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A STUDY OF
A STOCKING SURVEY SYSTEM AND
THE RELATIONSHIP OF STOCKING PERCENT AS DETERMINED BY THIS SYSTEM
TO NUMBER OF TREES PER ACRE

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FOREWORD

On July 5, 1947, the "State Forest Research and Experimental Tax Act" became effective. This act provides for silvicultural research on forest lands and waste utilization research on the wastage resulting from harvesting, processing and manufacture of forest products. The funds for this program are derived from a privilege tax levied on persons engaged in harvesting forest products for commercial use.

The silvicultural phase of this program is handled by the State Forester under the Oregon State Board of Forestry. This report is in line with the policy of keeping foresters and forest industries currently informed as to the progress of research findings. This is the first bulletin in the silvicultural field to be issued by the State Forestry Department. Additional bulletins and progress reports will be forthcoming whenever results of research projects become available.

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INTRODUCTION

One of the basic problems of the forest manager is to keep himself informed as to the current productive status of his forest area. In determining and describing the condition of denuded and restocking areas, the forester has need of an accepted standard of adequacy of stocking; and in order to classify his land by this standard he needs a reliable stocking survey system which will give data capable of being expressed in the terms of the standard.

With the enactment of the "Oregon Forest Conservation Act" in 1941, the state forester was faced with the problem of choosing such a standard and such a stocking survey system. This was necessary since the law required that a decision be made as to when logged-off lands were deemed to be "reseeded".

The standard chosen was "300 established live seedlings per acre which are sufficiently spaced for individual normal growth and development and 100 of which are well distributed over the acre".[1] This standard was chosen as a minimum for "adequate restocking" and was so used and defined in the amended Conservation Act of 1947.

A stocking survey system was devised for collecting data to determine the degree of stocking of areas in question. This system, which will be described later in this report, involves the simultaneous tabulation of stocking by both milacre quadrants and single four milacre sample plots. Since 100 percent stocking by milacres would theoretically insure at least 1000 trees per acre spaced 6.6 feet by 6.6 feet, 30 percent of this, or 30 percent stocking by milacres, would similarly insure at least 300 trees per acre spaced not closer than 6.6 feet by 6.6 feet and thus fulfill the first of the two provisions of the standard for "adequate stocking".

1. This standard has since been approved by the West Coast Forestry Procedures Committee (affiliated with the Western Forestry and Conservation Association).

Since 100 percent stocking by four milacres would theoretically insure at least 250 trees per acre spaced 13.2 feet by 13.2 feet, 40 percent of this, or 40 percent stocking by four milacres, would similarly insure at least 100 trees per acre not closer than 13.2 feet by 13.2 feet, and would in addition insure that stocking was present on at least 40 percent of the area examined. This then fulfills the second of the two provisions of the standard for "adequate stocking".

This survey system was believed to have advantages over most systems then in general use. It was felt that a requirement based on milacre stocking was superior for the purpose of assuring a greater number of trees per acre than would normally become "crop trees" and would thereby be a step in the attainment of normal self-pruning, necessary to good stand development. The use of the milacre as a unit for stocking surveys was first developed and advocated by W. C. Lowdermilk (7) in 1921. It was felt that a requirement based on four milacre stocking was superior for the purpose of assuring better stocking distribution. Haig (5) defended the four milacre system for stocking surveys in 1929 on the theory of better distribution. He maintained that a stocking survey should consider only those trees which were spaced so as to be able to become eventual "crop trees".

PURPOSE OF STUDY

This study was initiated and designed, first, to determine the reliability of the stocking survey system, and, second, to construct free hand curves which would give the ratio of percent of stocking to number of trees per acre.[2] The need for a determination of the reliability of the sampling system is self evident. The need for the curves for conversion of percent of stocking to number of trees per acre is twofold. To fulfill the original premise that an adequate stocking survey system should "give data capable of being expressed in the terms of the standard" the curves are needed inasmuch as the stocking survey system gives results directly in percent of milacres and percent of four milacres, whereas the standard is expressed in terms of number of trees per acre. Also, the conversion was desired, because it is true that many foresters and forestry agencies prefer to state stocking in terms of number of trees per acre and number of trees per acre seems to be more readily understood by the general public.

It was not until the advent of the state research program[3] that the use of this stocking survey system on research projects provided enough samples to justify the construction of free-hand curves which would give a reliable estimate of number of trees per acre based on percent of stocking.

2. There are in existance curves based on the milacre and four milacre survey systems such as those produced by Wellner (10) in the western white pine type. It was felt, however, that a similar study should be made for this particular survey system and timber type.

3. "State Forest Research and Experiment Tax Act" popularly called the "Severance Tax Act".

PERSONNEL INVOLVED

The author wishes to make acknowledgement of the credit due John B. Woods, Jr. Assistant State Forester, Oregon State Board of Forestry, for his guidance and advice throughout the entire study; Dr. George H. Barnes, Associate Professor, School of Forestry, Oregon State College, for his advice and instruction in the methods of statistical analysis used herein and for his "Comments on the Method of Determination of the Adequacy of Restocking of Cutover Lands Employed by the Oregon State Board of Forestry" included in this report; Harold Dixon, Research Assistant, Oregon State Board of Forestry, for his help in the collection and compilation of data used in this report; and all the personnel of the Conservation Section and the Conservation Research Section who collected field data for this study.

REVIEW OF LITERATURE

The published material which was consulted before the undertaking of this study, some of which is referred to in the text of the Bulletin, was mainly that written by personnel of the U. S. Forest Service stationed at the Pacific Northwest Forest & Range Experiment Station and the Northern Rocky Mountain Experiment Station. A bibliography of all material reviewed is listed on page 24.

DESCRIPTION OF STUDY AREAS

The samples used for the construction of the curves were all taken at random from the cutover areas of the Douglas-fir type in Western Oregon. Table number 1 gives the location of each of the 100 samples used. Each sample represents a 40 acre area.

TABLE 1
LOCATION OF SAMPLE PLOTS

Sample No.	Township	Range	Section	Sub.	Acres
1	15 S	1 E	8	SWNW	40
2	3 N	6 W	6	SESW	40
3	3 N	6 W	5	NWNW	40
4	3 N	6 W	6	SWSW	40
5	3 N	6 W	6	NESE	40
6	15 S	1 E	7	NENE	40
7	3 N	6 W	6	SESE	40
8	5 N	8 W	35	SENE	40
9	4 N	5 W	30	SESW	40
10	9 S	10 W	25	NENW	40
11	3 N	6 W	6	NENW	40
12	5 N	8 W	35	NWSW	40
13	3 N	6 W	6	SWSW	40
14	5 N	8 W	35	NENE	40
15	4 N	5 W	30	SWSW	40
16	15 S	1 E	7	SENE	40
17	6 S	3 E	25	NWSE	40
18	9 S	10 W	25	SENW	40
19	4 N	6 W	31	SWSE	40
20	5 N	8 W	36	SWSW	40
21	8 S	9 W	2	SWNW	40
22	6 S	3 E	25	SESE	40
23	6 S	3 E	25	SWSE	40
24	5 N	8 W	35	SENE	40
25	11 S	1 E	13	NENW	40
26	6 S	9 W	13	SESW	40
27	14 S	2 E	1	SENE	40
28	5 N	8 W	36	NESW	40
29	5 N	8 W	35	NWSE	40
30	5 N	8 W	35	NENW	40
31	14 S	1 E	24	SWSW	40
32	6 S	3 E	25	NESE	40
33	3 N	6 W	6	SENE	40
34	6 S	9 W	13	NWSW	40
35	15 S	1 E	8	NWNW	40
36	11 S	1 E	12	SWSE	40
37	11 S	1 E	12	SWSE	40
38	14 S	2 E	1	NWNE	40
39	14 S	1 E	24	NWSW	40
40	11 S	1 E	13	SENW	40
41	11 S	1 E	13	NWNE	40
42	15 S	2 W	28	SENE	40
43	11 S	1 E	12	NWSE	40
44	6 S	8 W	30	NWSE	40
45	5 N	8 W	35	SESW	40
46	6 S	8 W	30	SWSW	40
47	9 S	10 W	25	NWNW	40
48	9 S	10 W	25	SWNW	40
49	15 S	2 W	28	NENE	40
50	15 S	2 W	28	NWNE	40

TABLE 1 - continued

Sample No.	Township	Range	Section	Sub.	Acres
51	8 S	9 W	2	SENW	40
52	11 S	1 E	12	SWSW	40
53	11 S	1 E	12	SESE	40
54	6 S	9 W	13	SWSW	40
55	15 S	2 W	28	SWNE	40
56	11 S	2 E	7	SWNW	40
57	6 S	9 W	19	SENE	40
58	14 S	2 E	1	NENE	40
59	14 S	2 E	1	SWNE	40
60	6 S	8 W	30	SWNW	40
61	5 N	8 W	35	SESE	40
62	11 S	1 E	13	SWNE	40
63	8 S	9 W	2	NWNW	40
64	6 S	8 W	30	SWSE	40
65	9 S	6 W	10	NWSW	40
66	6 S	8 W	30	NWSE	40
67	9 S	6 W	10	SWSW	40
68	17 S	1 E	27	NENE	40
69	11 S	1 E	13	NWNW	40
70	14 S	1 E	24	SESW	40
71	11 S	1 E	12	NESE	40
72	11 S	1 E	12	SESE	40
73	11 S	1 E	12	SESW	40
74	5 N	10 W	5	SWNW	40
75	11 S	1 E	13	NESE	40
76	6 S	2 E	34	NESW	40
77	5 N	10 W	5	NENW	40
78	9 S	6 W	10	SESW	40
79	11 S	1 E	36	NWSE	40
80	4 N	6 W	32	SESW	40
81	9 S	6 W	10	NESW	40
82	11 S	1 E	13	NENE	40
83	5 N	10 W	20	SENE	40
84	6 S	9 W	19	SESE	40
85	6 S	8 W	30	NESE	40
86	5 N	10 W	20	SWNE	40
87	17 S	1 E	27	NENE	40
88	11 S	1 E	36	SWSE	40
89	11 S	1 E	36	NESE	40
90	11 S	1 E	36	SESE	40
91	5 N	10 W	5	SWNE	40
92	14 S	1 E	24	NESW	40
93	6 S	9 W	13	NESW	40
94	6 S	2 E	34	NWSW	40
95	17 S	1 E	27	NWNE	40
96	6 S	8 W	30	SESE	40
97	8 S	9 W	2	NENW	40
98	6 S	8 W	30	SWSE	40
99	5 N	10 W	5	NENE	40
100	17 S	1 E	27	SWNE	40

Note: All sample descriptions refer to W.M.

