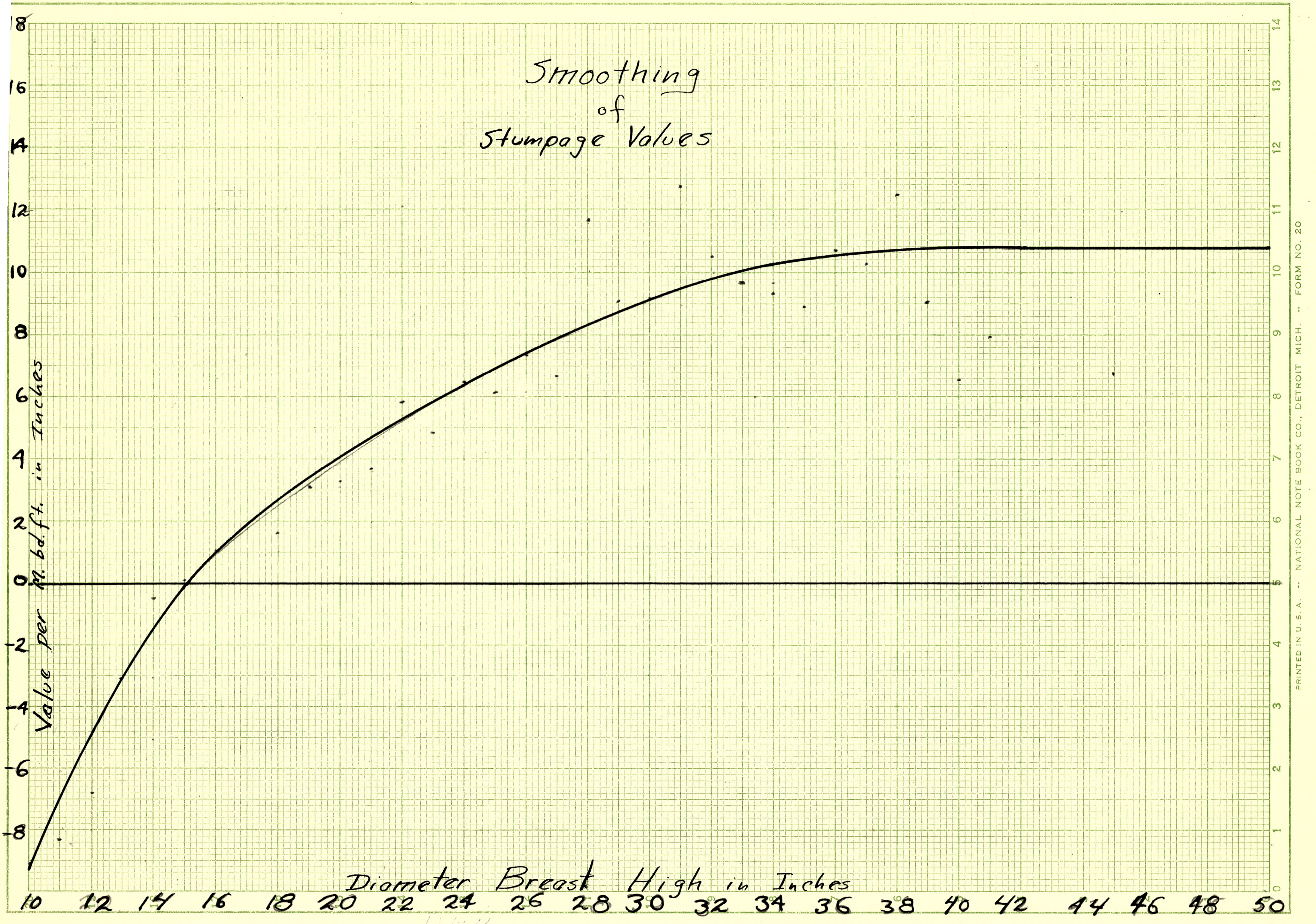
Derrivation

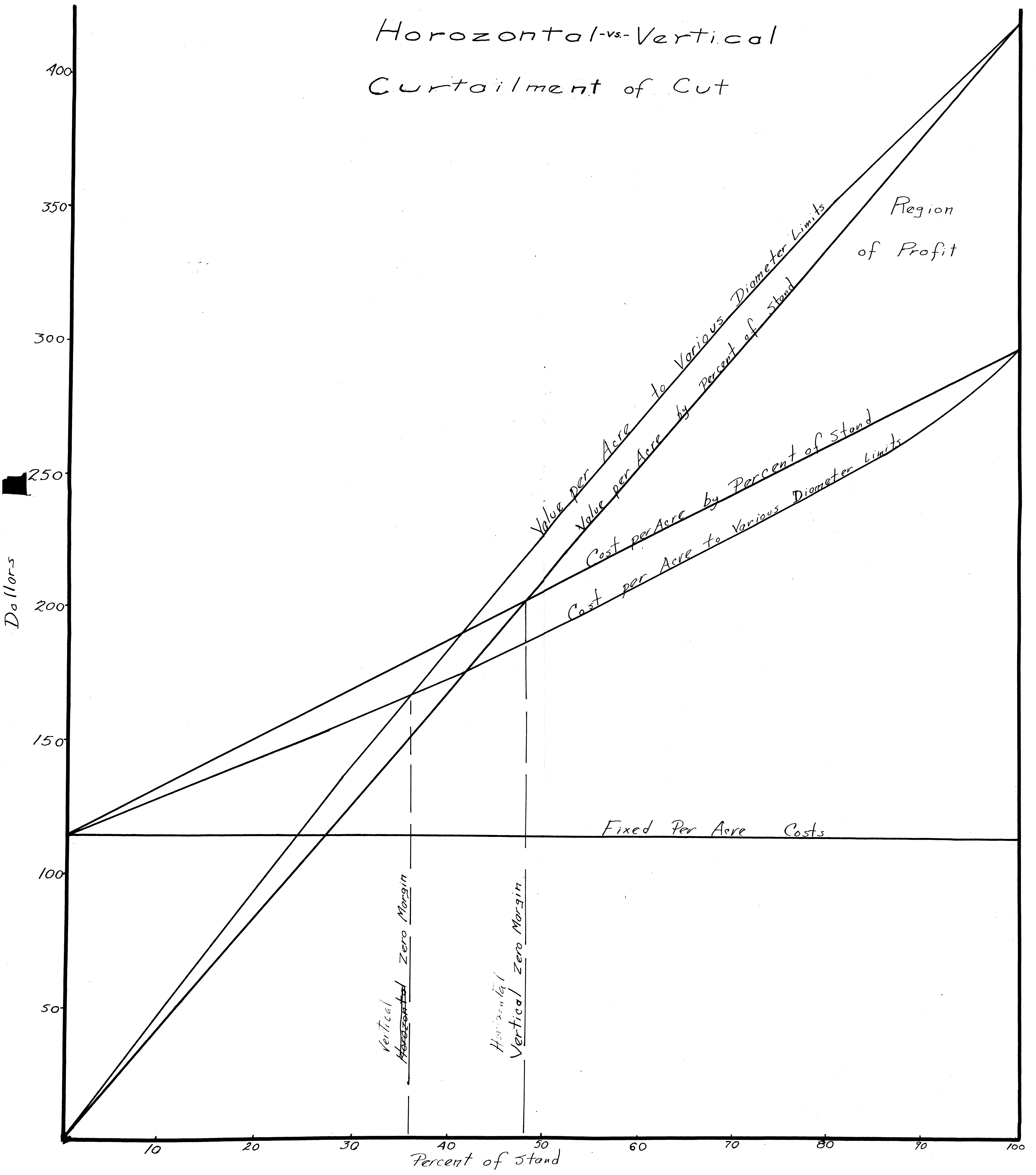
of Growth Rates

D. B. H.	Basal* area Growth Percent	Diameter Growth Pefcent	D.B.H. 25 Years Hence	Diameter Growth in inches 25 Years	Smoothed Diameter Growth In. 25 Y.
4	1.064	1.032	8.78	4.78	4.8
6	1.064	1.032	12.00	6.00	5.6
8	1.064	1.032	13.89	5.89	5.9
10	1.064	1.032	15.58	5.58	6.1
12	1.033	1.016	17.58	5.58	6.1
14	1.033	1.016	19.52	5.52	6.0
16	1.033	1.016	21.3	5.3	5.9
18	1.022	1.011	23.7	5.7	5.7
20	1.022	1.011	25.4	5.4	5.4
22	1.022	1.011	27.0	5.0	5.0
24	1.015	1.007	28.6	4.6	4.7
26	1.015	1.007	30.2	4.2	4.4
28	1.015	1.007	32.1	4.1	4.2
30	1.012	1.005	34.0	4.0	4.0
32	1.012	1.005	35.9	3.9	3.9
34	1.012	1.005	37.7	3.7	3.8
36	1.009	1.004	39.8	3.8	3.7
38	1.009	1.004	41.7	3.7	3.6
40	1.009	1.004	43.4	3.4	3.5
42	1.007	1.003	45.2	3.2	3.3

*From Table 3 of (3)


Smoothing
of
Diameter Growth
Growth in Inches Next 25 Years
Diameter Breast High in Inches
0 1 2 3 4 5 6
4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44
PRINTED IN U.S.A. -- NATIONAL NOTE BOOK CO., DETROIT MICH. -- FORM NO. 20


Smoothing
of
Stumpage Values
Value per M. bd. ft. in Inches
Diameter Breast High in Inches
18
16
14
12
10
8
6
4
2
0
-2
-4
-6
-8
10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50
