Lumber Grade Yields from Paper Birch and Balsam Poplar Logs in the Susitna River Valley, Alaska

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Foreword

Susitna River Valley paper birch stands are of continuing interest to forest mana because they believe them to be a useful and usable timber resource. The forest indu has shown recurring rather than continuing interest. A number of factors are responsi One remedial factor is the acquisition and dissemination of more specific information paper birch and associated commercial species. More reliable estimates of the volume quality in standing trees and the lumber yield, including quality, from these trees w immediate objectives. This report is focused primarily on the latter.

We asked for and received the support of a variety of individuals and organizati Our appreciation is acknowledged. Because of necessity, we drew from Forest Ser units outside of Alaska those men with the special competence required. It was their c tribution that made the study successful. Thus, we are especially appreciative to Ros D. Carpenter, hardwood specialist from the Northeastern Forest Experiment Stat and Hiram Hallock and Arno Wollin, sawmilling and lumber grading specialists from Forest Products Laboratory.

Richard M. Hurd, Director
Institute of Northern Forestry

COVER PHOTO: Some good-quality paper birch logs from the Susitna River Valley, Alaska.

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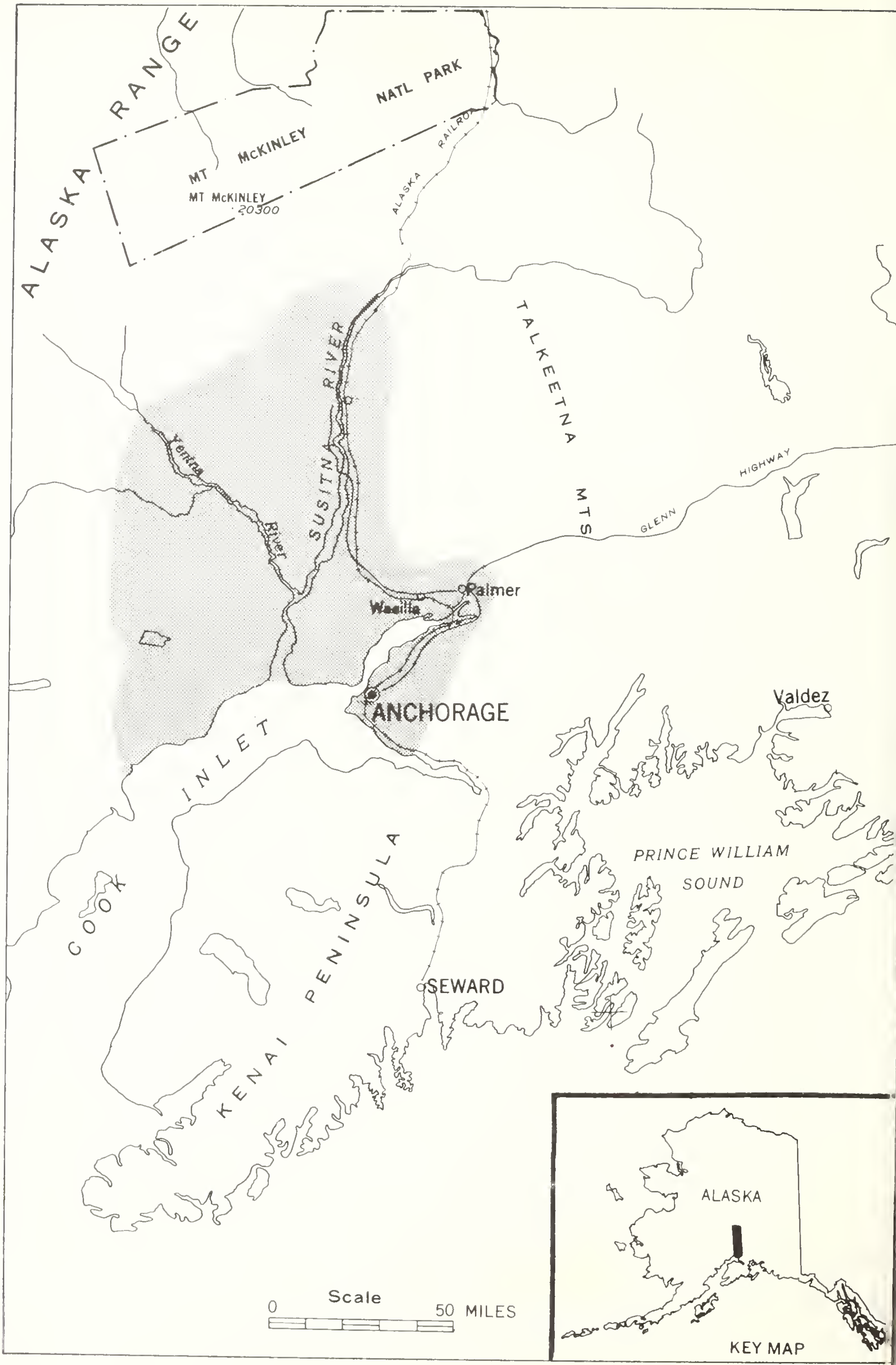

Figure 1. The Susitna River Valley.

Introduction

HE SUSITNA River Valley (fig. 1), located at the head of Knik Arm in Cook Inlet, con-
ins a considerable acreage of hardwoods. Paper birch (*Betula papyrifera*) and its varieties
e the most common tree species; but balsam poplar (*Populus balsamifera*), quaking aspen
'opulus tremuloides), and white spruce (*Picea glauca*) also are major stand components in
me areas. This valley is a logical site for establishing a hardwood industry since it is traversed
y the Alaska Railroad and is close to the port cities of Anchorage and Seward.

The earliest plans to use this hardwood resource were made in 1916 by Robert Dollar, who
ade an initial survey of the Goose Bay area of the Knik stand for the steamship company
at he headed. The plan was to develop cargo for the Orient, but World War I stopped that
iterprise.

More recently, both the Knik and Talkeetna birch stands have been under sporadic
rutiny by a succession of entrepreneurs. Many have been impressed by the birch stands,
it most have concluded that, because of high operational cost, the time was not ripe for
mmercial use of the resource.

The Alaska Hardwoods Company has been operating a sawmill in Wasilla since 1960
ig. 2). Most of the mill's output of paper birch and balsam poplar has been marketed
cally, although some lumber has been shipped to California and the Pacific Northwest.
these and other outside markets are to be developed fully, basic operating and economic
iformation must be obtained.

In 1964, through the cooperative efforts of several agencies, a study was conducted with
ie Alaska Hardwoods Company to determine the lumber grade recovery from paper birch
id balsam poplar logs for each of the three U.S. Forest Service log grades.[1]

Pertinent information contained in the Alaska Forest Survey report[2] has been included
this paper. This information, together with the lumber grade yields, should be valuable to
iyone interested in the commercial aspects of Alaska's hardwoods.

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[1] *U.S. Forest Service. Hardwood log grades for standard lumber. Forest Prod. Lab. U.S. Forest Serv. Res. Pap. FPL-63 ?ep. D1737], 52 pp. 1966.*

[2] *U.S. Forest Service. Preliminary Forest Survey statistics for the Susitna River Valley of Alaska. Inst. North. Forest., 5 pp. December 1966.*

Figure 2. The Alaska Hardwoods Co., Wasilla, Alaska.

Figure 3. – Each log was scaled by a hardwood timber-quality specialist. Log diagrams were also verified and corrected to assure uniformity.

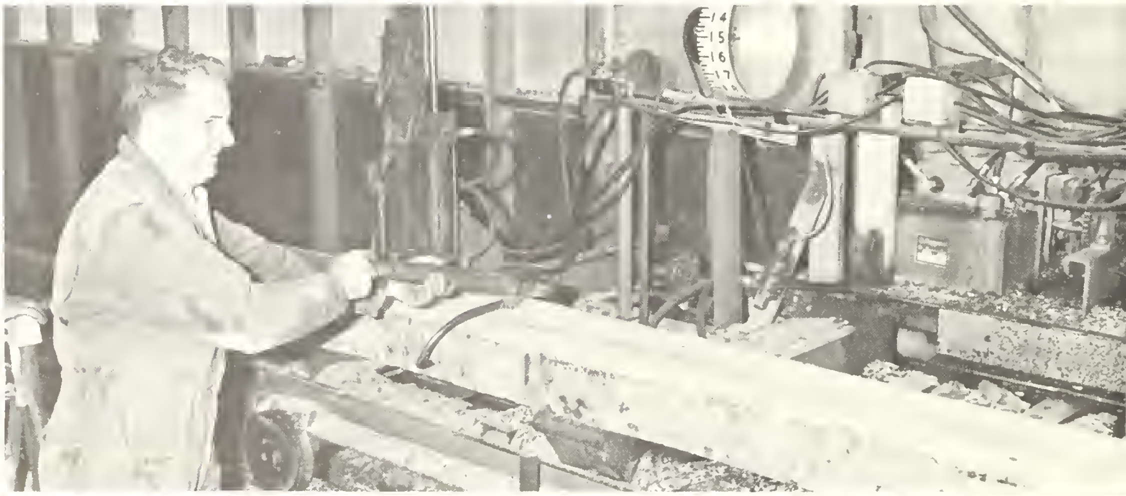

Figure 4. A sawmill specialist from the Forest Products Laboratory positioned each log on the carriage to assure maximum recovery of high-grade boards.

Figure 5. To identify the boards through the kiln-drying and lumber-grading phases of the study, each board was numbered as it left the headsaw.

Procedure

og Preparation

Logs for the study came from trees on a sale area of Goose Bay, approximately 32 miles rom Wasilla. In all, 54 birch and 57 balsam poplar trees were selected. They were chosen o that the full range of tree diameters and butt log grades was represented.

After felling, each tree was bucked to yield logs of the highest grade possible. This resulted n 162 birch and 174 poplar logs that were scaled according to the International 1/4-inch nd Scribner Decimal-C log rules (fig. 3).

A diagram of each log was made that showed the location and size of all defect indicators resent on the log's surface and ends.

awing

The balsam poplar logs were sawed into 4/4 lumber, the birch into 4/4 and 5/4 lumber, nd some of the birch hearts into 14/4 car stakes. A Forest Products Laboratory sawmill pecialist directed the sawing (fig. 4). Each board was numbered so that it could be related o the tree and log from which it was sawed (fig. 5).

umber Drying and Grading

All lumber was kiln-dried on a 5-day drying schedule to between 6 and 9 percent moisture ontent. Then the Forest Products Laboratory grading specialist graded each board accord-ng to National Hardwood Lumber Association rules.[3] A board tally was kept that included og number and board grade, thickness, and surface measure.

Bark pocket defect that adversely affected lumber grade was encountered in several of he balsam poplar boards. Bark pockets can be caused by one or more agents, among the nore common being sapsuckers and insects. In this case, the defect probably resulted from nsect activity. How much timber may be damaged is unknown.

The poplar boards were graded by two systems: (1) by the standard lumber grades, in vhich bark pockets were considered as defects; and (2) by a second system that ignored he presence of bark pockets. Yields obtained by the latter method should be similar to hose where insect damage is not prevalent.

.og Grading

Each log diagram was graded with the Forest Service Standard Grades. Log and board nformation were placed on IBM punch cards. Dry lumber grade yields and overrun percent-ages were summarized by log grade and scaling diameter.

Yields based on green lumber tally are not presented in this report. However, they may be obtained from the Institute of Northern Forestry.

Logs that did not meet the minimum requirements for grade III were examined to deter-mine if they could be placed in either the Construction or Local Use Class. Specifications for these two classes of logs may be found in "A Guide to Hardwood Log Grading."[4]

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[3] *These rules for measuring and inspecting hardwood and cypress lumber are published biennially by the National Hardwood Lumber Association, Chicago, Ill.*

[4] *Ostrander, M.D., and others. A guide to hardwood log grading (revised). U.S. Forest Serv., Northeast. Forest Exp. Sta., 50 pp., illus. 1965.*

Results

Paper Birch

Lumber grade recovery for birch is summarized in tables 1 to 5. Because of the sma number of grade I logs, there is little that can be said about these yields. It is possible tha in most stands, grade I logs do not exist, primarily because the trees do not produce log that are large enough. Likewise, the yields for grade II logs beyond 15 inches are of littl significance.

A lumber-thickness distribution accompanies each yield table.

Lumber grade recoveries from this study were compared with those from a study o paper birch in Minnesota (table 6).

More No. 1 Common lumber was taken from all grades of the Alaska logs. The percentag yield of No. 1 Common and Better for log grades II and III was nearly equal for the tw locations. For these same log grades, considerably more grade 3B lumber was present in tl Alaska logs. This was, in part, because they contained more rot than those in the Minneso study. However, it was noted that the Alaska logs exhibited less sweep.

Overrun percentages for the International 1/4-inch and Scribner Decimal-C log rules a shown in tables 7 to 12. The headsaw at the Alaska Hardwoods mill had an 11/32-inch ker and for 4/4 lumber the total set was 1-1/2 inches. This is 1/8 inch greater than normal fo hardwood circular mills. Because of the excessive total set, yields and overruns were le than would normally be expected. The effect that this factor has upon total recovery shown below:

Lumber thickness (inches)	Expected recovery	
	Standard set (percent)	1/8-inch overset (percent)
4/4	100	91
5/4	100	92
6/4	100	93
7/4	100	94
8/4	100	95
9/4	100	95
14/4	100	96

Results of the recent forest survey indicate that birch sawtimber stands cover 490,700 ›res of the 5,366,000-acre Susitna River Valley. About 70 percent of the birch stands ›ntain over 1,500 board feet per acre, according to International 1/4-inch log rule. This ılley contains slightly over 1 billion board feet of birch sawtimber, and about three-fourths f this is in trees that are 11 to 15 inches d.b.h.

Net volume of sawtimber in each log grade, expressed as a percentage of total net volume, shown below:

Grade	Percent of total net volume
Log grade I	1.5
Log grade II	13.6
Log grade III	76.7
Other	8.2

The low volume in grade I logs is related to the high proportion of small trees.

alsam Poplar

Recovery results for poplar based on the standard lumber grades are summarized in ıbles 13 to 17, and recoveries on a "bark pockets no defect" basis are shown in tables 8 to 22. We suggest that the second set of tables be used when yields are predicted for alsam poplar logs that come from areas where bark pockets do not occur.

In table 23 lumber grade yields for balsam poplar are compared with those for cotton- /ood. It is evident that the Alaska logs did not produce the amount of high grade lumber ound in eastern cottonwood.

Tables 24 to 29 contain overruns by log grade and scaling diameter.

Results of the forest survey show that nearly 1.3 billion board feet of balsam poplar ıwtimber grow in the Susitna River Valley. Seventy percent of the 120,400 acres, classed s balsam poplar, has a volume greater than 5,000 board feet. The log grade distribution hat follows is more favorable than that for birch.

Grade	Percent of total net volume
Log grade I	13.8
Log grade II	25.0
Log grade III	56.7
Other	4.5

Summary and Conclusions

Lumber grade yields and overruns by log grade and scaling diameter were determined f 162 paper birch and 174 balsam poplar logs from Alaska. The information obtained will useful for timber appraisal and, when coupled with the saw-log volume and quality inforr tion contained in the preliminary Susitna Valley Forest Survey report,[5] could have imp cations for industrial development.

This study has shown that U.S. Forest Service standard grades for hardwood logs adaptable to birch and balsam poplar in Alaska. However, additional recovery informat is required for grade 1 birch logs. Grading rules of the National Hardwood Lumber Associat also proved to be well suited for use with these species.

Those who desire to pursue further the economic aspects of a hardwood industry Alaska are directed to a recent report from the University of Alaska's Institute of Soc Economic, and Government Research.[6]

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[5] *See footnote 2.*

[6] *Massie, Michael R. C. Marketing hardwoods from Alaska's Susitna Valley, Univ. Alaska Inst. Soc. Econ. Go Res. SEG Rep. 9. 1966.*

Table 1. – Log grade I

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
13	2	119	21.0	5.9	46.2	16.8	0.0	10.1
14	1	60	.0	16.7	53.3	15.0	8.3	6.7
15	1	98	19.4	33.7	29.5	8.2	.0	9.2
16	1	152	.0	.0	40.8	27.0	.0	32.2
			Total tally, board feet					
All diameters	4	429	44	50	178	78	5	74
			Percentage distribution					
			10.3	11.7	41.4	18.4	1.0	17.2

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	2.2	0.0	0.0	0.0
4/4	20.5	24.0	16.9	26.9	100.0	36.5
5/4	79.5	76.0	76.4	68.0	.0	39.2
7/4	.0	.0	.0	5.1	.0	.0
8/4	.0	.0	4.5	.0	.0	24.3
	Total tally, board feet					
	44	50	178	78	5	74

Table 2. – Log grade II

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade						
			Fas	Sel	1C	2C	3A	3B	Stakes
Inches	No.	Board feet	Percent of total dry tally						
10	4	154	3.9	8.4	22.7	17.5	3.3	20.8	23.4
11	12	627	.8	19.0	21.5	12.8	6.8	30.5	8.6
12	21	1,137	.0	12.0	36.9	17.8	2.3	21.5	9.5
13	6	427	5.6	15.2	29.8	23.2	.0	17.8	8.4
14	8	603	18.4	10.4	32.5	19.1	2.0	17.6	.0
15	2	133	18.0	23.4	20.3	19.5	3.8	15.0	.0
16	1	70	.0	.0	24.3	31.4	15.7	28.6	.0
17	1	41	.0	.0	39.0	39.0	.0	22.0	.0
			Total tally, board feet						
All diameters	55	3,192	170	428	973	587	102	698	234
			Percentage distribution						
			5.3	13.4	30.5	18.4	3.2	21.9	7.3

Distribution of above yields by thickness

Lumber thickness	Lumber grade						
	Fas	Sel	1C	2C	3A	3B	Stakes
Inches	Percent within grade						
3/4	0.0	1.4	1.5	1.7	5.9	0.6	0.0
4/4	17.1	27.6	34.9	47.0	43.1	42.2	.0
5/4	82.9	69.6	62.2	47.9	25.5	16.8	.0
6/4	.0	1.4	.0	.0	.0	.0	.0
7/4	.0	.0	.0	1.7	.0	.0	.0
8/4	.0	.0	1.4	1.7	25.5	37.2	.0
9/4	.0	.0	.0	.0	.0	3.2	.0
14/4	.0	.0	.0	.0	.0	.0	100.0
	Total tally, board feet						
	170	428	973	587	102	698	234

Table 3. – Log grade III

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade						
			Fas	Sel	1C	2C	3A	3B	Stakes
Inches	No.	Board feet	Percent of total dry tally						
8	14	280	0.0	1.1	6.8	20.0	4.6	48.2	19.3
9	26	680	.0	4.3	14.8	19.3	6.3	34.1	21.2
10	22	634	.6	8.4	17.3	29.0	3.0	30.3	11.4
11	13	406	.0	2.2	21.9	27.1	2.7	38.2	7.9
12	2	60	.0	18.3	25.0	10.0	16.7	30.0	.0
13	6	356	.0	.8	33.7	31.5	2.8	31.2	.0
14	6	341	.0	4.7	25.5	34.6	.9	34.3	.0
15	2	105	.0	.0	18.1	47.6	8.6	25.7	.0
			Total tally, board feet						
All diameters	91	2,862	4	124	560	767	118	987	302
			Percentage distribution						
			0.1	4.3	19.7	26.8	4.1	34.5	10.5

Distribution of above yields by thickness

Lumber thickness	Lumber grade						
	Fas	Sel	1C	2C	3A	3B	Stakes
Inches	Percent within grade						
3/4	0.0	0.0	0.4	0.5	0.0	1.1	0.0
4/4	100.0	56.5	55.7	75.0	75.4	50.0	.0
5/4	.0	38.7	43.9	19.2	11.9	4.6	.0
6/4	.0	.0	.0	1.3	.0	.0	.0
7/4	.0	.0	.0	.0	.0	1.0	.0
8/4	.0	4.8	.0	2.6	5.1	39.3	.0
9/4	.0	.0	.0	1.4	7.6	4.0	.0
14/4	.0	.0	.0	.0	.0	.0	100.0
	Total tally, board feet						
	4	124	560	767	118	987	302

Table 4. – Construction class

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade						
			Fas	Sel	1C	2C	3A	3B	Stakes
Inches	No.	Board feet	Percent of total dry tally						
8	1	15	0.0	0.0	0.0	0.0	20.0	80.0	0.0
9	2	43	.0	.0	11.6	13.9	.0	32.6	41.9
10	2	71	.0	4.2	5.6	19.7	11.3	8.5	50.7
			Total tally, board feet						
All diameters	5	129	0	3	9	20	11	32	54
			Percentage distribution						
			0.0	2.3	7.0	15.5	8.5	24.8	41.9

Distribution of above yields by thickness

Lumber thickness	Lumber grade						
	Fas	Sel	1C	2C	3A	3B	Stakes
Inches	Percent within grade						
4/4	0.0	100.0	100.0	80.0	100.0	81.3	0.0
5/4	.0	.0	.0	20.0	.0	.0	.0
8/4	.0	.0	.0	.0	.0	18.7	.0
14/4	.0	.0	.0	.0	.0	.0	100.0
	Total tally, board feet						
	0	3	9	20	11	32	54

Table 5. — Local-use class

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
9	1	23	0.0	0.0	0.0	26.1	0.0	73.9
10	1	39	.0	.0	.0	23.1	23.1	53.8
11	2	66	.0	.0	.0	30.3	7.6	62.1
13	1	75	.0	14.7	9.3	33.3	.0	42.7
14	1	10	.0	.0	.0	.0	.0	100.0
			Total tally, board feet					
All diameters	6	213	0	11	7	60	14	121
			Percentage distribution					
			0.0	5.1	3.3	28.2	6.6	56.8

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	0.0	7.4
4/4	.0	100.0	100.0	91.7	100.0	52.1
5/4	.0	.0	.0	8.3	.0	3.3
8/4	.0	.0	.0	.0	.0	13.2
9/4	.0	.0	.0	.0	.0	24.0
	Total tally, board feet					
	0	11	7	60	14	121

Table 6. – Lumber grade yields for paper birch in Alaska and Minnesota

Log grade	Lumber grade						
	Fas	Sel	1C	2C	3A	3B	Stakes
	Percent of total dry tally						
	PAPER BIRCH IN ALASKA						
I	10.3	11.7	41.4	18.4	1.0	17.2	––
II	5.3	13.4	30.5	18.4	3.2	21.9	7.3
III	.1	4.3	19.7	26.8	4.1	34.5	10.5
	PAPER BIRCH IN MINNESOTA						
I	20.0	28.2	25.3	12.4	7.3	6.8	––
II	10.1	19.3	21.9	24.1	19.2	5.4	––
III	.6	7.4	12.2	23.5	35.3	21.0	––

PAPER BIRCH IN ALASKA

Table 7. – Log grade I
Overruns based on dry lumber tally[1]

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
13	2	119	170	150	-20.7	140	116	2.6
14	1	60	80	58	3.4	70	44	36.4
15	1	98	115	108	-9.3	110	100	-2.0
16	1	152	180	173	-12.1	160	149	2.0
Total	5	429	545	489	-12.3	480	409	4.9

[1] *Throughout this study scale deductions for the International ¼-inch log rule were obtained by the methods outlined in "Shortcuts for Cruisers and Scalers," by L. R. Grosenbaugh, U.S. Forest Serv. South. Forest Exp. Sta. Occas. Pap. 126. 1952. For each log, percent deductions were rounded to the nearest whole percent and board-foot deductions were rounded to the nearest board foot.*

Scale deductions for the Scribner Decimal-C log rule were computed to the nearest board foot in accordance with "The National Forest Log Scaling Handbook." These volumes, however, were not rounded to the nearest 10.