EXPERIMENTAL PROCEDURES

Reliability of the Stocking Survey System:

The stocking survey system which is under consideration is fully explained below. The problem of determining its statistical reliability was referred to Dr. George H. Barnes, Associate Professor, Oregon State College, School of Forestry. His analysis and comments are to be found under the heading "Analysis of Data and Results of Study".

The Stocking Survey System: Under the Oregon State Stocking Survey System, stocking data are taken from equidistant points along two compass lines running north and south and two compass lines running east and west through each forty. In regular forties, parallel survey lines are ten chains apart and are five chains inside respective forty boundaries. If the forty is irregular, the lines are adjusted to provide the same proportionate division of the forty. The first sample plot on each line is taken one chain from the starting point; and the remaining plots are taken at two-chain intervals (see Fig. 1). All distances are normally measured by pacing.

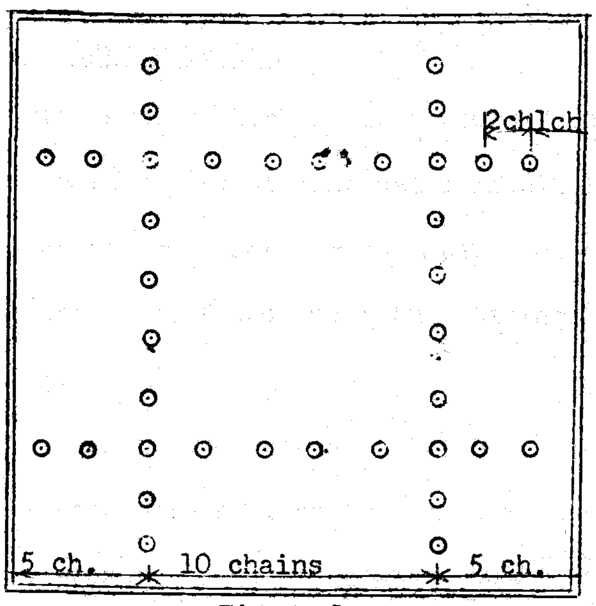


Figure 1.

STOCKING SURVEY DIAGRAM

Each sample plot is a .004 acre circle of horizontal area which is divided by cardinal lines into four milacre quadrants.

In tabulating stocking, three classes of reproduction are recognized, as follows:

1. First-year reproduction -- seedlings which are in their first season of growth and have not as yet become definitely established.
2. Established reproduction -- seedlings which are in a healthy condition after one or more seasons of growth.
3. Advanced reproduction -- seedlings which are in a healthy condition after five or more seasons of growth.

Stocking counts are made in terms of advanced reproduction and established reproduction. Three first-year seedlings are considered the equivalent of one established seedling.

Stocking tabulations are made on a specially designed stocking and seed tree survey card (see Fig. 2A). On this card each of the square diagrams on the left side represents a .004 acre sample plot divided into milacre quadrants. The line to the left of each diagram is for the number of the plot. Check marks are made on all milacre quadrants in which three or more first-year seedlings or one or more established or advanced seedlings are found. All seedlings found on each plot are tabulated as established and advanced seedlings by species in the blanks provided in the center of the card. Established seedlings are designated by lower case letters and advanced seedlings by capitals.

At the conclusion of the stocking survey all stocking data are transferred from the survey cards to a stocking and seed tree survey summary sheet (see Fig.2B). Each summary sheet will accommodate the data from four forties. The small squares are square chains and the dotted lines represent the stocking survey lines. Stocking is shown graphically by coloring in at each sample plot station along the survey

OREGON
STATE BOARD OF FORESTRY

CONSERVATION
STOCKING AND SEED TREE SURVEY

T.	R.	Sec.	160	40	10	2½

Method ____________ Done by ____________ Date ____________

Plot No.	Quadrat Stocking	No. Trees		Location of Seed Trees By Classes	
		D.	d		
		H.	h.		
		S.	s		
		D	d.		
		H	h.		
		S	s.		
		D.	d.		
		H.	h.		
		S.	s.		
		D	d.		
		H	h		
		S	s.		
		D	d		
		H	h		
		S	s		

Slope % ____________ *Exposure* ____________ *Site* ____________

Soil ____________ *Cover* ____________

Remarks ____________

Form 49-11-47-5M STATE PRINTING DEPT.

FIGURE 2 CONSERVATION STOCKING & SEED TREE SURVEY CARD

Form 49A—4-46—2M

OREGON STATE BOARD OF FORESTRY

STOCKING AND SEED TREE SURVEY SUMMARY

Area Covered: Township 6 S Range 3 E Section 25 160 SW 40
Method 2 x 10 Done by H. DIXON Date 28-29 OCT. 1947
Operator B. A. LOGGER Landowner I. N. VESTOR

SEED TREES						STOCKING			
Class	Weight	No. Trees DF	No. Trees Other	Wt. Value DF	Wt. Value Other	By 1/1000 Acre Plots		By 1/250 Acre Plots	
I	2					Total No. Plots	640	Total No. Plots	160
II	1					Total Plots Stocked	90	Total Plots Stocked	53
III	0.5					Per cent Plots Stocked	14	Per cent Plots Stocked	33
	Total								

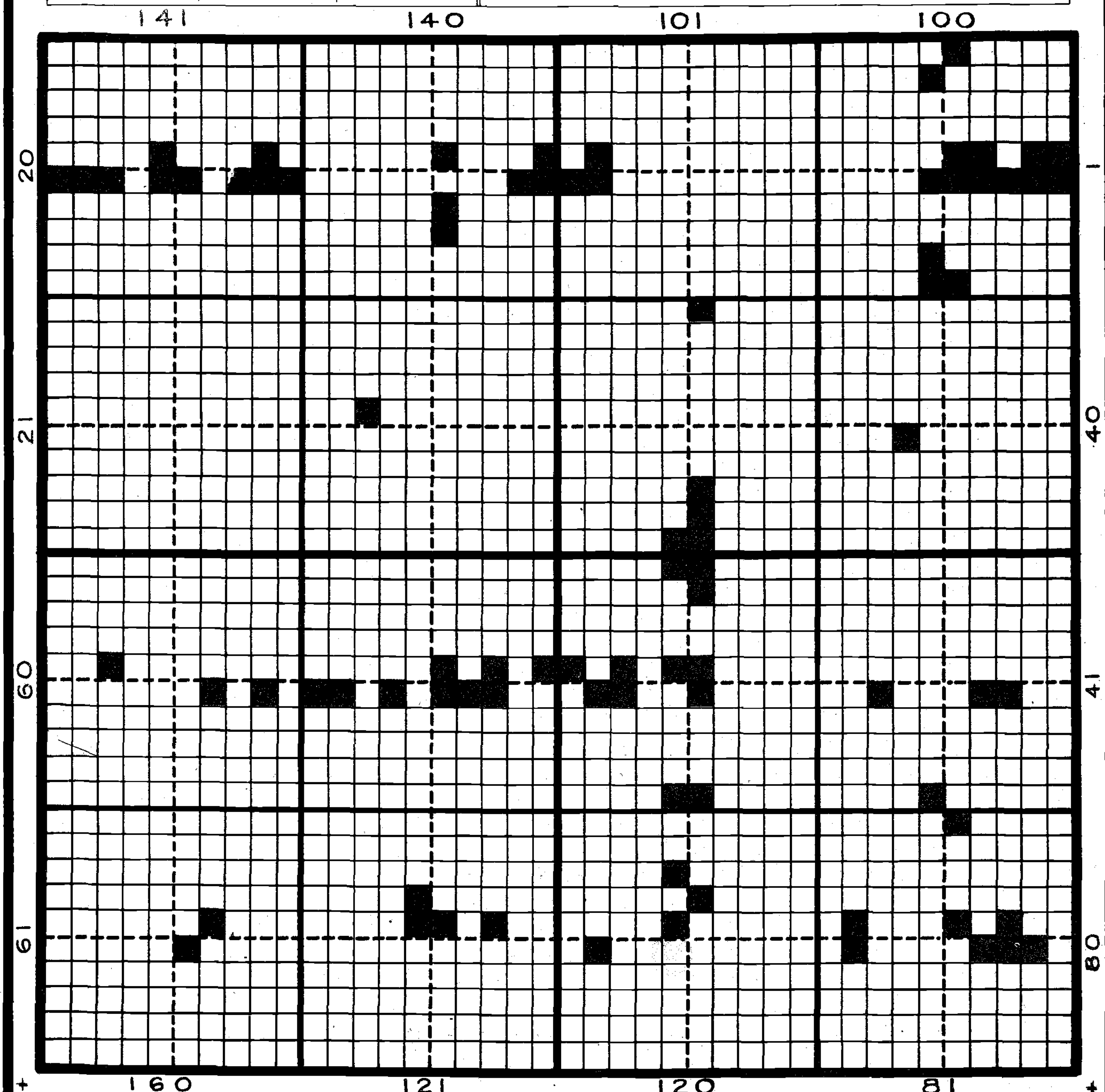


FIGURE 2 B
STOCKING AND SEED TREE SURVEY SUMMARY

lines from one to four squares, depending upon the number of stocked quadrants shown on the survey card.

Stocking survey data are then summarized by forties by first counting the number of .004 acre plots in which one or more quadrants are shown as stocked; and then counting the total number of milacre quadrants shown as stocked. These counts are then expressed as the percentage of .004 acre plots stocked and the percentage of milacre plots stocked.

Construction of the Curves:

Using the data from the 100 forty acre sample areas (see table number 2) and applying standard statistical methods, free-hand curves were constructed[4] and are shown as Figures 3 and 4. This process included the elimination of unreliable samples, balancing of the curves, computation of the standard errors of estimate, calculation of fiducial limits, and the addition of straight line curves representing the practical lower limits of the number of trees per acre for any selected stocking percent.

