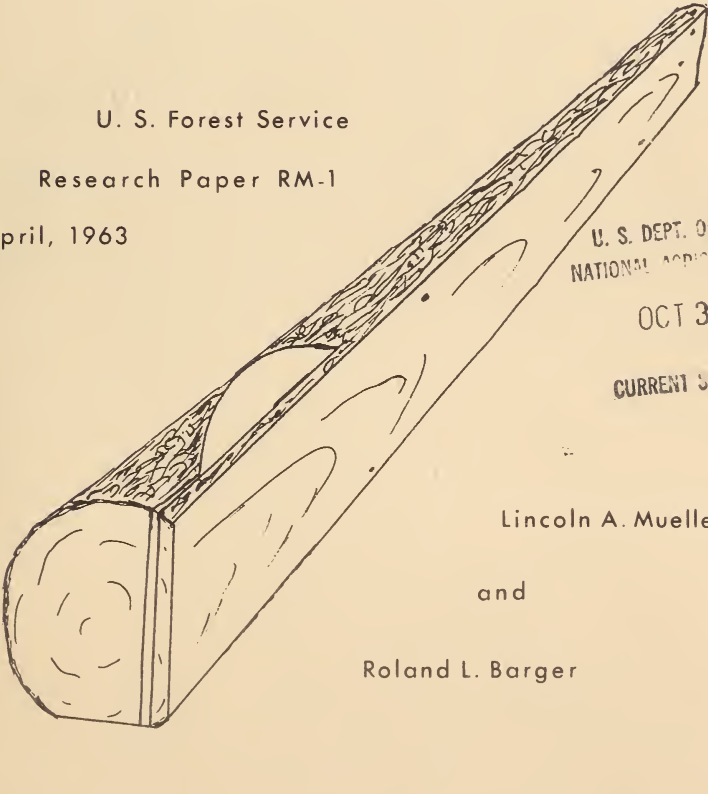
LUMBER GRADE RECOVERY

from

ENGELMANN SPRUCE IN COLORADO



U. S. Forest Service

Research Paper RM-1

April, 1963

Lincoln A. Mueller

and

Roland L. Barger

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
RAYMOND PRICE, DIRECTOR — FORT COLLINS, COLORADO
FOREST SERVICE — U. S. DEPARTMENT OF AGRICULTURE

PLEASE NOTE

This is the first of a new series of reports to be issued by the Rocky Mountain Forest and Range Experiment Station. These reports will be designated "U. S. Forest Service Research Paper RM-__." They replace the Station Paper series, the last one of which was Station Paper 73.

ACKNOWLEDGMENT

This study was made possible through the cooperation and assistance of the Weidman Lumber Company of Durango, Colorado; College of Forestry, Colorado State University; and U. S. Forest Service personnel of the Division of Timber Management, Denver, San Juan National Forest, Durango, and Forest Products Laboratory, Madison, Wisconsin. Dr. Carl Newport, formerly with the CSU College of Forestry, now with the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, was especially helpful in the analytical phases of the work. E. M. Conway, formerly with the Rocky Mountain Forest and Range Experiment Station, now with the Central States Experiment Station assisted with the field work.

U. S. Forest Service Research Paper RM-1 April 1963

LUMBER GRADE RECOVERY FROM ENGELMANN SPRUCE IN COLORADO

By

Lincoln A. Mueller and Roland L. Barger, Technologists

Rocky Mountain Forest and Range Experiment Station[1]

[1] Central headquarters maintained in cooperation with Colorado State University, Fort Collins.

CONTENTS

LUMBER GRADE RECOVERY FROM ENGELMANN SPRUCE IN COLORADO

By

Lincoln A. Mueller and Roland L. Barger

\- - - - - - -

INTRODUCTION

Engelmann spruce (Picea engelmannii Parry) is Colorado's most important sawtimber species. It makes up approximately 50 percent of the total sawtimber volume, and 40 percent of the growing stock. The species is recognized for its straight, well-rounded boles, and light-weight, soft-textured wood. It is well adapted to a wide range of uses, both as a building material and as a source of fiber. Heavy utilization of more accessible pine stands during and after World War II shifted emphasis to Engelmann spruce as a primary source of sawtimber. With increased utilization came recognition of its many desirable properties, which progressively strengthened demand.

Engelmann spruce occurs at the higher elevations in the mountains of Colorado. The generally higher logging costs associated with such sites, plus an overall increase in manufacturing costs, have created an increasing need for better stumpage pricing data. The major objective of this study was, therefore, to determine the lumber volume and grade yields currently being recovered from Engelmann spruce sawtimber available to the industry. A secondary objective was to test the feasibility of grading Engelmann spruce logs by application of a set of trial log grades developed for associated species in the Pacific Northwest region.

METHODS

MILL SELECTION

The study was conducted at the J. Stanley Weidman Lumber Company sawmill at Durango, Colorado, in 1957. This milling firm, one of the major spruce lumber producers in the State, produces a full range of standard lumber grades.[2] The stands

[2] Western Pine Association. Standard grading rules for .... Engelmann spruce .... lumber. 141 pp., illus. Portland 4, Oregon. 1957.

supplying this mill represent the quality of Engelmann spruce sawtimber available in Colorado.

The sawmill is equipped with a 6-foot single-cut band headrig and a vertical band resaw. Logs are stored in a pond. Lumber is green graded and sorted by grade and width as it leaves the mill on the green chain to facilitate seasoning, yard inventory, and surfacing. The lumber is air dried in piles that have been carefully stacked and stickered. Pile covers are not used, although select and high-common grade piles are partially protected by a top course of cull lumber. Dried, surfaced lumber is graded by certified Western Pine Association graders.

LOG SAMPLE

To meet the study objectives and have as nearly as possible a random sample of logs from the timber available, arrangements were made to have logs delivered from four landings in a sale area on the San Juan National Forest. The logs were delivered to the mill in both long and short lengths. Long logs were bucked to length upon entrance to the mill. Of 675 logs selected, 621 were 16 feet in length, and 54 were shorter.

LOG SCALING, DIAGRAMING, AND GRADING

All logs were scaled by a recently checked Forest Service scaler in accordance with the 1956 revision of the National Forest Scaling Handbook[3] (Scribner Decimal C Log Rule).

Logs were diagramed by a member of the Forest Products Laboratory staff, who followed the diagraming system adopted by the Laboratory.[4] Due to the layout of the mill, it was necessary to diagram the logs on the jackladder. White fir (Abies concolor (Gord. & Glend.) Lindl.) logs intermixed with the spruce study logs provided additional time to complete diagraming. The down face was diagramed as the log was ejected from the conveyor to the mill deck.

Grading was done by personnel of the Rocky Mountain Station, who worked closely with the log diagraming operation. The logs were graded according to the trial log grades developed in the Pacific Northwest, Region 6, for associated species. (appendix, page 19.) The minimum diameter limits specified by the grading system were reduced to fit the diameter range common in Engelmann spruce, and knot size limits were extended to include 10-inch grade 3 logs.

MILL PROCEDURE

As the study logs entered the mill, they were assigned consecutive mill log numbers. These numbers were cross referenced with the scale log numbers to identify scale and grade of the logs. The mill log numbers were posted in the mill

---

[3] U. S. Forest Service. National Forest scaling handbook. 119 pp. 1956 revision.

[4] U. S. Forest Service. Sawlog grades for hardwoods -- Central States studies. Forest Prod. Lab. Rpt. D 1699, 22 pp., illus. 1947.

in a position readily visible to all lumber markers. Sawing instructions specified that the mill follow normal sawing and log break-down practices.

Lumber markers were positioned throughout the mill so that each board from a given log could be properly identified with the mill log number. Upon reaching the green chain, the lumber from the study logs was pencil trimmed and ripped, and graded by a certified Western Pine Association lumber grader. It was then tallied by mill log number, lumber grade, and dimension. The lumber moved from the green chain to the drying yard for air drying.

Later, samples of dry lumber from each grade and width were selected for a study of grade change and volume loss as a result of drying and surfacing. The sample included lumber produced from logs other than study logs, but from the same general area and sawn under the same conditions. This lumber was regraded and tallied after surfacing and end trimming. The resulting change-of-grade and volume-loss factors were applied to green recovery data to obtain the estimated dry surfaced recovery.

In addition to grade and volume recovery data, the time required to saw each log was recorded. Board thickness measurements were also made on a sample of 4/4 boards as a check of sawing accuracy.

ANALYSIS

Electronic data processing methods were used in compiling the study data. Log characteristics from the log diagram and scale sheets, and lumber grade and volume data from the mill tally sheets, were punched directly on data processing cards. These cards were processed to obtain green lumber grade and volume recovery by specified log groups and classes.