PAPER BIRCH IN ALASKA

Table 8. – Log grade II
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
10	4	154	160	153	0.7	120	113	36.3
11	12	627	705	679	-7.7	550	524	19.7
12	21	1,137	1,420	1,306	-12.9	1,230	1,088	4.5
13	6	427	510	485	-12.0	440	415	2.9
14	8	603	795	737	-18.2	690	614	-1.8
15	2	133	190	140	-5.0	180	111	19.8
16	1	70	130	87	-19.5	120	63	11.1
17	1	41	125	71	-42.3	120	53	-22.6
Total	55	3,192	4,035	3,658	-12.7	3,450	2,981	7.1

PAPER BIRCH IN ALASKA

Table 9. – Log grade III
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	14	280	270	258	8.5	220	205	36.6
9	26	680	735	695	-2.2	680	631	7.8
10	22	634	805	741	-14.4	660	580	9.3
11	13	406	525	485	-16.3	440	387	4.9
12	2	60	115	78	-23.1	100	49	22.4
13	6	356	555	475	-25.1	470	363	-1.9
14	6	341	510	439	-22.3	460	384	-11.2
15	2	105	190	175	-40.0	180	160	-34.4
Total	91	2,862	3,705	3,346	-14.5	3,210	2,759	3.7

PAPER BIRCH IN ALASKA

Table 10. — Construction class
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	1	15	15	15	0.0	10	10	50.0
9	2	43	50	50	-14.0	50	50	-14.0
10	2	71	70	70	1.4	60	60	18.3
Total	5	129	135	135	-4.4	120	120	7.5

PAPER BIRCH IN ALASKA

Table 11. — Local-use class
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
9	1	23	20	20	15.0	20	20	15.0
10	1	39	45	43	-9.3	30	28	39.3
11	2	66	90	77	-14.3	70	53	24.5
13	1	75	100	84	-10.7	80	58	29.3
14	1	10	100	67	-85.1	90	60	-83.3
Total	6	213	355	291	-26.8	290	219	-2.7

Table 12. – All logs
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	15	295	285	273	8.1	230	215	37.2
9	29	746	805	765	-2.5	750	701	6.4
10	29	898	1,080	1,007	-10.8	870	781	15.0
11	27	1,099	1,320	1,241	-11.4	1,060	964	14.0
12	23	1,197	1,535	1,384	-13.5	1,330	1,137	5.3
13	15	977	1,335	1,194	-18.2	1,130	952	2.6
14	16	1,014	1,485	1,301	-22.1	1,310	1,102	-8.0
15	5	336	495	423	-20.6	470	371	-9.4
16	2	222	310	260	-14.6	280	212	4.7
17	1	41	125	71	-42.3	120	53	-22.6
Total	162	6,825	8,775	7,919	-13.8	7,550	6,488	5.2

Table 13. – Log grade I

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
13	2	129	0.0	0.0	9.3	64.3	9.3	17.1
14	2	221	4.1	18.1	24.9	33.0	13.1	6.8
15	1	72	.0	.0	30.6	20.8	25.0	23.6
16	2	194	12.9	7.7	24.7	45.9	6.2	2.6
17	4	546	6.0	22.2	33.3	26.4	5.9	6.2
18	4	664	1.4	6.2	38.8	30.4	6.9	16.3
19	2	356	5.3	13.2	38.3	20.5	1.1	21.6
21	4	980	6.3	7.4	37.4	29.4	7.4	12.1
26	1	203	11.3	4.4	21.2	21.7	10.8	30.6
			Total tally, board feet					
All diameters	22	3,365	180	346	1,121	1,011	248	459
			Percentage distribution					
			5.4	10.3	33.3	30.0	7.4	13.6

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	2.8	0.0	1.0	0.0	0.0	0.0
4/4	92.8	87.9	93.9	85.4	87.9	64.7
5/4	4.4	12.1	5.1	2.3	.0	.0
8/4	.0	.0	.0	3.2	6.5	10.0
9/4	.0	.0	.0	9.1	5.6	25.3
	Total tally, board feet					
	180	346	1,121	1,011	248	459

Table 14. – Log grade II

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
10	1	40	0.0	15.0	0.0	75.0	0.0	10.0
11	5	320	.0	.0	14.1	41.9	11.2	32.8
12	4	260	.0	6.5	13.1	43.1	10.4	26.9
13	8	616	.8	2.1	10.6	38.3	5.2	43.0
14	6	506	1.0	7.7	17.8	42.7	9.1	21.7
15	10	1,071	1.9	5.0	21.7	39.3	7.2	24.9
16	6	778	.0	2.1	19.0	54.3	8.4	16.2
17	4	559	2.9	8.8	40.0	25.4	3.4	19.5
18	8	1,238	.0	1.8	24.0	42.9	8.0	23.3
19	3	577	5.0	4.9	24.6	40.2	11.1	14.2
20	1	200	.0	3.5	39.5	22.5	8.0	26.5
22	1	215	11.6	4.2	48.4	13.0	3.7	19.1
			Total tally, board feet					
All diameters	57	6,380	100	260	1,460	2,550	489	1,521
			Percentage distribution					
			1.6	4.1	22.9	40.0	7.6	23.8

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	1.2	0.8	1.2	0.3
4/4	100.0	96.2	92.5	88.7	74.8	63.8
5/4	.0	3.8	6.3	5.3	.0	.8
8/4	.0	.0	.0	2.7	7.4	17.2
9/4	.0	.0	.0	2.5	16.6	17.9
	Total tally, board feet					
	100	260	1,460	2,550	489	1,521

Table 15. – Log grade III

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	5	112	0.0	0.0	0.0	51.8	12.5	35.7
9	9	265	.0	.0	3.0	40.4	10.9	45.7
10	11	469	.0	.0	7.5	47.3	6.0	39.2
11	13	554	.0	.0	.9	32.5	13.9	52.7
12	8	276	.0	.0	4.3	24.6	15.2	55.9
13	10	562	.0	.0	6.2	35.1	15.3	43.4
14	10	655	.0	.0	.6	33.9	20.9	44.6
15	4	358	.0	.0	7.5	49.8	17.0	25.7
16	3	306	.0	.0	19.0	54.2	10.1	16.7
17	3	266	.0	.0	6.8	40.6	21.8	30.8
18	1	118	.0	.0	6.8	49.9	29.7	13.6
			Total tally, board feet					
All diameters	77	3,941	0	0	210	1,565	598	1,568
			Percentage distribution					
			0	0	5.3	39.7	15.2	39.8

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	0.3	0.0
4/4	.0	.0	87.6	90.0	84.0	57.8
5/4	.0	.0	12.4	5.7	1.0	1.3
6/4	.0	.0	.0	.5	.0	.0
8/4	.0	.0	.0	2.4	6.7	24.7
9/4	.0	.0	.0	1.4	8.0	16.2
	Total tally, board feet					
	0	0	210	1,565	598	1,568

Table 16. — Construction class

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	3	92	0.0	0.0	0.0	13.0	4.3	82.7
9	3	92	.0	.0	.0	42.4	12.0	45.6
10	2	93	.0	.0	7.5	51.6	.0	40.9
14	1	63	.0	.0	25.4	38.1	.0	36.5
			Total tally, board feet					
All diameters	9	340	0	0	23	123	15	179
			Percentage distribution					
			0	0	6.8	36.2	4.4	52.6

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	0.0	0.0
4/4	.0	.0	100.0	91.9	100.0	49.1
5/4	.0	.0	.0	.0	.0	2.8
8/4	.0	.0	.0	8.1	.0	31.3
9/4	.0	.0	.0	.0	.0	16.8
	Total tally, board feet					
	0	0	23	123	15	179

Table 17. – Local-use class

Dry lumber grade yields, by scaling diameter, based on NHLA rules

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	1	15	0.0	0.0	0.0	0.0	0.0	100.0
9	3	74	.0	.0	.0	4.1	36.5	59.4
11	4	96	.0	.0	.0	16.7	9.4	73.9
12	1	31	.0	.0	.0	29.0	6.5	64.5
			Total tally, board feet					
All diameters	9	216	0	0	0	28	38	150
			Percentage distribution					
			0	0	0	13.0	17.6	69.4

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	5.3	0.0
4/4	.0	.0	.0	78.6	65.7	72.7
5/4	.0	.0	.0	21.4	.0	.0
6/4	.0	.0	.0	.0	7.9	.0
8/4	.0	.0	.0	.0	21.1	13.3
9/4	.0	.0	.0	.0	.0	14.0
	Total tally, board feet					
	0	0	0	28	38	150

Table 18. – Log grade I

Dry lumber grade yields, by scaling diameter, graded bark pockets no defect

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
13	2	129	0.0	0.0	9.3	64.3	9.3	17.1
14	2	221	4.1	18.1	24.9	33.0	13.1	6.8
15	1	72	.0	.0	30.6	20.8	25.0	23.6
16	2	194	12.9	7.7	24.7	45.9	6.2	2.6
17	4	546	14.7	15.6	38.2	21.0	5.9	4.6
18	4	664	3.8	6.6	43.2	26.8	5.6	14.0
19	2	356	9.3	13.2	39.9	28.9	1.1	7.6
21	4	980	24.9	4.9	32.8	25.3	3.7	8.4
26	1	203	15.8	.0	23.6	26.6	5.9	28.1
			Total tally, board feet					
ll ameters	22	3,365	448	279	1,145	958	192	343
			Percentage distribution					
			13.3	8.3	34.0	28.5	5.7	10.2

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	1.1	0.0	1.0	0.0	0.0	0.0
4/4	88.0	92.5	95.8	84.7	84.4	52.8
5/4	10.9	7.5	3.2	2.4	.0	.0
8/4	.0	.0	.0	3.3	8.3	13.4
9/4	.0	.0	.0	9.6	7.3	33.8
	Total tally, board feet					
	448	279	1,145	958	192	343

Table 19. – Log grade II

Dry lumber grade yields, by scaling diameter, graded bark pockets no defect

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
10	1	40	0.0	15.0	0.0	75.0	0.0	10.0
11	5	320	.0	.0	15.6	50.3	9.1	25.0
12	4	260	.0	6.5	13.1	43.1	10.4	26.9
13	8	616	2.6	2.1	24.1	37.8	2.9	30.5
14	6	506	1.0	7.7	20.0	41.4	9.1	20.8
15	10	1,071	6.4	3.7	33.0	30.1	4.5	22.3
16	6	778	.0	2.1	23.1	50.2	8.4	16.2
17	4	559	5.2	8.4	40.1	33.8	1.8	10.7
18	8	1,238	2.8	1.1	37.2	34.9	8.0	16.0
19	3	577	5.0	4.9	24.6	43.7	11.1	10.7
20	1	200	.0	3.5	43.5	37.0	8.0	8.0
22	1	215	11.6	9.3	43.3	21.4	.0	14.4
			Total tally, board feet					
All diameters	57	6,380	207	247	1,872	2,453	422	1,179
			Percentage distribution					
			3.2	3.9	29.3	38.5	6.6	18.5

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	1.0	0.8	1.4	0.3
4/4	100.0	96.0	94.1	88.2	70.9	53.3
5/4	.0	4.0	4.9	5.6	.0	1.0
8/4	.0	.0	.0	2.8	8.5	22.2
9/4	.0	.0	.0	2.6	19.2	23.2
	Total tally, board feet					
	207	247	1,872	2,453	422	1,179

Table 20. – Log grade III

Dry lumber grade yields, by scaling diameter, graded bark pockets no defect

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	5	112	0.0	0.0	0.0	51.8	12.5	35.7
9	9	265	.0	.0	4.9	38.5	10.9	45.7
10	11	469	.0	.0	7.5	47.3	6.0	39.2
11	13	554	.0	.0	3.6	36.8	13.9	45.7
12	8	276	.0	.0	6.5	33.3	11.6	48.6
13	10	562	.0	.0	8.2	35.4	13.7	42.7
14	10	655	.0	.0	.6	35.6	19.2	44.6
15	4	358	2.0	1.1	22.1	40.2	14.8	19.8
16	3	306	.0	.0	20.3	52.9	10.1	16.7
17	3	266	.0	.0	6.8	40.6	21.8	30.8
18	1	118	.0	.0	6.8	49.9	29.7	13.6
			Total tally, board feet					
All diameters	77	3,941	7	4	303	1,583	560	1,484
			Percentage distribution					
			0.1	0.2	7.7	40.2	14.2	37.6

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	0.4	0.0
4/4	100.0	100.0	91.4	90.0	82.8	55.5
5/4	.0	.0	8.6	5.6	1.1	1.4
6/4	.0	.0	.0	.5	.0	.0
8/4	.0	.0	.0	2.5	7.1	26.0
9/4	.0	.0	.0	1.4	8.6	17.1
	Total tally, board feet					
	7	4	303	1,583	560	1,484

Table 21. – Construction class

Dry lumber grade yields, by scaling diameter, graded bark pockets no defect

Scaling diameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	3	92	0.0	0.0	0.0	13.0	4.3	82.7
9	3	92	.0	.0	.0	42.4	12.0	45.6
10	2	93	.0	.0	7.5	51.6	.0	40.9
14	1	63	.0	.0	25.4	38.1	.0	36.5
			Total tally, board feet					
All diameters	9	340	0	0	23	123	15	179
			Percentage distribution					
			0	0	6.8	36.2	4.4	52.6

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	0.0	0.0
4/4	.0	.0	100.0	91.9	100.0	49.1
5/4	.0	.0	.0	.0	.0	2.8
8/4	.0	.0	.0	8.1	.0	31.3
9/4	.0	.0	.0	.0	.0	16.8
	Total tally, board feet					
	0	0	23	123	15	179

Table 22. – Local-use class

Dry lumber grade yields, by scaling diameter, graded bark pockets no defect

Scaling iameter	Logs	Total dry tally	Lumber grade					
			Fas	Sel	1C	2C	3A	3B
Inches	No.	Board feet	Percent of total dry tally					
8	1	15	0.0	0.0	0.0	0.0	0.0	100.0
9	3	74	.0	.0	.0	4.1	36.5	59.4
11	4	96	.0	.0	.0	16.7	9.4	73.9
12	1	31	.0	.0	.0	29.0	6.5	64.5
			Total tally, board feet					
ll ameters	9	216	0	0	0	28	38	150
			Percentage distribution					
			0	0	0	13.0	17.6	69.4

Distribution of above yields by thickness

Lumber thickness	Lumber grade					
	Fas	Sel	1C	2C	3A	3B
Inches	Percent within grade					
3/4	0.0	0.0	0.0	0.0	5.3	0.0
4/4	.0	.0	.0	78.6	65.7	72.7
5/4	.0	.0	.0	21.4	.0	.0
6/4	.0	.0	.0	.0	7.9	.0
8/4	.0	.0	.0	.0	21.1	13.3
9/4	.0	.0	.0	.0	.0	14.0
	Total tally, board feet					
	0	0	0	28	38	150

Table 23. – Lumber grade yields for balsam poplar in Alaska and eastern cottonwood

Log grades	Lumber grade						
	Fas	Sel	1C	2C	3A	3B	3C
	Percent of total dry tally						
	BALSAM POPLAR IN ALASKA						
I	5.4	10.3	33.3	30.0	7.4	13.6	––
II	1.6	4.1	22.9	40.0	7.6	23.8	––
III	.0	.0	5.3	39.7	15.2	39.8	––
	BALSAM POPLAR IN ALASKA (BARK POCKETS NO DEFECT)						
I	13.3	8.3	34.0	28.5	5.7	10.2	––
II	3.2	3.9	29.3	38.5	6.6	18.5	––
III	.1	.2	7.7	40.2	14.2	37.6	––
	EASTERN COTTONWOOD						
I	34.4	6.4	31.1	23.7	––	––	4.4
II	8.0	3.9	39.9	40.3	––	––	7.9
III	1.3	1.0	30.5	59.2	––	––	8.0

BALSAM POPLAR IN ALASKA

Table 24. — Log grade I
Overruns based on dry lumber tally

caling ameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
nches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
13	2	129	185	161	-19.9	150	121	6.6
14	2	221	235	219	.9	200	180	22.8
15	1	72	135	111	-35.1	120	92	-21.7
16	2	194	260	232	-16.4	240	207	-6.3
17	4	546	740	637	-14.3	660	538	1.5
18	4	664	830	766	-13.3	780	698	-4.9
19	2	356	450	392	-9.2	420	354	.6
21	4	980	1,240	1,101	-11.0	1,170	1,017	-3.6
26	1	203	290	238	-14.7	280	216	-6.0
Total	22	3,365	4,365	3,857	-12.8	4,020	3,423	-1.7

BALSAM POPLAR IN ALASKA

Table 25. — Log grade II
Overruns based on dry lumber tally

caling iameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
nches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
10	1	40	65	57	-29.8	60	48	-16.7
11	5	320	355	337	-5.0	280	260	23.1
12	4	260	265	261	-.4	230	226	15.0
13	8	616	725	681	9.5	600	552	11.6
14	6	506	610	543	-6.8	530	459	10.2
15	10	1,071	1,325	1,213	-11.7	1,200	1,067	.4
16	6	778	885	828	-6.0	800	726	7.2
17	4	559	685	641	-12.8	620	568	-1.6
18	8	1,238	1,510	1,419	-12.8	1,410	1,302	-4.9
19	3	577	780	626	-7.8	720	548	5.3
20	1	200	290	246	-18.7	280	228	-12.3
22	1	215	260	208	3.4	250	187	15.0
Total	57	6,380	7,755	7,060	-9.6	6,980	6,171	3.4

BALSAM POPLAR IN ALASKA

Table 26. – Log grade III
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	5	112	125	125	-10.4	80	80	40.0
9	9	265	345	335	-20.9	300	291	-8.9
10	11	469	570	523	-10.3	490	446	5.2
11	13	554	685	637	-13.0	520	481	15.2
12	8	276	445	406	-32.0	390	341	-19.1
13	10	562	795	745	-24.6	670	624	-9.9
14	10	655	990	904	-27.5	870	780	-16.0
15	4	358	440	425	-15.8	420	406	-11.8
16	3	306	420	373	-18.0	380	320	-4.4
17	3	266	340	336	-20.8	320	316	-15.8
18	1	118	170	151	-21.9	160	134	-11.9
Total	77	3,941	5,325	4,960	-20.5	4,600	4,219	-6.6

BALSAM POPLAR IN ALASKA

Table 27. – Construction class
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	3	92	100	100	-8.0	70	70	31.4
9	3	92	125	125	-26.4	90	90	2.2
10	2	93	95	95	-2.1	90	90	3.3
14	1	63	80	80	-21.3	70	70	-10.0
Total	9	340	400	400	-15.0	320	320	6.2

BALSAM POPLAR IN ALASKA

Table 28. — Local-use class
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	1	15	15	15	0.0	10	10	50.0
9	3	74	85	85	-12.9	80	80	-7.5
11	4	96	170	167	-42.5	150	147	-34.7
12	1	31	45	40	-22.5	40	35	-11.4
Total	9	216	315	307	-29.6	280	272	-20.6

BALSAM POPLAR IN ALASKA

Table 29. — All logs
Overruns based on dry lumber tally

Scaling diameter	Logs	Total dry tally	International 1/4-inch log rule			Scribner Decimal-C log rule		
			Scale		Overrun	Scale		Overrun
			Gross	Net		Gross	Net	
Inches	No.	Board feet	Board feet	Board feet	Percent	Board feet	Board feet	Percent
8	9	219	240	240	-8.8	160	160	36.9
9	15	431	555	545	-20.9	470	461	-6.5
10	14	602	730	675	-10.8	640	584	3.1
11	22	970	1,210	1,141	-15.0	950	888	9.2
12	13	567	755	707	-19.8	660	602	-5.8
13	20	1,307	1,705	1,587	-17.6	1,420	1,297	.8
14	19	1,445	1,915	1,746	-17.2	1,670	1,489	-3.0
15	15	1,501	1,900	1,749	-14.2	1,740	1,565	-4.1
16	11	1,278	1,565	1,433	-10.8	1,420	1,253	2.0
17	11	1,371	1,765	1,614	-15.1	1,600	1,422	-3.6
18	13	2,020	2,510	2,336	-13.5	2,350	2,134	-5.3
19	5	933	1,230	1,018	-8.3	1,140	902	3.4
20	1	200	290	246	-18.7	280	228	-12.3
21	4	980	1,240	1,101	-11.0	1,170	1,017	-3.6
22	1	215	260	208	3.4	250	187	15.0
26	1	203	290	238	-14.7	280	216	-6.0
Total	174	14,242	18,160	16,584	-14.1	16,200	14,405	-1.1

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Natural Reforestation On A Mile-Square Clearcut In Southeast Alaska

By A. S. Harris

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Pacific Northwest Forest and Range Experiment Station
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Juneau, Alaska

CONTENTS

INTRODUCTION

Prompt and adequate restocking of cutover land is a primary concern of forest managers. After clearcutting, the forest cover must be re-established promptly to restore the landscape's natural beauty, to minimize erosion, and to assure a sustained yield of timber from productive forest land. Natural regeneration requires little or no investment and so is preferable if the resulting stands compare favorably with those originating under artificial methods.

Large-scale timber harvesting in Alaska began in 1953, providing timber for the State's first modern pulpmill. A second mill entered production in 1959, and more are expected to follow. A study of natural regeneration began in 1954 on the Maybeso Experimental Forest near Hollis, Prince of Wales Island, Alaska. One cutting unit, referred to here as the "mile-square" unit (fig. 1), was made especially large to determine distance of seed dispersal. This 700-acre cutting unit is approximately square and has a southwest exposure. It varies in steepness from a flat flood plain adjacent to Maybeso Creek to upper slopes in excess of 100 percent (45°). Elevation of the cutting unit ranges from 100 to 1,700 feet above sea level. Soils[1/] on the steep upper slopes are of the Karta series, consisting of moderately well-drained, very gravelly, loam soils derived from glacial till, and Tolstoi series of well-drained, very stony, silt loam soils overlying bedrock. On moderate slopes near the toe of steep slopes are moderately well-drained Karta soils derived from glacial till and well-drained soils (presently unclassified) from alluvial fan deposits. Imperfectly drained Wadleigh (very gravelly, silt loam soils) occur on glacial moraines and drumlins. Well-drained Tonowek loam and Tuxekan silt loam soils are common on the flat valley bottom. All but the Tonowek are podzols with thick, organic surface layers. Tonowek is a weakly developed alluvial soil.

The climate of Maybeso valley, as in all of southeast Alaska, is generally cool and moist

1/ Gass, C. R.; Billings, R. S.; Stevens, M. E.; and Stephens, F. R. Hollis area soil management report. (In preparation for publication, U.S. Forest Serv., Region 10.) Official soil series descriptions are available from U.S. Soil Conservation Service and U.S. Forest Service.

Figure 1.—The mile-square cutting unit lies between two timbered leave strips. Maybeso Experimental Forest, near Hollis, Alaska.

(Andersen 1955a).[2] The growing season extends from mid-May to mid-October. During the years 1954 to 1962, January temperatures were coldest with a 9-year average of 31.9° F. July was warmest with an average temperature of 58.3° F. Average monthly temperatures exceeded 60° F. during only 6 months: August 1954, 60.2° F.; August 1957, 62.2° F.; June 1958, 61.4° F.; July 1958, 62.2° F.; July 1961, 60.5° F.; and August 1961, 60.3° F.

Average annual precipitation during the years 1954 to 1962 was 104 inches. Precipitation was usually well distributed throughout each of the years with an average July low of 3.04 inches and an October high of 18.48 inches. During the 9-year period, at least 1.5 inches of precipitation fell each month with the exception of 4 months—0.42 inch during August 1954, 0.91 inch during July 1955, 0.56 inch during June 1958, and 0.80 inch during February 1962.

Within the growing season, the most noteworthy departure from the norm occurred during the abnormally hot and dry summer of 1958. From May 22 through July 18, only 0.61 inch of rain fell and daily maximum temperatures averaged 72° F. The highest temperature during the 9-year period occurred on June 3, 1958, when a maximum of 91° F. was recorded.

Logging on the mile-square cutting unit began in 1954 and was completed in 1957, with most done during 1954 and 1955. Logging was done by the high-lead system except for small areas that were tractor logged. The stand harvested was typical old growth composed of about 76 percent western hemlock,[3] 20 percent Sitka spruce, and 2 percent each of western redcedar and Alaska-cedar. Net timber volumes averaged 37,000 board feet (Scribner) per acre. Logging slash was left unburned.

This report describes restocking of the mile-square cutting unit in the first 9 years after logging began. It follows a progress report by James and Gregory (1959) describing regeneration on the cutting unit in 1958. Previous work by James and Gregory has been used freely throughout.

[2] Names and dates in parentheses refer to Literature Cited, p.16.

[3] Scientific names of plants mentioned are on page 15.

METHODS

For sampling tree regrowth, the cutting unit was divided into four zones, each 10 chains[4] wide, by distance from seed source (fig. 2). In 1957, after logging was completed,[5] 294 1-milacre circular plots were established and their centers marked with permanent stakes. Plot locations were selected randomly from a 2-chain grid superimposed on a cutting map. The number of plots sampled in each zone was allocated proportionately by area. These plots were reexamined during later surveys. A total of 308 plots were examined in 1958, 325 in 1960, and 321 in 1962. Differences in plot numbers examined during each survey were due to the loss of plots from roadbuilding or other ground disturbance and to additional plot establishment.

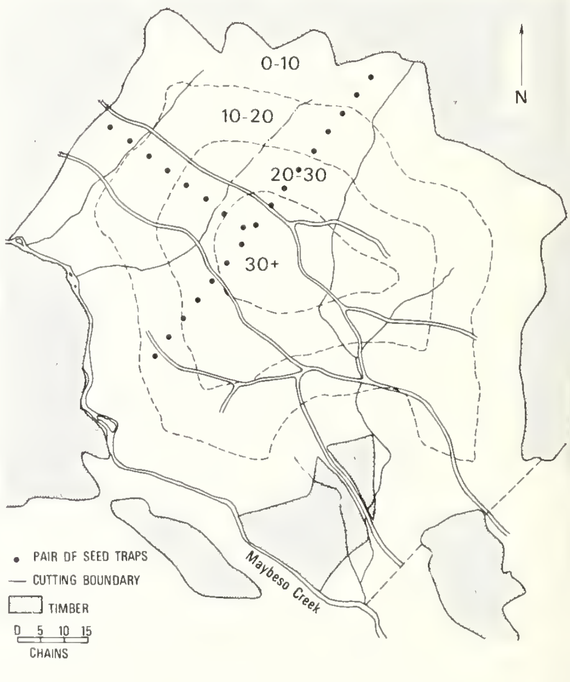

Figure 2.—Mile-square cutting unit, Maybeso Experimental Forest showing seedtrap locations and 10-chain zones indicating distance from seed source.

[4] "Chain" as used in this paper is 66 feet.

[5] Approximately 350 acres were surveyed in 195[illegible] when logging was still in progress. This survey included 162 4-milacre quadrats, each divided into four 1-milacre plots.

Seedlings were counted on 1-milacre circular plots and listed in three classes: Seedlings that germinated before the stand was harvested and that survived logging were called advanced; those that germinated after logging were called subsequent; within the latter group, seedlings less than 1 year old were listed separately. In 1962, cover type or ground conditions were described on each plot that contained no seedlings.

In addition to stocking percent measured on 1-milacre plots, stocking was also determined on 4-milacre circular plots located at each 1-milacre plot location. The height and species of the dominant seedling on each 4-milacre plot were recorded.

To provide information on seed dispersal, 48 seedtraps (2 feet by 3 feet) were installed on the cutting unit during August 1956 (fig. 3). Traps were placed in pairs, 33 feet apart, at 5-chain intervals for a distance of 1 mile from the upper timber edge in a southwesterly direction beginning 5 chains from timber (fig. 2). Another line of paired traps with the same spacing was placed in a southeasterly direction, beginning 5 chains from the west timber edge. Four seedtraps were placed in adjacent uncut timber. Traps were examined annually. To insure that seed came only from outside the cutting unit, residual trees of seed-bearing age left within the cutting unit were either felled or poisoned before seed ripened in 1956.

Figure 3.—Box-type seedtrap used to determine seed dispersal distance. Mile-square cutting unit, Maybeso Experimental Forest.