4. For complete details on the computations and construction of the curves see Appendix, pp. 25 to 40.

TABLE NO. 2

FIELD DATA FROM 100 FORTY ACRE SAMPLE PLOTS

1	2	3	4	5	6	7	8	9
Sample #	# Plots		# Plots Stocked		Total # Trees Found on Plots	Stocking %		No. Trees Per Acre Actual
	4 Mil A.	Mil A.	4 Mil A.	Mil A.		4 Mil A.	Mil A.	
1	21	84	2	2	2	9.5	2.4	24
2	40	160	3	4	6	7.5	2.5	38
3	40	160	3	4	7	7.5	2.5	44
4	40	160	4	6	8	10.0	3.8	50
5	40	160	5	6	8	12.5	3.7	50
6	38	152	5	7	8	13.2	4.6	53
7	40	160	5	8	14	12.5	5.0	88
8	40	160	7	9	29	17.5	5.6	181
9	40	160	10	11	13	25.0	6.9	81
10	33	132	6	9	129	18.2	6.8	977*
11	40	160	10	20	28	25.0	12.5	175
12	40	160	13	20	52	32.5	12.5	325
13	40	160	4	12	21	10.0	7.5	131
14	40	160	10	15	21	25.0	9.4	131
15	40	160	6	15	39	15.0	9.4	244
16	26	104	6	10	41	23.1	9.6	394
17	40	160	9	17	26	22.5	10.6	163
18	40	160	9	18	46	22.5	11.3	288
19	40	160	8	19	51	20.0	11.9	319
20	40	160	11	19	20	27.5	11.9	125
21	40	160	16	20	25	40.0	12.5	156
22	40	160	19	27	40	47.5	16.9	250
23	40	160	14	22	23	35.0	13.8	144
24	40	160	15	22	36	37.5	13.8	225
25	40	160	14	22	28	35.0	13.8	175
26	40	160	13	22	39	32.5	13.8	244
27	40	160	15	23	53	37.5	14.4	331
28	40	160	14	23	102	35.0	14.4	638
29	40	160	16	23	57	40.0	14.4	356
30	40	160	12	23	31	30.0	14.4	194
31	40	160	15	24	29	37.5	15.0	181
32	40	160	10	25	43	25.0	15.6	269
33	40	160	15	28	55	37.5	17.5	344
34	40	160	15	29	60	37.5	18.1	375
35	40	160	19	29	41	47.5	18.1	256
36	40	160	22	30	34	55.0	18.8	213
37	40	160	22	31	37	55.0	19.4	231
38	40	160	18	31	63	45.0	19.4	394
39	40	160	18	31	41	45.0	19.4	256
40	40	160	20	34	54	50.0	21.3	338
41	40	160	20	35	44	50.0	21.9	275
42	40	160	21	35	51	52.5	21.9	319
43	40	160	20	35	46	50.0	21.9	288
44	40	160	19	35	47	47.5	21.9	294
45	40	160	19	36	80	47.5	22.5	500
46	40	160	22	36	58	55.0	22.5	363
47	40	160	20	36	119	50.0	22.5	744
48	40	160	20	37	80	50.0	23.1	500

1	2	3	4	5	6	7	8	9
49	40	160	22	37	60	55.0	23.1	375
50	40	160	22	37	58	55.0	23.1	363
51	40	160	24	37	44	60.0	23.1	275
52	40	160	25	37	57	62.5	23.1	356
53	40	160	22	37	44	55.0	23.1	275
54	40	160	19	38	96	47.5	23.8	600
55	40	160	23	40	122	57.5	25.0	763
56	40	160	26	40	56	65.0	25.0	350
57	40	160	21	40	60	52.5	25.0	375
58	40	160	21	42	108	52.5	26.3	675
59	39	156	23	41	49	59.0	26.3	314
60	40	160	23	43	76	57.5	26.9	475
61	40	160	20	44	107	50.0	27.5	669
62	40	160	28	44	53	70.0	27.5	331
63	40	160	25	45	71	62.5	28.1	444
64	40	160	21	47	67	52.5	29.4	419
65	40	160	22	47	95	55.0	29.4	594
66	40	160	26	48	123	65.0	30.0	769
67	40	160	20	49	94	50.0	30.6	588
68	40	160	27	49	80	67.5	30.6	500
69	40	160	24	49	68	60.0	30.6	425
70	40	160	20	51	117	50.0	31.9	731
71	31	124	18	40	122	58.1	32.3	984
72	40	160	31	52	70	77.5	32.5	438
73	40	160	28	53	107	70.0	33.1	669
74	40	160	22	53	229	55.0	33.1	1431
75	40	160	29	54	68	72.5	33.8	425
76	40	160	22	55	113	55.0	34.4	706
77	40	160	27	56	230	67.5	35.0	1438
78	38	152	25	56	78	65.8	36.8	513
79	40	160	26	60	107	65.0	37.5	669
80	40	160	27	61	148	67.5	38.1	925
81	40	160	28	62	106	70.0	38.8	663
82	40	160	29	62	78	72.5	38.8	488
83	40	160	33	63	128	82.5	39.4	800
84	40	160	29	63	104	72.5	39.4	650
85	40	160	28	65	149	70.0	40.6	931
86	40	160	27	66	189	67.5	41.3	1181
87	40	160	33	66	127	82.5	41.3	794
88	30	120	23	50	114	76.7	41.7	950
89	40	160	30	67	148	75.0	41.9	925
90	37	148	24	62	142	64.9	41.9	959
91	40	160	30	68	247	75.0	42.5	1544
92	40	160	33	69	117	82.5	43.1	731
93	40	160	27	71	205	67.5	44.4	1281
94	40	160	29	73	175	72.5	45.6	1094
95	40	160	34	75	123	85.0	46.9	769
96	40	160	30	75	174	75.0	46.9	1088
97	40	160	33	76	155	82.5	47.5	969
98	40	160	32	80	232	80.0	50.0	1450
99	40	160	28	81	515	70.0	50.6	3219*
100	40	160	34	85	149	85.0	53.1	931

* Samples omitted by inspection.
Column #7 = Column 4 ÷ Column 2
Column #8 = Column 5 ÷ Column 3
Column #9 = (Column 6 ÷ Column 3)1000

ANALYSIS OF DATA AND RESULTS OF STUDY

Reliability of the Stocking Survey System:

COMMENTS ON THE METHOD OF DETERMINATION OF THE
ADEQUACY OF RESTOCKING OF CUTOVER LANDS
EMPLOYED BY THE OREGON STATE BOARD OF FORESTRY

By

Dr. George H. Barnes, Associate Professor
School of Forestry, Oregon State College

I have examined the methods employed by the Oregon State Board of Forestry in determining the adequacy of restocking on cutover lands, as described in the Administrative Handbook of the Oregon Conservation Act. (Bulletin No. 11). In brief the method consists of laying out 40 circular plots of four milacres each, distributed mechanically over each forty examined. Each of the 40 plots is further subdivided into four quadrants of one milacre giving a total of 160 milacre quadrants. The examiners record the number of quadrants in each plot that are stocked with one or more established seedlings. The stocking of the forty is then expressed as the percentage of the total number of quadrants stocked, and as the percentage of the total number of the four-milacre plots that are stocked.

In the Administrative Handbook adequate stocking has been defined as a stand of at least 300 established live seedlings per acre, all of which are adequately spaced for normal growth and development and 100 of which are well distributed. These requirements are deemed to be met if 30 per cent of the quadrants, and 40 per cent of the four-milacre plots are found to be stocked. In order to judge the distribution of the seedlings a plat is drawn showing the location of each plot and the number of quadrants stocked.

The following questions might be raised with respect to the procedure followed:

1. Is the standard set for adequate stocking satisfactory?

2. Is the plan of sampling sufficient for reaching a decision as to whether or not the ground is satisfactorily stocked according to definition?

3. Is interpretation of the data correct?

The writer's opinion on these questions is set forth below:

1. Standard for Adequate Stocking.

The West Coast Forestry Procedures Committee has declared, "'Adequate Stocking' shall be considered, for the present, to apply to lands where 40 per cent or more of the 1/250-acre quadrants are stocked with one or more established seedlings - - - - - -." The Oregon State Standard contains all of this and goes even further in requiring that 30 per cent of the milacre quadrants be stocked with one or more established seedlings. The latter requirement represents a higher level than the former. Thirty per cent stocking on the milacre basis is the equivalent of at least 300 stocked milacres per acre, whereas 40 per cent stocking on the four-milacre basis is equivalent to at least 100 stocked milacres per acre. Many of the stocked milacres of course will carry more than one seedling.

Investigations of the State Department of Forestry indicate also that 30 per cent stocking on the milacre quadrant basis, means considerably more in total number of seedlings per acre than does 40 per cent on the four-milacre basis. Since the State Standard is higher than that proposed by the West Coast Forest Procedures Committee it should be considered satisfactory for the present. It should be noted, however, that lands which just pass the standard are considerably understocked and that the next crop produced by the stand will be of poor quality due to development of large limbs, and to lack of natural pruning unless there is some improvement in stocking subsequent to the time of the stocking survey.

Examinations of cutover lands are not made until they have had the advantage of at least four years of seeding. Generally they are made soon after the four year interval has passed. It has been found that restocking will continue for much longer than four or five years. It is therefore evident that if land is satisfactorily stocked after four or five years of seeding, it should improve considerably over the next decade. Thirty per cent stocking on the milacre basis, or a minimum of 300 seedlings per acre after four or five seed years seems to be a satisfactory standard for the present at least.

2. Plan of Sampling.

The plan designed for sampling the 40 acre tracts conforms with general procedures followed in conducting reproduction surveys. The plots are ideally distributed over the tract, and are arranged so as to permit efficiency in collection of the field data.

After a 40 acre tract has been sampled, the number of milacre quadrants actually stocked may be calculated readily, and thence this number may be expressed as a percentage of the total 160 milacres actually examined. It is then assumed that the percentage value so obtained may be applied to the 40 acre tract as a whole. The stocking percentage value is, in other words, merely an estimate of the true but unknown value for the tract. The standard error of the stocking percentage so obtained is relatively low on well stocked lands running over 50 per cent. The error reaches a maximum of approximately $\pm$ 15 per cent of the estimated value for a stocking percentage of 30 which is $\pm$ 4.5 per cent in absolute terms. Since this is the critical point at which decisions must be made it would seem advisable to increase the number of samples taken on such tracts. At the same time the number of samples taken on well stocked areas might well be decreased.

The standard set for adequate stocking also specified that at least 100 seedlings must be well distributed over the area. By plotting the occurrence of the stocked milacre quadrants, their distribution may be observed readily. A quantitative method of evaluating the distribution is established by specifying that each 10 acre quarter of a forty should have at least 12 of the milacre quadrants stocked with one or more established seedlings.

Interpretation of Data

In general, interpretation of the data collected is quite sound, and leads to a valid determination of the adequacy of stocking. Basically the problem consists of determining if the land carries 300 or more seedlings per acre, 100 of which are well distributed. The data collected permits an estimate to be made of the average number of seedlings per acre. A decision made therefrom would be in error, it is believed, in such a small proportion of cases as to be of little practical significance.