Green lumber grade recovery was converted to dry surfaced recovery by applying the grade-change and volume-loss factors developed in the degrade study. An IBM 650 program developed for this purpose was employed.[5] This program also computed individual log value, based on 1959 lumber grade selling values. A second IBM 650 program was employed to compute regressions of log volume and value on log diameter, and average value per M board feet.[6]

RESULTS

LOG SAMPLE

A total of 675 merchantable logs were used in the study. Of these, 621 were 16 feet in length and 54 were shorter. Logs scaled as sound made up 84 percent of

---

[5] Newport, C. A., and Leach, Joe. A method for the application of change in grade factors to individual logs .... an IBM 650 program. U. S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta., Tech. Paper 41. 9 pp. 1959.

[6] Frazier, George D., and Carney, Ronald B. Computing average log values for timber appraisals using IBM 650 or Univac Solid State 80 computers. U. S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta., Tech Paper 54. 16 pp., illus. 1961.

the sample, or 567 logs. The diameter distribution of the study logs is shown in figure 1. Log scaling diameters ranged from 7 to 27 inches. The average scaling diameter was 12.4 inches, while the most frequently occurring diameter was 11.0 inches.

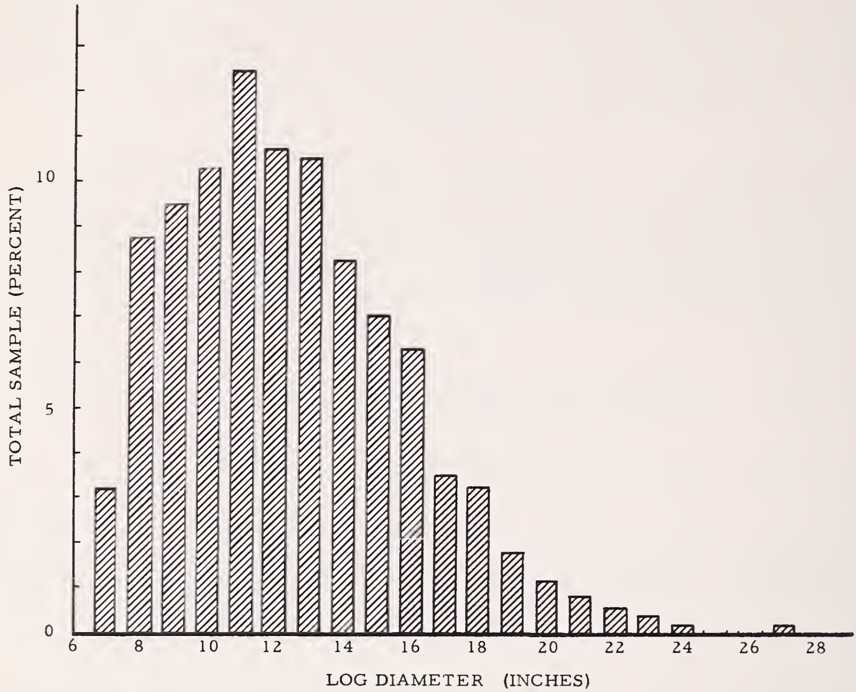


Figure 1. --Diameter distribution of study logs.

LOG SCALE AND DEFECT

The study logs yielded a gross scale of 66,040 board feet. Deduction for defect which amounted to 2,970 board feet or 4.5 percent of total gross scale, left a total net scale of 63,070 board feet. Defect deduction accounted for 24.5 percent of the gross scale of defective (partial-scale) logs. Table 1 shows gross and net scale and percent scale deduction by log grade and log diameter class.

Table 2 indicates amount and type of defect deduction by log diameter class. The relation of diameter to percent of defect is not so pronounced as might be anticipated. Western red rot or heart rot (Polyporus anceps), the principal defect encountered, contributed 44 percent of the total scaling deduction (table 3). Sweep and crook second in importance, made up 29 percent of the deducted volume. Sap rot and shake accounted for 11 and 9 percent, respectively, with check and split making up the bulk of the remaining 7 percent. A small amount of defect was borderline between heart rot and sap rot.

Table 1. --Gross and net volume of study logs by log grade and log diameter class — all logs

Log grade and log diameter	Logs	Scribner scale		Scale deduction
		Gross	Net	
	Number	Board feet		Percent
LOG GRADE:				
1	3	880	870	1.1
2	47	9,410	8,730	7.2
3	323	39,710	38,000	4.3
4	302	16,040	15,470	3.6
Total	675	66,040	63,070	4.5
LOG DIAMETER (Inches):				
7	22	650	620	4.6
8	60	1,710	1,690	1.2
9	65	2,530	2,510	.8
10	71	4,060	3,850	5.2
11	85	5,700	5,400	5.3
12	73	5,720	5,520	3.5
13	71	6,970	6,860	1.6
14	56	6,120	5,990	2.1
15	48	6,690	6,470	3.3
16	43	6,780	6,480	4.4
17	24	4,240	4,020	5.2
18	22	4,540	4,220	7.0
19	12	2,880	2,600	9.7
20	8	2,240	2,110	5.8
21	6	1,800	1,760	2.2
22	4	1,320	1,020	22.7
23	3	1,140	1,060	7.0
24	1	400	390	2.5
27	1	550	500	9.1
Total	675	66,040	63,070	4.5

With respect to log position, scale deductions accounted for 7.4 percent of the gross scale of butt logs, 3.6 percent of middle logs, and 2.3 percent of top logs. All deduction in top logs was for sweep or crook. Table 3 shows type and amount of scale deduction by log position, as determined by the scaler.

Table 2. --Gross scale deductions by defect type and log diameter class -- all logs

Log diameter (inches)	Logs	Defect type						Total scale deduction
		Heart rot	Sap rot	Heart and sap rot	Check or split	Sweep or crook	Shake	
	Number	Percent						
7	22	0	0	0	0	4.6	0	4.6
8	60	0	0	0	0	1.2	0	1.2
9	65	0	0	0	0	.8	0	.8
10	71	2.2	0	0	0	3.0	0	5.2
11	85	.7	0	0	0	4.6	0	5.3
12	73	.9	.5	0	0	1.8	.3	3.5
13	71	.3	.3	0	0	1.0	0	1.6
14	56	1.0	0	.3	.5	.3	0	2.1
15	48	2.4	.6	0	0	0	.3	3.3
16	43	2.5	.6	0	0	.7	.6	4.4
17	24	2.8	.5	0	.5	1.2	.2	5.2
18	22	1.3	2.7	0	.4	.4	2.2	7.0
19	12	7.0	1.0	0	.7	0	1.0	9.7
20	8	4.0	0	0	.9	.9	0	5.8
21	6	0	0	0	2.2	0	0	2.2
22	4	17.4	0	0	0	3.0	2.3	22.7
23	3	3.5	0	0	3.5	0	0	7.0
24	1	2.5	0	0	0	0	0	2.5
27	1	0	9.1	0	0	0	0	9.1
Total	675	2.0	.5	0	.3	1.3	.4	4.5

Table 3. --Gross scale deductions by defect type and log position

Defect type	Log position[1]				Proportion of total defect
	Butt	Middle	Top	All	
	Percent of gross scale				Percent
Heart rot	3.4	1.8	0	2.0	44.4
Sap rot	.9	.4	0	.5	11.1
Heart and sap rot	0	0	0	0	([2])
Check or split	.3	.2	0	.3	6.7
Sweep or crook	2.4	.8	2.3	1.3	28.9
Shake	.4	.4	0	.4	8.9
Total	7.4	3.6	2.3	4.5	100.0

[1] Log position analysis is based upon defect data from 672 logs.
[2] Less than 0.1 percent.

LUMBER GRADE CHANGE AND VOLUME LOSS

A lumber sample of 33, 073 board feet was used to determine the change of grade and volume loss as a result of drying, surfacing, and end trimming. The sample included lumber of all available widths in each lumber grade. Table 4 indicates the distribution of the sample by grade and nominal width.

The lumber was air dried to a moisture content of 12 to 15 percent. Careful stacking and stickering, and adequate pile foundations, minimized warping, cupping, and other deformation. Pile covers were not used, although select and high-common grade lumber was protected by a top course of cull lumber.

The sample lumber was regraded and tallied after surfacing and end trimming. The resulting volume loss and grade changes are shown in tables 4 and 5. Because of the small volume involved, the select grades were combined in the green grade. Dimension lumber made up only 0.8 percent of green volume recovery, and was not represented in the degrade study.

The change-of-grade and volume-loss factors shown in table 5 were applied to green grade recovery to obtain estimated dry surfaced lumber grade recovery. This resulted in an 8.7 percent reduction in the total green volume of lumber in the recovery study.

Table 4. --Degrade lumber sample and related drying and surfacing volume losses

Green grade	Board width	Green volume	Finished volume combined grades	Volume loss
	Inches	- - - - Board feet	- - - -	Percent
Select	8	2,963	2,744	7.39
1-2 C	12	3,908	3,688	5.63
	10	1,528	1,422	6.94
	8	4,315	4,160	3.59
	6	3,895	3,745	3.85
3 C	12	1,848	1,626	12.01
	10	1,495	1,332	10.90
	8	5,767	5,237	9.19
	6	1,061	1,013	4.52
4 C	12	1,566	1,376	12.13
	10	1,132	940	16.96
	8	1,472	1,241	15.69
	4	1,157	976	15.64
5 C	12	272	226	16.91
	10	303	232	23.43
	8	213	164	23.00
	6	178	126	29.21

[1] Most losses were due to checking associated with spiral grain.