During the heavy seed crop of 1959-60, a daily record of seedfall was obtained from four seedtraps located in a timber stand about 1 mile east of the mile-square cutting unit. Weather records were obtained at a station midway between the cutting unit and the seed-trapping location. Traps were examined daily from October 1 through December 28, and finally in July 1960.

To determine the effect of seedbed and drainage on seedling establishment and early survival, forty-two 1-milacre plots representing seven seedbed conditions and two drainage classes, with three replications each, were selected or prepared in the spring of 1957. In May 1957, all plots were seeded with 100 seeds each of endrin-treated western hemlock and Sitka spruce to assure that some seed were present. The number of seed contributed to each plot from the natural seed source is not known. Seedling counts were made late in the summer of 1957 and annually thereafter until 1960. Seedlings were staked to show the year of germination.

Survival and growth of advanced seedlings were observed on eight ¼-milacre plots—four on well-drained alluvial soil and four on imperfectly drained Wadleigh soil. Plots included dense clumps of advanced seedlings, some of which were expected to survive. Survival and total height of seedlings were recorded in late summers from 1955 until 1961.

Table 1.—*Average annual seed catch since logging; mile-square cutting unit, Maybeso Experimental Forest*

SEED YEAR	AVERAGE SEEDS PER TRAP (6 square feet)	SPECIES COMPOSITION		
		Hemlock	Spruce	Cedar
	Number	- - -	*Percent*	- - -
1956-57[1/]	10.8	37	38	25
1957-58	13.8	95	3	2
1958-59	1.9	48	37	15
1959-60	40.8	39	46	15
1960-61	1.8	28	57	15
1961-62	.2	89	11	0

[1/] Incomplete data—include counts only until January 20, 1957.

RESULTS AND DISCUSSION

SEED PRODUCTION AND DISPERSAL DISTANCE

Seedtraps maintained in the cutover from 1956 to 1962 showed that some seed were dispersed from surrounding timber each year (table 1). However, only the 1957-58 and 1959-60 trap catches were large enough to provide meaningful estimates of seed dispersal distance.

The most striking relationship between trap catch and distance from seed source was provided by the 1959-60 seed crop (fig. 4). Seedfall decreased sharply up to 30 chains from seed source, less sharply thereafter. In comparison, the 1957-58 seed crop appeared to be more uniformly dispersed throughout the range of distance, although the relationship of trap catch to distance from seed source was highly significant.

An indirect measure of seed dispersal distance was provided by number of seedlings germinating from the two largest crops (table 2). Although overwinter storage and germination tend to obscure the relationship, the similar pattern of seedling establishment from the two crops is apparent. In both cases, number of seedlings germinating in each distance zone dropped sharply from the edge of timber to the 20- to 30-chain zone, increasing slightly in the

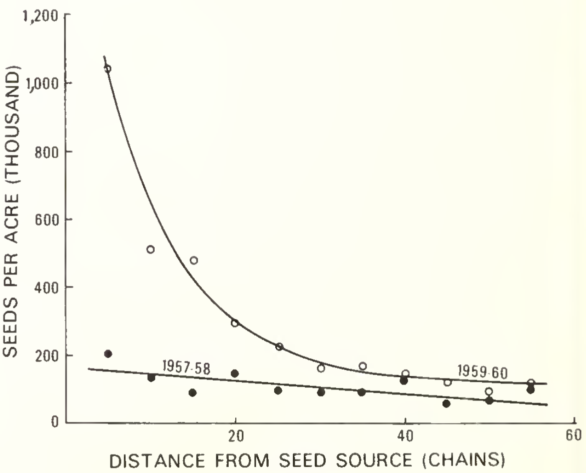

Figure 4.—Seed dispersal by distance from seed source, 1956-57 and 1959-60. Mile-square cutting unit, Maybeso Experimental Forest.

30+-chain zone. Percentage of plots in each zone stocked with at least two new seedlings followed a similar pattern by zone (table 2).

Seed production in uncut timber adjacent to the cutting unit was measured only during the 1957-58 seed year. Approximately 3.5 million seeds per acre were produced, 36 percent of which appeared sound by cutting test.

Table 2.—*A comparison of seedling germination following the two best seed years since logging; mile-square cutting unit, Maybeso Experimental Forest*

SEED YEAR	YEAR OF GERMINATION	CHAIN ZONE 0-10	10-20	20-30	30+	ADJUST MEAN
		Stems per acre				
1957-58	1958	2,660	1,430	550	780	1,698
1959-60	1960	11,225	3,257	1,525	1,906	6,092
		1-milacre stocking percentage [1]				
1957-58	1958	31	23	12	15	23
1959-60	1960	71	56	32	34	56

[1] At least two seedlings.

TIME OF SEED DISPERSAL

Seedfall occurred late in 1956. Almost no seed were released during September, October, or November. Many seed were dispersed on December 3 and 4 during clear, cold weather accompanied by strong northeast winds. On December 6, about 5 inches of snow lay on the cutting unit, and spruce and hemlock seeds were evenly distributed on the snow in protected spots. On windswept areas, seeds were concentrated in sheltered pockets, around obstacles, and in numerous melt pockets on the snow surface. Apparently, when slash is covered by snow, seed may be dispersed to greater distances by blowing along the snow surface.

Seedfall in 1958-59 was extremely light, making detailed observations impossible. However, the first light seedfall was observed early in December.

A detailed record of seedfall and associated weather conditions was obtained from October 1 through December 28 during the heavy seed year of 1959-60. In southeast Alaska, fall is typically wet with south to southeast winds. This weather pattern prevailed in 1959, and the first dry period after seed ripened began on October 4.

The first seeds, consisting of Sitka spruce and western redcedar, fell on October 6, the second consecutive day of no rainfall (fig. 5). Small amounts of seed continued to fall sporadically through November 10. During this period, minimum temperatures remained generally above freezing and rainfall persisted almost continuously. During the 5 days from November 11 through November 15, the heaviest seedfall of the test period took place—61 percent of the total amount of western hemlock seed, 73 percent of spruce, and 92 percent of western redcedar.

From November 16, 1959, through the end of the test period, precipitation remained generally uniform and persistent. Seed continued to fall at a reduced rate through December 28, 1959, when the study was discontinued. A count of trapped seed in July 1960 showed that the bulk of seedfall occurred after December 28, 1959. Total seed dispersed during the test period was 9.4 percent for hemlock, 22.2 percent for spruce, and 40.7 percent for western redcedar. Total seed production from October 6, 1959, through July 1960 was 26,646,000 western hemlock, 3,383,000 Sitka spruce, and 42,179,000 western redcedar seeds per acre.

During the 5 days of heaviest seedfall, prevailing wind direction was northerly with average hourly velocities up to 6 miles per hour, and gusts up to 20 miles per hour were estimated. On the last day of exceptionally heavy seedfall, wind direction switched to southerly shortly before noon. Temperatures were below freezing during the 5 days except for a maximum of 37 F. on November 11. No precipitation occurred during the period except for 0.12 inch of dry snow on November 13. Although including only part of the period during which seedfall occurred, the test confirmed previous observations that cones open during clear, cold weather. In southeast Alaska, northerly winds are generally associated with periods of dry weather, although local wind direction may be modified greatly by topography.

SUBSEQUENT SEEDLING GERMINATION AND EARLY SURVIVAL

The effect of seedbed and drainage conditions on germination and early survival was noted on seven seedbed types and two drainage classes (table 3). Seedlings germinating in 1957 were from sown seed and natural seedfall, whereas those germinating in 1958 were from natural seedfall alone.

Imperfectly drained mineral soil offered the best seedbed for establishment and early survival of both hemlock and spruce. During the abnormally hot and dry summer of 1958, partial shade offered by moderate slash appeared to aid seedling establishment. The additional moisture offered by imperfectly drained seedbeds was especially helpful for seedling establishment during this dry season, and few seedlings became established on well-drained seedbeds.

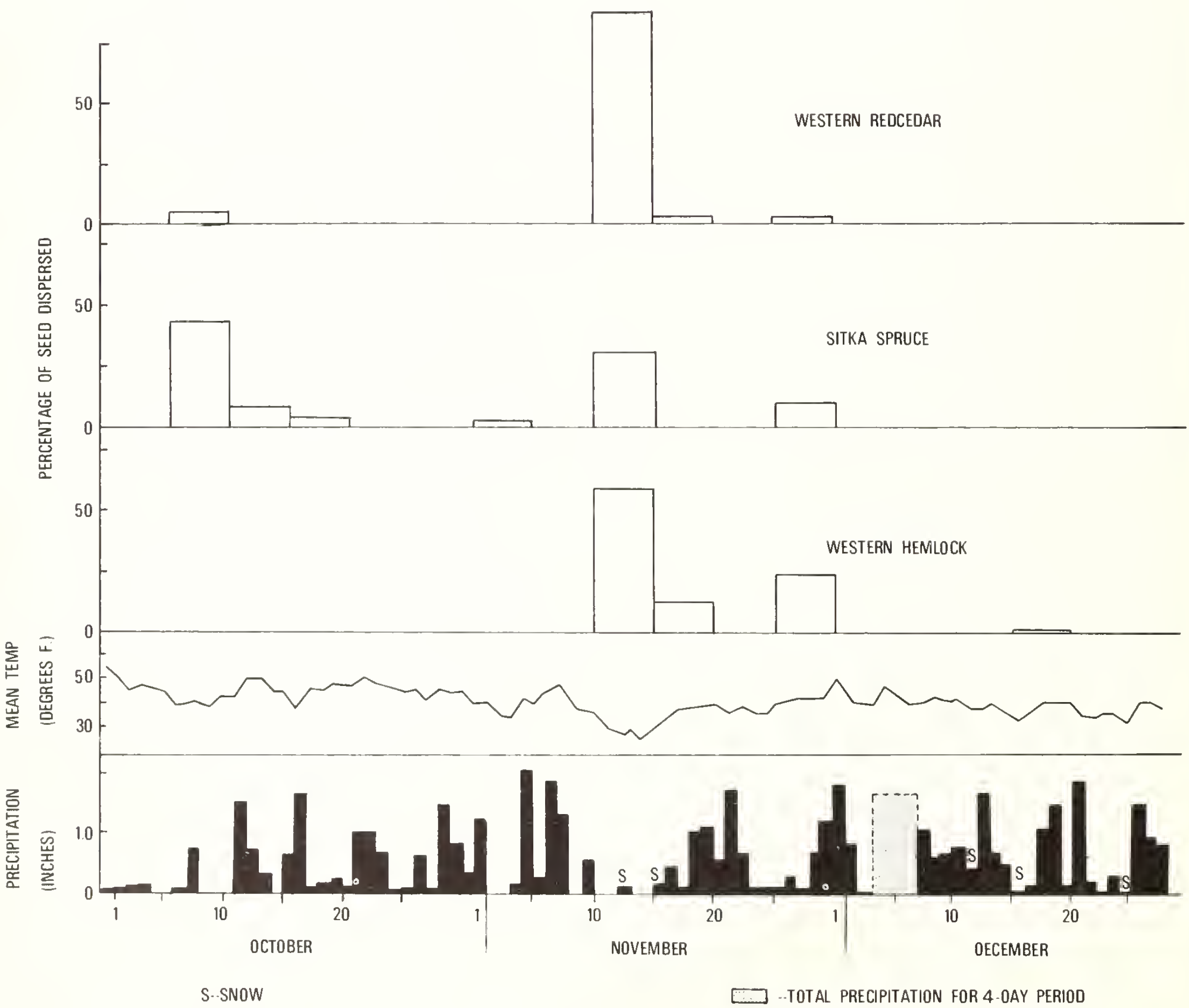

Figure 5.—Time of seed dispersal—October through December 1959. Maybeso Experimental Forest.

Table 3.—*Germination and survival of western hemlock and Sitka spruce seedlings, by drainage and seedbed conditions; mile-square cutting unit, Maybeso Experimental Forest*

YEAR OF GERMINATION AND SEEDBED CONDITIONS	GERMINATION			SURVIVAL AFTER: One growing season			SURVIVAL AFTER: Two growing seasons		
	Imperfect drainage		Good drainage	Imperfect drainage		Good drainage	Imperfect drainage		Good drainage
	Number of seedlings per 1-milacre plot								
1957:									
Mineral soil	†80	*	56	19	—	2	†15	*	1
Low shrub over moss	10	—	9	2	*	4	2	—	2
Slash over mineral soil	30	—	36	4	—	4	3	—	4
Rotten wood	38	*	15	11	*	3	6	*	3
Slash over moss	13	*	3	3	*	0	3	—	0
Moss	47	*	12	26	*	1	†26	*	1
Disturbed organic	47	*	17	9	*	6	4	—	4
1958:									
Mineral soil	†42	*	4	†35	*	3	†34	*	2
Low shrub over moss	8	*	2	2	—	1	1	—	1
Slash over mineral soil	†61	*	20	†46	*	14	†42	*	11
Rotten wood	10	*	6	7	*	4	7	*	3
Slash over moss	5	*	0	4	*	0	1	*	0
Moss	12	*	0	8	*	0	8	*	0
Disturbed organic	12	*	2	7	*	2	5	*	2

*Indicates a significant difference (at the 5-percent level) between drainage conditions within the same seedbed and year of germination.

†Indicates a significant difference (at the 5-percent level) between seedbed conditions so marked and those without symbol.

In 1957, imperfectly drained moss proved to be a good seedbed, but during 1958 few or no seedlings became established on imperfectly drained moss and none on well-drained moss seedbeds. In southeast Alaska, feather mosses, such as *Hylocomium* and others, are common beneath mature timber stands. After clearcutting, these shade-loving species give way to hair mosses, such as *Polytrichum* and others, which may immediately invade well-drained mineral soil. These mosses bind the surface, thereby preventing surface erosion. On drying out, they dissipate surface heat rapidly so that temperatures lethal to tree seedlings are seldom encountered (Smith 1951). As a general observation, spruce became established more readily on mineral soil after the invasion of hair mosses.

Germination and survival did not differ significantly by species except in the case of moss-covered seedbeds during 1958, when more spruce became established from natural seedfall and more of the spruce seedlings established the previous year survived.

Early height growth did not differ significantly by drainage classes, seedbeds, or species. Average heights of 1-, 2-, and 3-year-old seedlings on all seedbeds combined were 0.1, 0.2, and 0.5 foot, respectively.

ADVANCED REGENERATION

Survival and growth of advanced regeneration were measured on eight ¼-milacre (3.3 feet by 3.3 feet) plots located on imperfectly drained Wadleigh soil and well-drained alluvial soils within the mile-square cutting unit in the spring of 1955. Logging had been completed the preceding fall. Seedling numbers ranged from 11 to 75, averaging 40 on well-drained plots, and from 35 to 121 with an average of 77 on imperfectly drained plots. Initial species composition was 78 percent hemlock and 22 percent spruce on well-drained plots, 93 percent hemlock and 7 percent spruce on imperfectly drained plots.

Seven growing seasons later (1961), 55 percent of the seedlings survived on well-drained plots and 39 percent on imperfectly drained plots. Differences in survival were not significant. Greatest mortality occurred among seedlings less than 6 inches tall during the first 2 years following logging. Mortality decreased sharply during the next 2 years, and 4 to 7 years after logging almost no mortality occurred. By 1961 the remaining seedlings were competing for growing space within dense thickets (fig. 6). Dominance was well expressed

Figure 6.—Advanced seedlings on well-drained plot 8 years after logging. Mile-square cutting unit, Maybeso Experimental Forest.

by a few, and there was no evidence of stagnation.

Height growth over the 7-year test period was significantly better on well-drained plots. Hemlock grew faster than spruce on both drainages. On well-drained plots, release was evident the fourth growing season after logging (fig. 7). Average annual height growth of the three largest seedlings on each well-drained plot was 3.5 inches for the first three growing seasons after logging, 20 inches annually thereafter. On imperfectly drained plots, height growth of the three largest seedlings averaged 2 inches for the first 2 years after logging, 8 inches thereafter. Spruce showed release but to a lesser extent.

Dominant hemlock seedlings on well-drained plots reached breast height 5 years after logging. Dominant hemlock seedlings on imperfectly drained plots had not reached breast height at the termination of the study, but their growth rate indicated that they would likely reach it 8 years after logging. In 1961, species composition was 78 percent hemlock and 22 percent spruce on well-drained plots, 91 percent hemlock and 9 percent spruce on imperfectly drained plots.

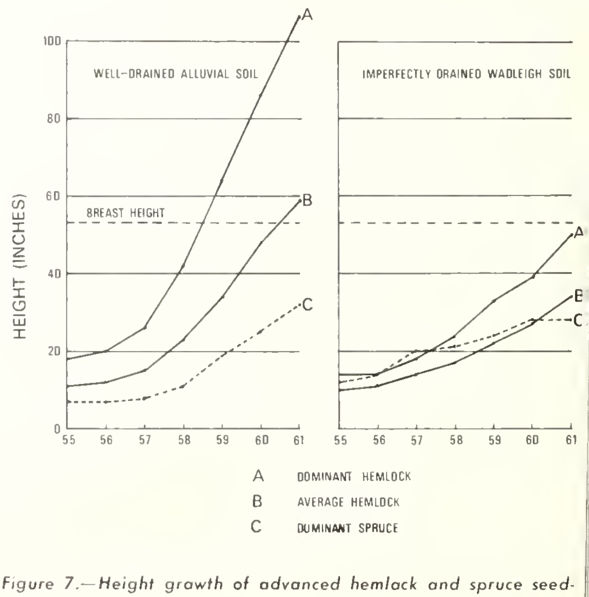

Figure 7.—Height growth of advanced hemlock and spruce seedlings by year on two sites. Mile-square cutting unit, Maybeso Experimental Forest.

TREND IN STOCKING SINCE LOGGING

The dynamic nature of natural restocking is apparent from changes in seedlings per acre and stocking percent since logging. Successive seed crops added seedlings, and mortality claimed all but the most firmly established. However, the number of seedlings 1 year and older changed little during the years following logging (fig. 8). In 1955, the area logged in 1954 contained predominantly advanced seedlings which had escaped logging. The few new seedlings present were located along roads and other areas previously disturbed. After 3 years, the effect of two seed crops was evident, with less than 1- and 2-year-old seedlings more than offsetting mortality of advanced seedlings. In 1960 many seedlings germinated from the excellent 1959-60 seed crop. Hemlock germinated profusely on a wide variety of seedbeds, many of which proved to be incapable of sustaining growth. Mortality of advanced reproduction continued. By 1962 most of the seedlings which germinated in 1960 were gone, the few remaining little more than offsetting losses of older seedlings. Advanced and subsequent seedlings were not tallied separately.

During the 8 years since logging, the percentage of plots stocked with at least one 1-year-old seedling showed a consistent increase from 38 to 69 percent (fig. 9). Thus, regeneration surveys should not be made too soon after logging. Five years appears to be a reasonable time to allow for natural regeneration, and extensive surveys should not be made sooner. If we also accept two or more 1st-year seedlings as evidence of stocking, the changes are less consistent, showing the influence of good seed years and heavy mortality of new sprouts. Because of this high initial mortality, two or more 1st-year seedlings should not be considered as evidence of stocking, and 1st-year seedlings should not be counted when seedling density is estimated.

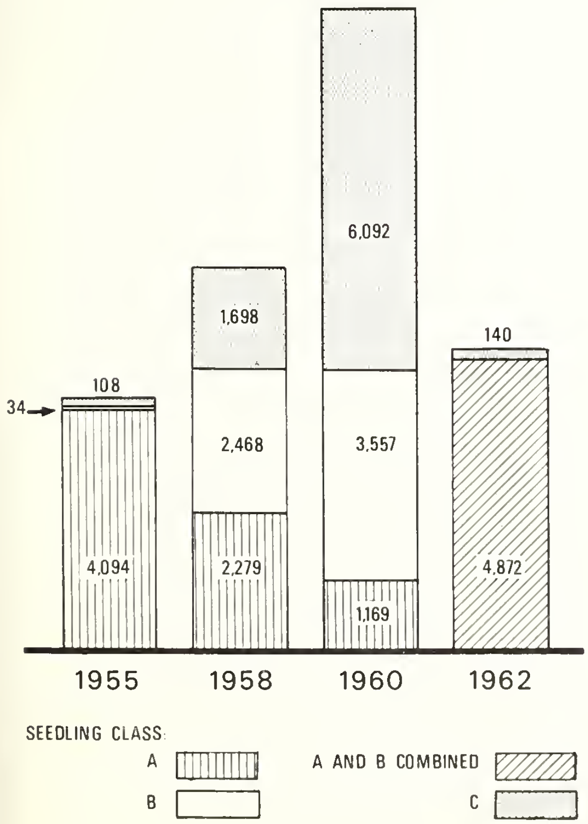

Figure 8.—Average number of seedlings per acre by year and age class: A—advanced seedlings; B—subsequent seedlings at least 1 year old; C—less than 1 year old. Mile-square cutting unit Maybeso Experimental Forest.

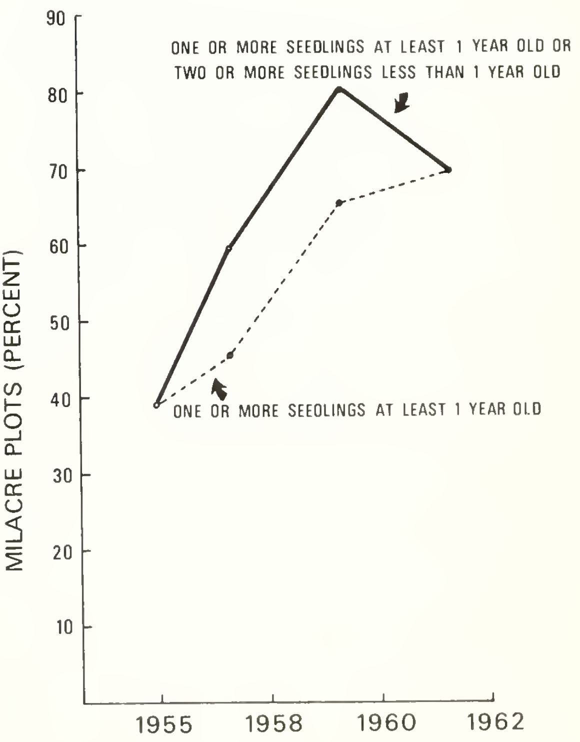

Figure 9.—Percentage of 1-milacre plots stocked by year. Mile-square cutting unit, Maybeso Experimental Forest.

REPRODUCTION 8 YEARS AFTER LOGGING

In 1962, 8 years after logging began, the mile-square cutting unit, as a whole, was well stocked. Stocking percent on the basis of both 1-milacre and 4-milacre plots decreased with increasing distance from seed source, with stocking of all zones within the level considered desirable by regional standards[6] (table 4). Stand density, as measured by number of seedlings per acre, decreased with increasing distance from seed source to 30 chains, increasing slightly beyond.

Table 4.—*Regeneration conditions on cutting unit 8 years after logging began (1962); mile-square cutting unit, Maybeso Experimental Forest*

DISTANCE FROM SEED SOURCE (CHAINS)	PLOTS STOCKED[1]		STAND DENSITY		
	1-milacre	4-milacre	Total stand	Seedlings at least 1 year old	Seedlings at least 1 year old (limit 15 per milacre plot)
	Percent		*Stems per acre*		
0-10	77	88	7,215	6,900	4,938
10-20	68	82	4,220	4,180	3,740
20-30	63	78	2,627	2,627	2,203
30+	53	75	2,940	2,940	2,938
Adjusted mean	69	83	5,012	4,872	4,305

[1] At least one seedling over 1 year old.

The difficulty of sampling natural regeneration is well known. Stocking percent, based as it is on a unit of area, gives an indication of seedling dispersal and defines the minimum number of seedlings per acre. For example, if 100 percent of 4-milacre (1/250 acre) plots were stocked, at least 250 trees per acre would be present. One-hundred-percent stocking of 1-milacre (1/1,000 acre) plots would likewise mean that at least 1,000 trees per acre were present. However, because stocked plots often contain more than one seedling, stocking percent gives no indication of the actual number of seedlings present.

On the other hand, stand density, measured by the average number of seedlings per acre, can be misleading since it tells nothing about seedling distribution. This is especially true in the case of natural regeneration, which is characteristically uneven or patchy because of differences in microsites, seedfall pattern, vegetation competition, ground disturbance, and other factors. Taken together, stocking percent and number of seedlings per acre provide a more detailed description of reforestation.

When small plots are sampled, uneven seedling distribution results in many plots with few or no seedlings and an occasional plot with many seedlings. In the past, attempts have been made to reduce the effect of plots containing dense clumps of seedlings by limiting the number of seedlings counted on each plot. For example, Cowlin (1932) limited seedling counts to 11 on 4-milacre plots. Munger (1945) limited seedlings to 15 on 4-milacre plots, and Allen et al. (1951) limited seedling counts to 12 trees on 1-milacre plots or 24 trees on 4-milacre plots.

In the study reported here, the tendency of seedlings to occur in clumps was apparent (table 5). Hemlock seedlings tended to occur in dense clumps more often than spruce or cedar. Because few 1-milacre plots contained more than 15 seedlings, this was chosen as an upper limit to be counted in some of the office calculations. Limiting seedling counts to 15 gave less weight to the few extremely dense plots, reducing the estimated average number of stems per acre on the cutting unit as a whole by 13 percent. The estimates of stand density shown in the last column of table 4 are therefore the most descriptive.

The good restocking level of the mile-square cutting unit was typical of natural regeneration on many cutting units in southeast Alaska. Regeneration surveys, made between 1957 and 1962 by eight Ranger Districts on 218 cutting units from 1 to 14 years after logging, showed that stocking averaged 80 percent on some 20,000 acres of cutover land examined. Less than 0.5 percent of this area was below the 40-percent stocking level which is adequate.[7]

[6] Region 10 stocking standards, based on the percentage of 4-milacre plots stocked, are:
Desired stocking, 70 percent or more
Satisfactory stocking, 40-69 percent
Poor or unsatisfactory stocking, 10-39 percent
Nonstocked, less than 10 percent

[7] Unpublished records on file at the Institute of Northern Forestry, Pacific Northwest Forest and Range Experiment Station, Juneau, Alaska.