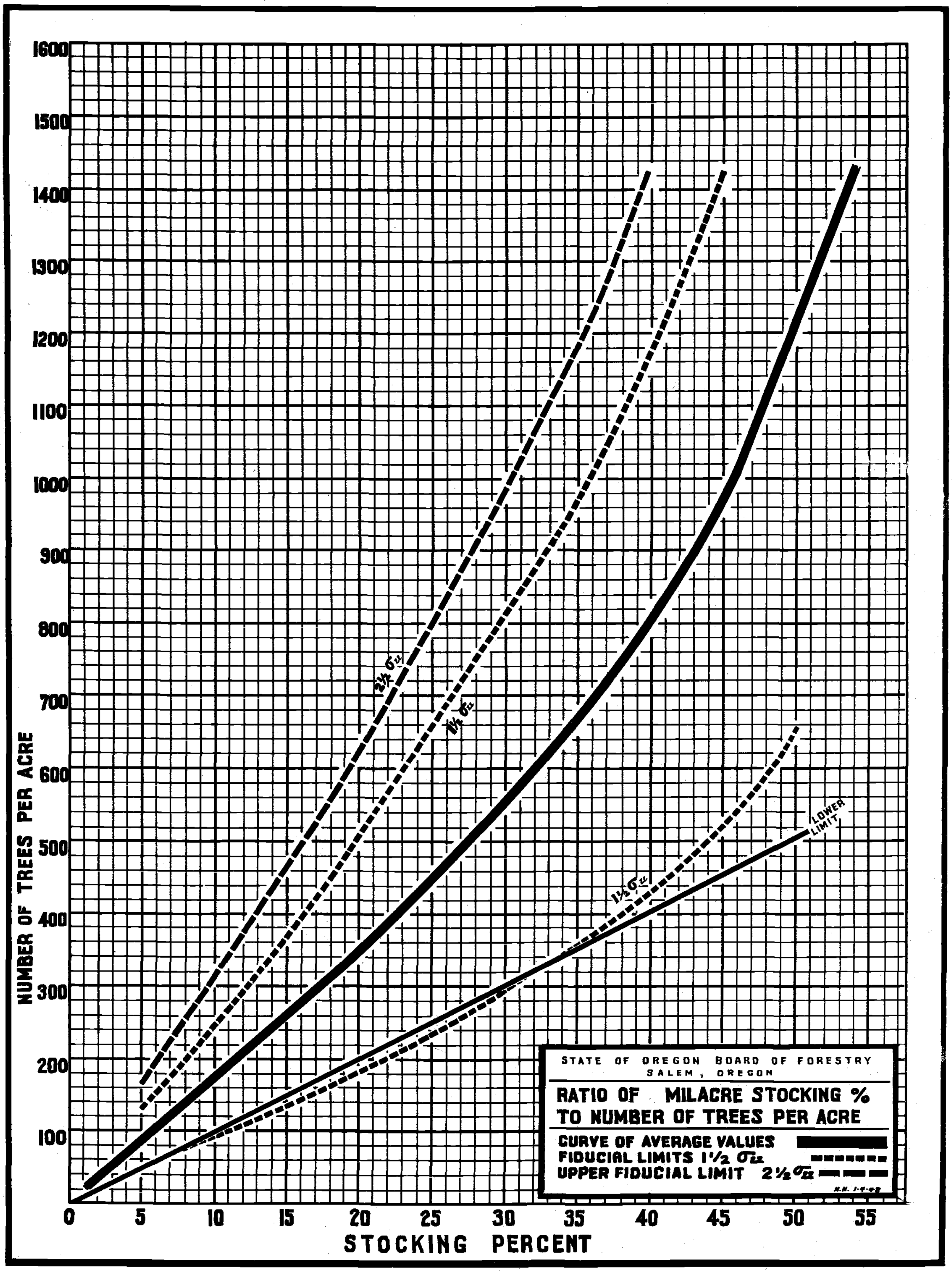
* * * * * * * * * * *

Use of the Curves:

The curves (Figures 3 and 4) are the final results of the study. They can be used to convert percent of stocking to number of trees per acre for either milacre or four milacre percentages. The main curves (curves of average values) will give the best answer to be had for a conversion of percent of stocking to number of trees per acre. Probable upper and lower limits for any desired degree of stocking can be calculated to any desired degree of accuracy within reason[5]. Fiducial limits of $1\frac{1}{2}$ standard errors of estimate and $2\frac{1}{2}$ standard errors of estimate have been placed on the curve graph for the convenience of the users. Fiducial limits of $1\frac{1}{2}$ standard errors of estimate include 86.6 percent of the probabilities within those limits, and give 93.3 percent above the lower limit. Fiducial limits of $2\frac{1}{2}$ standard errors of estimate include 98.8 percent within those limits and 99.4 percent above the lower limit. In using the fiducial limits, however, it should be noted that values below the straight line curve of minimum values are meaningless.

As a general policy it would be better to use the milacre curve for

5. A table of the "Area of the Normal Curve of Error" is included in the Appendix (page 40) for the convenience of those wishing to make such calculations. The standard error of estimate for each curve will be found in the curve computations, also in the Appendix.



1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
NUMBER OF TREES PER ACRE
0
5
10
15
20
25
30
35
40
45
50
55
STOCKING PERCENT
2½ σ
1½ σ
1½ σ
LOWER LIMIT
STATE OF OREGON BOARD OF FORESTRY
SALEM, OREGON
RATIO OF MILACRE STOCKING %
TO NUMBER OF TREES PER ACRE
CURVE OF AVERAGE VALUES
FIDUCIAL LIMITS 1½ σ
UPPER FIDUCIAL LIMIT 2½ σ

FIGURE NO. 3

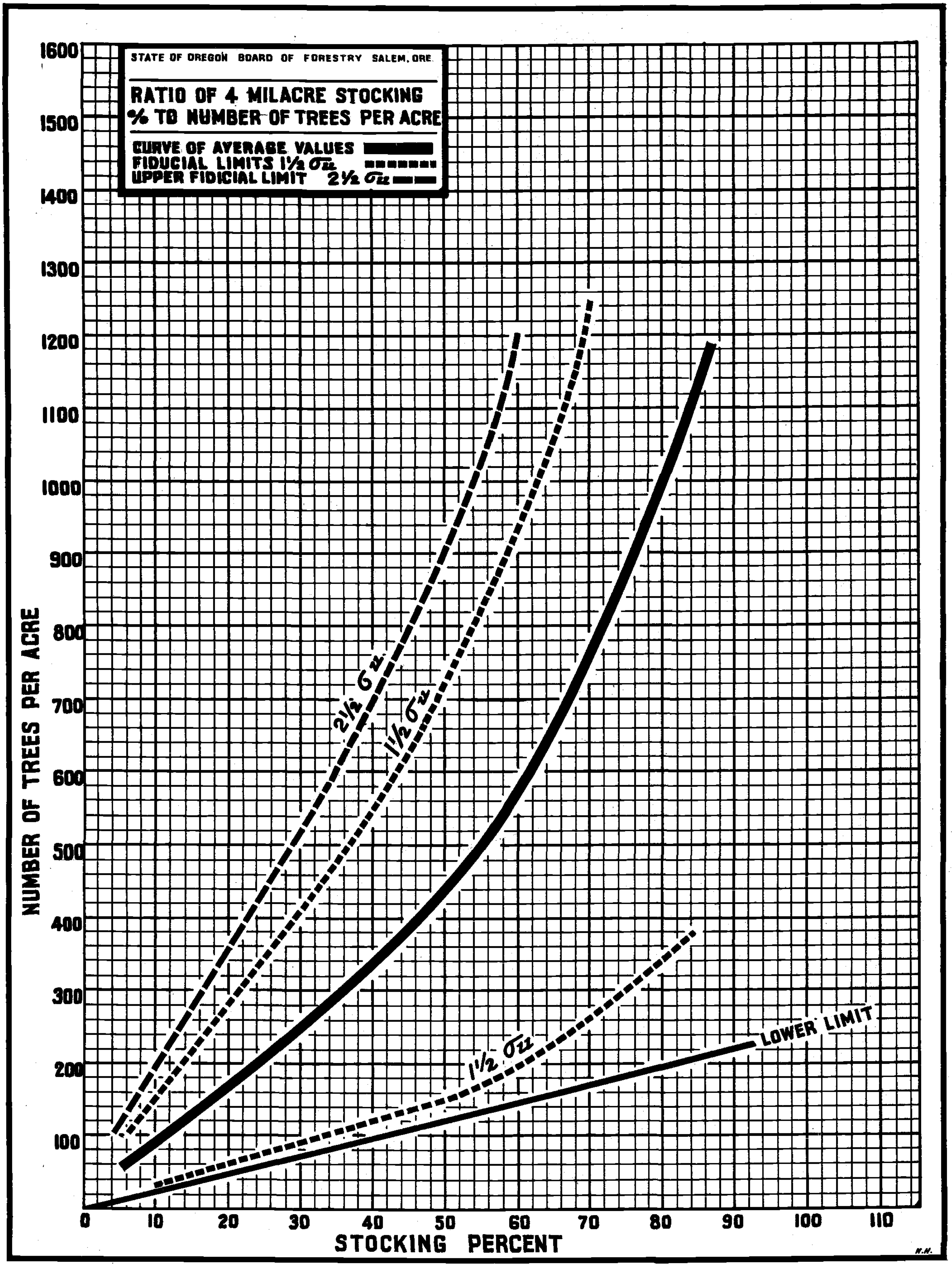

STATE OF OREGON BOARD OF FORESTRY SALEM, ORE.
RATIO OF 4 MILACRE STOCKING % TO NUMBER OF TREES PER ACRE
CURVE OF AVERAGE VALUES
FIDUCIAL LIMITS 1½ σzz
UPPER FIDICIAL LIMIT 2½ σzz
2½ σzz
1½ σzz
1½ σzz
LOWER LIMIT
NUMBER OF TREES PER ACRE
STOCKING PERCENT
0
10
20
30
40
50
60
70
80
90
100
110
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600

FIGURE NO. 4

conversion to number of trees per acre where a choice is possible. The lower standard estimate of error (31 percent as compared to 44 percent) is evidence of its greater worth.

Another use of the curves that can be made is that of conversion of figures for percent milacre stocking to percent four milacre stocking. For example, 30 percent milacre stocking can be converted to 555 trees per acre on the milacre curve (Fig. 3) and then converted to 59 percent stocking by four milacre on the four milacre curve (Fig. 4). This is done, of course, with full realization of the possible statistical limitations of estimate involved. However, a quick check of this agent against actual samples taken in the field shows it to be surprisingly accurate.

From curve	% milacre 30 %	% 4 milacre 59 %	Trees per acre 555
Field sample # 66	30 %	55 %	769
" " 67	30.6 %	50 %	588
" " 68	30.6 %	67.5 %	500
" " 69	30.6 %	60 %	425
From curve	20 %	43 %	345
Field sample # 37	19.4 %	55 %	231
" " 38	19.4 %	45 %	394
" " 39	19.4 %	45 %	256
" " 40	21.3 %	50 %	338

Inasmuch as the stocking surveys made for these curves were taken on areas logged from 3 to 5 years before the surveys, and the seedlings found were from 2 to 4 years old, it is felt that the tendency of the curves would be to give an answer of too few trees per acre rather than too many. This, of course, is due to the fact that where one or two seedlings were tallied in a sample plot there may have been more that were not found due to the difficulty of observing seedlings of such a small size. This would be especially true in areas having a moderate to dense ground cover.