Table 5. --Change of lumber grade and volume loss[1] from green to dry surfaced condition

Green grade	Dry surfaced grade								Volume loss
	Select			Common					
	B and better	C	D	1-2	3	4	5	Dimension	
	- - - - - - - - - - - - - - - - Percent of green volume - - - - - - - - - - - - - - - -								
Select	51.80	10.34	16.60	1.31	3.29	6.12	3.15	0	7.39
1-2 C	0	0	0	49.94	38.38	6.86	.19	0	4.63
3 C	0	0	0	7.01	65.87	16.87	.78	0	9.47
4 C	0	0	0	.23	6.86	72.77	5.24	0	14.90
5 C	0	0	0	0	.32	12.97	64.11	0	22.57
Dimension	0	0	0	0	0	0	0	100.00	0

[1] Largely from checking associated with spiral grain.

LUMBER VOLUME RECOVERY AND OVERRUN

The study logs yielded 73,558.8 board feet of rough lumber. Computed volume losses due to drying, surfacing, and end trimming reduced total recovery to 67,150.4 board feet. Log scale and lumber recovery values for the average study log are as follows:

	Board feet
Gross scale	97.8
Net scale	93.4
Green recovery	109.0
Finished recovery	99.5

Table 6 shows green and dry surfaced lumber recovery, and overrun, by log diameter class.

All overrun values are computed on the basis of dry surfaced lumber recovery. As generally expected, partial-scale logs yielded consistently higher overruns than did full-scale logs of comparable size, largely because portions of the deducted volumes are frequently recovered in the sawing operation. Also, hidden defect in full-scale logs reduces lumber yield below scaled volume. Overrun by 1-inch log diameter classes followed the irregular pattern that is typical of the Scribner Decimal C log rule, and declined as diameter increased. Figure 2 illustrates this trend for both full-scale and partial-scale logs.

Table 6. --Net log scale, lumber recovery, and overrun,[1] by log diameter class

Log diameter (inches)	Logs	Net Scribner scale	Lumber recovery		Overrun[1]
			Rough	Finished	
	Number	Board feet	Board feet		Percent
			FULL-SCALE LOGS		
7	22	620	686.0	631.7	1.9
8	60	1,690	2,327.5	2,105.8	24.6
9	65	2,510	3,058.7	2,787.3	11.0
10	71	3,850	4,186.0	3,839.1	-.3
11	85	5,400	6,022.6	5,505.2	1.9
12	73	5,520	6,977.5	6,415.6	16.2
13	71	6,860	7,986.4	7,313.5	6.6
14	56	5,990	7,520.9	6,889.8	15.0
15	48	6,470	7,452.6	6,833.0	5.6
16	43	6,480	7,538.3	6,871.2	6.0
17	24	4,020	4,601.6	4,196.2	4.4
18	22	4,220	4,906.6	4,435.6	5.1
19	12	2,600	3,066.0	2,781.0	7.0
20	8	2,110	2,153.6	1,953.0	-7.4
21	6	1,760	1,868.2	1,722.6	-2.1
22	4	1,020	1,265.1	1,117.8	9.6
23	3	1,060	1,132.3	1,035.7	-2.3
24	1	390	398.5	371.6	-4.7
27	1	500	410.4	344.7	-31.1
Total	675	63,070	73,558.8	67,150.4	
			PARTIAL-SCALE LOGS		
7	20	590	627.0	576.9	-2.2
8	59	1,670	2,296.7	2,076.9	24.4
9	63	2,450	2,965.6	2,704.7	10.4
10	60	3,400	3,510.0	3,227.2	-5.1
11	68	4,500	4,885.4	4,487.0	-.3
12	61	4,760	5,893.9	5,444.4	14.4
13	65	6,370	7,312.5	6,699.0	5.2
14	50	5,460	6,739.8	6,176.7	13.1
15	41	5,710	6,377.0	5,843.3	2.3
16	31	4,880	5,472.1	4,991.7	2.3
17	14	2,440	2,698.5	2,448.4	.3
18	15	3,070	3,384.4	3,075.6	.2
19	7	1,680	1,751.0	1,607.1	-4.3
20	5	1,400	1,340.4	1,236.2	-11.7
21	5	1,500	1,566.6	1,445.3	-3.6
22	1	330	354.0	321.9	-2.5
23	2	760	786.4	719.4	-5.3
24	0	0	0	0	0
27	0	0	0	0	0
Total	567	50,970	57,961.3	53,081.7	
			ALL LOGS		
7	2	30	59.0	54.8	82.7
8	1	20	30.8	28.9	44.5
9	2	60	93.1	82.6	37.7
10	11	450	676.0	611.9	36.0
11	17	900	1,137.2	1,018.2	13.1
12	12	760	1,083.6	971.2	27.8
13	6	490	673.9	614.5	25.4
14	6	530	781.1	713.1	34.5
15	7	760	1,075.6	989.7	30.2
16	12	1,600	2,066.2	1,879.5	17.5
17	10	1,580	1,903.1	1,747.8	10.6
18	7	1,150	1,522.2	1,360.0	18.3
19	5	920	1,315.0	1,173.9	27.6
20	3	710	813.2	716.8	1.0
21	1	260	301.6	277.3	6.7
22	3	690	911.1	795.9	15.3
23	1	300	345.9	316.3	5.4
24	1	390	398.5	371.6	-4.7
27	1	500	410.4	344.7	-31.1
Total	108	12,100	15,597.5	14,068.7	

[1] Overrun is based on dry surfaced lumber recovery.

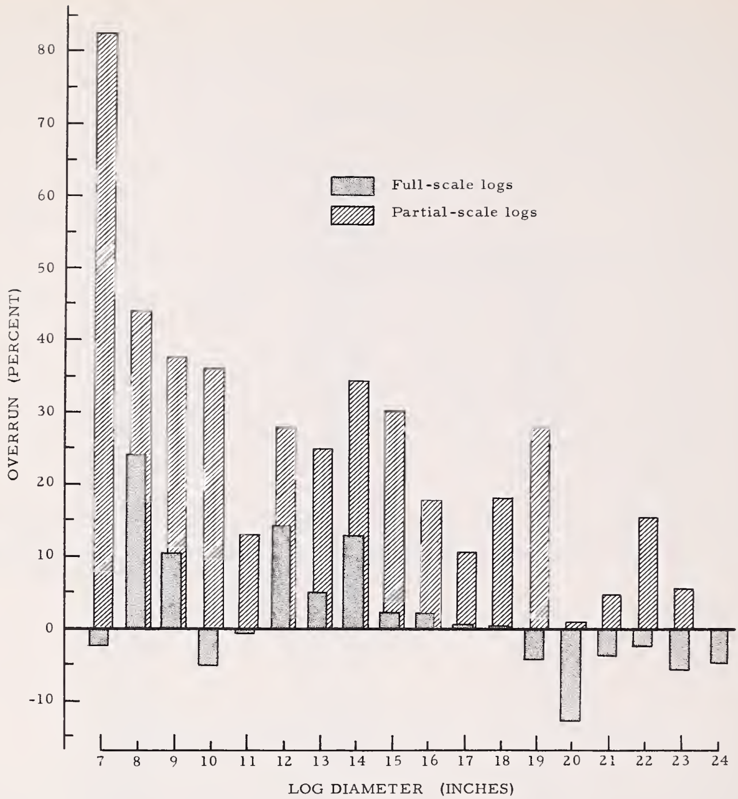


Figure 2. --Overrun by log diameter, based upon dry surfaced lumber recovery.

ESTIMATED LUMBER VOLUME RECOVERY

Average lumber volume recovery, when computed from study data for each log diameter class and grade, may be somewhat erratic. This is partially due to log diameter classes and grades that are inadequately represented, because of the inherent nature of the timber involved. It may also be partially ascribed to chance variation in the sample of logs selected. Consequently, average recovery volume can be estimated more reliably by statistical methods than from the raw data.

Lumber volume recovery was estimated by computing regressions that related individual log volume to log scaling diameter. Separate regressions were computed for each log grade, scaling class (full-scale, partial-scale, and all), and log-length class (16-foot and shorter). Regression estimates of dry surfaced lumber recovery are shown by log grade, scaling class, and diameter class in table 10, appendix. There were too few logs in grade 1 to warrant regression analysis.

All regressions were second-degree polynomials of the type $Y = a + bX + cX^2$, where Y = recovery volume and X = log scaling diameter. Standard error of estimate ($S_{y.x}$) for the regressions ranged from 9.9 to 25.8 board feet. Coefficients of determination (R^2) ranged from 0.78 to 0.95.