PRINTED IN U.S.A. -- NATIONAL NOTE BOOK CO., DETROIT MICH. -- FORM NO. 20



Horozontal -vs.- Vertical
Curtailment of Cut
Region of Profit
Value per Acre to Various Diameter Limits
Value per Acre by percent of Stand
Cost per Acre by Percent of Stand
Cost per Acre to Various Diameter Limits
Fixed Per Acre Costs
Vertical Horozontal Zero Margin
Horizontal Vertical Zero Margin
Dollars
400
350
300
250
200
150
100
50
10
20
30
40
50
60
70
80
90
100
Percent of Stand

REFERENCES

1. Dunning, D. and Reineke, L. H., Preliminary Yield Tables for Second Growth Stands in the California Pine Region. U. S. Dept. of Agr. Tech. Bulletin 354. 23 pp. 1933.

2. Matthews, D. M., Management of American Forests. McGraw-Hill Book Company, Incorporated, New York. 1935.

3. Dunning, D., Some Results of Cutting in the Sierra Forests of California. U. S. Dept. of Agr. Bulletin 1176. 26pp. 1923.

4. Gibbons, W. H., Johnson, H. M., and Spelman, H. R., The Effect of Tree Size on Western Yellow Pine Lumber Values and Production Costs, Reprinted from TIMBERMAN 30(12), 44, 46, 48-49; 31(1) 241-244; (2) 49, 50, 52, 54-55; (3) 54-56; (4) 49-59, 52; (5) 194, 196, 198. 1929-30.

5. Brundage, M. R., Krueger, M. E., and Dunning, D., The Economic Significance of Tree Size in Western Sierra Lumbering. California Agr. Exp. Sta. Bul. 549. 61 pp. 1933.