It is true also that the short elapsed time between logging and surveying tended to give an abundance of samples in the low to moderately stocked classes and very few in the well stocked classes. It would be well to confirm the curves in the future by the collection of additional samples in the higher percent of stocking brackets (45 percent + for the milacre curve and 80 percent + for the four milacre curve). Comparison of these curves with curves made in like studies[6] show them to be quite similar except in the higher percentages of stocking.

6. Wellner's (10) would be a good example.

SUMMARY

This study was undertaken to determine the reliability of the Oregon State stocking survey system and to construct free-hand curves for use in the conversion of percent of stocking to number of trees per acre.

The question of the reliability of the stocking survey system was referred to Dr. George H. Barnes, associate professor of the Oregon State College School of Forestry. According to Dr. Barnes the plan of sampling conforms with general procedures followed in reproduction surveys and permits efficiency in collection of field data. The standard error of stocking percentage so obtained amounts to only ± 4.5 percent in absolute terms which would make a decision based on the survey in error in such a small proportion of cases as to be of little practical significance.

The second objective is fulfilled by the actual construction of free-hand curves which give a conversion from stocking percent to number of trees per acre for both percent of milacre stocking and percent of four milacre stocking. Stocking surveys were made in the field of one hundred random areas each forty acres in size. Applying standard statistical methods the data from these surveys were used to construct the free-hand curves. The milacre curve proved to be the most reliable for general use. This is shown by its lower standard error of estimate (31 percent for the milacre curve as compared to 44 percent for the four milacre curve). Fiducial limits of 1½ and 2½ standard errors of estimate were placed on the finished curve

graphs for the convenience of the user. A straight line curve of lower limit was placed on each finished curve graph. It is believed that the curves might not be entirely accurate in the higher brackets (45 percent + for the milacre curve and 80 percent + for the four milacre curve) due to insufficient samples in these brackets. It is also believed that the figures taken from any part of either curve may be slightly low due to the fact that the reproduction counts of two to four year old seedlings, upon which these curves are based, may have been low because of the difficulty of finding such small seedlings.

It is recommended that the curves be confirmed at a future date by the addition of more samples in the higher percent of stocking brackets.

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APPENDIX

Construction of the Curves

The original free-hand milacre curve (Figure 5) was made by plotting the points as shown, from the information obtained from table number 2. Column 8, "% of Stocking", and column 9, "Actual Number of Seedlings per Acre", gave the points for the milacre curve. Two samples, numbers 10 and 99, were eliminated by inspection as being unreliable.

After the free-hand curve had been drawn and balanced, table number 3 was compiled. The figures in column number 4 of this table were obtained from the curve drawn in figure 5. The columns 5, 6 and 7 are steps in the calculation of the standard error of estimate (σu). The standard error of estimate in percent was then computed using the formula $\sigma u = \sqrt{\frac{\sum (d\%)^2}{N}}$ where σu is the standard error of estimate, $\sqrt{\sum (d\%)^2}$ is the sum of the squared deviations in percent, and N is the number of samples.

For the milacre curve the calculation of the standard error of estimate was as follows:

$$\sigma u = \sqrt{\frac{\sum (d\%)^2}{N}}$$

$$\sigma u = \sqrt{\frac{171963.99}{98}}$$

$$\sigma u = \sqrt{1754.7345}$$

$$\sigma u = 41.89\ \%$$

Assuming that samples with a percent of deviation greater than two and one half times the standard error of estimate [2.5(41.89)= 104.73] were unreliable, samples numbered 28, 74 and 77 were dropped and the standard error of estimate was recomputed as follows:

$$\sigma_u = \sqrt{\frac{171963.99 - (24594.11 + 15625.00 + 12298.81)}{95}}$$

$$\sigma_u = \sqrt{\frac{119446.07}{95}}$$

$$\sigma_u = \sqrt{1257.327}$$

$$\sigma_u = 35.45$$

$$2.5\ \sigma_u = 88.63\ \%$$

On the same basis as above, sample number 16 was then dropped and the standard error of estimate was recomputed as follows:

$$\sigma_u = \sqrt{\frac{119446.07 - 9215.00}{94}}$$

$$\sigma_u = \sqrt{\frac{101016.07}{94}}$$

$$\sigma_u = \sqrt{1074.639}$$

$$\sigma_u = 32.78\ \%$$

$$2.5\ \sigma_u = 81.95\ \%$$

At this point all remaining samples were found to be within two and one-half standard errors of estimate.

The original free-hand four milacre curve (Figure 6) was constructed, standard error of estimate calculated, and samples eliminated in the same manner as just described for the milacre curve. The steps in calculation of the standard error of estimate and the elimination of samples are as follows:

$$\sigma_u = \sqrt{\frac{229005.97}{98}}$$

$$\sigma_u = \sqrt{2336.795}$$

$$\sigma_u = 48.34\ \%$$

$$2.5\ \sigma_u = 120.85\ \%$$

Sample number 74 dropped and standard error of estimate recomputed.

$$\sigma_u = \sqrt{\frac{229005.97 - 28561.00}{97}}$$

$$\sigma_u = \sqrt{2066.46}$$

$$\sigma_u = 45.46\ \%$$

Sample number 15 dropped and standard error of estimate recomputed.

$$\sigma_u = \sqrt{\frac{200444.97 - 14352.04}{96}}$$

$$\sigma_u = \sqrt{1938.47}$$

$$\sigma_u = 44.03\ \%$$

At this point all remaining samples were found to be within two and one-half standard errors of estimate.

With all unreliable samples eliminated, the remaining samples were replotted and both curves redrawn and balanced. These were the final, usable curves (Figures 3 and 4). For each of these curves the standard error of estimate was recalculated (Tables 5 and 6) , the results of which were as follows:

For the milacre curve $\sigma_u = 30.89$ or 31 %

For the four milacre curve $\sigma_u = 43.9$ or 44 %

Fiducial limits of $1\frac{1}{2}$ standard errors of estimate and $2\frac{1}{2}$ standard errors of estimate were then calculated (Tables 7 and 8) for each curve and these limits were added to the graphs of the final curves. Assuming that the stocking percent obtained by the survey system is representative of the universe sampled[7] a straight line curve of lower limits was computed and added to the graph of each curve.

7. This assumption is made with the full realization of the limits of such assumption. The accuracy of estimating the stocking percent of any area based on a sample of that area is discussed by Barnes in this report.

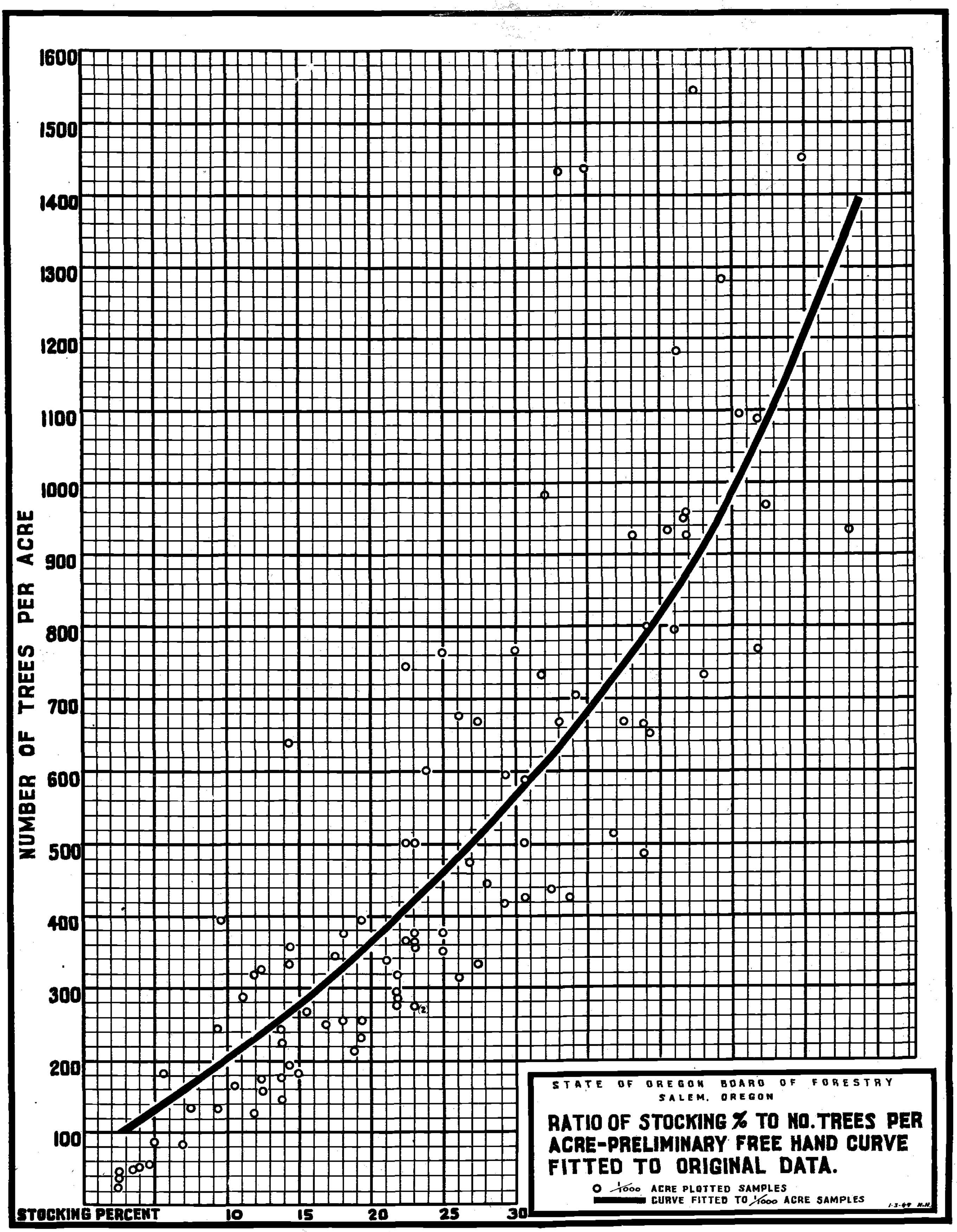
NUMBER OF TREES PER ACRE
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
STOCKING PERCENT
10
15
20
25
30
STATE OF OREGON BOARD OF FORESTRY
SALEM, OREGON
RATIO OF STOCKING % TO NO. TREES PER ACRE-PRELIMINARY FREE HAND CURVE FITTED TO ORIGINAL DATA.
1/1000 ACRE PLOTTED SAMPLES
CURVE FITTED TO 1/1000 ACRE SAMPLES