LUMBER GRADE RECOVERY

An important objective was to determine the lumber grade distribution of dry surfaced lumber recovered. Table 7 summarizes lumber grade recovery both by log grade and log diameter class. Lumber grade recovery is expressed as a percent of total recovery.

The high proportion of common grade lumber, characteristic of Engelmann spruce, is somewhat compensated for by the small volume in low-common grades. Common grades 1-2 and 3 account for 70.5 percent of total lumber recovery. Knots, although numerous, are for the most part small and sound, and seldom degrade the lumber seriously. The volume of grade 5 common lumber developed is due primarily to the presence of rot.

Select grade lumber recovery shows a general increasing trend with increase in log diameter, although no trends are apparent in common grade recovery. Generally, the smaller logs are top logs and therefore are more heavily limbed than larger logs.

Tables 11, 12, 13, and 14 of the appendix present lumber grade recovery by log grade, scaling class, diameter class, and length.

Table 7. --Percentage lumber grade recovery, dry finished basis, by log grade and log diameter class -- all logs

Log grade and log diameter	Logs	Select grades			Common grades					Total
		B and better	C	D	1-2	3	4	5	Dimension	
	Number	Percent								
LOG GRADE:										
1	3	19.0	3.8	6.1	21.9	31.2	13.7	1.8	2.5	100
2	47	5.9	1.2	1.9	21.1	46.2	20.6	1.8	1.3	100
3	323	1.4	.3	.4	22.2	49.4	23.7	2.2	.4	100
4	302	.6	.1	.2	18.4	51.9	25.3	2.0	1.5	100
Total	675									
LOG DIAMETER (Inches):										
7	22	0	0	0	10.1	42.3	19.3	3.8	24.5	100
8	60	0.3	0.1	0.1	16.8	49.3	29.4	2.4	1.6	100
9	65	.5	.1	.2	19.5	53.9	23.4	1.8	.6	100
10	71	.2	0	.1	24.2	52.4	21.5	1.3	.3	100
11	85	1.3	.3	.4	23.3	49.1	23.6	2.0	0	100
12	73	.9	.2	.3	26.1	50.1	20.7	1.4	.3	100
13	71	1.0	.2	.3	23.9	50.6	22.3	1.6	.1	100
14	56	.9	.2	.3	22.1	54.7	20.3	1.3	.2	100
15	48	3.2	.6	1.0	22.8	49.8	20.7	1.7	.2	100
16	43	2.4	.5	.7	20.2	50.2	24.3	1.7	0	100
17	24	4.0	.8	1.3	18.8	50.2	22.1	2.3	.5	100
18	22	2.0	.4	.6	17.5	47.0	27.5	3.9	1.1	100
19	12	1.9	.4	.6	17.0	47.8	27.9	2.3	2.1	100
20	8	3.8	.8	1.2	18.1	46.4	24.9	3.9	.9	100
21	6	3.5	.7	1.1	25.9	49.2	18.4	1.2	0	100
22	4	3.7	.7	1.2	7.9	32.4	48.0	4.5	1.6	100
23	3	10.3	2.1	3.3	13.1	35.2	25.0	2.1	8.9	100
24	1	30.4	6.1	9.7	16.3	18.8	10.7	2.2	5.8	100
27	1	0	0	0	.2	7.1	76.5	16.2	0	100
Total	675									

LOG AND LUMBER VALUE

Individual log value was computed by means of the Newport-Leach IBM 650 program mentioned earlier. The program applied current lumber grade selling prices to the lumber grade and volume recovery of each study log as shown below:

Lumber grade	Value per M b.m. (Dollars)
B and better select	151.20
C select	151.20
D select	151.20
1-2 common	92.92
3 common	71.61
4 common	67.36
5 common	42.67
2 and better dimension	83.19
3 and better dimension	80.56

All dimension material encountered in the study was valued as grade 3 and better.

These log values were used as observations in regressions calculated to obtain estimated log value. Regressions that related individual log value to log scaling diameter were computed in the same manner as those previously computed for volume recovery. Regression estimates of individual log value are shown in table 10, appendix. Again, grade 1 logs were excluded from regression analysis.

Standard error of estimate ($S_{y.x}$) for the log value regressions ranged from \$0.87 to \$3.47. Coefficients of determination (R^2) ranged from 0.58 to 0.88.

Lumber value per M b.m. for each class of logs was computed by the procedure outlined in the Frazier-Carney IBM 650 program. In this procedure, regression estimates of log value are used in conjunction with estimated lumber recovery to obtain value per M b.m. Lumber values thus computed are shown by log grade, scaling class, diameter class, and length in tables 11, 12, 13, and 14, appendix.

RESULTS OF GRADING ENGELMANN SPRUCE LOGS

Log grading systems, when adequate for the species, form an effective basis for more accurate timber quality appraisal and pricing. One of the objectives of this study was to test the feasibility of grading Engelmann spruce saw logs.

The study logs were graded by means of a modification of the trial log grades developed for associated species in the Pacific Northwest region (appendix, page 19) The minimum diameter limits specified in the grading system were reduced to fit the diameter range common in Engelmann spruce. Knot size limits were extended to include 10-inch grade 3 logs.

Table 8 shows the grade distribution of study logs, and presents lumber recovery and overrun by log grade. Log grades 2, 3, and 4 are well represented, but grade 1 does not contain enough logs for valid comparison with the other grades.

That some quality separation was obtained through grading the logs is apparent in the lumber grade recovery pattern (table 12; and fig. 3). The recovery of select and low-common lumber varies with log grade (fig. 3). Lower grade logs produce proportionately more grade 4 and 5 common lumber, and less select lumber. The proportion of grades 1-2 and 3 common lumber produced remains relatively constant.

Lumber value for each log grade-diameter class was computed from regression estimates of lumber recovery and log value, as discussed previously. Figures 4 and 5 illustrate the resulting lumber value curves for each log grade.

Table 8. --Net log scale, lumber recovery, and overrun, by log grade

Log grade	Logs	Net Scribner scale	Lumber recovery: Rough	Lumber recovery: Finished	Overrun[1]
	Number	Board feet	Board feet	Board feet	Percent
		FULL-SCALE LOGS			
1	2	480	522.8	484.4	0.9
2	30	6,000	6,690.0	6,159.1	2.7
3	269	30,960	35,472.7	32,508.5	5.0
4	266	13,530	15,275.8	13,929.7	3.0
Total	567	50,970	57,961.3	53,081.7	
		PARTIAL-SCALE LOGS			
1	1	390	398.5	371.6	-4.7
2	17	2,730	3,477.8	3,164.9	15.9
3	54	7,040	9,053.3	8,141.1	15.6
4	36	1,940	2,667.9	2,391.1	23.3
Total	108	12,100	15,597.5	14,068.7	
		ALL LOGS			
1	3	870	921.3	856.0	-1.6
2	47	8,730	10,167.8	9,324.0	6.8
3	323	38,000	44,526.0	40,649.6	7.0
4	302	15,470	17,943.7	16,320.8	5.5
Total	675	63,070	73,558.8	67,150.4	

[1] Overrun based on dry surfaced lumber recovery.

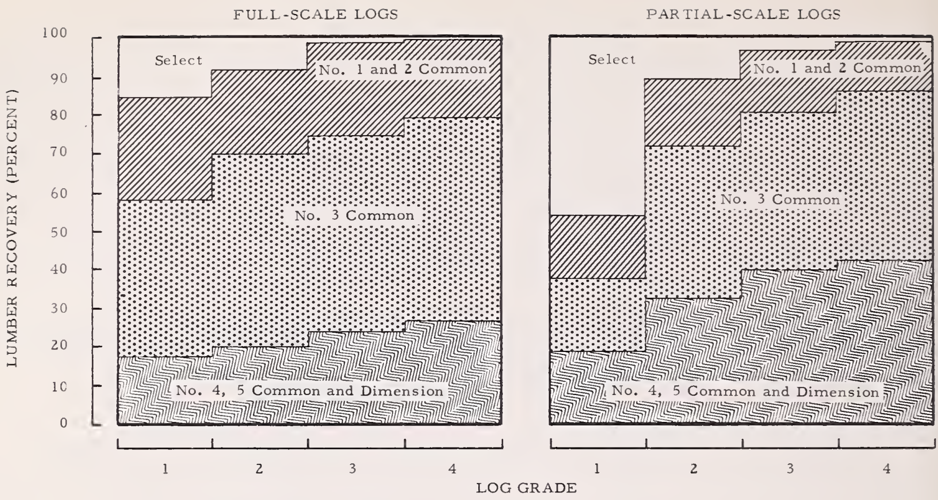


Figure 3. --Lumber grade recovery, dry surfaced basis, by log grade -- 16-foot logs.