RELATIONSHIP BETWEEN STOCKING PERCENT AND SEEDLINGS PER ACRE

A loose relationship exists between stocking percent and number of seedlings per acre — as stocking percent increases, the number of seedlings per acre also increases. This relationship has been found to vary by species and region (Bever 1949, 1952; Lynch and Schumacher 1941; Wellner 1940). Although relationships differ, all studies agree that there are actually many more seedlings per acre than the minimum number indicated by stocking percent.

The relationship between stocking percent and seedlings per acre was developed by arbitrarily dividing the mile-square cutting unit into 32 parts, each containing 10 plots, and relating stocking percent to seedlings per acre on each. The resulting relationships (figs. 10 and 11), although based on limited data, show that the actual number of seedlings per acre greatly exceeds the lower limit indicated by stocking percent.

Extensive stocking surveys of the type used here fail to reveal small areas of extremely dense

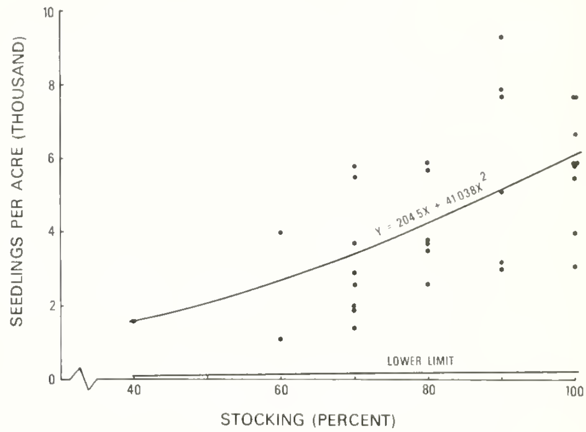

Figure 11.—Relationship of 4-milacre stocking percent (the percentage of 4-milacre plots containing at least one tree, 1 or more years old) to number of trees per acre. Mile-square cutting unit, Maybeso Experimental Forest.

Table 5.—*Percent of 1-milacre plots containing various numbers of seedlings at least 1 year old, by species, 1962; mile-square cutting unit, Maybeso Experimental Forest*

SPECIES	NUMBER OF SEEDLINGS PER PLOT								
	0	1-5	6-10	11-15	16-20	21-30	31-40	41-50	50+
	Percent								
Hemlock	51	33	9	4	0	1	1	0	1
Spruce	46	44	7	2	0	1	0	0	0
Cedar	87	12	0	1	0	0	0	0	0
All species combined	31	41	14	8	1	2	1	1	1

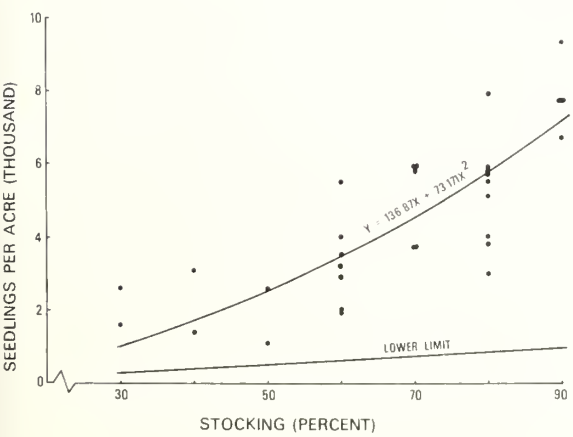

Figure 10.—Relationship of 1-milacre stocking percent (the percentage of 1-milacre plots containing at least one tree, 1 or more years old) to number of trees per acre. Mile-square cutting unit, Maybeso Experimental Forest.

stocking. Such areas were common throughout the cutting unit. Although dominance was well expressed by tree individuals and there was no evidence of stagnation, such stands would doubtless benefit from early thinning. More detailed observation will be needed to locate them for treatment.

SPECIES COMPOSITION

Hemlock has been the dominant species in the regenerating stand since logging, both in numbers and size. However, a trend toward more spruce at the expense of hemlock is evident (fig. 12). The higher percentage of hemlock soon after logging reflects the prevalence of advanced hemlock seedlings in the stand. As many of these died, more spruce became established from natural seedfall after logging. The percentage of cedar remained nearly constant.

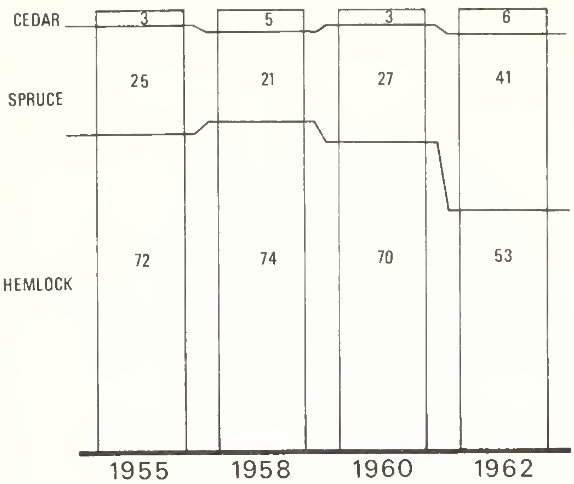

Figure 12.—Species composition in percent—seedlings at least 1 year old. Mile-square cutting unit, Maybeso Experimental Forest.

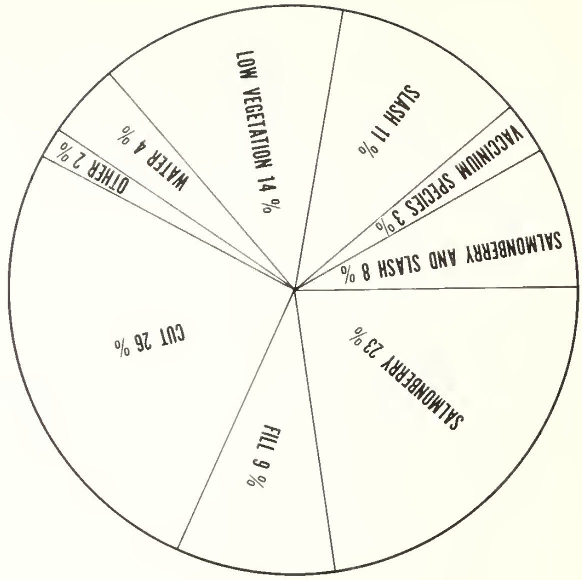

Figure 13.—One-milacre nonstocked plots by percentage of ground cover or surface condition, 1962. Mile-square cutting unit, Maybeso Experimental Forest.

Hemlock seedlings were not only more numerous than spruce or cedar, but also tended to be larger. In 1962, a hemlock was the largest seedling present on 57 percent of 4-milacre plots examined, a spruce on 40 percent, and a cedar on 3 percent. Dominant hemlock seedlings averaged 5 feet in height with a maximum of 11 feet, dominant spruce seedlings averaged 2 feet in height with a maximum of 5 feet, and dominant cedar averaged 2 feet in height with a maximum of 3 feet. Hemlock seedlings were larger because more were advanced seedlings, well established before logging, that survived to become the dominant early stand component.

How far the present trend in species composition toward more spruce will continue is uncertain now. Taylor (1934) found that second-growth stands in southeast Alaska usually contained from 10 to 75 percent spruce by basal area, depending on soil type and stand age, and estimated that, on the average, the proportion of spruce in second-growth stands at the end of a rotation period of 75 to 100 years will be about 50 percent.

DESCRIPTION OF NONSTOCKED PLOTS

In 1962, ninety-nine 1-milacre plots, or 31 percent of the total examined were not stocked with coniferous seedlings (fig. 13).

Disturbed soil was the most common surface condition on nonstocked plots. Soil movement on all but one plot was the result of landslides or debris flows occurring after 1958. Slides are common on steep, forested slopes throughout southeast Alaska, but their frequency may increase after logging. For example, the frequency of slides on the steep hillsides of Maybeso valley increased by a factor of 50 in the 10 years since logging (Bishop and Stevens 1964).

Landslides and debris avalanche flows may seriously retard regeneration by removing the soil mantle down to glacial till or rock on steep slopes and by covering high-site land on lower slopes and the valley bottom with debris and rubble (fig. 14). Under natural conditions, the lower parts of slides quickly revegetate, pass through a red alder successional stage, and eventually support excellent stands of spruce. Alder contributes to the buildup of nutrients in mineral soil, and from this standpoint, may be beneficial to the future spruce crop. For example, net annual accumulation of 700 pounds of organic carbon and 55 pounds of nitrogen per acre per year has been measured under a 50-year-old alder stand which originated on the bare mineral soil of a glacial moraine (Crocker and Major 1955). On the other hand, the time required to pass through the alder successional stage will add many years to the rotation period of the future merchantable stand. Alder control will be necessary on these areas to produce a merchantable conifer stand in a shorter time. Upper portions of slides, where soil was removed to glacial till, appeared to be still actively sloughing and contained no vegetation.

Figure 14.—Deposition of soil, rock, and logging debris on a formerly well-stocked site, 1962. Note alder in foreground. Mile-square cutting unit, Maybeso Experimental Forest.

Dense salmonberry brush, sometimes together with logging slash, was the second most common surface condition on nonstocked plots. Salmonberry brush occurred on gently sloping alluvium at scattered locations but was most common on flat, well-drained Tonowek soil along Maybeso Creek on good sites subject to periodic high water table and recurring floods (fig. 15). Dense brush patches were often located near a good spruce and hemlock seed source. Tree seedlings appeared to be confined largely to raised microsites on or beside stumps, on rotten logs, or on hummocks. Leaders of spruce seedlings were often abraded by surrounding brush.

Before the logging operation, these alluvial soils supported open stands of spruce and hemlock with a dense understory of salmonberry, elderberry, thimbleberry, and devilsclub. Many of the original trees were stilt-rooted, having germinated on down logs or upturned roots. Being along the creek, the areas were near the periphery of high-lead settings where ground

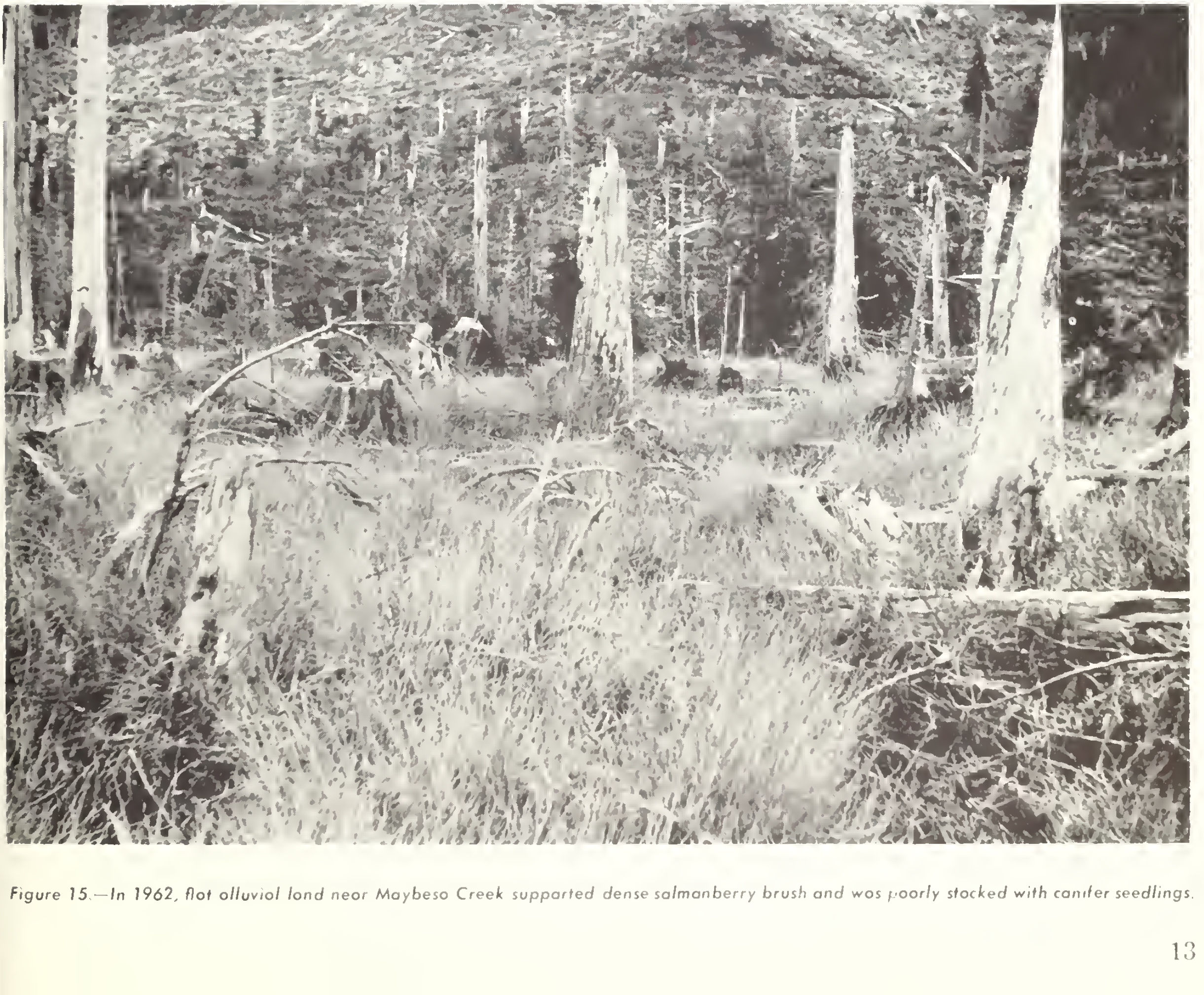

Figure 15.—In 1962, flat alluvial land near Maybeso Creek supported dense salmonberry brush and was poorly stocked with conifer seedlings.

disturbance from logging was slight. The well-established brush was damaged little by logging, and it resprouted quickly when timber was cut. There appears to be little possibility of natural restocking here within a reasonable time, and brush control, together with seeding or planting, will be necessary. Included within these areas, small, bare patches devoid of brush and seedlings suggest that brush competition alone is not the only cause of nonstocking. The fact that many seedlings are on raised microsites points to the possibility that drainage is an important factor. Seedlings could fail to become established as a direct result of a high water table, periodic flooding, frost heaving, or other reasons. Seedbed treatment in addition to brush removal and planting may be needed to reclaim these sites for timber production.

A similar restocking problem exists in coastal Oregon (Ruth 1956) where research has shown that stocking may be improved by brush control and planting immediately after logging.

Figure 16.—Spruce seedlings beneath alder on a skidroad 8 years after logging. The spruce is spindly because it lacks sufficient light. Mile-square cutting unit, Maybeso Experimental Forest.

Low vegetation, composed of bunchberry dogwood, currant, five-leaved bramble, fern, grass, moss, sedge, etc., was the third most frequent cover on nonstocked plots. However, competition from this vegetation did not appear likely to impede seedling establishment.

Neither logging slash nor *Vaccinium* brush appeared to seriously impede regeneration. Slash distribution is uneven, with only scattered, small areas occupied by slash accumulations dense enough to prevent seedling establishment. *Vaccinium* tends to occur in small clumps and is seldom uniform over large areas. Tree seedlings usually become established in the intervening spaces between clumps.

Alder did not appear to be a serious problem on the cutover, being mostly confined to disturbed ground along the edges of a few primary roads, on skidtrails, and in borrow areas. By 1962, alder was also coming in densely on gravel outwash from recent landslides and debris flows (fig. 16).

An attempt was made in 1954 to remove the alder seed source in Maybeso valley by poisoning trees growing along Maybeso Creek (Andersen 1955b). Although not completely successful, the attempt probably helped to limit alder establishment. Surviving alder trees along the creek and scattered trees in timber near the cutover perimeter provided seed, and by 1960, trees established within the cutover since logging were producing seed. With this added seed source, outwash from landslides and debris flows was subject to rapid colonization by alder. Spruce seedlings were often present beneath alder (fig. 16), and although their color was good, they were spindly and slow growing because of inadequate light. As previously stated, some alder control will be necessary.

SUMMARY AND CONCLUSIONS

Eight growing seasons after logging began, the mile-square cutting unit, as a whole, was well stocked, as shown by the regeneration survey. However, it was apparent that stocking was far from uniform, with some small areas occupied by dense thickets of spruce and hemlock and others sparsely stocked. Because problem areas were localized, the extensive stocking survey based on widely separated milacre or 4-milacre plots failed to reveal their location, and they were only identified by close observation of the area.

Extremes of stocking and stand density appeared to be related to site rather than to seed source. No lack of seed on any part of the cutting was apparent, either from the regeneration survey or from general observation. The mile-square cutting unit is situated so that the most effective seed source is located at the upper edge and to the north of the cutting unit, apparently offering ideal conditions for seed dispersal over long distances. Some of the densest stocking was farthest from seed source, near the center of the cutting unit, on well-drained, gently sloping alluvium.

Because the mile-square cutting unit represents only one condition of topography, seed source, and soil, it is obviously impossible to extend the results of the study to all cuttings in southeast Alaska. However, the good restocking level of the mile-square cutting unit agreed with regeneration surveys made recently by eight Ranger Districts on many cutting units from 1 to 14 years after logging.

Large-scale clearcutting has been done only recently in southeast Alaska. Timber distribution, topography, and consideration of fire hazard, wildlife, or esthetic values have usually limited the size of cutting units, so that few have been made as large as the mile-square cutting unit described here. Until more experience with natural regeneration becomes available, caution should be used in planning cutting units this large. When planning large cutting units, the land manager should bear in mind that most seed is dispersed from a northerly direction and, although a seed source located high on the northerly side of a cutting unit may be effective up to 40 chains or more, seed dispersal distance may be less if the seed source is at a lower elevation or located to the south.

Extensive regeneration surveys need not be made on all land after logging. However, they should be made on alluvial soils and on areas over 40 chains from a high northerly or westerly seed source. In addition, close observation is needed to reveal small problem spots which may not be detected from extensive surveys. Because of their great 1st-year mortality, seedlings less than 1 year old should not be included in estimates of seedling density, and two or more seedlings less than 1 year old should not be considered as evidence that a plot is stocked. Five years appears to be a reasonable time to allow for natural regeneration, and surveys should not be made sooner.

Flat, streamside alluvial sites may be identified as potential brush-threat areas before logging. Brush control together with planting may be necessary to reclaim these sites for timber production.

COMMON AND SCIENTIFIC NAMES OF PLANTS MENTIONED

SHRUBS AND HERBS

Bunchberry dogwood . . *Cornus canadensis* L.

Stink currant . . . . *Ribes bracteosum* Dougl.

Trailing black currant *Ribes laxiflorum* Pursh

Devilsclub . . . . *Oplopanax horridus* (Sm.) Mig.

Pacific red elder . . . . . . *Sambucus callicarpa* Greene

Salmonberry . . . . *Rubus spectabilis* Pursh

Western thimbleberry . *Rubus parviflorus* Nutt.

Five-leaved bramble . . *Rubus pedatus* Smith

Ovalleaf whortleberry[8] . . . . . *Vaccinium ovalifolium* Smith

Red whortleberry[9] . . . *Vaccinium parvifolium* Smith

Alaska blueberry . . . . . *Vaccinium alaskensis* Howell

TREES

Alaska-cedar . . . . *Chamaecyparis nootkatensis* (D. Don) Spach

Red alder . . . . *Alnus rubra* Bong.

Sitka spruce . . . . *Picea sitchensis* (Bong.) Carr.

Western hemlock . . . . . *Tsuga heterophylla* (Raf.) Sarg.

Western redcedar . . . . *Thuja plicata* Donn

OTHER

Ladyfern . . . . *Athyrium filixfemina* (L.) Roth

Western bracken . . . . . *Pteridium aquilinum* (L.) Kuhn

Moss . . . . *Musci* (class)

Sedge . . . . *Carex* (sp.)

[8] Known locally as early blueberry.

[9] Known locally as red huckleberry.

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ROWTH AND YIELD OF WELL - STOCKED WHITE SPRUCE STANDS IN ALASKA

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CONTENTS

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INTRODUCTION

Normal yield tables are presented here for white spruce (*Picea glauca* (Moench) Voss) in interior Alaska. White spruce accounts for 64 percent of the commercial cubic-foot volume and 81 percent of the commercial board-foot volume of this region (Hutchison 1967).[1] These yield tables, like those prepared by Gregory and Haack (1965) for the two principal hardwoods, paper birch (*Betula papyrifera* Marsh.) and quaking aspen (*Populus tremuloides* Michx.), were prepared to show the range of sites in the interior and the effect of site on stand development. They also provide estimates of yield for the range of sites and ages found in the interior.

Although the many limitations of normal yield tables are recognized (Spurr 1952, pp. 260-261), they are of value for interior Alaska where well-stocked, even-aged stands are common and the forests are not being managed. Forests of the interior are, for the most part, inaccessible and little cutting has taken place except for limited local use near population centers. Intensive forest management is still many years off.

[1] *Names and dates in parentheses refer to Literature Cited on inside back cover.*

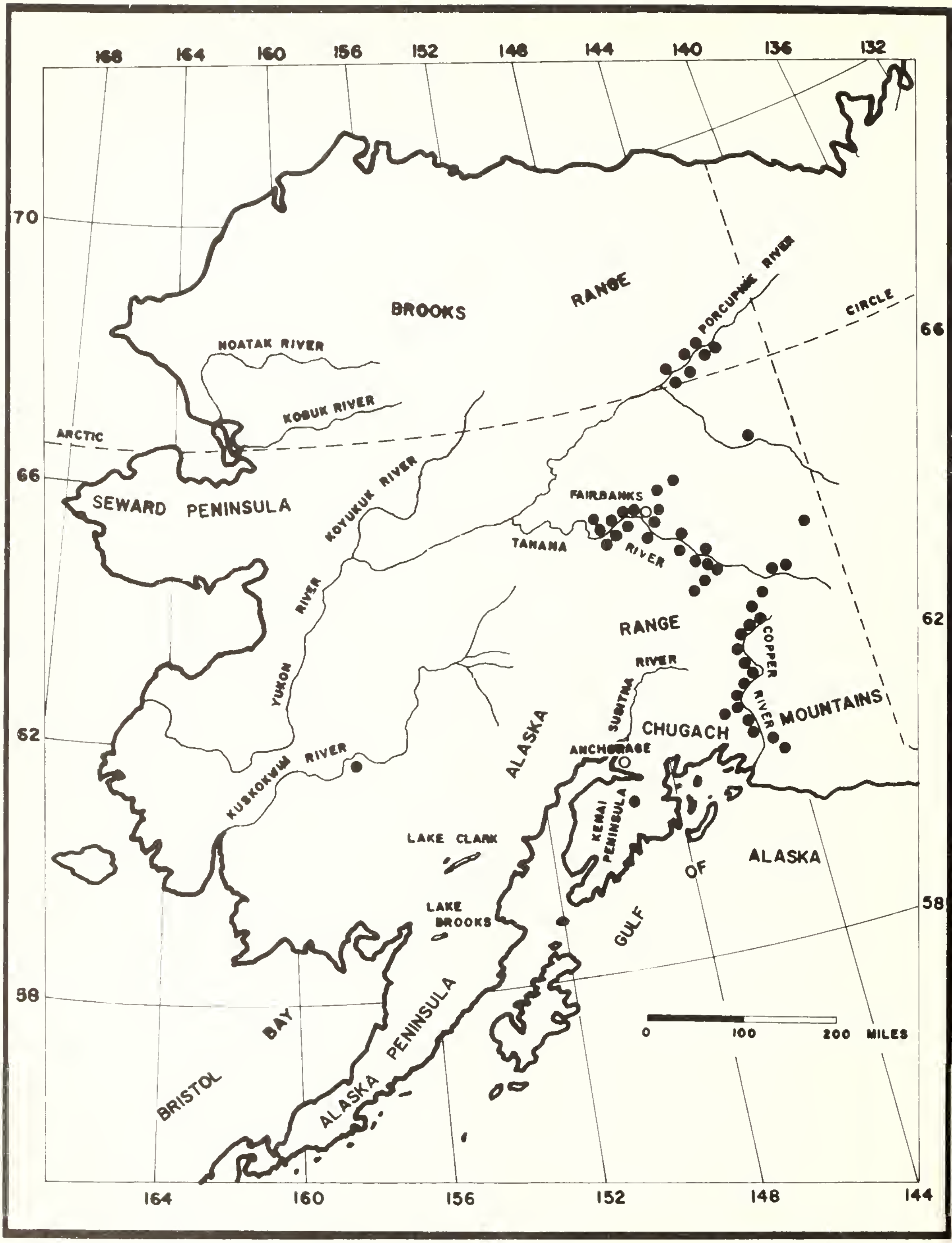

Figure 1. – Location of sample plots. Each black dot represents one or more temporary plots used in this study.

THE FOREST REGION

Alaska's interior comprises some 332,555,000 acres. Sixty-eight percent of this total consists of grassland, brush, swamps, tundra, barren rock, ice, and snow. The remaining 32 percent, or 106,000,000 acres, is forested (Hutchison 1967).

The interior forests are a westward extension of the boreal forests of Canada. Within Alaska, the forests extend westward to about 164^{o} west longitude on the Seward Peninsula and as far north as the Brooks Range. The Chugach Mountains, bordering the Gulf of Alaska and Bristol Bay to the westward, form the southern boundary. The southern limit of forest types common to the interior is near Lake Brooks on the Alaska Peninsula, about latitude 58^{o}N. (fig. 1).

GEOGRAPHY

Interior Alaska is characterized by rugged mountains and broad river valleys; the most prominent feature is the Alaska Range, which arcs northeasterly from near Lake Clark on the west to the St. Elias Range on the east. North of the Alaska Range the principal river valleys are those of the Noatak, Kobuk, Yukon, and Kuskokwim Rivers and their tributaries. The Koyukuk, Porcupine, and Tanana Rivers are tributaries of the Yukon River. South of the Alaska Range, the chief river valleys are those of the Susitna and Copper Rivers and their tributaries (fig. 1).