FIGURE NO. 5

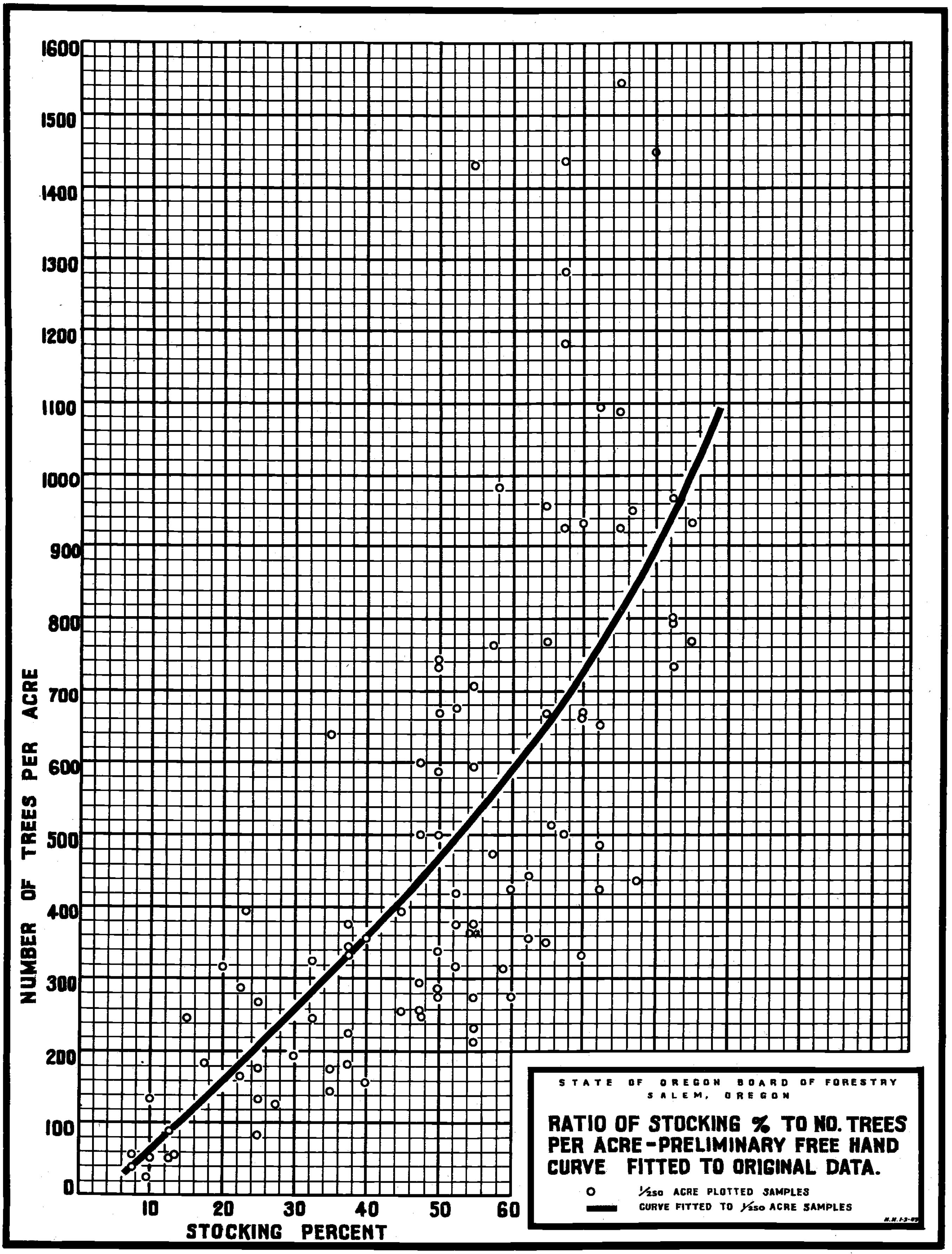
NUMBER OF TREES PER ACRE
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
10
20
30
40
50
60
STOCKING PERCENT
STATE OF OREGON BOARD OF FORESTRY
SALEM, OREGON
RATIO OF STOCKING % TO NO. TREES PER ACRE - PRELIMINARY FREE HAND CURVE FITTED TO ORIGINAL DATA.
1/250 ACRE PLOTTED SAMPLES
CURVE FITTED TO 1/250 ACRE SAMPLES

FIGURE NO. 6

TABLE NO. 3

STEPS IN COMPUTATION OF STANDARD ERROR OF ESTIMATE FOR ORIGINAL MILACRE CURVE (Fig.5)

1	2	3	4	5	6	7
Sample No.	% Stocked Mil Acres	No.Seedlings Per Acre Actual	No.Seedlings Per Acre (Est. From orig. curve)	Deviations (3) - (4)	Deviation % (5) / (4)	Deviation $\%^2$ $(6)^2$
1	2.4	24	104	- 80	76.9	5913.61
2	2.5	38	105	- 67	63.8	4070.44
3	2.5	44	105	- 61	58.1	3375.61
4	3.8	50	120	- 70	58.3	3398.89
5	3.7	50	118	- 68	57.6	3317.76
6	4.6	53	129	- 76	58.9	3469.21
7	5.0	88	134	- 46	34.3	1176.49
8	5.6	181	141	+ 40	28.4	806.56
9	6.9	81	161	- 80	49.7	2470.09
11	12.5	175	239	- 64	26.8	718.24
12	12.5	325	239	+ 86	36.0	1296.00
13	7.5	131	170	- 39	22.9	524.41
14	9.4	131	196	- 65	33.2	1102.24
15	9.4	244	196	+ 48	24.5	600.25
16	9.6	394	200	+194	97.0	9215.00 out
17	10.6	163	212	- 49	23.1	533.61
18	11.3	288	222	+ 66	29.7	882.09
19	11.9	319	231	+ 88	38.1	1451.61
20	11.9	125	231	-106	45.9	2106.81
21	12.5	156	239	- 83	34.7	1204.09
22	16.9	250	308	- 58	18.8	353.44
23	13.8	144	258	-114	44.2	1953.64
24	13.8	225	258	- 33	12.8	163.84
25	13.8	175	258	- 83	32.2	1036.84
26	13.8	244	258	- 14	5.4	29.16
27	14.4	331	268	+ 63	23.5	552.25
28	14.4	638	268	+370	138.1	24594.11 out
29	14.4	356	268	+ 88	32.8	1075.84
30	14.4	194	268	- 74	27.6	761.76
31	15.0	181	277	- 96	34.7	1204.09
32	15.6	269	286	- 17	5.9	34.81
33	17.5	344	320	+ 24	7.5	56.25
34	18.1	375	329	+ 46	14.0	196.00
35	18.1	256	329	- 73	22.2	492.84
36	18.8	213	342	-129	37.7	1421.29
37	19.4	231	352	-121	34.4	1183.36
38	19.4	394	352	+ 42	11.9	141.61
39	19.4	256	352	- 96	27.3	745.29
40	21.3	338	388	- 50	12.9	166.41
41	21.9	275	401	-126	31.4	985.96
42	21.9	319	401	- 82	20.4	416.16
43	21.9	288	401	-113	28.2	795.24
44	21.9	294	401	-107	26.7	712.89
45	22.5	500	413	+ 87	21.1	445.21
46	22.5	363	413	- 50	12.1	146.41
47	22.5	744	413	+331	80.1	6416.01
48	23.1	500	424	+ 76	17.9	320.41
49	23.1	375	424	- 49	11.6	134.56

1	2	3	4	5	6	7	
50	23.1	363	424	- 61	14.4	207.36	
51	23.1	275	424	-149	35.1	1232.01	
52	23.1	356	424	- 68	16.0	256.00	
53	23.1	275	424	-149	35.1	1232.01	
54	23.8	600	442	+158	35.7	1274.49	
55	25.0	763	465	+298	64.1	4108.81	
56	25.0	350	465	-115	24.7	610.09	
57	25.0	375	465	- 90	19.4	376.36	
58	26.3	675	490	+185	37.8	1428.84	
59	26.3	314	490	-176	35.9	1288.81	
60	26.9	475	501	- 26	5.2	27.04	
61	27.5	669	513	+156	30.4	924.16	
62	27.5	331	513	-182	35.5	1260.25	
63	28.1	444	528	- 84	15.9	252.81	
64	29.4	419	556	-137	24.6	605.16	
65	29.4	594	556	+ 38	6.8	46.24	
66	30.0	769	570	+199	34.9	1218.01	
67	30.6	588	581	+ 7	1.2	1.44	
68	30.6	500	581	- 81	13.9	193.21	
69	30.6	425	581	-156	26.9	723.61	
70	31.9	731	610	+121	19.8	392.04	
71	32.3	984	618	+366	59.2	3504.64	
72	32.5	438	622	-184	29.6	876.16	
73	33.1	669	636	+ 33	5.2	27.04	
74	33.1	1431	636	+795	125.0	15625.00	out
75	33.8	425	652	-227	34.8	1211.04	
76	34.4	706	667	+ 39	5.8	33.64	
77	35.0	1438	682	+756	110.9	12298.81	out
78	36.8	513	730	-217	29.7	882.09	
79	37.5	669	750	- 81	10.8	116.64	
80	38.1	925	763	+162	21.2	449.44	
81	38.8	663	782	-119	15.2	231.04	
82	38.8	488	782	-294	37.6	1413.76	
83	39.4	800	799	+ 1	.1	.01	
84	39.4	650	799	-149	18.6	345.96	
85	40.6	931	833	+ 98	11.8	139.24	
86	41.3	1181	856	+325	38.0	1444.00	
87	41.3	794	856	- 62	7.2	51.84	
88	41.7	950	864	+ 86	10.0	100.00	
89	41.9	925	873	+ 52	6.0	36.00	
90	41.9	959	873	+ 86	9.9	98.01	
91	42.5	1544	894	+650	72.7	5285.29	
92	43.1	731	913	-182	19.9	396.01	
93	44.4	1281	965	+316	32.7	1069.29	
94	45.6	1094	1008	+ 86	8.5	72.25	
95	46.9	769	1061	-292	27.5	756.25	
96	46.9	1088	1061	+ 27	2.5	6.25	
97	47.5	969	1083	-114	10.5	110.25	
98	50.0	1450	1206	+244	20.2	408.04	
100	53.1	931	1362	-431	31.6	998.56	
						171963.99	

Page 2 - TABLE NO. 3 cont.