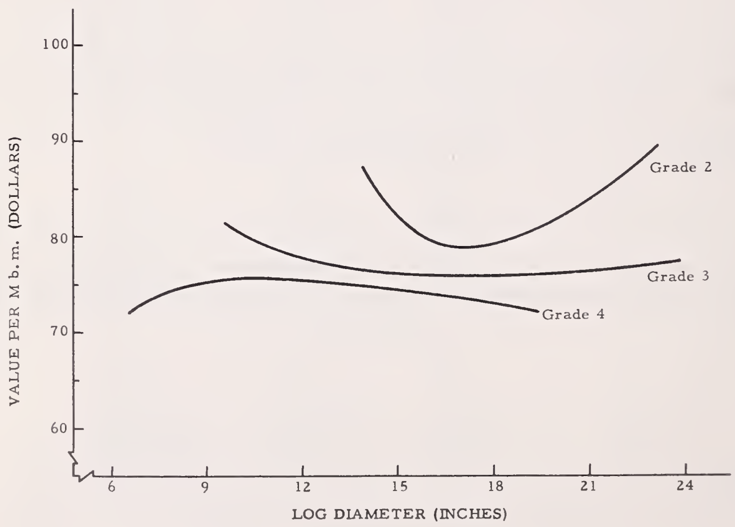


Figure 4. --Average value per M b.m. dry surfaced lumber, by log grade and diameter class--full-scale 16-foot logs.

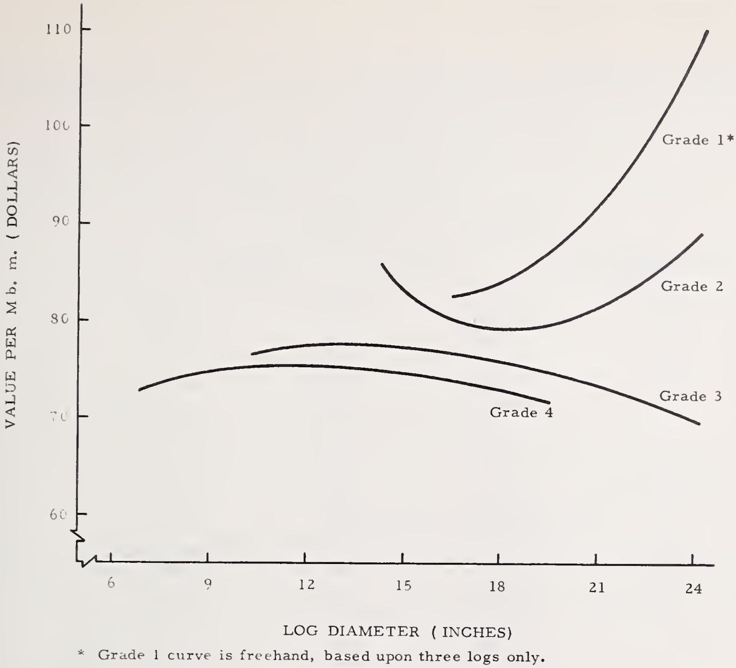


Figure 5. --Average value per M b. m. dry surfaced lumber, by log grade and diameter class--all 16-foot logs.

Diameter classification accomplishes very nearly as much quality separation as does log grading for logs up to 14 inches in diameter. This would be expected, since diameter predetermines to a certain extent the grade of smaller diameter logs. In the larger diameter classes, where the full range of log grades is applicable, logs can be separated as to quality by means of the log grade system. To the extent that quality separation is achieved, log grading appears to warrant further consideration.

Detailed lumber volume and grade recovery, and log and lumber value, are presented by log grade in tables 10 through 14 of the appendix.

LOG SAWING TIME

The headsaw time required per unit of lumber increases as log size decreases. To determine this diameter-sawing time relationship for Engelmann spruce, sawing time was recorded for 669 study logs. Variable sawing time (actual time on the carriage) was subtracted from total elapsed time to obtain fixed time. Fixed time was pro-rated equally among the logs, since log size does not materially affect handling and loading time. Table 9 shows variable, fixed, and total sawing time per log, and sawing time per M b.m., by log diameter. Figure 6 illustrates graphically the relationship between log size and sawing time. The curves are based upon a regression of sawing time on log diameter.

Table 9.--Average sawing time per log and per M b.m. dry surfaced lumber -- 669 logs

Log diameter (Inches)	Logs	Sawing time per log			Sawing time per M b.m.[1]
		Variable	Fixed	Total	
	Number	Minutes			
7	22	0.434	0.062	0.496	17.274
8	60	.474	.062	.536	15.272
9	64	.545	.062	.607	14.155
10	69	.573	.062	.635	11.744
11	84	.710	.062	.772	11.920
12	73	.943	.062	1.005	11.435
13	71	1.055	.062	1.117	10.844
14	55	1.130	.062	1.192	9.689
15	47	1.250	.062	1.312	9.217
16	43	1.321	.062	1.383	8.655
17	24	1.518	.062	1.580	9.036
18	22	1.575	.062	1.637	8.118
19	12	1.538	.062	1.600	6.904
20	8	1.970	.062	2.032	7.270
21	6	1.983	.062	2.045	7.123
22	3	2.413	.062	2.475	8.856
23	3	2.843	.062	2.905	8.416
24	1	3.430	.062	3.492	9.397
27	1	3.170	.062	3.232	9.376

[1] Computed averages, based upon average number of logs per M b.m. dry surfaced lumber.

SAWING ACCURACY

A sample of the 4/4 lumber produced was measured to determine the dimensional variation. Three board thickness measurements were taken along the length of each of 198 sample boards. Measurements, taken at board midpoint and 2 feet from each end, were alternated between board edges, and averaged to obtain board average thickness. Figure 7 shows the range of board thickness encountered in the sample, and the proportion of boards in each thickness class.

The board average thickness that occurred most frequently was the target thickness of 34/32 inches; it accounted for 25 percent of the lumber sampled. The eight most frequented consecutive thickness classes (31/32 through 38/32 inches), representing a total spread of 1/4 inch, contain 94 percent of the sample lumber.

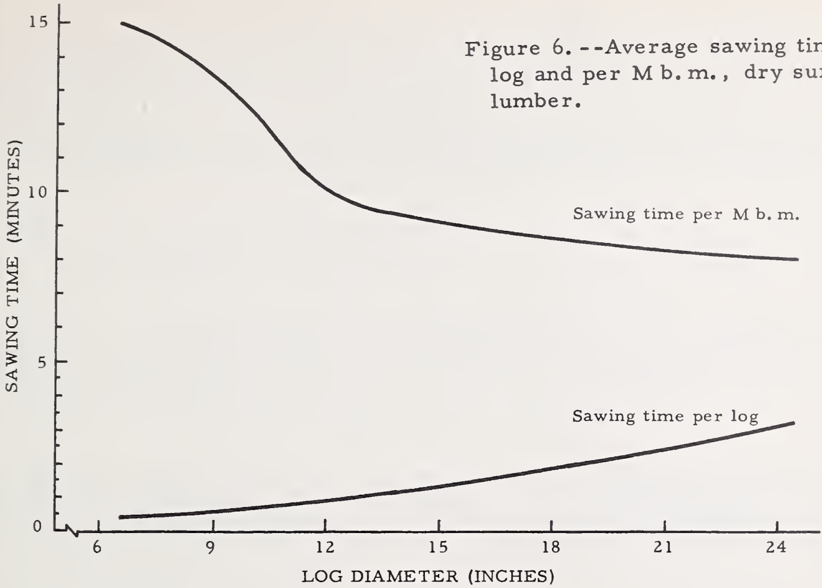


Figure 6. --Average sawing time per log and per M b. m., dry surfaced lumber.

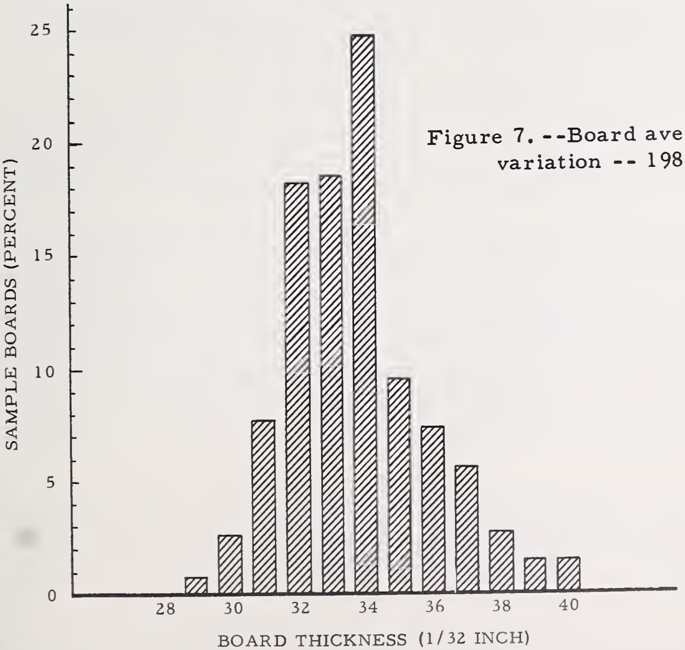


Figure 7. --Board average thickness variation -- 198 boards.