CLIMATE

Alaska's interior has a climate of extreme contrasts. Winter days are short and extremely cold, and summer days are long and mild. Annual precipitation, north of the Alaska Range and on the Copper River plateau to the south, averages 10 to 13 inches – low for a forested region. The summer months receive the heaviest rainfall – close to 2 inches a month (Watson 1959). Tree growth is greatest during June and July when the days are warm and daylight is nearly continuous. Most of this area is also within the zone of discontinuous permafrost, the occurrence of which tends to keep the water table near the soil surface.

South of the Alaska Range, the Susitna Valley and Kenai Peninsula have warmer winters, cooler summers, receive more precipitation (15 to 30 inches annually), and have fewer growing degree days than do areas to the north of the Range (Funsch 1964).

FORESTS

About 21 percent (22-1/2 million acres) of the interior's forested land is classified as commercial; that is, capable of producing at least 20 cubic feet of wood per acre annually. The remaining 79 percent (83 million acres) consists of sparse and stunted woodlands presently considered noncommercial (Hutchison 1967). White spruce, black spruce (*Picea mariana* (Mill.) B.S.P.), tamarack (*Larix laricina* (Du Roi) K. Koch), paper birch, quaking aspen, balsam poplar (*Populus balsamifera* L.), and black cottonwood (*P. trichocarpa* Torr. & Gray) are the native tree species.

White spruce is the most important forest type, covering 57 percent (12.8 million acres) of the commercial forest land. By comparison, paper birch accounts for 23 percent, aspen for 11 percent, and poplar and cottonwood for 9 percent of the commercial forest land (Hutchison 1967). Black spruce is abundant but rarely reaches commercial size. Tamarack occurs as a minor stand component on poorly drained, noncommercial sites north of the Alaska Range.

The interior forests are susceptible to destruction by fire. Low precipitation, high air temperatures, and long hours of sunshine during the summer increase the hazard of fire, especially in the uplands where natural barriers are few.

As a result of past fire history, the uplands typically are covered with dense, even-aged stands of paper birch and quaking aspen. Aspen is limited chiefly to southern exposures whereas birch predominates on northeast- and northwest-facing slopes (Gregory and Haack 1965). The colder north-facing slopes usually support poor stands of black spruce. Although white spruce occurs in pure, even-aged stands in the uplands below about 1,500 feet, most stands are located on moderately well drained soils of lowland sites adjacent to the rivers.

White spruce reaches its best development along the Tanana River and on the south-facing slopes of the Tanana-Yukon uplands. Site quality is generally poorer elsewhere (table 1). Dense spruce stands grow along the major rivers far north of the Arctic Circle, but their site index is low. For example, along the Porcupine River, sample plot trees seldom exceeded 70 feet in height and 12 inches diameter at breast height (d.b.h.); site index averaged 55 (table 1).

CHARACTERISTICS OF WHITE SPRUCE STANDS

White spruce is a hardy tree species that grows throughout interior Alaska on a variety of sites. Although its best development takes place near the base of slopes and on moderately well drained alluvial soils, its range does extend to the northern, western, and altitudinal limits of tree growth.

Above about 1,500 feet and at the limits of tree growth where there is little competition from hardwoods, white spruce develops in pure or nearly pure, sparsely stocked stands. At lower upland elevations, white spruce regenerates following fire both in pure stands and in mixture with the common hardwoods. The reasons for pure spruce stands at these lower upland elevations are not known. Possibly they develop if fire is severe enough to expose mineral soil, if seed is abundant, and if the area receives adequate moisture for germination and survival.

When the uplands regenerate to a spruce-hardwood mixture, the short-lived hardwoods initially outgrow the spruce and maintain an overstory position for 80 or more years until the hardwoods begin to die out. Only then does the spruce assume the dominant stand position.

Stream meanders, sloughs, wet muskegs, and the occurrence of many islands provide effective fire barriers for river-bottom sites. Because of this, ecological succession possibly accounts for most white spruce stands found growing on the wide alluvial flats of the major rivers, where soil erosion and deposition is active. Mature and overmature stands, 100 to 240 years old, occupy extensive areas along most of the major rivers.

Windthrow as an important cause of destruction of river-bottom stands seems unlikely. Periodic flooding over a hundred years deposits a foot or more of alluvium on the forest floor, and root systems become well anchored. Such river-bottom trees are more likely to be snapped off above the ground by strong winds than uprooted.

Pure stands of white spruce are typically well stocked although they often do not appear so. White spruce in Alaska is characteristically narrow crowned, and even the well-stocked stands do not have closed canopies. Crown cover seldom exceeds 50 to 70 percent.

By age 30 years at breast height, basal area of well-stocked stands will reach 126 square feet or more (table 4) in stands of 1,500 or more trees per acre (table 12). At theoretical rotation age (70-150 years, depending on site) 15 to 30 percent of the trees are sawtimber size (larger than 8.5 inches d.b.h.). Most trees are limby.

White spruce stands remain well stocked for 180 years or more. As the mature trees die and openings appear, brush species, principally Sitka alder (*Alnus sinuata* (Reg.) Rydb.) become established. Remnant spruce may live for 350 years or more. The oldest trees found during this study were along the Tanana River near Fairbanks -- they were 329 years old at breast height.

Unless fire again reclaims the site after a stand reaches maturity, a thick insulating layer of organic material accumulates on the soil surface; underlying soils thaw later in the growing season, or may even remain permanently frozen, causing site quality to decrease with time.

GROWTH AND YIELD

'ERMS AND MEASURES

\ge. – Average breast-height age of the tallest white pruce trees, provided they are not remnants of an arlier stand.

3reast-height age was used because early height levelopment is slow and total age is difficult to letermine accurately, particularly in the case of iver-bottom stands where alluvial deposits of 1 foot r more may accumulate over the rotation of the tand. Also, decay at ground level in the older stands bscured the annual rings.

leight. – Total height from ground to tip of the tallest ree on a 1/4-acre plot, provided the tree is of average tand age.

ite index. – Height of the tallest tree on a 1/4-acre lot at index age 100 years.

'olume. – Cubic-foot volumes per acre to different ıerchantability standards, computed with tree volume quations published by Gregory and Haack (1964). lerchantability standards are given in the table eadings (tables 17 through 22).

ıternational 1/4-inch board-foot volumes per acre were omputed from a tree volume equation (Farr 1967) erived from the same basic data used to develop ubic-foot volume tables (Gregory and Haack 1964). oard-foot volumes per acre are given for trees larger ıan 8.5 inches, from a 1-foot stump to a 6-inch top ıside bark.

lean annual increment. – Determined by dividing resent volume (table 17) by present age. The age of ılmination of mean annual increment is the theoretical ɔtation age. Volume of all trees larger than 4.5 inches .b.h. is measured in cubic feet from a 1-foot stump to 4-inch top inside bark.

ASIC DATA

inety-nine yield plots were sampled; 97 of these 'ere distributed over the eastern interior, and two ere measured along the Kuskokwim River near IcGrath (fig. 1). Most of the plots were one-quarter :re in size. Some 1/10- and 1/20-acre plots were used young stands, and nine 1/3-acre plots were used in der stands on the best sites to insure that at least 00 trees were measured per plot. On 20 of the /4-acre plots, the four to six tallest trees were felled ıd sectioned for height-age determinations to be used construction of site-index curves.

Table 2 summarizes the distribution of yield plots by age and site index. Well-stocked white spruce stands of site index less than 50 or greater than 100 are rare occurrences in the interior. The four plots in the less than 50 site index class in table 2 were sampled from along the Porcupine River north of the Arctic Circle.

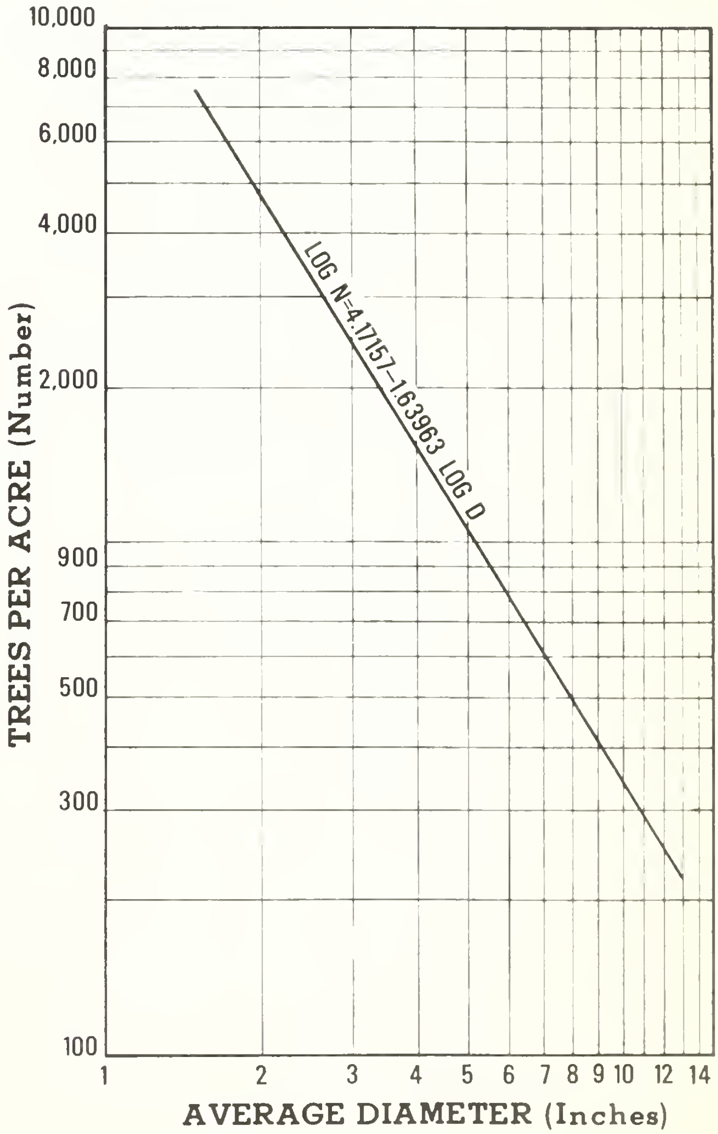

Figure 2. – Relationship of number of white spruce trees per acre and average stand diameter; trees larger than 0.5 inch.

The two plots with site quality greater than 100 were sampled from along the Tanana River about 120 miles east of Fairbanks.

An expression of stocking based on the sample data is shown in figure 2.

Data taken on each plot included:

1. Diameter at breast height of all live trees larger than 0.5 inch, by 1-inch classes.

2. Enough total-height measurements (10 to 20) to construct a reliable height-diameter curve.

3. Breast-height age of at least the six tallest white spruce per plot.

4. A description of the plot including latitude, longitude, aspect, slope, and elevation.

ANALYSES

Site index. – The method of Johnson and Worthington (1963) was used to derive the equation:

White spruce site index = height (0.49638+50.36166/age). Solution of the equation is shown graphically in figure 3 and numerically in table 3. Realignment of the axes, with height as the dependent variable, provides the more traditional solutions (fig. 4, table 4).

Because relative height of the four to six tallest trees per plot shifted with time, Dahms' (1963) method of using the tallest tree at any given stand age was used.

Yield estimates. – Equations to estimate basal area per acre, basal area of the average tree, and volumes per acre (tables 5 through 22) were derived by stepwise regression (Dixon 1965). The basic equation used was:

$$Y_i = b_{i0} + b_{i1} A + b_{i2} A^2 + b_{i3} A^3 + b_{i4} S + b_{i5} S^2 + b_{i6} S^3 + b_{i7} SA + b_{i8} S^2 A + b_{i9} SA^2 + b_{i10} S^2 A^2 + b_{i11} 1/A$$

where:

Y_1 = Basal area per acre for trees larger than 0.5 inch d.b.h.

Y_2 = Basal area per acre for trees larger than 4.5 inches d.b.h.

Y_3 = Basal area per acre for trees larger than 6.5 inches d.b.h.

Y_4 = Basal area per acre for trees larger than 8.5 inches d.b.h.

Y_5 = Average basal area of trees larger than 0.5 inch d.b.h.

Y_6 = Average basal area of trees larger than 4.5 inches d.b.h.

Y_7 = Average basal area of trees larger than 6.5 inches d.b.h.

Y_8 = Average basal area of trees larger than 8.5 inches d.b.h.

Y_9 = Cubic-foot volume per acre for trees larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{10} = Cubic-foot volume per acre for trees larger than 6.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{11} = Cubic-foot volume per acre for trees larger than 6.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark.

Y_{12} = Cubic-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark.

Y_{13} = Cubic-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark.

Y_{14} = International 1/4-inch board-foot volume per acre for trees larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bar

A = Breast-height stand age.

S = Site index.

b_{ij} = Regression constants.

Quadratic mean diameters[2] (diameters of trees of mean basal area) corresponding to Y_5 through Y_8 were calculated.

The average number of trees per acre, N_i, was estimated by solving:

$N_1 = Y_1/Y_5$, $N_2 = Y_2/Y_6$, $N_3 = Y_3/Y_7$, and N_4 = Y

For some combinations of site index and age, the equations for computing partial stand basal area (Y Y_3, and Y_4) give higher values than can be expecte the entire stand (Y_1). Statistically, this is reasonabl because the equations were derived independently, use of stepwise regression. In nature, however, such condition does not exist. Where the computed Y_2, or Y_4 values were higher than those computed for the Y_1 values were used. The age at which merging the equations occurs is given for each site class in ta 6, 7, and 8. Merging ages were computed by setting equations equal to each other and solving. Merging occurred between cubic-foot equations Y_9 and Y_{10}

Equations for calculating tabular values and mergin points, and the precision of them in terms of the multiple coefficient of determination (R^2), are give as footnotes to the tables.

Diameter frequencies. – A graphical method of constructing stand tables described by Meyer (1937

[2] *Curtis, Robert O. Which average diameter? 1967. (In pre J. Forest.)*

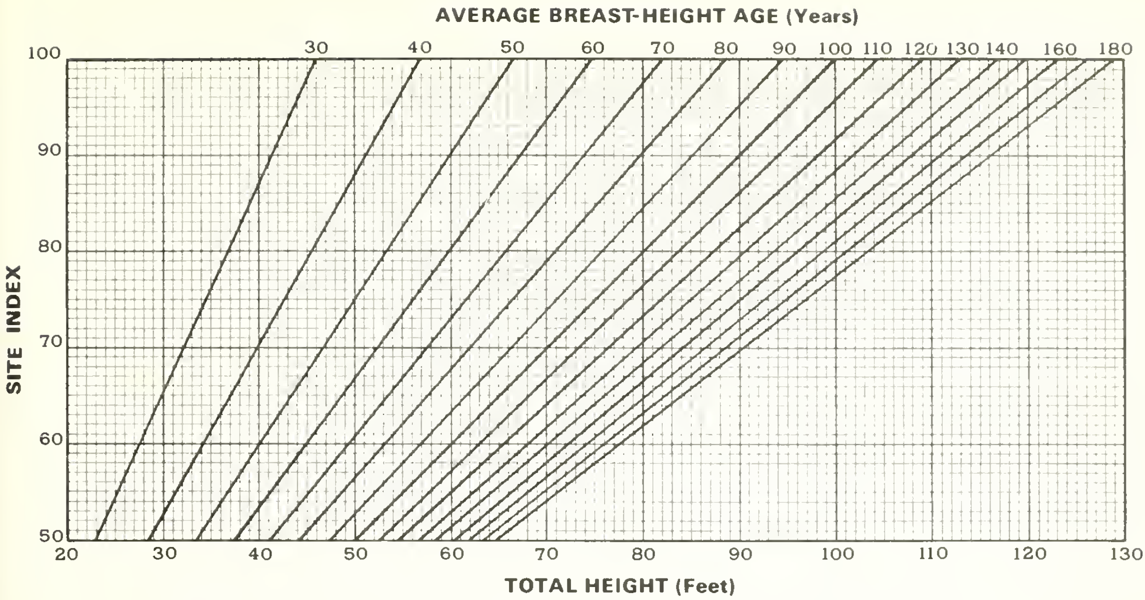

Figure 3. – Site index for white spruce, by breast-height age and height of the tallest white spruce tree per one-fourth acre.

p. 84-85) was used to develop table 24 which shows, y average stand diameter, the percentage of trees in ach 1-inch diameter class. Table 24 may be used with ables 9 and 13 to estimate the number of trees in ach diameter class for any site-age combination.

lean annual increment. – Table 23, which shows mean nnual increment per acre for trees larger than 4.5 inches .b.h., was prepared by dividing the cubic-foot volume y age for each site-age combination in table 17. The ge of culmination of mean annual increment is the ieoretical rotation age. Sites capable of producing at ast 20 cubic feet per acre per year are classified as ommercial forest land by Forest Survey; stands roducing less are considered noncommercial. An area f site quality 63 would, therefore, be borderline etween commercial and noncommercial forest land.

STIMATING SITE INDEX

or any white spruce stand that is at least moderately ell stocked, site index can be determined by measuring tal height of the tallest white spruce tree (per ne-quarter acre) of average stand age and estimating east-height stand age. Stand age must be found by eraging the breast-height age of at least the six tallest hite spruce trees per one-quarter acre.

site index system based on the height of the tallest dividual in a stand is easy to apply – an important onsideration in comparison with some of the more omplicated systems that require 10 to 20 heights of ominants and codominants or dominants alone. Even ough the use of more individuals may show a reduction in estimation error, the increase in precision may be small. Dahms (1966) found this to be true of lodgepole pine on the pumice soils of eastern Oregon. The problem encountered in using site index curves based on average height of dominant and codominant trees is that invariably the fieldman will measure heights of just the better dominants.

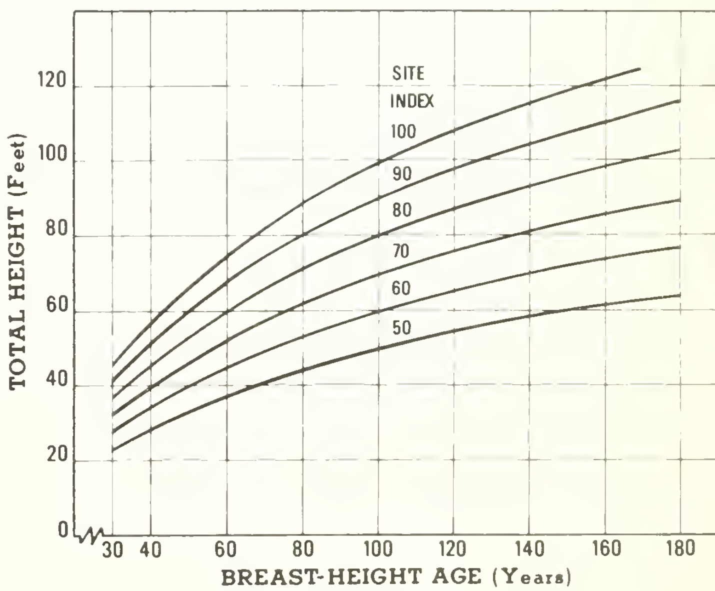

Figure 4. – Height of the tallest white spruce tree per one-fourth acre, by breast-height age and site index.

Table 1. – Site index and number of sample plots by geographical location[1]

Area	No. of plots	Minimum and maximum site index	Average site inde
Porcupine River	10	41 – 64	55
Tanana River uplands between Fairbanks and Nenana	12	71 – 100	84
Tanana River:			
West of Fairbanks	10	73 – 94	82
East of Fairbanks	20	73 – 106	90
Copper River plateau:			
North of Glennallen	7	54 – 85	70
South of Glennallen	14	50 – 64	58

[1] *16 of the 99 plots sampled in this study are not included in the table. They were distributed singly or in pairs . other areas of the interior.*

Table 2. – Distribution of white spruce sample plots by age and site index, interior Alask

Breast-height age (years)	Site index (feet)							Total
	<50	51-60	61-70	71-80	81-90	91-100	>100	
	Number of plots							
31 – 50	0	0	2	2	2	3	1	10
51 – 70	0	0	2	2	2	0	0	6
71 – 90	0	5	1	3	4	1	0	14
91 – 110	0	4	3	7	1	2	1	18
111 – 130	0	1	1	6	1	3	0	12
131 – 150	0	2	3	2	4	2	0	13
151 – 170	2	4	1	3	2	2	0	14
171+	2	4	1	2	3	0	0	12
Total	4	20	14	27	19	13	2	99

Table 3. – Site index for white spruce, by breast-height age and height of the tallest tree, interior Alaska[1]

Breast-height age (years)	Total height (feet)																				
	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125
	Feet																					
30	44	54	65	76	87	98	109	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
35	—	48	58	68	77	87	97	106	—	—	—	—	—	—	—	—	—	—	—	—	—	—
40	—	—	53	61	70	79	88	96	105	—	—	—	—	—	—	—	—	—	—	—	—	—
45	—	—	48	56	65	73	81	89	97	105	—	—	—	—	—	—	—	—	—	—	—	—
50	—	—	45	53	60	68	75	83	90	98	105	—	—	—	—	—	—	—	—	—	—	—
55	—	—	—	49	56	64	71	78	85	92	99	106	—	—	—	—	—	—	—	—	—	—
60	—	—	—	47	53	60	67	73	80	87	93	100	107	—	—	—	—	—	—	—	—	—
65	—	—	—	—	51	57	64	70	76	83	89	95	102	—	—	—	—	—	—	—	—	—
70	—	—	—	—	49	55	61	67	73	79	85	91	97	103	—	—	—	—	—	—	—	—
75	—	—	—	—	47	53	58	64	70	76	82	88	93	99	105	—	—	—	—	—	—	—
80	—	—	—	—	—	51	56	62	67	73	79	84	90	96	101	—	—	—	—	—	—	—
85	—	—	—	—	—	49	54	60	65	71	76	82	87	93	98	103	—	—	—	—	—	—
90	—	—	—	—	—	48	53	58	63	69	74	79	84	90	95	100	106	—	—	—	—	—
95	—	—	—	—	—	46	51	56	62	67	72	77	82	87	92	98	103	—	—	—	—	—
100	—	—	—	—	—	—	50	55	60	65	70	75	80	85	90	95	100	105	—	—	—	—
105	—	—	—	—	—	—	49	54	59	63	68	73	78	83	88	93	98	102	—	—	—	—
110	—	—	—	—	—	—	48	52	57	62	67	72	76	81	86	91	95	100	105	—	—	—
115	—	—	—	—	—	—	47	51	56	61	65	70	75	79	84	89	93	98	103	—	—	—
120	—	—	—	—	—	—	46	50	55	60	64	69	73	78	82	87	92	96	101	105	—	—
125	—	—	—	—	—	—	—	49	54	58	63	67	72	76	81	85	90	94	99	103	—	—
130	—	—	—	—	—	—	—	49	53	57	62	66	71	75	80	84	88	93	97	102	—	—
135	—	—	—	—	—	—	—	48	52	56	61	65	70	74	78	83	87	91	96	100	104	—
140	—	—	—	—	—	—	—	47	51	56	60	64	68	73	77	81	86	90	94	98	103	—
145	—	—	—	—	—	—	—	46	51	55	59	63	67	72	76	80	84	89	93	97	101	105
150	—	—	—	—	—	—	—	—	50	54	58	62	67	71	75	79	83	87	92	96	100	104
155	—	—	—	—	—	—	—	—	49	53	57	62	66	70	74	78	82	86	90	94	99	103
160	—	—	—	—	—	—	—	—	49	53	57	61	65	69	73	77	81	85	89	93	97	101
165	—	—	—	—	—	—	—	—	48	52	56	60	64	68	72	76	80	84	88	92	96	100
170	—	—	—	—	—	—	—	—	48	52	55	59	63	67	71	75	79	83	87	91	95	99
175	—	—	—	—	—	—	—	—	47	51	55	59	63	67	71	74	78	82	86	90	94	98
180	—	—	—	—	—	—	—	—	46	50	54	58	62	66	70	74	78	81	85	89	93	97

[1] *Tabular values derived from the equation:* $S = H(0.49638 + 50.36166/A)$.

where: S = *site index*

H = *height of the tallest white spruce per one-fourth acre*

A = *average breast-height age of at least the six tallest white spruce trees.*

Table 4. — Height of tallest white spruce, by breast-height age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Feet					
30	23	28	32	37	41	46
40	28	34	40	46	51	57
50	33	40	47	53	60	66
60	37	45	52	60	67	75
70	41	49	58	66	74	82
80	44	53	62	71	80	89
90	47	57	66	76	85	95
100	50	60	70	80	90	100
110	52	63	73	84	94	105
120	55	65	76	87	98	109
130	57	68	79	91	102	113
140	58	70	82	93	105	117
150	60	72	84	96	108	120
160	62	74	86	99	111	123
170	63	76	88	101	114	--
180	64	77	90	103	116	--

[1] *Tabular values were derived from the equation:*

$$H = \frac{S}{0.49638 + 50.36166/A}$$

where: H = *height of the tallest white spruce per one-fourth acre*
S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

Table 5 — Basal area per acre of white spruce larger than 0.5 inch d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	126	128	130	133	136	139
40	127	130	133	137	141	145
50	129	132	136	141	146	151
60	130	134	139	144	151	158
70	132	136	142	148	156	164
80	133	139	145	152	160	170
90	135	141	148	156	165	176
100	136	143	151	160	170	182
110	138	145	154	164	175	188
120	139	147	157	168	180	194
130	141	150	160	171	185	200
140	142	152	163	175	190	206
150	144	154	166	179	195	212
160	145	156	169	183	200	218
170	147	158	172	187	204	––
180	148	160	175	191	209	––

Basal area $= 121.28 + 0.00006036\, S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.445$ *Basis, number of plots = 99*

Table 6. – Basal area per acre of white spurce larger than 4.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	49	54	60	65	71	77
40	57	64	72	79	86	93
50	65	74	83	91	100	109
60	72	83	93	103	114	124
70	79	91	103	115	126	138
80	86	99	112	125	138	151
90	92	106	120	135	149	163
100	98	113	128	144	159	174
110	103	119	136	152	168	185
120	107	125	142	159	177	194
130	112	130	148	166	184	200
140	115	134	153	172	190	206
150	119	138	158	177	195	212
160	122	142	162	182	200	218
170	124	145	165	186	204	--
180	126	147	168	189	209	--
	Years					
Merging Age	--	--	--	--	132	119

Below merging age: Basal area $= 20.89 - (46.018\ SA^2 - 19949\ SA)10^{-6}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*
$R^2 = 0.659$ *Basis, number of plots = 99*

Above merging age: same as table 5.