TABLE NO. 4
STEPS IN COMPUTATION OF STANDARD ERROR OF ESTIMATE
FOR ORIGINAL FOUR MILACRE CURVE (Fig. 6)

1	2	3	4	5	6	7	
Sample No.	% Stocked 4 Mil Acres	No. Seedlings Per Acre Actual	No. Seedlings Per Acre (Est. From orig. curve)	Deviations (3) - (4)	Deviation % (5) / (4)	Deviation $\%^2$ $(6)^2$	
2	7.5	38	40	- 2	5.0	25.00	
3	7.5	44	40	+ 4	10.0	100.00	
1	9.5	24	57	- 33	57.9	3352.41	
13	10.0	131	63	+ 68	107.9	11642.41	
4	10.0	50	63	- 13	20.6	424.36	
5	12.5	50	88	- 38	43.2	1866.24	
7	12.5	88	88	0	0.0	0.00	
6	13.2	53	95	- 42	44.2	1953.64	
15	15.0	244	111	+133	119.8	14352.04	out
8	17.5	181	135	+ 46	34.1	1162.81	
19	20.0	319	160	+159	99.4	9880.36	
17	22.5	163	185	- 22	11.9	141.61	
18	22.5	288	185	+113	61.1	3733.21	
16	23.1	394	191	+203	106.3	11299.69	
9	25.0	81	210	-129	61.4	3769.96	
11	25.0	175	210	- 35	16.7	278.89	
14	25.0	131	210	- 79	37.6	1413.76	
32	25.0	269	210	+ 59	28.1	789.61	
20	27.5	125	234	-109	46.6	2171.56	
30	30.0	194	260	- 66	25.4	645.16	
12	32.5	325	283	+ 42	14.8	219.04	
26	32.5	244	283	- 39	13.8	190.44	
23	35.0	144	309	-165	53.4	2851.56	
25	35.0	175	309	-134	43.4	1883.56	
28	35.0	638	309	+329	106.8	11406.24	
24	37.5	225	334	-109	32.6	1062.76	
27	37.5	331	334	- 3	.9	.81	
31	37.5	181	334	-153	45.8	2097.64	
33	37.5	344	334	0	0.0	0.00	
34	37.5	375	334	+ 41	12.3	151.29	
21	40.0	156	360	-204	56.7	3317.76	
29	40.0	356	360	- 4	1.1	1.21	
38	45.0	394	417	- 23	5.5	30.25	
39	45.0	256	417	-161	38.6	1489.96	
22	47.5	250	445	-195	43.8	1918.44	
35	47.5	256	445	-189	42.5	1806.25	
44	47.5	294	445	-151	33.9	1149.21	
45	47.5	500	445	+ 55	12.4	153.76	
54	47.5	600	445	+155	34.8	1211.04	
40	50.0	338	473	-135	28.5	812.25	
41	50.0	275	473	-198	41.9	1755.61	
43	50.0	288	473	-185	39.1	1528.81	
47	50.0	744	473	+271	57.3	3283.29	
48	50.0	500	473	+ 27	5.7	32.49	
61	50.0	669	473	+196	41.4	1713.96	
67	50.0	588	473	+115	24.3	590.49	

Page 2 - TABLE NO. 4 - cont.

1	2	3	4	5	6	7
70	50.0	731	473	+258	54.5	2970.25
42	52.5	319	500	-181	36.2	1310.44
57	52.5	375	500	-125	25.0	625.00
58	52.5	675	500	+175	35.0	1225.00
64	52.5	419	500	- 81	16.2	262.44
36	55.0	213	532	-319	60.0	3600.00
37	55.0	231	532	-301	56.6	3203.56
46	55.0	363	532	-169	31.8	1011.24
49	55.0	375	532	-157	29.5	870.25
50	55.0	363	532	-169	31.8	1011.24
53	55.0	275	532	-257	48.3	2332.89
65	55.0	594	532	+ 62	11.7	136.89
74	55.0	1431	532	+899	169.0	28561.00 out
76	55.0	706	532	+174	32.7	1069.29
55	57.5	763	563	+200	35.5	1260.25
60	57.5	475	563	- 88	15.6	243.36
71	58.1	984	570	+414	72.6	5270.76
59	59.0	314	582	-268	46.0	2116.00
51	60.0	275	595	-320	53.8	2894.44
69	60.0	425	595	-170	28.6	817.96
52	62.5	356	624	-268	42.9	1840.41
63	62.5	444	624	-180	28.8	829.44
90	64.9	959	657	+302	46.0	2116.00
56	65.0	350	658	-208	46.8	2190.24
66	65.0	769	658	+111	16.9	285.61
79	65.0	669	658	+ 11	1.7	2.89
78	65.8	513	668	-155	23.2	538.24
77	67.5	1438	693	+745	107.5	11556.25
68	67.5	500	693	-193	27.8	772.84
80	67.5	925	693	+232	33.5	1122.25
86	67.5	1181	693	+488	70.4	4956.16
93	67.5	1281	693	+588	84.8	7191.04
62	70.0	331	730	-399	54.7	2992.09
73	70.0	669	730	- 61	8.4	70.56
81	70.0	663	730	- 67	9.2	84.64
85	70.0	931	730	+201	27.5	756.25
75	72.5	425	772	-347	44.9	2016.01
82	72.5	488	772	-284	36.9	1361.61
84	72.5	650	772	-122	15.8	249.64
94	72.5	1094	772	+322	41.7	1738.89
96	75.0	1088	820	+268	32.7	1069.29
91	75.0	1544	820	+724	88.3	7796.89
89	75.0	925	820	+105	12.8	163.84
88	76.7	950	850	+100	11.8	139.24
72	77.5	438	862	-424	49.2	2420.64
98	80.0	1450	905	+545	60.2	3624.04
83	82.5	800	952	-152	16.0	256.00
87	82.5	794	952	-158	16.6	275.56
92	82.5	731	952	-221	23.2	538.24
97	82.5	969	952	+ 17	1.8	3.24
95	85.0	769	1003	-234	23.3	542.89
100	85.0	931	1003	- 72	7.2	51.84
						229005.97

TABLE NO. 5

STEPS IN CALCULATION OF STANDARD ERROR OF ESTIMATE FOR FINAL MILACRE CURVE (Fig.3)

1	2	3	4	5	6	7
Sample No.	% Stocked Mil Acres	No. Seedlings Per Acre Actual	No.Seedlings Per Acre (Est. From orig.curve)	Deviations (3) - (4)	Deviation % (5) / (4)	Deviation $\%^2$ $(6)^2$
1	2.4	24	43	- 19	44.2	1953.64
2	2.5	38	45	- 7	15.6	243.36
3	2.5	44	45	- 1	2.2	4.84
5	3.7	50	65	- 15	23.1	533.61
4	3.8	50	67	- 17	25.4	645.16
6	4.6	53	80	- 27	33.8	1142.44
7	5.0	88	88	0	0.0	0.00
8	5.6	181	97	+ 84	86.6	7499.56
9	6.9	81	119	- 38	32.0	1024.00
13	7.5	131	128	+ 3	2.3	5.29
14	9.4	131	160	- 29	18.1	327.61
15	9.4	244	160	+ 84	52.5	2756.25
17	10.6	163	179	- 16	8.9	79.21
18	11.3	288	190	+ 98	51.6	2662.56
19	11.9	319	201	+118	58.7	3445.69
20	11.9	125	201	- 76	37.8	1428.84
11	12.5	175	210	- 35	16.7	278.89
12	12.5	325	210	+115	54.8	3003.04
21	12.5	156	210	- 54	25.7	660.49
23	13.8	144	232	- 88	37.9	1436.41
24	13.8	225	232	- 7	3.0	9.00
25	13.8	175	232	- 57	24.6	605.16
26	13.8	244	232	+ 12	5.2	27.04
27	14.4	331	242	+ 89	36.8	1354.24
29	14.4	356	242	+114	47.1	2218.41
30	14.4	194	242	- 48	19.8	392.04
31	15.0	181	250	- 69	27.6	761.76
32	15.6	269	265	+ 4	1.5	2.25
22	16.9	250	296	- 41	13.9	193.21
33	17.5	344	301	+ 43	14.3	204.49
34	18.1	375	312	+ 63	20.2	408.04
35	18.1	256	312	- 56	17.9	320.41
36	18.8	213	325	-112	34.5	1190.25
37	19.4	231	337	-106	31.5	992.25
38	19.4	394	337	+ 57	16.9	285.61
39	19.4	256	337	- 81	24.0	576.00
40	21.3	338	372	- 34	9.1	82.81
41	21.9	275	383	-108	28.2	795.24
42	21.9	319	383	- 64	16.7	278.89
43	21.9	288	383	- 95	24.8	615.04
44	21.9	294	383	- 89	23.2	538.24
45	22.5	500	395	+105	26.6	707.56
46	22.5	363	395	- 32	8.1	65.61
47	22.5	744	395	+349	88.4	7814.56
48	23.1	500	407	+ 93	22.9	524.41
49	23.1	375	407	- 32	7.9	62.41
50	23.1	363	407	- 44	10.8	116.64

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1	2	3	4	5	6	7
51	23.1	275	407	-132	32.4	1049.76
52	23.1	356	407	- 51	21.5	156.25
53	23.1	275	407	-132	32.4	1049.76
54	23.8	600	423	+177	41.8	1747.24
55	25.0	763	448	+315	70.3	4942.09
56	25.0	350	448	- 98	21.9	479.61
57	25.0	375	448	- 73	16.3	265.69
58	26.3	675	474	+201	42.4	1797.76
59	26.3	314	474	-160	33.8	1142.44
60	26.9	475	485	- 10	2.1	4.41
61	27.5	669	497	+172	34.6	1197.16
62	27.5	331	497	-166	33.4	1115.56
63	28.1	444	510	- 66	12.9	166.41
64	29.4	419	540	-121	22.4	501.76
65	29.4	594	540	+ 54	10.0	100.00
66	30.0	769	555	+214	38.6	1489.96
67	30.6	588	548	+ 40	7.3	53.29
68	30.6	500	565	- 65	11.5	132.25
69	30.6	425	565	-140	24.8	615.04
70	31.9	731	594	+137	23.1	533.61
71	32.3	984	601	+383	63.7	4057.69
72	32.5	438	504	-186	27.5	756.25
73	33.1	669	618	+ 51	8.3	68.89
75	33.8	425	635	-210	33.1	1095.61
76	34.4	706	648	+ 58	9.0	81.00
78	36.8	513	713	-200	28.1	789.61
79	37.5	669	731	- 62	8.5	72.25
80	38.1	925	747	+178	23.8	566.44
81	38.8	663	770	-107	13.9	193.21
82	38.8	488	770	-272	35.3	1246.09
83	39.4	800	796	+ 4	.5	.25
84	39.4	650	796	-146	18.3	334.89
85	40.6	931	819	-112	13.7	187.69
86	41.3	1181	846	+335	39.6	1568.16
87	41.3	794	846	- 52	6.1	37.21
88	41.7	950	855	+ 95	11.1	123.21
89	41.9	925	864	+ 61	7.1	50.41
90	41.9	959	864	+ 95	11.0	121.00
91	42.5	1544	882	+662	75.1	5640.01
92	43.1	731	900	-149	16.6	275.56
93	44.4	1281	946	+335	35.4	1253.16
94	45.6	1094	991	+107	10.8	116.64
95	46.9	769	1060	-291	27.5	756.25
96	46.9	1088	1060	+ 28	2.6	6.76
97	47.5	969	1085	-116	10.7	114.49
98	50.0	1450	1220	+230	18.9	357.21
100	53.1	931	1380	-449	32.5	1056.25
						89738.70

$$\sigma u = \sqrt{\frac{89738.70}{94}} = \sqrt{954.667} = 30.89 = 31\ \%$$

TABLE NO. 6

STEPS IN CALCULATION OF STANDARD ERROR OF ESTIMATE FOR FINAL FOUR MILACRE CURVE(Fig.4)