SUMMARY

Engelmann spruce is the most important single sawtimber species in Colorado. It contributes over 50 percent of the annual sawtimber supply.

To develop more reliable data for Engelmann spruce sawtimber appraisal, lumber grade recovery was studied at the J. S. Weidman mill in Durango, Colorado. The specific objectives of the study were: (1) to determine the lumber grades and volumes currently being recovered from Engelmann spruce sawtimber, and (2) to test the feasibility of grading Engelmann spruce saw logs. In addition, variations in log sawing time and sawing accuracy were investigated.

A total of 675 saw logs from 7 to 27 inches in diameter, made up the study sample. Of these, 84 percent were scaled as sound or full-scale logs.

The study logs yielded a gross scale of 66,040 board feet. Deductions for defect amounted to 4.5 percent of gross scale, or 2,970 board feet, which left a net scale of 63,070 board feet. Heart rot, the most common defect encountered, accounted for 44 percent of total cull. Sweep and crook contributed 29 percent of the loss.

Rough lumber volume recovery totaled 73,558.8 board feet. Volume losses due to drying, surfacing, and end-trimming reduced total recovery to 67,150.4 board feet. Change-of-grade and volume-loss factors were developed from a sample of 33,073 board feet of lumber.

Log size and overrun were significantly correlated, with overrun greatest in the smaller diameter classes. Partial-scale logs yielded consistently higher overruns than did full-scale logs of comparable size.

Common lumber grades 1-2 and 3 contained over 70 percent of total dry surfaced lumber recovery. Select grades accounted for 3 percent of the lumber recovered; the remaining 27 percent was in low-common and dimension grades. Select-grade recovery improved as log diameter increased.

All study logs were graded in accordance with a modification of the trial log grades developed for associated species in the Pacific Northwest region. Both log grading and straight diameter classification accomplished some quality separation, although log grading accomplished very little for logs smaller than 14 inches in diameter. Minimum diameter specifications limit grading possibilities in these size classes. In the larger diameter classes, where the full range of log grades is applicable, logs can be separated as to quality by means of the log grade system. To the extent that quality separation is achieved, log grading appears to warrant further consideration.

Headsaw time required per unit of lumber produced varied inversely with log diameter. Study data indicated that lumber produced from 7-inch logs required approximately twice as much headsaw time per M b.m. as did lumber produced from 24-inch logs.

A sample of the study lumber was measured to determine dimensional variation. Board thickness averaged 34/32 inches, and ranged from 29/32 to 40/32 inches. Ninety-four percent of the lumber sampled fell within a 1/4 inch spread, from 31/32 to 38/32 inches.

APPENDIX

Trial log grades developed for associated species in the Pacific Northwest Region,[7] June 21, 1955.

Grade 1	Minimum diameter 20 inches Minimum length 12 feet 16-foot logs shall be 75 percent surface clear (3 clear faces or 12 feet of length) 14-foot logs shall have 12 feet of clear length 12-foot logs shall be 100 percent surface clear 2 pin knots allowed on clear portion of 16-foot logs that have 3 clear faces
Grade 2	Minimum diameter 16 inches, minimum length 12 feet Shall have two clear faces with one pin knot allowed on one clear face
Grade 3	Minimum diameter 12 inches, minimum length 12 feet May have knots in proportion to size of logs as follows: 12-inch logs, 2-inch live, 1-inch dead 18-inch logs, 3-inch live, 1-1/2-inch dead 24-inch logs, 4-inch live, 2-inch dead 30-inch logs, 5-inch live, 2-1/2-inch dead One knot over maximum size permitted
Grade 4	Minimum diameter 6 inches, minimum length 8 feet. Shall include logs not considered merchantable in the above classes
Knot clusters	Knot clusters other than the sap knot type (adventitious buds) shall be treated the same as a single knot of the same size as the cluster. Sap knot clusters shall be treated the same as the largest limb or knot in the cluster

[7] The trial log grades were applied as written, with these exceptions: minimum diameter limits were reduced to 16 inches in grade 1, 14 inches in grade 2, and 10 inches in grade 3; 10-inch grade 3 logs may have 1-3/4-inch live, 3/4-inch dead knots.

Table 10. --Average net scale, lumber recovery, and log values for log grades 1-4, 16-foot logs

Log diameter (inches)	Full-scale logs: Logs	Full-scale logs: Net Scribner scale	Full-scale logs: Dry surfaced recovery	Full-scale logs: Log value	Partial-scale logs: Logs	Partial-scale logs: Net Scribner scale	Partial-scale logs: Dry surfaced recovery	Partial-scale logs: Log value	All logs: Logs	All logs: Net Scribner scale	All logs: Dry surfaced recovery	All logs: Log value
	No.	Board feet	Board feet	Dollars	No.	Board feet	Board feet	Dollars	No.	Board feet	Board feet	Dollars
					LOG GRADE 1[1]							
17	1	180	164.0	13.56	--	--	--	--	1	180	164.0	13.56
21	1	300	320.0	29.31	--	--	--	--	1	300	320.0	29.31
24	--	--	--	--	1	390	372.0	41.38	1	390	372.0	41.38
					LOG GRADE 2[2]							
14	2	110	141.4	12.24	--	--	--	--	2	110	134.3	11.99
15	9	140	154.7	12.70	2	110	131.1	12.48	11	135	148.5	12.52
16	3	160	170.8	13.60	5	135	152.7	13.06	8	143	165.1	13.42
17	2	180	189.7	14.94	4	153	174.6	13.95	6	161	184.0	14.67
18	5	210	211.4	16.72	2	165	197.1	15.17	7	197	205.1	16.29
19	2	240	235.8	18.94	2	170	219.9	16.71	4	205	228.6	18.26
20	3	280	263.1	21.60	--	--	--	--	3	280	254.5	20.60
21	2	300	293.1	24.70	--	--	--	--	2	300	282.6	23.29
22	1	330	326.0	28.24	1	270	291.1	23.24	2	300	313.1	26.35
23	1	380	361.6	32.22	1	300	315.8	26.06	2	340	345.8	29.76
					LOG GRADE 3[2]							
10	5	60	61.0	4.94	2	35	38.1	2.55	7	53	52.2	3.91
11	22	70	75.0	5.93	5	46	59.9	4.46	27	65	70.3	5.40
12	48	80	90.2	7.01	5	62	81.3	6.27	53	78	88.6	6.87
13	53	100	106.5	8.20	5	80	102.3	7.99	58	98	107.0	8.31
14	42	110	124.0	9.50	5	90	122.8	9.61	47	108	125.6	9.73
15	28	140	142.8	10.89	5	108	142.8	11.13	33	135	144.4	11.12
16	25	160	162.7	12.39	6	140	162.4	12.56	31	156	163.3	12.50
17	9	180	183.8	13.99	5	162	181.6	13.89	14	174	182.4	13.85
18	9	210	206.1	15.70	5	164	200.2	15.12	14	194	201.6	15.18
19	4	240	229.6	17.50	3	193	218.5	16.25	7	220	221.0	16.48
20	2	280	254.3	19.41	3	237	236.2	17.29	5	254	240.5	17.76
21	2	300	280.1	21.42	1	260	253.5	18.23	3	287	260.2	19.02
22	--	--	--	--	2	210	270.4	19.08	2	210	280.1	20.26
23	1	380	335.5	25.76	--	--	286.8	19.82	1	380	300.1	21.47
27	--	--	--	--	1	500	347.9	21.84	1	500	381.8	26.10
					LOG GRADE 4[2]							
7	19	30	27.2	1.99	2	15	27.0	1.96	21	29	27.7	2.04
8	50	30	35.9	2.68	1	20	33.3	2.43	51	30	35.8	2.67
9	56	40	45.7	3.45	2	30	41.8	3.04	58	40	45.2	3.40
10	48	60	56.8	4.30	9	42	52.5	3.81	57	57	56.1	4.21
11	37	70	69.0	5.22	12	56	65.3	4.74	49	67	68.3	5.12
12	6	80	82.4	6.21	7	64	80.3	5.81	13	72	81.9	6.12
13	7	100	97.0	7.29	1	90	97.4	7.04	8	99	97.0	7.21
14	4	110	112.8	8.42	1	80	116.7	8.42	5	104	113.4	8.39
15	3	140	129.7	9.64	--	--	--	--	3	140	131.1	9.67
16	1	160	147.9	10.93	--	--	--	--	1	160	150.3	11.03
17	--	--	--	--	1	160	187.6	13.48	1	160	170.9	12.49
19	1	240	209.4	15.26	--	--	--	--	1	240	216.1	15.68

[1] Due to the extremely small sample of grade 1 logs, regression estimates of lumber recovery and log value were not computed. Lumber recovery and log value were computed directly from raw data.

[2] Dry surfaced volume recovery and log value are predicted values computed from regressions.