Merging age: $100.39 + (60.36\ S^2 A - 46.018\ SA^2 - 19949\ SA)10^{-6} = 0$ *for site index 83 and higher.*

Table 7. — Basal area per acre of white spruce larger than 6.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	--	--	--	--	12	20
40	8	14	20	28	37	47
50	20	27	36	45	56	69
60	29	38	48	60	73	88
70	36	46	58	72	88	105
80	43	54	68	84	101	121
90	48	61	77	94	114	137
100	54	68	85	105	127	152
110	58	74	93	115	139	167
120	63	80	101	124	151	181
130	67	86	108	134	163	195
140	72	92	116	143	174	206
150	76	97	123	152	186	212
160	80	103	130	162	197	218
170	84	108	137	171	204	--
180	87	113	144	180	209	--
	Years					
Merging age	--	--	--	--	164	136

Below merging age: Basal area = $38.01 + 0.0001313\ S^2 A - 1729.7/A$

where: S = *site index*

A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.744$ *Basis, number of plots = 98*

Above merging age: same as table 5.

Merging age: $83.27 - (71\ S^2 A)10^{-6} + 1729.7/A = 0$

Table 8. – Basal area per acre of white spruce larger than 8.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Square feet					
30	--	--	--	--	1	10
40	--	--	--	3	14	27
50	--	--	1	14	28	43
60	--	--	9	24	41	60
70	--	2	17	35	54	76
80	--	8	25	45	67	92
90	--	14	33	56	81	109
100	2	20	42	66	94	125
110	6	26	50	77	107	142
120	10	32	58	87	121	158
130	14	38	66	98	134	174
140	19	44	74	108	147	191
150	23	50	82	119	160	207
160	27	56	90	129	174	218
170	31	62	98	140	187	--
180	35	67	106	150	200	--
	Years					
Merging age	--	--	--	--	--	155

Below merging age: $Basal\ area = -38.89 + 0.000164\ S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.821$ *Basis, number of plots = 89*

Above merging age: same as table 5.

Merging age $= 1545446/S^2$

Table 9. — Quadratic mean diameter of white spruce larger than 0.5 inch d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	2.6	2.8	3.1	3.4	3.7	4.0
40	2.8	3.1	3.5	3.9	4.3	4.7
50	3.0	3.4	3.8	4.3	4.8	5.3
60	3.2	3.6	4.2	4.7	5.3	5.9
70	3.3	3.9	4.5	5.2	5.8	6.4
80	3.5	4.2	4.9	5.6	6.3	7.0
90	3.7	4.5	5.2	6.0	6.8	7.6
100	3.9	4.7	5.6	6.4	7.3	8.2
110	4.1	5.0	5.9	6.9	7.8	8.8
120	4.3	5.3	6.3	7.3	8.3	9.3
130	4.5	5.6	6.6	7.7	8.8	9.9
140	4.7	5.8	7.0	8.1	9.3	10.4
150	4.9	6.1	7.3	8.5	9.8	11.0
160	5.1	6.4	7.6	9.0	10.3	11.6
170	5.3	6.6	8.0	9.4	10.8	--
180	5.4	6.9	8.3	9.8	11.2	--

Basal area of average tree = $[2068800 + 17.794\, S^2 A + 0.25688\, S^2 A^2 - 0.9056\, S A^2]\ 10^{-8}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.884$ *Basis, number of plots = 99*

Table 10. – Quadratic mean diameter of white spruce larger than 4.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	5.2	5.3	5.4	5.6	5.8	6.0
40	5.3	5.4	5.6	5.9	6.1	6.4
50	5.3	5.6	5.8	6.1	6.5	6.8
60	5.4	5.7	6.0	6.4	6.8	7.2
70	5.5	5.8	6.2	6.7	7.2	7.7
80	5.6	6.0	6.5	7.0	7.6	8.1
90	5.7	6.2	6.7	7.3	7.9	8.6
100	5.8	6.3	6.9	7.6	8.3	9.1
110	5.9	6.5	7.2	7.9	8.7	9.5
120	6.0	6.6	7.4	8.2	9.1	10.0
130	6.0	6.8	7.7	8.6	9.5	10.5
140	6.1	7.0	7.9	8.9	9.9	11.0
150	6.2	7.2	8.2	9.2	10.4	11.5
160	6.3	7.3	8.4	9.6	10.8	12.0
170	6.4	7.5	8.7	9.9	11.2	--
180	6.5	7.7	9.0	10.3	11.6	--

Basal area of average tree $= [13252000 + 16.542\, S^2 A + 0.27128\, S^2 A^2 - 11.995\, SA^2]\ 10^{-8}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.889$ *Basis, number of plots = 99*

Table 11. – Quadratic mean diameter of white spruce larger than 6.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	--	--	--	--	7.0	7.3
40	--	--	6.7	7.1	7.4	7.8
50	--	6.7	7.0	7.4	7.8	8.2
60	6.5	6.8	7.2	7.7	8.2	8.7
70	6.6	7.0	7.5	8.0	8.5	9.1
80	6.7	7.2	7.7	8.3	8.9	9.5
90	6.9	7.4	8.0	8.6	9.2	9.8
100	7.0	7.6	8.2	8.8	9.5	10.2
110	7.1	7.7	8.4	9.1	9.8	10.6
120	7.3	7.9	8.6	9.3	10.1	10.9
130	7.4	8.1	8.8	9.6	10.4	11.2
140	7.5	8.2	9.0	9.8	10.7	11.5
150	7.6	8.4	9.2	10.1	11.0	11.9
160	7.8	8.5	9.4	10.3	11.2	12.2
170	7.9	8.7	9.6	10.5	11.5	--
180	8.0	8.9	9.8	10.7	11.7	--

Basal area of average tree = $[1689800 + 3.9936\, S^2 A]\; 10^{-7}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.858$ *Basis, number of plots = 98*

Table 12. – Quadratic mean diameter of white spruce larger than 8.5 inches d.b.h., by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Inches					
30	--	--	--	--	8.8	9.0
40	--	--	--	8.9	9.1	9.3
50	--	--	8.8	9.1	9.4	9.7
60	--	--	9.0	9.3	9.6	10.0
70	--	8.8	9.2	9.5	9.9	10.3
80	--	9.0	9.3	9.7	10.1	10.6
90	--	9.1	9.5	9.9	10.4	10.9
100	8.8	9.2	9.6	10.1	10.6	11.2
110	8.9	9.3	9.8	10.3	10.8	11.4
120	9.0	9.4	9.9	10.5	11.1	11.7
130	9.1	9.6	10.1	10.7	11.3	12.0
140	9.2	9.7	10.2	10.9	11.5	12.2
150	9.3	9.8	10.4	11.0	11.7	12.5
160	9.3	9.9	10.5	11.2	12.0	12.7
170	9.4	10.0	10.7	11.4	12.2	--
180	9.5	10.1	10.8	11.6	12.4	--

Basal area of average tree $= [3408300 + 3.3832\, S^2 A]\ 10^{-7}$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.769$ *Basis, number of plots = 89*

Table 13. — Average number of white spruce per acre larger than 0.5 inch d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	3,512	2,944	2,480	2,101	1,806	1,566
40	3,060	2,477	2,034	1,687	1,427	1,228
50	2,706	2,127	1,705	1,395	1,170	1,002
60	2,403	1,844	1,454	1,182	985	840
70	2,160	1,621	1,262	1,020	846	721
80	1,946	1,440	1,112	892	739	629
90	1,771	1,289	986	789	654	556
100	1,620	1,164	885	706	584	497
110	1,488	1,058	800	637	527	449
120	1,374	969	728	578	479	409
130	1,272	888	666	529	438	374
140	1,186	819	614	487	403	345
150	1,107	760	567	450	373	320
160	1,036	706	527	418	347	298
170	972	660	491	390	324	--
180	916	618	459	364	303	--

[1] *Tabular values derived by dividing table 5 values by basal area of average tree (table 9).*

Table 14. – Average number of white spruce per acre larger than 4.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	334	356	371	381	388	392
40	379	401	414	421	422	418
50	419	437	446	446	441	431
60	451	467	468	461	450	433
70	480	488	482	468	449	428
80	504	503	489	469	443	417
90	523	513	491	462	433	404
100	536	518	489	454	420	388
110	548	519	482	442	405	371
120	555	518	472	429	388	354
130	559	512	461	413	372	331
140	560	504	448	398	352	312
150	558	494	433	380	333	294
160	555	483	418	363	315	278
170	549	469	400	346	299	--
180	542	454	384	328	284	--

[1] *Tabular values derived by dividing table 6 values by basal area of average tree (table 10).*

Table 15. — Average number of white spruce per acre larger than 6.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	--	--	--	--	45	69
40	--	--	81	103	124	143
50	--	112	135	152	169	187
60	127	149	168	186	201	215
70	151	171	190	207	223	234
80	173	190	209	225	236	248
90	185	204	223	236	248	259
100	201	217	233	247	258	267
110	208	226	242	255	265	275
120	218	234	250	261	271	279
130	224	242	255	267	277	283
140	233	248	262	271	280	283
150	238	252	266	275	284	276
160	243	258	270	280	287	270
170	248	261	273	283	284	--
180	250	264	276	286	278	--

[1] *Tabular values derived by dividing table 7 values by basal area of average tree (table 11).*

Table 16. – Average number of white spruce per acre larger than 8.5 inches d.b.h., by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Number					
30	--	--	--	--	2	23
40	--	--	--	7	32	56
50	--	--	3	30	58	84
60	--	--	21	51	81	109
70	--	6	38	70	102	131
80	--	19	54	88	120	150
90	--	32	68	104	137	168
100	5	43	82	119	153	184
110	14	55	95	132	167	198
120	23	66	107	145	180	212
130	32	76	118	157	191	223
140	40	86	128	168	203	234
150	48	95	137	178	213	244
160	56	104	148	188	223	246
170	64	112	157	197	232	--
180	71	120	165	205	240	--

[1] *Tabular values derived by dividing table 8 values by basal area of average tree (table 12).*

Table 17. — Cubic-foot volume per acre of white spruce larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	92	544
40	--	--	141	602	1,092	1,611
50	--	263	742	1,257	1,807	2,393
60	192	675	1,201	1,769	2,379	3,032
70	485	1,007	1,578	2,199	2,870	3,590
80	726	1,287	1,904	2,578	3,309	4,096
90	933	1,533	2,197	2,924	3,715	4,569
100	1,117	1,756	2,465	3,245	4,096	5,018
110	1,283	1,961	2,716	3,550	4,461	5,450
120	1,437	2,153	2,954	3,841	4,812	5,868
130	1,580	2,335	3,183	4,122	5,154	6,277
140	1,715	2,510	3,403	4,396	5,487	6,678
150	1,845	2,678	3,617	4,663	5,814	7,072
160	1,969	2,841	3,826	4,925	6,137	7,462
170	2,089	3,000	4,031	5,183	6,455	--
180	2,205	3,155	4,232	5,437	6,769	--

Volume $= -158.90 + 24.953\ S + 0.0035378\ S^2 A - 85625.0/A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.883$ *Basis, number of plots = 98*

Table 18. – Cubic-foot volume per acre of white spruce larger than 6.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	92	544
40	--	--	141	567	923	1,320
50	--	169	509	902	1,347	1,844
60	12	358	766	1,237	1,771	2,367
70	143	546	1,022	1,572	2,194	2,891
80	274	734	1,279	1,907	2,618	3,414
90	405	923	1,535	2,242	3,042	3,937
100	535	1,111	1,792	2,577	3,466	4,461
110	666	1,300	2,048	2,911	3,890	4,984
120	797	1,488	2,304	3,246	4,314	5,507
130	928	1,676	2,561	3,581	4,738	6,031
140	1,059	1,865	2,817	3,916	5,162	6,554
150	1,190	2,053	3,074	4,251	5,586	7,072
160	1,320	2,242	3,330	4,586	6,010	7,462
170	1,451	2,430	3,587	4,921	6,434	--
180	1,582	2,618	3,843	5,256	6,769	--
	Years					
Merging ages	--	--	42	39	36	34
	--	--	--	--	172	150

Between merging ages: $Volume = -772.96 + 0.0052336S^2A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.844$ *Basis, number of plots = 98*

Below the low and above the high merging ages: same as table 17.
Merging age: $-614.06 + 0.0016958S^2A - 24.953S + \frac{85625.0}{A} = 0$

Table 19. – Cubic-foot volume per acre of white spruce larger than 6.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	38	329
40	--	--	--	104	451	839
50	--	--	48	431	865	1,350
60	--	--	298	758	1,279	1,861
70	--	84	548	1,084	1,692	2,371
80	--	267	798	1,411	2,106	2,882
90	--	451	1,049	1,738	2,519	3,392
100	73	635	1,299	2,065	2,933	3,903
110	201	819	1,549	2,392	3,347	4,414
120	329	1,003	1,799	2,718	3,760	4,924
130	456	1,187	2,050	3,045	4,174	5,435
140	584	1,370	2,300	3,372	4,587	5,946
150	712	1,554	2,550	3,699	5,001	6,456
160	839	1,738	2,800	4,026	5,415	6,967
170	967	1,922	3,050	4,353	5,828	--
180	1,095	2,106	3,301	4,679	6,242	--

Volume $= -1203.2 + 0.0051063\, S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.894$ *Basis, number of plots = 89*

Table 20 – Cubic-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	--	--
40	--	--	--	--	78	492
50	--	--	--	56	519	1,037
60	--	--	--	405	961	1,582
70	--	--	182	754	1,402	2,127
80	--	--	449	1,102	1,843	2,672
90	--	78	716	1,451	2,285	3,216
100	--	274	983	1,800	2,726	3,761
110	--	470	1,249	2,148	3,167	4,306
120	--	667	1,516	2,497	3,609	4,851
130	84	863	1,783	2,846	4,050	5,396
140	220	1,059	2,050	3,195	4,491	5,941
150	356	1,255	2,317	3,543	4,933	6,485
160	492	1,451	2,584	3,892	5,374	7,030
170	628	1,647	2,851	4,241	5,815	--
180	765	1,843	3,118	4,589	6,257	--

Volume $= -1687.2 + 0.0054484\, S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.855$ *Basis, number of plots = 98*

Table 21. – Cubic-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	--	--
40	--	--	--	--	--	387
50	--	--	--	--	413	902
60	--	--	--	305	830	1,416
70	--	--	93	634	1,246	1,931
80	--	--	346	963	1,663	2,446
90	--	--	598	1,293	2,080	2,960
100	--	181	850	1,622	2,497	3,475
110	--	366	1,102	1,952	2,914	3,990
120	--	552	1,354	2,281	3,331	4,504
130	1	737	1,607	2,610	3,748	5,019
140	130	922	1,859	2,940	4,165	5,534
150	258	1,107	2,111	3,269	4,582	6,048
160	387	1,293	2,363	3,599	4,998	6,563
170	516	1,478	2,615	3,928	5,415	--
180	644	1,663	2,868	4,257	5,832	--

Volume = -1671.90 + 0.0051469 $S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

R^2 *= 0.860 Basis, number of plots = 89*

Table 22. – Board-foot volume per acre of white spruce larger than 8.5 inches d.b.h. from a 1-foot stump to a 6-inch top inside bark, by age and site index, interior Alaska

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Board feet[1]					
30	--	--	--	--	--	--
40	--	--	--	--	--	2,349
50	--	--	--	--	2,500	5,375
60	--	--	--	1,864	4,951	8,402
70	--	--	623	3,801	7,403	11,428
80	--	--	2,106	5,738	9,855	14,455
90	--	--	3,590	7,675	12,306	17,482
100	--	1,138	5,073	9,612	14,758	20,508
110	--	2,228	6,556	11,549	17,209	23,535
120	--	3,317	8,039	13,486	19,661	26,561
130	79	4,407	9,522	15,424	22,112	29,588
140	835	5,496	11,005	17,361	24,564	32,615
150	1,592	6,586	12,488	19,298	27,015	35,641
160	2,349	7,675	13,971	21,235	29,467	38,668
170	3,105	8,765	15,454	23,172	31,918	--
180	3,862	9,855	16,937	25,109	34,370	--

Volume $= -9757.8 + 0.030266\ S^2 A$

where: S = *site index*
A = *average breast-height age of at least the six tallest white spruce trees.*

$R^2 = 0.854$ *Basis, number of plots = 89*

[1] *International ¼-inch rule.*

Table 23. — Cubic-foot mean annual increment per acre for white spruce larger than 4.5 inches d.b.h. from a 1-foot stump to a 4-inch top inside bark, by age and site index, interior Alaska[1]

Breast-height age (years)	Site index (feet)					
	50	60	70	80	90	100
	Cubic feet					
30	--	--	--	--	3.1	18.1
40	--	--	3.5	15.1	27.3	40.3
50	--	5.3	14.8	25.1	36.1	47.9
60	3.2	11.3	20.0	29.5	39.6	50.5
70	6.9	14.4	22.5	31.4	41.0	51.3
80	9.1	16.1	23.8	32.2	41.4	51.2
90	10.4	17.0	24.4	32.5	41.3	50.8
100	11.2	17.6	24.6	32.4	41.0	50.2
110	11.7	17.8	24.7	32.3	40.6	49.5
120	12.0	17.9	24.6	32.0	40.1	48.9
130	12.2	18.0	24.5	31.7	39.6	48.3
140	12.2	17.9	24.3	31.4	39.2	47.7
150	12.3	17.8	24.1	31.1	38.8	47.1
160	12.3	17.7	23.9	30.8	38.4	46.6
170	12.3	17.6	23.7	30.5	38.0	--
180	12.2	17.5	23.5	30.2	37.6	--

[1] *Tabular values were derived by dividing table 17 values by breast-height age.*

Table 24. — Relative frequency distribution of white spruce by 1-inch diameter classes and average d.b.h., interior Alaska

Average d.b.h.[1] (inches)	Diameter class (inches)[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Percent of trees in stand																			
2	50	33	11	4	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--
3	36	27	19	10	5	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--
4	17	23	22	18	10	6	2	2	--	--	--	--	--	--	--	--	--	--	--	--
5	10	15	18	19	15	11	6	4	1	1	--	--	--	--	--	--	--	--	--	--
6	6	9	13	16	16	15	11	7	4	2	1	--	--	--	--	--	--	--	--	--
7	3	7	10	13	14	15	12	10	8	3	3	1	1	--	--	--	--	--	--	--
8	1	6	7	7	11	13	14	12	10	7	5	3	1	1	1	--	--	--	--	--
9	--	3	5	7	7	12	12	14	11	10	7	5	3	2	1	1	--	--	--	--
10	--	1	5	6	7	7	11	11	11	11	10	7	5	4	2	1	1	1	--	--
11	--	--	3	4	6	7	8	10	11	11	10	8	7	5	4	2	2	1	--	--
12	--	--	1	4	4	5	5	10	10	10	11	10	9	7	6	4	1	1	1	1

[1] *Includes all d.b.h. larger than 0.5 inch.*
[2] *Midpoint of class (e.g., 8 = 7.6 through 8.5 inches).*

NUTRIENT CYCLING BY THROUGHFALL AND STEMFLOW PRECIPITATION IN THREE COASTAL OREGON FOREST TYPES

by

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INTRODUCTION

In the Pacific Northwest, where annual precipitation ranges from about 40 to 120 inches per year in commercial forest areas, rainfall washing through the forest canopy returns a part of the nutrient capital of the ecosystem to the soil. Nitrogen is of special interest in this connection because it is the only nutrient element thus far found to appreciably stimulate growth of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) when applied as fertilizer (Gessel et al. 1965).

A number of tree species throughout the world have been shown to contribute to the enrichment of throughfall and stemflow,[1] but in most studies of this phenomenon, only nonnitrogenous nutrient ions have been determined. Few investigators have determined N content in throughfall and stemflow (Voigt 1960b; Sviridova 1960; Mina 1965; Maruyama et al. 1965; Carlisle, Brown, and White, 1967; Cole, Gessel, and Dice, 1967), and only one study (Rahman[2]) included red alder (*Alnus rubra* Bong.), a nitrogen-fixing, nodulated woody plant that is also the major hardwood tree in the Pacific Northwest.

In connection with studies of nitrogen cycling, airborne chemical pollutants, and rhizosphere microflora, we wished to determine the significance of alteration of some chemical constituents of rainfall by its passage through the forest canopy. In the study reported here, we asked: What is the nature and magnitude of alteration of total N and dissolved solids content, and how is pH of gross rainfall altered by throughfall and stemflow in stands of (1) red alder; (2) conifer—Douglas-fir, Sitka spruce (*Picea sitchensis* (Bong.) Carr.), and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.); and (3) mixtures of alder and the conifers?

---

[1] *Gross rainfall* is rainfall measured in the open. *Throughfall* is that portion of the gross rainfall which directly reaches the forest litter through spaces in the vegetative canopy and as drip from leaves. *Stemflow* is that portion of the gross rainfall which is caught on the canopy and reaches the litter or mineral soil by running down the stems (Helvey and Patric 1965).

[2] Rahman, A. H. A study of the movement of elements from tree crowns by natural litterfall, stem flow and leaf wash. 118 pp. 1964. (Unpublished M.F. thesis on file at Univ. Wash.)

EXPERIMENTAL PROCEDURES

The study was conducted at Cascade Head Experimental Forest about 6 miles inland from the Pacific Ocean at latitude 45°3' N., longitude 123°55' W. Here, a series of three growth measurement plots—pure alder, pure conifer, and a mixture of alder and conifer—were established in 1937. The stands are now about 40 years old and occupy the following basal areas (square feet per acre): alder, 156; conifer, 268; and mixed stand, 221.

Soils beneath all three stands are Astoria-like Sols Bruns Acides developed from deeply weathered tuffaceous siltstone of Eocene epoch. Detailed morphological and chemical characteristics of soils beneath the three stands are reported by Franklin et al. (1968).

Three polyethylene rainfall collectors were randomly located in each stand and in an adjacent opening of about 21 acres. Three polyethylene funnels, having a total top opening area of 1 square foot, were inserted through the lid of each container Each funnel was fitted with a Pyrex glass wool filter plug and a 10-mesh copper screen to keep coarse debris out of the collector. Two milliliters of toluene were added to each container to inhibit microbial action.

Three trees, selected at random in each stand, were fitted with lead troughs which conducted stemflow through Tygon tubing into a polyethylene container protected against contamination in the same manner as the throughfall collectors.

Collectors were emptied monthly from late spring through fall, then bimonthly during the winter. The volume of precipitation collected was measured to the nearest 1 milliliter. After being passed through Whatman No .5 filter paper, the water was analyzed for nitrite nitrogen with 1-naphthylamine sulfanilic acid and sodium acetate buffer (American Public Health Association 1955). Nitrate nitrogen was determined by the phenoldisulfonic method (Harper 1924) which included special precautions to avoid loss of nitrate. Free ammonium was determined for 50 milliliter samples by distillation with phosphate buffer at pH 7.4 (Nichols and Foote 1931). Organic nitrogen was determined for 50 milliliter samples by a semimicro modification of the standard Kjeldahl procedure; 25 milliliters of distillate were collected in 6 milliliters of saturated boric acid and titrated with N/70 sulfuric acid using methyl red—bromcresol green mixed indicator.

Total dissolved solids were determined by evaporating a filtered 100-milliliter aliquot of water on a steam bath, drying the residue in a desiccator, then weighing. A glass electrode was used to determine pH.

RESULTS AND DISCUSSION

itrogen

Average concentration of total N was 0.05 illigram per liter in gross rainfall (table 1). 'e found no measurable NO_2^- or NH_4^+ and ·ry little NO_3^-. Most of the N brought down precipitation collected in the open was in the ganic form and was attributed to locally gen- ated airborne organic debris, including pollen 'arrant et al.[3])

For all forms of N determined, the order of agnitude of concentration in relation to kind precipitation was: stemflow > through- ll > gross rainfall. Concentrations of total in throughfall and stemflow were increased out 3 to 14 times over that of gross rainfall. most instances, more than 80 percent of e total N was in organic form. Concentration NO_3^- in stemflow from conifer trees, both the pure conifer stand and in the mixed nd, was much greater than in any other pre- ·itation-forest type combinations observed. his finding suggests that rough conifer bark ay harbor large numbers of nitrifying bac- ·ia that could aid in altering organic N to ore readily available forms.

Although we found no measurable NH_4^+ in oss rainfall, this ion was present in varying iounts in throughfall and stemflow. The con- ntration of NH_4^+ in alder throughfall was ice that in the conifer or mixed stands. In ler stemflow, NH_4^+ concentration was slight- greater than in the conifer type and 50 per- nt greater than in the mixed stand. These dings may indicate that alder in some way courages development of ammonifying bac- ·ia in the phyllosphere and on the tree stem.

Organic N concentration was greatly increas- in all stands over that of gross rainfall. As th the other forms of N, concentration of ·ganic N in stemflow was greater than that of roughfall.

[3] Tarrant, R. F., Lu, K.C., Chen, C.S., and Bollen, B. Nitrogen content of precipitation in a coastal C·gon forest opening. Tellus. (In press.)