1	2	3	4	5	6	7
Sample No.	% Stocked 4 Mil Acres	No. Seedlings Per Acre Actual	No. Seedlings Per Acre (Est. From orig. curve)	Deviations (3) - (4)	Deviation % (5) / (4)	Deviation %² (6)²
2	7.5	38	72	- 34	47.2	2227.84
3	7.5	44	72	- 28	38.9	1513.21
1	9.5	24	87	- 63	72.4	5241.76
13	10.0	131	91	+ 40	44.0	1936.00
4	10.0	50	91	- 41	45.1	2034.01
5	12.5	50	108	- 58	53.7	2883.69
7	12.5	88	108	- 20	18.5	342.25
6	13.2	53	113	- 60	53.1	2819.61
8	17.5	181	145	+ 36	24.8	615.04
19	20.0	319	163	+156	95.7	9158.49
17	22.5	163	186	- 23	12.4	153.76
18	22.5	288	186	+102	54.8	3003.04
16	23.1	394	192	+202	105.2	11067.04
9	25.0	81	206	-125	60.7	3684.49
11	25.0	175	206	- 31	15.0	225.00
14	25.0	131	206	- 75	36.4	1324.96
32	25.0	269	206	+ 63	30.6	936.36
20	27.5	125	224	- 99	44.2	1953.64
30	30.0	194	246	- 52	21.1	445.21
12	32.5	325	268	+ 57	21.3	453.69
26	32.5	244	268	- 24	9.0	81.00
23	35.0	144	290	- 46	15.9	252.81
25	35.0	175	290	-115	39.7	1576.09
28	35.0	638	290	+348	120.0	14400.00
24	37.5	225	310	- 85	27.4	750.76
27	37.5	331	310	+ 21	6.8	46.24
31	37.5	181	310	- 29	9.4	88.36
33	37.5	344	310	+ 34	11.0	121.00
34	37.5	375	310	+ 65	21.0	441.00
21	40.0	156	332	-176	53.0	2809.00
29	40.0	356	332	+ 24	7.2	51.84
38	45.0	394	378	+ 16	4.2	17.64
39	45.0	256	378	-122	32.3	1043.29
22	47.5	250	405	-155	38.3	1466.89
35	47.5	256	405	-149	36.8	1354.24
44	47.5	294	405	-111	27.4	750.76
45	47.5	500	405	+ 95	23.5	552.25
54	47.5	600	405	+195	48.1	2313.61
40	50.0	338	428	- 90	21.0	441.00
41	50.0	275	428	-153	35.7	1274.49
43	50.0	288	428	-140	32.7	1069.29
47	50.0	744	428	+316	73.8	5446.44
48	50.0	500	428	+ 72	16.8	282.24
61	50.0	669	428	+241	56.3	3169.69
67	50.0	588	428	+160	37.4	1398.76
70	50.0	731	428	+303	70.8	5012.64
42	52.5	319	458	-139	30.3	918.09

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1	2	3	4	5	6	7
57	52.5	375	458	- 83	18.1	327.61
58	52.5	675	458	+217	47.4	2246.76
64	52.5	419	458	- 39	8.5	72.25
36	55.0	213	493	-280	56.8	3226.24
37	55.0	231	493	-262	53.1	2819.61
46	55.0	363	493	-130	26.4	696.96
49	55.0	375	493	-118	23.9	571.21
50	55.0	363	493	-130	26.4	696.96
53	55.0	275	493	-218	44.2	1953.64
65	55.0	594	493	+101	20.5	420.25
76	55.0	706	493	+213	43.2	1866.24
55	57.5	763	530	+233	44.0	1936.00
60	57.5	475	530	- 55	10.4	108.16
71	58.1	984	541	+443	81.9	6707.61
59	59.0	314	555	-241	43.4	1883.56
51	60.0	275	572	-297	51.9	2693.61
69	60.0	425	572	-147	25.7	660.49
52	62.5	356	612	-256	41.8	1747.24
63	62.5	444	612	-168	27.5	756.25
90	64.9	959	650	+309	47.5	2256.25
56	65.0	350	652	-302	46.3	2143.69
66	65.0	769	652	+117	17.9	320.41
79	65.0	669	652	+ 17	2.6	6.76
78	65.8	513	670	-157	23.4	547.56
77	67.5	1438	702	+736	104.8	10983.04
68	67.5	500	702	-202	28.8	829.44
80	67.5	925	702	+223	31.8	1011.24
86	67.5	1181	702	+479	68.2	4651.24
93	67.5	1281	702	+579	82.5	6806.25
62	70.0	331	750	-419	55.9	3124.81
73	70.0	669	750	- 81	10.8	116.64
81	70.0	663	750	- 87	11.6	134.56
85	70.0	931	750	+181	24.1	580.81
75	72.5	425	798	-373	47.3	2237.29
82	72.5	488	798	-310	39.3	1544.49
84	72.5	650	798	-148	18.8	353.44
94	72.5	1094	798	+296	37.5	1406.25
96	75.0	1088	866	+222	25.6	655.36
91	75.0	1544	866	+678	78.3	6730.89
89	75.0	925	866	+ 59	6.8	46.24
88	76.7	950	907	+ 43	4.7	22.09
72	77.5	438	928	-490	52.8	2787.24
98	80.0	1450	988	+462	46.8	2190.24
83	82.5	800	1058	-258	24.4	595.36
87	82.5	794	1058	-264	25.0	625.00
92	82.5	731	1058	-327	30.9	954.81
97	82.5	969	1058	- 89	8.4	70.56
95	85.0	769	1125	-356	31.6	998.56
100	85.0	931	1125	-194	17.2	295.84
						185565.52

$$\sigma u = \sqrt{\frac{185565.52}{96}} = \sqrt{1932.97} = 43.9 = 44\ \%$$

TABLE NO. 7

Fiducial Limits For Milacre Curve

1	2		3		4	5	6
%	Ave.		$2\frac{1}{2}\sigma u$				(Upper limit) (2 + 4)
5	88	x	77.5 %	=	68		156
10	170	x	77.5	=	132		302
15	250	x	77.5	=	194		444
20	347	x	77.5	=	269		616
25	448	x	77.5	=	347		795
30	555	x	77.5	=	430		985
35	660	x	77.5	=	512		1172
40	800	x	77.5	=	620		1420
45	970	x	77.5	=	752		1722
50	1220	x	77.5	=	946		2166

FIDUCIAL LIMITS

2½ Standard errors of estimate = 98.8 % within
99.4 % above lower limit

1	2		3		4	5	6
%	Ave.		$1\frac{1}{2}\sigma u$			(Lower limit) (2 - 4)	(Upper limit) (2 + 4)
5	88	x	46.5 %	=	41	47	129
10	170	x	46.5	=	79	91	249
15	250	x	46.5	=	116	134	366
20	347	x	46.5	=	161	186	508
25	448	x	46.5	=	208	240	656
30	555	x	46.5	=	258	297	813
35	660	x	46.5	=	307	353	967
40	800	x	46.5	=	372	428	1172
45	970	x	46.5	=	451	519	1421
50	1220	x	46.5	=	567	653	1787

FIDUCIAL LIMITS

1½ Standard errors of estimate = 86.6 % within
93.3 % above lower limit

TABLE NO. 8

Fiducial Limits For Four Milacre Curve

1	2		3		4	5	6
							(Upper limit) (2 + 4)
%	Ave.		$2\frac{1}{2}\sqrt{u}$				
15	90	x	110 %	=	99		189
20	165	x	110	=	182		347
30	245	x	110	=	270		515
40	330	x	110	=	363		693
50	430	x	110	=	473		903
60	570	x	110	=	627		1197
70	750	x	110	=	825		1575
80	990	x	110	=	1089		2079

FIDUCIAL LIMITS

$2\frac{1}{2}$ Standard errors of estimate = 98.8 % within
99.4 % above lower limit

1	2		3		4	5	6
						(Lower limit) (2 - 4)	(Upper limit) (2 + 4)
%	Ave.		$1\frac{1}{2}\sqrt{u}$				
10	90	x	66 %	=	59	31	149
20	165	x	66	=	109	56	274
30	245	x	66	=	162	83	407
40	330	x	66	=	218	112	548
50	430	x	66	=	284	146	714
60	570	x	66	=	376	194	946
70	750	x	66	=	495	255	1245
80	990	x	66	=	653	337	1643

FIDUCIAL LIMITS

$1\frac{1}{2}$ Standard errors of estimate = 86.6 % within
93.3 % above lower limit

TABLE NO. 9

Area of the Normal Curve of Error

Abscissa x/σ	Area from left extreme	Abscissa x/σ	Area from left extreme
- 4.0	0.00003	+ 0.1	0.53983
- 3.0	0.00135	+ 0.2	0.57926
- 2.5	0.00621	+ 0.3	0.61791
- 2.2	0.01390	+ 0.4	0.65542
- 2.0	0.02275	+ 0.5	0.69146
- 1.9	0.02872	+ 0.6	0.72575
- 1.8	0.03593	+ 0.7	0.75804
- 1.7	0.04457	+ 0.8	0.78814
- 1.6	0.05480	+ 0.9	0.81594
- 1.5	0.06681	+ 1.0	0.84134
- 1.4	0.08076	+ 1.1	0.86433
- 1.3	0.09680	+ 1.2	0.88493
- 1.2	0.11507	+ 1.3	0.90320
- 1.1	0.13567	+ 1.4	0.91924
- 1.0	0.15866	+ 1.5	0.93319
- 0.9	0.18406	+ 1.6	0.94520
- 0.8	0.21186	+ 1.7	0.95543
- 0.7	0.24196	+ 1.8	0.96407
- 0.6	0.27425	+ 1.9	0.97128
- 0.5	0.30854	+ 2.0	0.97725
- 0.4	0.34458	+ 2.2	0.98610
- 0.3	0.38209	+ 2.5	0.99379
- 0.2	0.42074	+ 3.0	0.99865
- 0.1	0.46017	+ 4.0	0.99997
0	0.50000	+ 5.0	0.9999997