Table 11. --Percentage lumber grade recovery, dry finished basis -- log grade 1[1]

Log diameter (inches)	Logs	Select: B and better	Select: C	Select: D	Common: 1-2	Common: 3	Common: 4	Common: 5	Dimension	Value per M b.m.
	No.	Percent								Dollars
					FULL-SCALE LOGS					
17	1	8.1	1.6	2.6	13.9	43.0	28.6	2.2	0	82.68
21	1	11.3	2.3	3.6	32.6	39.7	9.5	1.0	0	91.59
					PARTIAL-SCALE LOGS					
24	1	30.4	6.1	9.7	16.3	18.8	10.7	2.2	5.8	111.24
					ALL LOGS					
17	1	8.1	1.6	2.6	13.9	43.0	28.6	2.2	0	82.68
21	1	11.3	2.3	3.6	32.6	39.7	9.5	1.0	0	91.59
24	1	30.4	6.1	9.7	16.3	18.8	10.7	2.2	5.8	111.24

[1] All grade 1 study logs were 16 feet in length.

Table 12. --Percentage lumber grade recovery, dry finished basis -- log grade 2[1]

Log diameter (inches)	Logs	Select: B and better	Select: C	Select: D	Common: 1-2	Common: 3	Common: 4	Common: 5	Dimension	Value[2] per M b.m.
	No.	Percent								Dollars
					FULL-SCALE LOGS					
14	2	2.9	0.6	0.9	35.8	46.9	12.2	0.7	0	86.54
15	9	4.5	.9	1.5	23.4	51.0	16.7	1.1	0.9	82.09
16	3	9.4	1.9	3.0	29.4	43.5	11.8	1.0	0	79.63
17	2	3.0	.6	1.0	9.4	61.8	22.8	1.4	0	78.77
18	5	3.8	.8	1.2	19.0	53.1	19.9	1.3	1.0	79.12
19	2	2.9	.6	.9	35.0	48.5	11.5	.6	0	80.32
20	3	7.0	1.4	2.2	19.4	51.3	17.4	1.3	0	82.11
21	2	1.3	.3	.4	22.1	49.5	24.9	1.5	0	84.27
22	1	11.0	2.2	3.5	13.7	43.6	24.0	2.0	0	86.64
23	1	15.8	3.2	5.1	18.9	34.5	15.3	1.7	5.5	89.10
					PARTIAL-SCALE LOGS					
15	2	14.2	2.9	4.6	31.6	31.8	13.4	1.5	0	95.19
16	5	4.7	.9	1.5	21.9	43.7	25.1	2.2	0	85.53
17	4	9.9	2.0	3.2	27.7	43.0	13.0	1.2	0	79.89
18	2	4.5	.9	1.4	11.0	36.5	39.8	5.9	0	76.98
19	2	1.8	.4	.6	9.1	35.1	44.2	6.4	2.4	75.97
22	1	0	0	0	12.1	50.5	31.8	1.9	3.7	79.84
23	1	12.8	2.6	4.1	5.2	33.0	24.1	2.2	16.0	82.54
					ALL LOGS					
14	2	2.9	0.6	0.9	35.8	46.9	12.2	0.7	0	89.25
15	11	6.1	1.2	2.0	24.8	47.9	16.1	1.1	0.8	84.31
16	8	6.7	1.3	2.1	25.0	43.6	19.6	1.7	0	81.28
17	6	7.6	1.5	2.4	21.6	49.4	16.3	1.2	0	79.77
18	7	4.0	.8	1.3	16.8	48.8	25.1	2.5	.7	79.40
19	4	2.4	.5	.8	23.0	42.2	26.7	3.3	1.1	79.88
20	3	7.0	1.4	2.2	19.4	51.3	17.4	1.3	0	80.95
21	2	1.3	.3	.4	22.1	49.5	24.9	1.5	0	82.42
22	2	5.8	1.2	1.9	12.9	46.7	27.7	2.0	1.8	84.15
23	2	14.5	2.9	4.6	12.8	33.8	19.3	1.9	10.2	86.05

[1] All grade 2 study logs were 16 feet in length.
[2] Value per M b.m. is based upon predicted average log volume recovery and log value, computed from regressions.

Table 13. --Percentage lumber grade recovery, dry finished basis -- log grade 3

Log diameter (inches)	Logs	Select			Common				Dimension	Value[1] per M b. m.
		B and better	C	D	1-2	3	4	5		
	No.	Percent								Dollars
					FULL-SCALE LOGS					
16-foot logs:										
10	5	1.2	0.2	0.4	26.7	48.6	20.8	2.1	0	80.93
11	22	.7	.1	.2	32.9	48.3	16.6	1.2	0	79.00
12	48	1.2	.3	.4	29.3	49.8	17.8	1.0	.2	77.78
13	53	.9	.2	.3	26.7	50.5	19.9	1.4	.1	77.02
14	42	.9	.2	.3	23.3	54.7	19.3	1.3	0	76.56
15	28	1.8	.4	.6	21.4	51.2	23.0	1.6	0	76.29
16	25	1.2	.2	.4	18.8	52.8	24.8	1.8	0	76.16
17	9	1.9	.4	.6	20.2	53.7	21.1	1.5	.6	76.13
18	9	1.0	.2	.3	19.8	46.7	25.8	5.2	1.0	76.16
19	4	0	0	0	13.8	61.0	21.8	1.2	2.2	76.23
20	2	3.5	.7	1.1	28.1	52.9	13.0	.7	0	76.34
21	2	3.1	.6	1.0	25.6	53.1	15.7	.9	0	76.47
23	1	1.5	.3	.5	13.9	38.0	37.2	2.5	6.1	76.78
Shorter logs:										
11	6	2.1	.4	.7	24.3	54.3	17.2	1.0	0	76.42
12	4	0	0	0	17.6	61.7	19.7	1.0	0	76.03
13	3	0	0	0	20.4	42.0	35.3	2.3	0	75.53
14	2	0	0	0	19.3	55.8	23.6	1.3	0	74.93
15	1	0	0	0	41.1	48.4	10.1	.4	0	74.23
16	1	0	0	0	31.3	35.2	31.5	2.0	0	73.57
17	2	.9	.2	.3	11.7	48.3	24.6	12.3	1.7	72.43
					PARTIAL-SCALE LOGS					
16-foot logs:										
10	2	0	0	0	25.5	50.0	23.1	1.4	0	66.96
11	5	0	0	0	18.6	41.2	37.8	2.4	0	74.42
12	5	0	0	0	18.2	45.2	34.4	2.2	0	77.13
13	5	4.0	.8	1.3	21.8	47.9	22.7	1.5	0	78.11
14	5	0	0	0	21.5	55.7	21.6	1.2	0	78.26
15	5	5.9	1.2	1.9	23.3	44.2	19.7	3.8	0	77.94
16	6	3.0	.6	1.0	19.9	46.5	27.2	1.8	0	77.32
17	5	4.3	.9	1.4	17.5	45.1	27.0	2.8	1.0	76.49
18	5	.4	.1	.1	14.2	43.2	35.8	4.0	2.2	75.50
19	3	3.9	.8	1.2	13.3	38.2	37.5	2.7	2.4	74.40
20	3	.7	.2	.2	9.7	36.8	41.1	8.9	2.4	73.20
21	1	0	0	0	26.3	52.0	20.6	1.1	0	71.91
22	2	1.1	.2	.4	1.8	15.2	72.5	7.5	1.3	70.55
27	1	0	0	0	.2	7.1	76.5	16.2	0	62.78
Shorter logs:										
16	1	0	0	0	14.8	43.1	39.5	2.6	0	72.33
					ALL LOGS					
16-foot logs:										
10	7	.9	.2	.3	26.4	49.0	21.3	1.9	0	74.93
11	27	.6	.1	.2	30.5	47.1	20.1	1.4	0	76.79
12	53	1.1	.2	.4	28.4	49.5	19.1	1.1	.2	77.49
13	58	1.2	.2	.4	26.3	50.3	20.1	1.4	.1	77.62
14	47	.8	.2	.2	23.1	54.8	19.6	1.3	0	77.43
15	33	2.4	.5	.8	21.7	50.1	22.5	2.0	0	77.05
16	31	1.5	.3	.5	19.0	51.7	25.2	1.8	0	76.54
17	14	2.7	.5	.9	19.3	50.9	23.1	1.9	.7	75.94
18	14	.8	.2	.3	17.8	45.4	29.3	4.8	1.4	75.29
19	7	1.7	.3	.6	13.6	50.9	28.8	1.8	2.3	74.59
20	5	1.9	.4	.6	17.3	43.5	29.4	5.5	1.4	73.85
21	3	2.1	.4	.7	25.8	52.8	17.3	.9	0	73.10
22	2	1.1	.2	.4	1.8	15.2	72.5	7.5	1.3	72.33
23	1	1.5	.3	.5	13.9	38.0	37.2	2.5	6.1	71.55
27	1	0	0	0	.2	7.1	76.5	16.2	0	68.36
Shorter logs:										
11	6	2.1	.4	.7	24.3	54.3	17.2	1.0	0	76.42
12	4	0	0	0	17.6	61.7	19.7	1.0	0	76.03
13	3	0	0	0	20.4	42.0	35.3	2.3	0	75.53
14	2	0	0	0	19.3	55.8	23.6	1.3	0	74.93
15	1	0	0	0	41.1	48.4	10.1	.4	0	74.23
16	2	0	0	0	22.8	39.3	35.6	2.3	0	73.40
17	2	.9	.2	.3	11.7	48.3	24.6	12.3	1.7	72.43

[1] Value per M b.m is based upon predicted average log volume recovery and log value, computed from regressions.