TABLE 1. — *Yearly N concentration by type of precipitation and forest cover — weighted average of three observations over nine sampling periods, Cascade Head, Oregon*

Precipitation and forest cover type	Yearly precipitation	NO_3^-	NH_4^+	Organic	Total
	Million liters per acre	------	Milligram per liter	------	
Gross precipitation	11.66	0.01	0	0.04	0.05
Throughfall (net):[1]					
Alder	10.33	.02	.02	.22	.26
Conifer	8.18	.01	.01	.14	.16
Mixed	9.11	.02	.01	.23	.26
Stemflow (net):[1]					
Alder	.01	.04	.06	.59	.69
Conifer	.06	.13	.05	.18	.36
Mixed	.05	.15	.04	.38	.57

[1] All values for throughfall and stemflow expressed as net after deducting amount of N in gross precipitation.

Compared with gross rainfall, total N (pounds per acre per year) in throughfall was nearly five times greater beneath alder; almost four times more beneath the alder-conifer stand; and about three times greater under conifers (table 2). Although the effect of stemflow on N concentration was substantial (table 1), the net effect on a weight-per-area basis was minor (table 2) because of the relatively small amount of stemflow per acre as was pointed out also by Carlisle, Brown, and White (1967).

TABLE 2. — *Precipitation and litterfall compared as sources of total nitrogen in three forest types of coastal Oregon*

Nitrogen source	Total N		
	Alder	Mixed	Conifer
	----Pounds per acre per year---		
1. Throughfall (net)[1]	5.88	5.18	3.44
2. Stemflow (net)	.02	.08	.04
3. (1) + (2)	5.90	5.26	3.48
4. Less N in conifer precipitation	2.42	1.78	0
5. Litterfall[2]	100.30	103.69	31.95
6. Less N in conifer litterfall	68.35	71.74	0
7. N accretion from alder (4) + (6)	70.77	73.52	0

[1] Throughfall and stemflow expressed as net after deducting 1.22 pounds per acre per year N input in gross precipitation.

[2] Tarrant, R. F., Lu., K. C., Bollen, W. B., and Franklin, J. F. Nitrogen enrichment of two forest ecosystems by red alder (*Alnus rubra*).(Unpublished data on file at Forestry Sciences Laboratory, Pacific Northwest Forest & Range Experiment Station, Corvallis, Oreg.)

Gross rainfall at this coastal Oregon location (113 inches during the year sampled) does not provide any significant accretion of N to the nutrient capital of the ecosystem (Tarrant et al.[4]), nor, probably, does the enriched throughfall and stemflow beneath the conifer stand. We deducted the N content of throughfall and stemflow from that for both the alder and mixed stands to obtain a conservative estimate of the N that might be regarded as an addition to nutrient capital through symbiotic fixation of atmospheric N by red alder. On this net basis, N accretions of about 2.4 pounds per acre beneath alder and 1.8 pounds per acre beneath the alder-conifer stand may be attributed to the function of red alder as a nitrogen-fixing woody plant (table 2).

Nitrogen increases to nutrient capital of the ecosystem from precipitation, however, are minor compared with the annual deposition of N in litterfall of red alder and the mixed stand (table 2). For a site of lower productivity tha that we observed, Rahman[5] found, over a month period, that, of the total return of N fro litterfall and from precipitation passing throug the forest canopy, about 78 percent was co tained in litterfall beneath Douglas-fir and percent in that beneath red alder. Thus, the ro of precipitation in the cycling of N apparently not great in coastal Pacific Northwest forests, finding supported also by the work of Cole, Ge sel, and Dice (1967) in Washington State.

[4] See footnote 3.

Total Dissolved Solid

As with N, total dissolved solids concentra tion was substantially greater in precipitatio influenced by forest cover than in gross rainfa (table 3). On a net-weight-per-area basis, ad ditions of dissolved solids in throughfall wer substantial but stemflow contributions wer negligible.

TABLE 3. — *Yearly dissolved solids concentration a weight by type of precipitation and fore cover: weighted average of three observ tions over nine sampling periods, Casca Head, Oregon*

Precipitation and forest cover type	Yearly precipitation	Dissolved solids	
		Concentration	Total wei
	Million liters per acre	Milligram per liter	Pounds per acre
Gross rainfall:			
Open	11.66	0.15	385
Throughfall (net):[1]			
Alder	10.33	.31	705
Conifer	8.18	.19	342
Mixed	9.11	.34	682
Stemflow (net):[1]			
Alder	.01	.47	1
Conifer	.06	.80	11
Mixed	.05	.85	10

[1] Net = gross throughfall and stemflow less gro rainfall.

[5] See footnote 2.

"Total dissolved solids" includes a number of ns as well as some dust that fell during dry riods or was washed from the air during rain- orms. Some measure of the constituents of tal dissolved solids is available in the findings Moodie (1964) who sampled nutrient inputs precipitation at Long Beach on the Washing- n coast about 100 miles north of our study ea. Here, where precipitation for the years 62-65 averaged about 77 inches per year (in ntrast to 113 inches at Cascade Head), aver- e total weight of dissolved constituents of oss rainfall for the 4-year period was 207 unds per acre per year.[6] Of this total, 82 per- nt was represented in three forms: Cl, 41 rcent; Na, 23 percent; and dustfall, 18 per- nt.

For the 384 pounds per acre per year of dis- ved solids we measured in gross precipitation, oodie's (1964) data would indicate possible infall inputs of nutrient elements (pounds r acre per year) in coastal Oregon forests be: P, 1.5; K, 6.1; Ca, 8.1; and Mg, .4. Phosphorus is apparently adequate for od tree growth in soils beneath the three nds, and K is very high (Franklin et al. 68). Base content of these soils, however, is v, especially beneath alder. Most of the dif- ence in base status between soils of the three nds is found in amounts of exchangeable Ca d Mg.

Rahman[7] found that at least two-thirds of K returned to the soil and half the P and g was brought down in throughfall and stem- w. On the basis of our present information, believe that future studies of alteration of iic content of precipitation by stemflow and oughfall in coastal Oregon forests should be icentrated on the cycling of exchangeable es.

Acidity of Precipitation

Average yearly pH level of throughfall was t different from that of gross rainfall (table although throughfall variation was greater n that of gross rainfall. Stemflow was al- ys more acid than gross rainfall. Alder stemflow was only slightly less so (pH 5.8 vs. 6.1), but in the mixed and conifer stands, stem- flow pH was 0.8 and 1.0 unit lower, respect- ively, than gross rainfall.

The throughfall process involves a relatively short duration of contact between rainfall and smooth-surfaced needles or leaves. In contrast, stemflow is affected especially by rough, corky conifer bark which provides greater opportuni- ty than smooth-barked alder for water retention and organic matter decomposition which yields acid residues. The ecological significance of stemflow pH being less than that in through- fall or gross rainfall is probably not great, since stemflow affects only a small area about the base of the tree (Voigt 1960a). No difference in pH was found in either the F layer or A11 soil horizon within 2 feet of the base of an alder tree compared with samples taken further from the stem (Bollen et al. 1968).

TABLE 4. — *Acidity of precipitation (pH) collected in open and beneath three forest types — yearly average of three observations in each forest cover type*

Precipitation and forest cover type	Yearly range	Yearly average
Gross rainfall:		
Open	5.7 — 6.3	6.1(±.02)
Throughfall:		
Alder	5.6 — 6.6	6.0(±.04)
Conifer	5.9 — 6.8	6.1(±.03)
Mixed	5.7 — 6.7	6.1(±.04)
Stemflow:		
Alder	4.8 — 6.4	5.8(±.11)
Conifer	4.7 — 5.7	5.0(±.08)
Mixed	3.8 — 6.0	5.3(±.20)

[6] Unpublished data for 1964-65 were kindly supplied C. D. Moodie, Washington State University.

[7] See footnote 2.

CONCLUSIONS

The role of precipitation in N-cycling in three coastal Oregon forest types appears to be minor in comparison with the much greater amounts of N cycled in litterfall. Concentration of NO_3^- was much greater in stemflow from conifers than in other precipitation-forest type combinations, and that of NH_4^+ was substantially greater in alder stemflow and throughfall. These observations indicate the need for more information on microbial populations on leaf and needle surfaces and on tree stems to elucidate possible differences between tree species in numbers of nitrifying and ammonifying bacteria.

Substantial differences between forest types in amount of dissolved solids in precipitation indicate that other nutrient elements might be more important subjects of investigation than N. The role of different tree species in influencing throughfall and stemflow content of exchangeable bases, especially, appears to require further investigation. Other factors th appear to require study include metabolit such as carbohydrates, amino acids, and orga ic acids in general.

Despite the generally greater content of n trient ions in stemflow than in throughfa stemflow appears to be of little importance nutrient cycling by precipitation because of t small volume of stemflow on an area basis. future studies of ionic content of precipitati in coastal Oregon forests, sampling effort mig better be concentrated on throughfall. Likewis determination of NO_2^--N is not necessary b cause of its extremely rare occurrence in mea urable amounts.

Acidity of throughfall precipitation was n different from that of open-collected rainfa Stemflow was always more acid than the oth two forms of precipitation, but the ecologic significance of this difference is not believed be great.

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imber Measurement Problems

THE DOUGLAS-FIR REGION OF

SHINGTON AND OREGON

by

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FOREST AND RANGE EXPERIMENT STATION
U.S. DEPT. OF AGRICULTURE · FOREST SERVICE
U. S. FOREST SERVICE RESEARCH PAPER PNW-55

FOREWORD

This analysis of timber measurement problems in the Douglas-fir region of Washington and Oregon was made by members of the Station staff under the leadership of Consultant Robert W. Cowlin. Available literature was reviewed to help identify the measurement systems used in the region, to gain familiarity with the background in which these systems were developed, and to make a preliminary determination of the problems encountered by users of the present systems.

Next, representatives of different user groups were consulted to determine their experience with and opinions about timber measurement problems and their objectives and standards of performance in use of measurements.

Station staff participating in these conferences were David Bruce, Paul H. Lane, Melvin E. Metcalf, Robert B. Pope, Donald R. Gedney, John W. Henley, Marlin E. Plank, and Richard Woodfin. In addition, Thomas C. Adams reported on timber measurement problems encountered in his field studies of timber sales arrangements, Walter H. Lund prepared a report on timber measurement systems now in use by Region 6 of the U.S. Forest Service, and Carl A. Newport prepared a report on timber measurement systems in use by private timber owners in the open market sale of standing timber.

About 120 people were consulted in over 70 separate conferences. This report does not attempt to describe all the small variations of measurement systems now used, to present all the varying viewpoints, or to tally up the votes for or against any features of the present measurement systems. It also does not include analyses of timber appraisals, sales contracts, or sales administration other than the problems of measurement, although other phases of these subjects were discussed in some conferences.

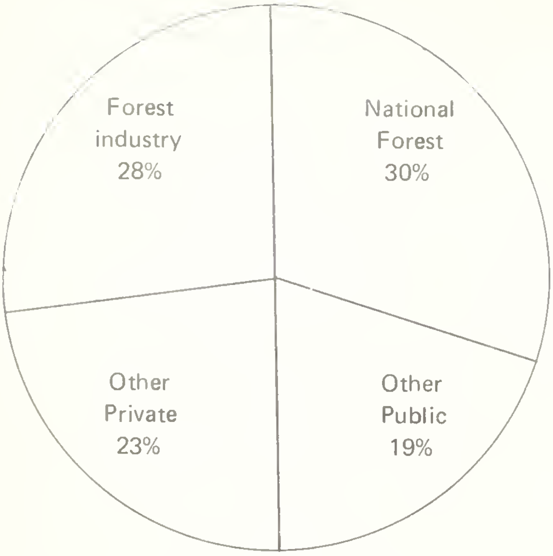
Since this report may be read by people not familiar with forest management and the timber industry, many details will be included that may seem unnecessary to some readers, although no attempt will be made to avoid all forestry and trade jargon.

CONTENTS

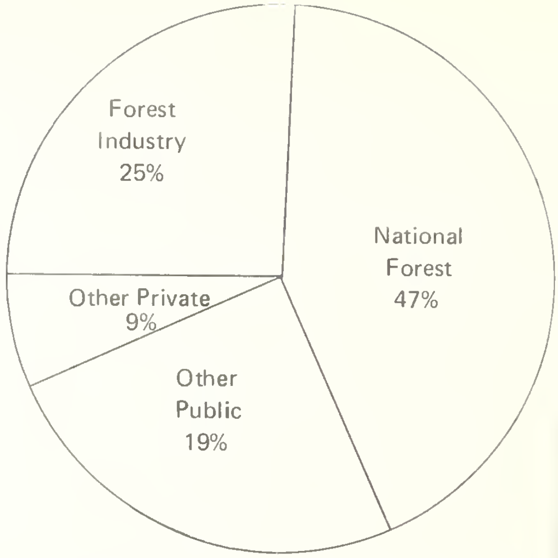
INTRODUCTION

Owners and managers of timberlands and timber processing plants are vitally concerned with measurement of trees and logs. Timberlands are the source of raw materials for the industry, and their best management requires knowledge of the quantity and value of present supplies and forecasts of the effect of this management on future supplies. These raw materials insure continued operation of timber processing plants if they can be procured at costs commensurate with the value of the products. An essential step in procurement is the estimation of volume and grade of trees or logs. Investment in new processing plants and equipment depends in part on forecasts of raw material availability. These forecasts are based on forest survey. Timber measurements are also needed in the industry's financial reports, records, and control systems. Many taxes paid by timberland and plant owners are based on some measurement of trees or logs.

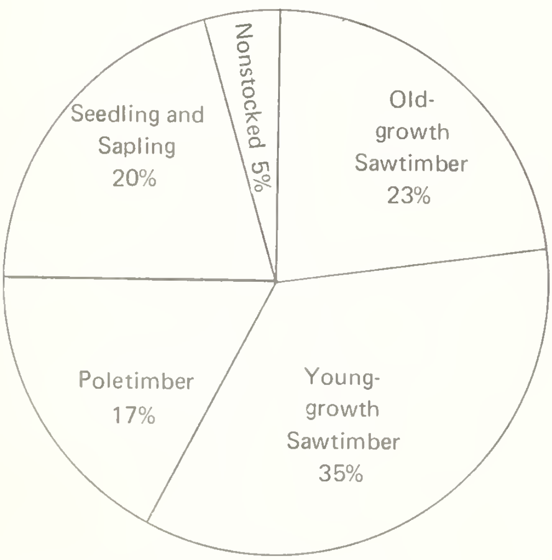
Many communities in the Douglas-fir region are largely dependent on the timber industry, which is one of the major contributors to the wealth of the region. Therefore, the many people employed in timber and related industries are affected by the results of these measurements. Also interested are a large group of people not too well versed in the intricacies of timber measurements, including bankers, legislators, newspapermen, members of the transportation industry, and taxpayers in general.



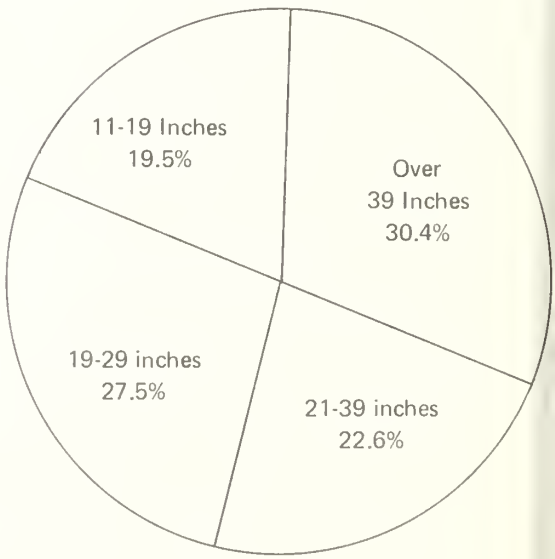
1a. Ownership of commercial forest land.



1b. Sawtimber volume on commercial forest land.



1c. Type of forest on commercial forest land.



1d. Sawtimber volume by diameter class.

Figure 1.--Commercial forest area and sawtimber volume in Douglas-fir region of Oregon and Washington, January 1, 1963.

In the Douglas-fir region of Washington and Oregon, 66 percent of the present sawtimber supply is on the 49 percent of commercial timberland in public ownership; 25 percent of the supply is on the 28 percent owned by timber industries; and 9 percent of the supply is on the 23 percent in other private ownerships (Figure 1). Of the 1966 annual cut of 12 billion board feet, 45 percent was from public lands. Most of this public timber was sold directly or indirectly to local mill operators. Much of the private timber was logged by industrial owners, mostly for processing in their own plants. In the last 3 years, the Japanese export market for logs has become increasingly important, accounting for over 8 percent of the harvest in 1966.

Practically all of the timber cut is scaled and graded as logs once, and some of it is scaled two or more times. Scaling may be by the seller, the buyer, or by a third-party log scaling and grading bureau.[1]

The sale of public timber on the stump has, in the past 20 to 30 years, largely replaced the log market where there was open bidding for rafts of logs harvested mostly from private lands. This has changed the main function of log scaling and grading bureaus. Where formerly their primary job was scaling and grading rafts of logs before the rafts were auctioned, now about half of their work is scaling and grading timber cut from public forests under sales contracts.

In the same period, there has been increasing harvest in second-growth stands. This has been accompanied by changes in harvesting and milling equipment and practices. More important to the present study, this change in timber source has reduced the size of trees and logs considered merchantable and changed the kind and amount of defect.

Another recent change in the Northwest is use of sorting and concentration yards. In these, logs whose species and quality do not make their end use obvious are measured and sorted for shipment or sale to different plants (for example, pulpwood logs are sorted and loaded separately at the woods landing). Since measurement itself adds nothing to the intrinsic value of the log and since sorting will assign most logs to the most profitable use, the sorting or concentration yard introduces the value-producing sorting operation for what otherwise would be only an operating expense. There is also much exchange of logs between plants which serves the same purpose, although possibly less efficiently. When log prices increase, more use of sorting or concentration yards may be stimulated to match logs to plant requirements.

Further change in the last 10 to 20 years has been the increasing concentration of the timber processing plants and industrial timberland ownership. With plant capacity remaining about the same, number of plant and timberland owners is decreasing. This reduction appears to have had little or no effect on competition in public timber sales. An important effect has been more multiproduct industries and industrial tree farms, and increased incentive for determining the most profitable use of each log.

Most trees and logs sold in the Douglas-fir region of Washington and Oregon are measured in board feet, Scribner Decimal C rule.[2] Some export sales are based on the Brereton rule[3] and some pulpwood sales on cubic feet. Both pulp logs and culls may be

[1] *There are now four scaling and grading bureaus in the Douglas-fir region of Washington and Oregon: Columbia River, Grays Harbor, Puget Sound, and Southern Oregon.*

[2] *A description of the Scribner rule is on page 6.*

[3] *Brereton scale is 12 times the cubic-foot content of a cylinder with diameter equal to the average of the two end diameters and length equal to that of the log.*

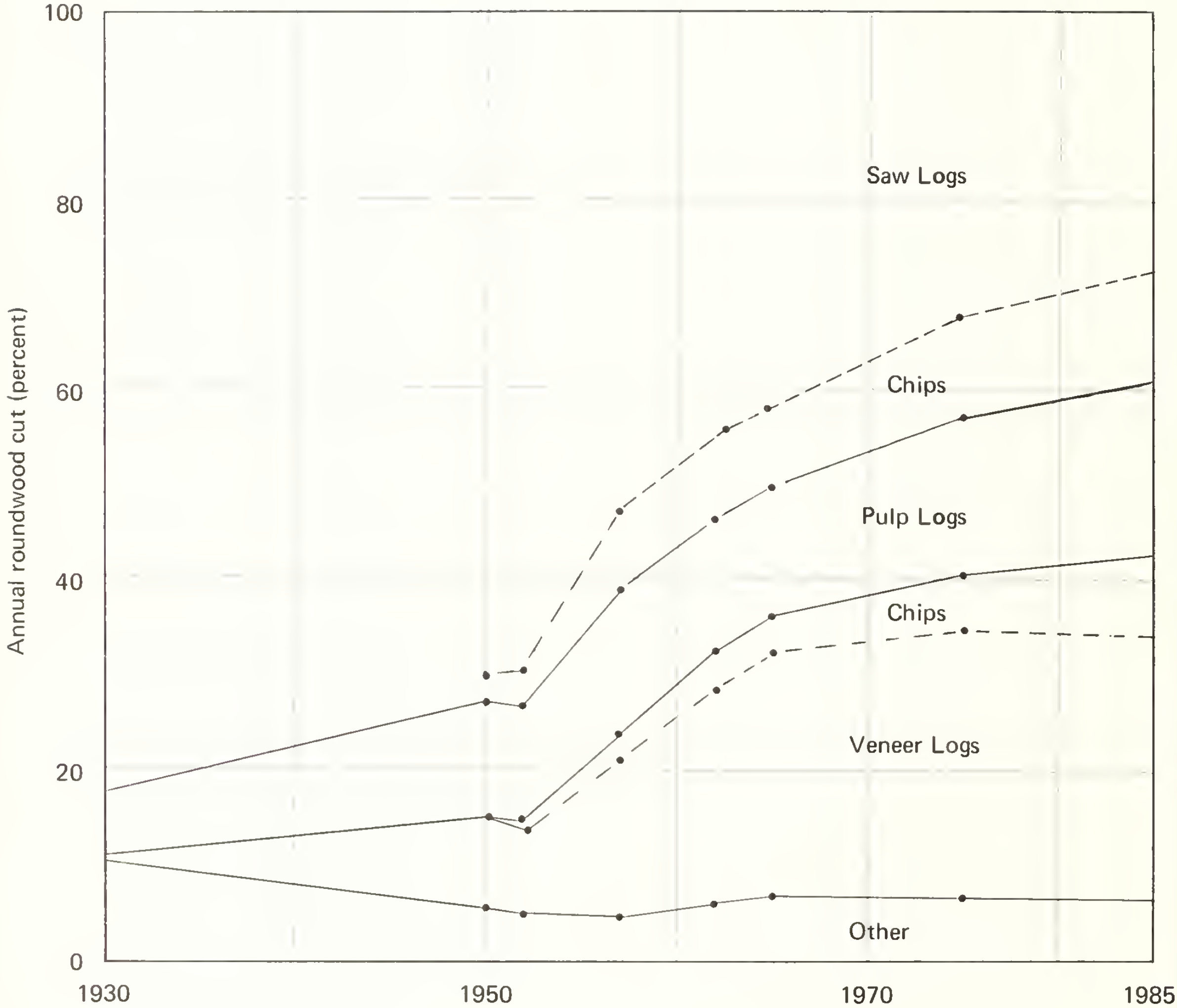


Figure 2.--Roundwood use in Douglas-fir region.

weighed. Poles and piling are sold by the lineal foot or piece.

Procedures for using the Scribner rule in the Douglas-fir region differ in several ways from methods common elsewhere: no allowance for taper is made on logs up to 40 feet long; fractional inches of diameter are dropped; in water scaling, a single (usually smallest) diameter is measured; and defect deductions are made only by reducing scaling diameter or length.

The annual costs of cruising and measuring trees and logs in the Douglas-fir region are about $15 million, slightly over $1 per thousand board feet harvested.

Apparently, this large expenditure does not produce all the estimates of potential product volumes needed by the timber industry because there are repeated requests for accurate and up-to-date conversion factors. These factors usually are used to convert estimates of volume or weight of logs to estimates of their potential products, but also may be used to convert from one log measurement to another. The list of conversion factors is long, reflecting the many different uses of wood.

Today, about half the logs harvested in the Douglas-fir region are sawed into lumber, one-fourth are peeled into veneer, and the rest are either chipped for pulp or used as poles, piling, or other wood products (Figure 2).[4] A large proportion of the residues from sawmills and veneer mills is chipped for pulp.

If present trends in production continue, even larger proportions of the logs will be made into veneer and pulp chips and smaller proportions will go into sawmills.

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[4]*Data from:*

Andrews, H. J., and Cowlin, R. W. Forest resources of the Douglas-fir region. U.S. Dep. Agr. Misc. Pub. 389, 169 pp., illus. 1940.

Gedney, Donald R., Newport, Carl A., and Hair, Dwight. Prospective economic developments based on the timber resources of the Pacific Northwest. V. 2, pt. 6, Forest Industries. 174 pp., illus. 1966. (Prepared under cooperative agreement with Bonneville Power Administration as part of their "Pacific Northwest Economic Base Study for Power Markets.")

THE STUDY

In October 1966, the Pacific Northwest Forest and Range Experiment Station's Advisory Committee urged that research be started to develop log and tree measurement systems with adequate accuracy in conversions from one unit of measure to another. A first step toward this undertaking is the present study which has as its objective an analysis of timber measurement systems now in use in the Douglas-fir region of Oregon and Washington. This analysis includes consideration of the objectives and standards of performance of the many different classes of users.

Specific objectives are to: (1) determine what information about tree or log dimensions, defect, quality, and other characteristics is now being used to estimate tree, log, and product volume, weight, or value, and how it is acquired and summarized; (2) look into the problem of accurate conversion factors; (3) define the criteria by which different classes of users judge present systems and by which they would judge any changes in present systems; (4) use these criteria to appraise the strengths and weaknesses of existing systems.

The accomplishment of these objectives should furnish the basis for consideration of changes and improvements needed in the measurements systems and for the further development of a program of specific studies to solve identified problems.

The authors believe that a complete timber measurement system should supply all the information about tree and log dimensions, defect, quality, or other characteristics needed to estimate: (1) volume or weight of wood in trees or logs, (2) quantity of one or more products that can be made from trees or logs, and (3) valu of trees or logs. It should also include th means of acquiring, summarizing, and usin this information.

Many timber measurement system have limited objectives and therefore ar not complete systems as defined above However, a characteristic of most system is that a unit of estimated volume or weigh is used as the basis for sale of wood. Estab lishing prices for the sale of trees or log requires estimates of their quality – hence quality is usually assayed when trees an logs are measured.