Table 14. --Percentage lumber grade recovery, dry finished basis -- log grade 4

Log diameter (inches)	Logs	Select: B and better	Select: C	Select: D	Common: 1-2	Common: 3	Common: 4	Common: 5	Dimension	Value[1] per M b.m.
	No.	Percent								Dollars
				FULL-SCALE LOGS						
16-foot logs:										
7	19	0	0	0	10.7	43.1	18.7	4.0	23.5	73.12
8	50	.3	.1	.1	18.1	49.7	28.3	2.4	1.0	74.80
9	56	.5	.1	.2	20.5	53.5	22.9	1.9	.4	75.50
10	48	.1	0	0	26.8	52.4	19.6	1.1	0	75.69
11	37	1.7	.3	.5	20.4	53.4	21.9	1.8	0	75.60
12	6	1.0	.2	.3	26.6	54.2	16.8	.9	0	75.36
13	7	.3	.1	.1	9.1	54.6	32.7	3.1	0	75.03
14	4	.8	.2	.3	6.7	63.1	27.3	1.6	0	74.68
15	3	0	0	0	21.6	54.9	22.3	1.2	0	74.30
16	1	0	0	0	25.5	58.5	15.3	.7	0	73.93
19	1	0	0	0	15.7	49.4	27.2	1.6	6.1	72.87
Shorter logs:										
7	1	0	0	0	0	8.8	85.3	5.9	0	72.48
8	9	0	0	0	7.2	48.2	35.4	2.2	7.0	72.91
9	7	0	0	0	13.8	59.0	22.8	1.3	3.1	73.41
10	7	0	0	0	10.6	60.8	23.6	1.3	3.7	73.93
11	3	7.3	1.5	2.3	20.2	48.4	18.8	1.5	0	74.43
12	3	0	0	0	18.5	59.1	21.3	1.1	0	74.91
13	2	0	0	0	8.0	60.7	29.5	1.8	0	75.36
16	1	0	0	0	7.7	72.8	18.6	.9	0	75.79
18	1	4.8	1.0	1.5	15.9	60.4	15.4	1.0	0	76.19
				PARTIAL-SCALE LOGS						
16-foot logs:										
7	2	0	0	0	3.8	36.3	21.9	1.5	36.5	72.53
8	1	0	0	0	2.8	31.1	61.9	4.2	0	72.73
9	2	0	0	0	5.4	52.5	39.6	2.5	0	72.75
10	9	.3	.1	.1	16.6	50.4	30.6	1.9	0	72.67
11	12	.6	.1	.2	14.5	37.8	42.1	4.7	0	72.55
12	7	0	0	0	12.7	43.5	37.6	4.4	1.8	72.42
13	1	0	0	0	14.6	49.8	33.5	2.1	0	72.29
14	1	2.0	.4	.7	13.8	24.2	41.9	3.0	14.0	72.17
17	1	0	0	0	8.5	56.2	33.3	2.0	0	71.87
				ALL LOGS						
16-foot logs:										
7	21	0	0	0	10.1	42.5	19.0	3.8	24.6	73.75
8	51	.3	.1	.1	17.9	49.5	28.7	2.4	1.0	74.77
9	58	.5	.1	.2	20.0	53.4	23.5	1.9	.4	75.13
10	57	.1	0	.1	25.1	52.1	21.4	1.2	0	75.14
11	49	1.4	.3	.5	19.1	49.9	26.4	2.4	0	74.95
12	13	.5	.1	.2	19.1	48.4	27.9	2.8	1.0	74.68
13	8	.2	.1	.1	9.9	54.0	32.8	2.9	0	74.36
14	5	1.0	.2	.3	7.9	56.8	29.7	1.8	2.3	74.03
15	3	0	0	0	21.6	54.9	22.3	1.2	0	73.70
16	1	0	0	0	25.5	58.5	15.3	.7	0	73.39
17	1	0	0	0	8.5	56.2	33.3	2.0	0	73.08
19	1	0	0	0	15.7	49.4	27.2	1.6	6.1	72.53
Shorter logs:										
7	1	0	0	0	0	8.8	85.3	5.9	0	72.48
8	9	0	0	0	7.2	48.2	35.4	2.2	7.0	72.91
9	7	0	0	0	13.8	59.0	22.8	1.3	3.1	73.41
10	7	0	0	0	10.6	60.8	23.6	1.3	3.7	73.93
11	3	7.3	1.5	2.3	20.2	48.4	18.8	1.5	0	74.43
12	3	0	0	0	18.5	59.1	21.3	1.1	0	74.91
13	2	0	0	0	8.0	60.7	29.5	1.8	0	75.36
16	1	0	0	0	7.7	72.8	18.6	.9	0	75.79
18	1	4.8	1.0	1.5	15.9	60.4	15.4	1.0	0	76.19

[1] Value per M b.m. is based upon predicted average log volume recovery and log value, computed from regressions.

Agriculture --- CSU, Ft. Collins

Mueller, Lincoln A., and Barger, Roland L.
1963. Lumber grade recovery from Engelmann spruce in Colorado. Rocky Mountain Forest and Range Expt. Sta., Fort Collins, Colo. 23 pp., illus. (U. S. Forest Serv. Res. Paper RM-1)

Engelmann spruce accounts for over half the annual sawtimber cut in Colorado. Specific objectives of this study were (1) determine lumber grades and volumes currently being recovered, (2) test feasibility of grading saw logs. Variations in sawing time and accuracy were also investigated. Dry surfaced lumber was recovered as follows: selects, 3 percent; grades 3 and better, 70 percent; 4 and 5, 26 percent, dimension, about 1 percent. Study logs were graded by a modification of trial log grades developed for associated species in the Pacific Northwest. The grading system appeared to be most effective for logs in the larger diameters.

Mueller, Lincoln A., and Barger, Roland L.
1963. Lumber grade recovery from Engelmann spruce in Colorado. Rocky Mountain Forest and Range Expt. Sta., Fort Collins, Colo. 23 pp., illus. (U. S. Forest Serv. Res. Paper RM-1)

Engelmann spruce accounts for over half the annual sawtimber cut in Colorado. Specific objectives of this study were (1) determine lumber grades and volumes currently being recovered, (2) test feasibility of grading saw logs. Variations in sawing time and accuracy were also investigated. Dry surfaced lumber was recovered as follows: selects, 3 percent; grades 3 and better, 70 percent; 4 and 5, 26 percent, dimension, about 1 percent. Study logs were graded by a modification of trial log grades developed for associated species in the Pacific Northwest. The grading system appeared to be most effective for logs in the larger diameters.

Mueller, Lincoln A., and Barger, Roland L.
1963. Lumber grade recovery from Engelmann spruce in Colorado. Rocky Mountain Forest and Range Expt. Sta., Fort Collins, Colo. 23 pp., illus. (U. S. Forest Serv. Res. Paper RM-1)

Engelmann spruce accounts for over half the annual sawtimber cut in Colorado. Specific objectives of this study were (1) determine lumber grades and volumes currently being recovered, (2) test feasibility of grading saw logs. Variations in sawing time and accuracy were also investigated. Dry surfaced lumber was recovered as follows: selects, 3 percent; grades 3 and better, 70 percent; 4 and 5, 26 percent, dimension, about 1 percent. Study logs were graded by a modification of trial log grades developed for associated species in the Pacific Northwest. The grading system appeared to be most effective for logs in the larger diameters.

Mueller, Lincoln A., and Barger, Roland L.
1963. Lumber grade recovery from Engelmann spruce in Colorado. Rocky Mountain Forest and Range Expt. Sta., Fort Collins, Colo. 23 pp., illus. (U. S. Forest Serv. Res. Paper RM-1)

Engelmann spruce accounts for over half the annual sawtimber cut in Colorado. Specific objectives of this study were (1) determine lumber grades and volumes currently being recovered, (2) test feasibility of grading saw logs. Variations in sawing time and accuracy were also investigated. Dry surfaced lumber was recovered as follows: selects, 3 percent; grades 3 and better, 70 percent; 4 and 5, 26 percent, dimension, about 1 percent. Study logs were graded by a modification of trial log grades developed for associated species in the Pacific Northwest. The grading system appeared to be most effective for logs in the larger diameters.