SOME HISTORY OF LOG SCALING AND GRADING

In the United States before 1805, if log volumes were measured at all, the unit of measurement apparently was cubic feet. Sometime during the next 20 years, estimation of number of superficial feet (square feet of surface area) of 1-inch boards in logs started. This was done either by direct estimates of board feet or by comparing the estimated cubic volume of the log with that of a "standard" log. The oldest surviving publication of the Scribner log rule is dated 1846. It includes logs 12 to 44 inches in diameter and 10 to 24 feet long. It may be the first log rule based on diagrams of the boards that might be cut from the log. Various extensions of the Scribner rule were made. The one now generally accepted – the Decimal C – was first published in 1910 after 4 years of use by the Forest Service (for logs 6 to 120 inches in diameter and 6 to 16 feet long by even feet). This extension appears to have accepted the Lufkin Rule Company's Decima C extension from 11- to 6-inch diameter rounded Scribner's original values to th nearest 10 board feet from 12 to 44 inches rounded Spaulding values from 48 inches t about 72 inches in diameter, and estab lished higher values by extending th Spaulding curve using the International 1/ inch as a guide to shape of curve.[5] Th Spaulding rule was developed in Californi in 1868 for logs 10 to 96 inches in diamete and 12 to 24 feet long. It was based on dia grams, but values appear to have bee smoothed. From 12 to 44 inches, th Spaulding values look like smoothe Scribner values.

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[5] A footnote to the 1910 Forest Service table add confusion by stating "the original rule did not exten beyond a diameter of 60 inches." This implies that som venerable table attributed to Scribner extended to 6 inches. In 1903, the Forest Service published a Scribne rule table that extended only to 44 inches.

It is not certain what log rules were first used in the Douglas-fir region. The fact that the Scribner rule was used for many years around Puget Sound and the Spaulding around the Columbia River is suggestive. The Drew rule, formerly used in western Washington, was based on diagrams for logs over 20 feet long (adjusted for mill tally) and was developed by Fred Drew, log buyer for Pope & Talbot, Inc.

Early use of log rules was to determine wages to be paid fallers and buckers, payments to logging contractors, and price to be paid for logs delivered to mills by settlers. Timberland usually was acquired for a fixed price per acre (under the Timber & Stone Act of 1879 for $2.50 per acre). In 1900, 900,000 acres in western Washington were sold at a rate of about 10 cents per thousand feet ($6 per acre). However, census reports show the average value of Douglas-fir stumpage was 68 cents in 1890 and $1.05 in 1904. These price differences were probably largely a matter of accessibility, competition, and quality.

Early records (back to 1860 for Puget Sound) suggest that most logs were purchased camp run (ungraded). From 1902 to 1908, "Flooring" logs were selling for $8 to $14 in Puget Sound, "Merchantable" for $6 to $11, and "No. 2" for $3.50 to $7. In the record for 1909 to 1916, No. 1, No. 2, and No. 3 replaced these earlier grades but maintained the $3 differential between grades. In 1910, the manager of the Columbia River Scaling Bureau stated that under the old system of scaling the scaler took enough off the diameter to make a knotty log the same in value as a log without black, loose, spiked, or large knots, but that under the grading system, the price takes care, to a great extent, of the knot problem. He also said that scalers should not be required to deduct for defects they could not see, but that these should be price considerations.

In the early days of the plywood industry, veneer logs were selected from rafts of sawmill logs. In 1924, plywood mills were reported to take only 1-1/2 percent of the logs they looked at and every log was rolled a dozen times before being accepted. In 1926, a scaling book mentioned payment of a premium for selected No. 2 sawmill logs and selection of No. 3 sawmill logs for core stock.

Changes in manufacturing technology have caused changes in log grades and end use of logs. Currently, Selects are logs too small for a regular Peeler grade. Veneer mills often cannot compete with sawmills for Peelers. Fir Wood logs are no longer classed as No. 1 and No. 2. Special Culls (logs with white pocket rot that will make at least mill-certified plywood) are regularly peeled. Peewees, or gang-mill logs, are not recognized by scaling Bureau rules but are by gang-mill operators.

A relatively recent change in the Douglas-fir region is the use of cubic-foot log scaling by industries that operate pulpmills. Some of these industries have made the cubic foot the basis of all their inventories, business control records, and transfers of wood from one division to another. In 1948, cubic-foot scaling was adopted as the official log measurement in British Columbia. Methods of determining cubic-foot content vary, some using two-end diameter measurement and some small-end with taper allowance. The most notable inaccuracies of cubic-foot scaling are associated with butt swell. Some criticism of British Columbia cubic-foot scale is aimed at underallowance for butt swell. Another criticism of cubic-foot scaling and grading in coastal British Columbia is that the three grades used do not adequately segregate logs into value classes.

Another change has been the partial substitution of weighing for other wood measurement. This is done in one of two ways. Either weight is the unit of sale or a subsample of weighed truckloads is measured in some volume unit and an average conversion ratio is calculated. Experience elsewhere suggests that if reasonably accurate conversion to board feet, log scale, is wanted, both weight and total length of logs must be measured. Weight scaling is most popular for low- or uniform-value logs. Weight-to-volume ratios vary if percent sapwood changes, if species are mixed, and if small material is left on the ground after felling for varying periods. High-value logs with highly variable defect are seldom weighed, because this precludes individual log examination.

It is sometimes stated that the United States and Canada are the only parts of the world where board-foot estimates are used and, hence, implied that these are the only countries that use log measures incompatible with those used in other nations. This is far from true. Some South and Central American countries and Liberia use board feet, and in parts of the world where there formerly were British colonies, the "super" foot and quarter girth measure (Hoppus) are common. Elsewhere, cubic feet or cubic meters are used to measure logs, but the rules for determining them are bewilderingly various. Logs may be measured inside bark or outside bark; diameters may be small end, two end, or midlog; and fractions may be dropped or rounded to the nearest whole number.

TREE MEASUREMENT

Inventories of standing timber are made for at least four general purposes. National and regional inventories of timber resources are made to provide broad guides to public and private forest policy. More detailed inventories are made to appraise market values of large blocks of timberland for sale, purchase, or exchange. Diagnostic inventories provide a basis for such management decisions as which specific areas to include in the annual cutting budget and which are highest in priority for cultural investments. Timber sale inventories are made to estimate the volume and quality of stumpage offered for sale.

In all these kinds of inventory, estimates of tree volume and quality are important, although amount of detail and standards of accuracy vary widely. Each kind of inventory will be discussed to examine the measurement systems used and some of the problems encountered.

TIMBER RESOURCE INVENTORIES

An example of timber resource inventory in the Douglas-fir region is the Forest Survey, conducted on a continuing basis by the U.S. Forest Service under authority of the McSweeney-McNary Forest Research Act of 1928. Forest Survey also is responsible for preparation of timber resource analysis reports. Because Forest Survey is a national effort, basic information is gathered and summarized according to national standards. The standard units for reporting timber volume are cubic feet and board feet, the latter estimates based on the International 1/4 inch rule (a log scale rule that allows for taper and closely approximates sawmill production). In the Douglas-fir region, Forest Survey data are also summarized in board feet estimated by the

Scribner rule (based on tree volume equations giving 32-foot log formula Scribner values for trees with measured d.b.h., total height, and Girard form class) to facilitate regional reports in units similar to those now used by the Douglas-fir timber industry.

Forest Survey starts with land classification on aerial photographs, systematically choosing points for interpretation at a density of about 1.3 per square mile. Then the points that fall nearest a 3.4-mile-square grid are ground checked if their land class is not obviously nonforest. If the ground check shows the area to be commercial forest, a cluster of 10 prism points and 1/300-acre plots is installed that covers about an acre. On these plots, diameter, quality, and stocking are tallied and a subsample of height and growth is taken. Provision is made for reidentifying the plots at the time of the next survey, thus making possible a direct measure of growth, mortality, and other changes. These records are the basis of survey reports of acreage by land type, timber volume and growth, and forest condition. Sampling errors at one standard deviation are 3 percent per million acres and 10 percent per billion cubic feet.

Forest Survey's major problems with measurement arise from the need to translate estimates of standing-timber volumes into units of potential product – tons of pulp, board feet of lumber, and square feet of veneer or plywood. Forest Survey is also faced with the problem of translating reports of product output and log production into estimates of drain on the timber resource. A large part of the difficulty comes from the fact that accurate conversions to and from Scribner board-foot estimates depend on knowledge of length and diameter of the logs in question. However, part comes from lack of specificity of the term Scribner scale. It may mean long logs, bureau net scale (without taper allowance on logs up to 40 feet); or it may mean 8-foot veneer blocks, gross scale. It may imply water, truck, or rollout scaling, which often produce different estimates. Other Survey measurement problems are those common to all tree and log measurement systems.

The 10-point plot design is standard for both Forest Survey and National Forest inventories and provides data useful for both Survey reports and National Forest planning. National Forest crews intensify the sample by using a 1.7-mile grid instead of a 3.4-mile grid. In 1966, the Bureau of Land Management in its reinventory work also started using Forest Service field procedures on an intensified grid.

Survey processes these field data to Survey standards, and the two agencies process them to the standards used in their management planning and allowable cut calculations. For the past 3 years, National Forest inventory estimates have been based on net local tree volume estimates derived from log measurements on active timber sale areas. (National Forest Douglas-fir scaling and grading rules closely resemble those of the Puget Sound Bureau.) This gives a volume estimate based on local defect and current utilization and scaling practice. The Bureau of Land Management bases its inventory on volume of 16-foot logs by the Scribner-formula rule and estimates of defect deductions for each sample tree.

No other agency or industry was found to be using current Forest Service sampling design in inventory, although quite similar field measurements are made by the timber industry on CFI (continuous forest inventory) plots. These CFI plots are established in second-growth stands. They attempt to sample directly stand changes due to growth, damage, mortality, cutting and cultural practices. Such inventories provide more accurate estimates of growth than can be derived from yield tables. They are similar in most respects to regional surveys and the inventories on which public agencies base their calculation of allowable cut.

Some of the problems arising from Forest Service and Bureau of Land Management inventories center around public statements about allowable cut. Some people appear to ignore and others to not understand differences between the board-foot estimates of the two agencies, others make invalid comparisons of log or finished product data with allowable cut, and still others restate allowable cut as percent of inventory without qualifications. Some of these are not strictly measurement problems and some are due to differences among Forest Survey, National Forest, and Bureau of Land Management board-foot estimates and to the differences between log scale estimates and lumber volumes.

National Forest inventory estimates should come closest to log scale on sales, provided the local sample base is truly representative.

TIMBERLAND VALUATION

Timberland valuation inventories are made for sale, purchase, or exchange of timberland, to assess taxes, to appraise damages, to determine compensation under condemnation, or to determine value when timber property is offered as collateral. Such valuation assumes there is an open market for the property.

Inventory intensity varies with the size of the property, value per acre, uniformity of the stands, and with the purpose of the valuation. A common procedure is to map or estimate areas in types that are classified by major species, five size classes, three densities of stocking, plus indications of site, minor species, age of origin, and condition class. Noncommercial forest or nonforest land types are estimated separately. Basal area and age of poletimber stands is sometimes estimated and compa with normal yield tables.

To complete the valuation, an as of current and future accessibility and o ability is included with the inventory establish present market value.

Merchantable sawtimber volume ally includes sound trees, 11 or 12 inc d.b.h. and over, estimated by the Scrib rule on the basis of 32-foot logs to a top percent of d.b.h. or 8 inches. Quality be assessed on basis of butt log grade estimates of grades of all logs may be ma Visible defect is deducted tree by tree, hidden defect and breakage may be ducted tree by tree or on an area ba Trees suitable for poles and piling usually tallied separately as is dead r chantable material.

Most estimates make use of volu tables such as the Mason, Bruce, Girard form class tables; the Washing tarif tables; or local volume tables. H ever, ocular estimates of total net volu ("volume direct") for samples or en stands are still occasionally used.

The measurement problems in timl land valuation are of two classes. The f is determination of the species, tree s top diameter, defect, quality, etc., t differentiate trees or portions of trees t have positive stumpage value. The secon accurate estimation of volume to these m chantable limits. This estimate is usu based on one of the various kinds of volu tables made from detailed measurement felled trees to merchantable limits selec by the table's author. Single-entry tal based on d.b.h. alone are quite likely be unrepresentative of the area being ventoried. Double- and triple-entry ta provide more safeguards against this kin bias. A greater source of inaccuracy in e mation of net volume than volume tabl the deduction for defect. The cruiser t to estimate the amount that will be deducted when logs are scaled. The ends of a log expose its interior defect, hidden from the cruiser. Surface indicators of defect usually can be examined closely during the scaling but are often hard to see on the standing tree. Knowledge of defect typical of the species, locality, and stand condition is helpful but not infallible in estimating hidden defect.

DIAGNOSTIC INVENTORIES

A diagnostic inventory involves inspection of many acres with enough volume estimation to determine relative operability and management needs. Often this is done in the course of other travel in extensively managed timberland. However, with intensive management, this type of survey should cover the entire property at a minimum of 10-year intervals. This inspection is needed to determine current accessibility, operability, and opportunities for stand or site improvement by scheduled commercial cuts or cultural treatments. (There appear to be no specific timber measurement problems in this type of survey not encountered in other inventories of standing timber.)

TIMBER SALE AND PURCHASE INVENTORIES

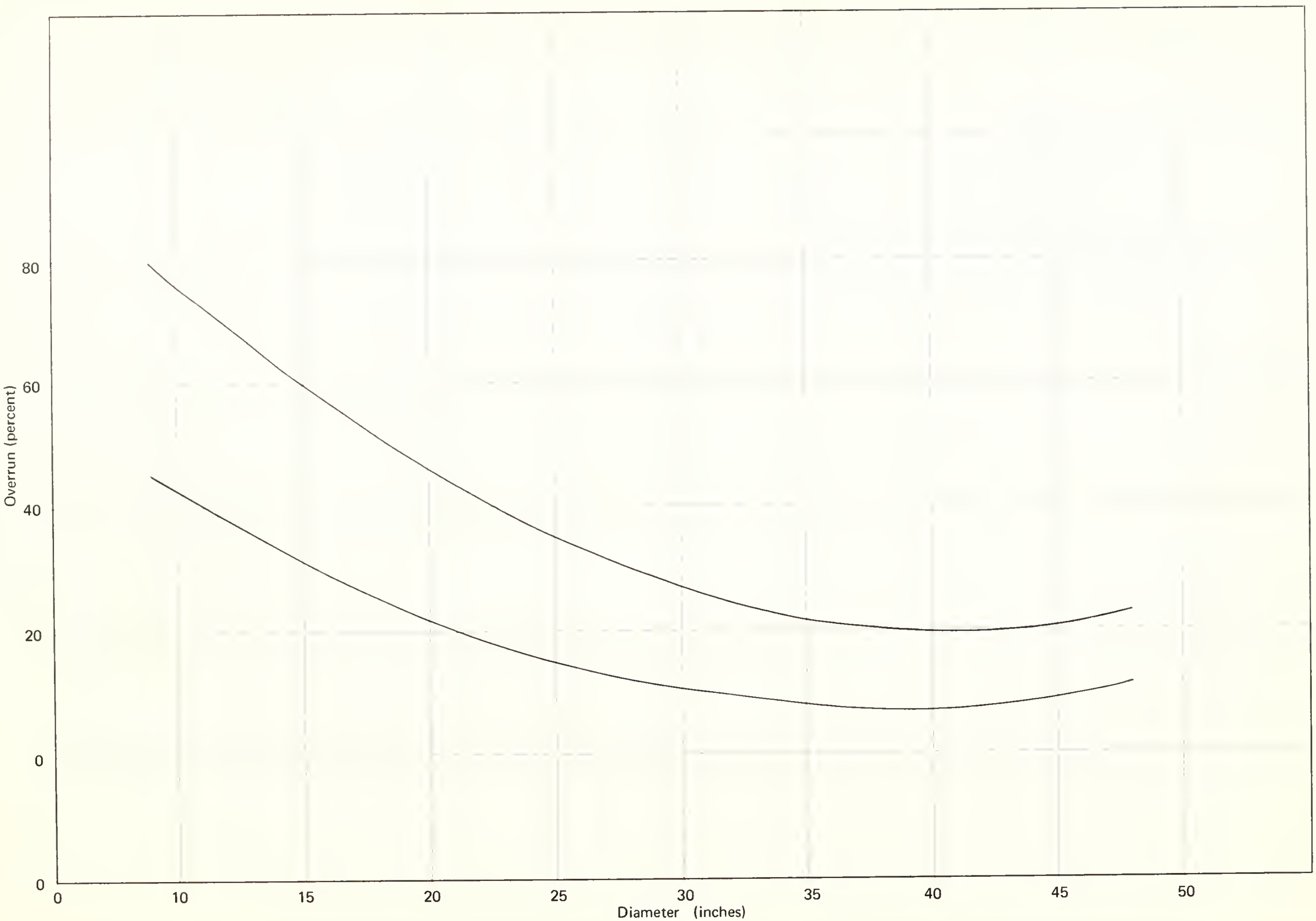
Measurement systems used for timber sales or purchases differ more widely than those used in other timber inventories. The measurement procedures and problems are different for partial cutting than for clear-cutting. They also are quite different for old-growth than for young stands. Sales arrangements also differ. For example, some sales are lump sum, some have flat rates by species for all net volume scaled, and some have different rates for log grades within species. Some sales are negotiated, some are by sealed bid, and some are by oral auction. These different sales arrangements impose different inventory problems on both the seller and the prospective buyer.

A major difference between buyers and sellers is that in a locality where there is competition each buyer has to examine many more sale areas than the sellers. (Average number of bidders per sale is four to five.) On the other hand, the seller makes detailed plans for road location and standards, silvicultural treatments, fire control, and slash disposal for each sale area; these become part of the sales prospectus and sales contract and assist the buyer in deciding whether or not he is interested in the sale.

Rather than examine each of these possible variations individually, we will discuss the general measurement system, with comments on major differences in procedure.

The purpose of the sale or purchase inventory is to establish a price the seller will accept or a price the buyer will pay for the specific timber under whatever restrictions or requirements (roads, fire protection, and cutting methods) the seller establishes. These prices ideally approach fair market values, although there is seldom an open market to confirm these values.

Studies of logging and milling costs and product value or studies of logging costs and log values may be used to establish stumpage values. The former is customary in Federal sales and the latter in State and private sales. Some private stumpage prices are in part based on knowledge of bid prices in recent public auctions. In any of these approaches, the generally applied test of accuracy of the net volume estimate is the log scale and grade of the timber removed from the sale area. Where the seller incorporates current scaling and grading rules and practices into his sales inventory and uses an allowance for breakage, the scale tests his ability to foresee breakage, bucking



80
60
40
20
0
0
Overrun (percent)
0
10
15
20
25
30
35
40
45
50
Diameter (inches)

practice, utilization, and unseen defect as well as to estimate gross tree volume and log grade. Where the seller estimates sale volume according to other scaling or grading practices, the volume and value estimates must be adjusted before a meaningful comparison with scale can be made (Figure 3). In scale sales, both buyer and seller get copies of the scale tickets. In lump sum sales, the buyer usually has the logs scaled and can compare this scale with the sales inventory, but the seller gets no independent estimate of the scale.

Usually, in the Douglas-fir region, the estimate of net volume is based on a line-plot inventory using either fixed-area or prism plots. Sampling rates of 5 to 20 percent are common. Often, diameters of all sample trees and the total or merchantable heights of a subsample of trees are measured. Sometimes all heights are estimated. Grades are assigned to all logs of sample trees. Visible defect is deducted, and hidden defect and breakage are estimated on an area basis.

An important variation in this procedure is the 100-percent inventory used by the Bureau of Land Management for lump sum sales. Here an attempt is made to record the height and diameter of each tree in the sale. Hidden and visible defect are estimated tree by tree. Every 10th tree is graded by 16-foot logs.

Some partial cut sales are thinnings in young stands, some are thinnings in stands near rotation age, and some are sanitation-salvage cuts in overmature stands. Either trees to be cut or trees to be left are marked. Either arrangement makes it difficult for the buyer to sample cruise the timber, since he cannot be positive that marking is uniform throughout the sale area or that his standards of merchantability (both size and cull) are identical with the seller's.

As in other inventories, various volume tables are available or can be prepared for use in sales and purchase inventories. Sampling errors are calculated to estimate the probable limits within which the volume estimate would fall if all trees had been measured by the same procedures as sample trees. However, sampling errors are not valid estimates of the limits within which the scale will actually fall.

The buyers interviewed generally felt that the seller's volume estimate and scale should agree within 10 percent on scale sales and 5 percent on lump sum sales. Many examples of failures to meet these or similar standards were cited. It was not always clear how recent these examples were or whether needed adjustments had been made for the cruiser's assumptions about utilization, unseen defect, and scaling practice.

These same standards usually were applied to comparisons of buyer's and seller's cruises. Generally, it was felt that tree counts and gross-volume estimates were satisfactory, although one or two instances were mentioned where the buyer's and seller's cruisers apparently disagreed on limits of merchantability. Major discrepancies were almost always attributed by purchasers to failure to make accurate allowance for defect. Sellers pointed out that it is not possible for them to predict bucking practice, which can affect gross scale, grade, and cull, when the purchaser is not known before the sale. On the other hand, the buyer's cruiser usually knows by experience the bucking practice and utilization to expect. Occasionally, it may be difficult for the buyer's cruiser to identify exact sale boundaries.

Two recent developments in sales inventories should be mentioned here. Both are being used on some Bureau of Land Management sales. One is 3-P sampling (probability proportional to prediction); the other is tree measurement with an optical dendrometer (Figure 4). The 3-P sampling scheme ensures heavier sampling of large, more valuable trees and lighter sampling of small, less valuable trees than conventional plot samples. (Prism cruising also selects a heavier sample of large trees.) The 3-P system substitutes a sampling error based on a kind of continuous stratification

of volumes for one based on little or
stratification. This sampling error is ba
on the volume of trees as directly measu
rather than on some volume table va
with attendant possible bias and usu
unspecified error of estimate. The opt
dendrometer makes possible accurate
biased direct estimates of gross volume
can be used to examine the stem for de
indicators.

Figure 4.--Optical dendrometer used to measure upper-stem diameters and heights on standing trees.

LOG MEASUREMENT

The major purpose of log measurement is to estimate grade, volume, or weight as a basis for payment in sales. Sometimes logs are scaled and not graded. Log scale may be the basis for payments to logging contractors and for log transportation. Today, practically all fallers and buckers are paid on hourly rates, and log measurements are no longer the basis for wages. Logs are also measured to update or check yard or pond inventories and to measure daily or shift input into mills.

The first time logs are measured is when trees are marked for bucking. At this time, decisions are made that affect grade and volume of the logs produced from the tree. With high-value trees and variable defect, this marking should be done by well-trained and experienced men. In low- or uniform-value material, this job is less critical. Each operator has his own set of decision guides for bucking.

Most logs in the Douglas-fir region of Washington and Oregon are measured by scaling bureaus. The aggregate volume scaled by the four bureaus each year is about 10 billion board feet. It is not known what proportion of the yearly cut of 12 billion board feet is scaled more than once.

Largely because of the efforts of the Northwest Log Rules Advisory Group, the log scaling .and grading rules of different scaling bureaus are identical in all but a few respects (such as descriptions of No. 3 peelers and pulpwood logs). The Forest Service has incorporated these rules into its scaling manual for the Douglas-fir region in Washington and Oregon. The Bureau of Land Management uses procedures that are customary elsewhere in the United States (short-log scaling and scaling to nearest inch). Industrial landowners and mill operators use other scaling and grading rules internally, but generally use scaling bureau rules for purchase and sale of logs. In southwestern Oregon, logs from east of the Cascade divide and from California are scaled by short-log rules, and some plants use short-log scale.

Although published scaling and grading rules are the same in most respects, instructions for application vary somewhat among bureaus, and some people commented on local variation in application of the rules. These variations apparently are greater between bureaus and agencies and between localities than within agencies and locations. Many people stated that grades, defect indicators, or both meant different things in different parts of the Douglas-fir region. Most important of all, the problem of variation between individual scalers appears to plague all those concerned with accuracy of scale and grade determinations.

Standards of check scaling are generally 5 percent of net volume and value for batches of 100 logs or 100,000 board feet. If a rescale of a raft of logs by one of the bureaus is requested and is less than 5 percent different in volume from the original scale, the requesting party pays for the rescale and the original estimate is accepted. If the difference is greater than 5 percent, the rescale is accepted and is not charged for. With truck and rollout scaling, there seldom can be a rescale, and the dissatisfied party can only request an early check scale. The Forest Service scaling manual sets as its standards 2 percent for sound logs and 5 percent for defective logs. It is generally recognized that scalers can' be far apart in grade, defect, and gross volume on individual logs, and that the only reasonable check is on large batches of logs, where two or more scalers are expected to "average out."

Generally, people recognize that there will be differences between water, rollout, and truck scale, although there is no concensus on what the percentage differences will be (Figure 5). Most consider truck scale highest and most erratic, particularly with eight or more logs on the truck. Defect indicators are hidden, and lengths of interior logs are hard to estimate. Occasionally, it is difficult to identify the small end of some logs. Rollout scale, where there is room to turn logs, is generally most accurate for sound or small logs. Rollout scale, with measurement of average diameters, is somewhat higher than water scale where a single diameter is measured. Some kinds of defect indicators show up best in water scale. For these reasons, scale and grade of one batch of logs will vary with scaling conditions; to be a valid comparison, the check scale should be made under the same conditions as the original scale.

Some of the difficulty in yard and pond inventory and tally into the mill is caused by differences in scaling conditions. Log tagging is used in some instances to maintain tight control of volume in storage and volume used by the mill. Most mill operators find this too expensive, and some rely on individual raft or deck total volumes. Some use net scale into storage and gross scale adjusted by average defect out of storage. Others calculate average net log volume going into storage from scale tickets, and count logs going into the mill. Where logs are bucked in yard or pond and the segments do not go directly to the mill – or where part goes to a veneer mill and part to a sawmill – storage inventory commonly becomes quite inaccurate. A discrepancy of about a million feet in inventory, with some 20 million feet moving through storage, was mentioned.

The Scribner Decimal C rule is generally used in the Douglas-fir region for scaling logs. Some export logs are scaled net

a: Rollout or yard

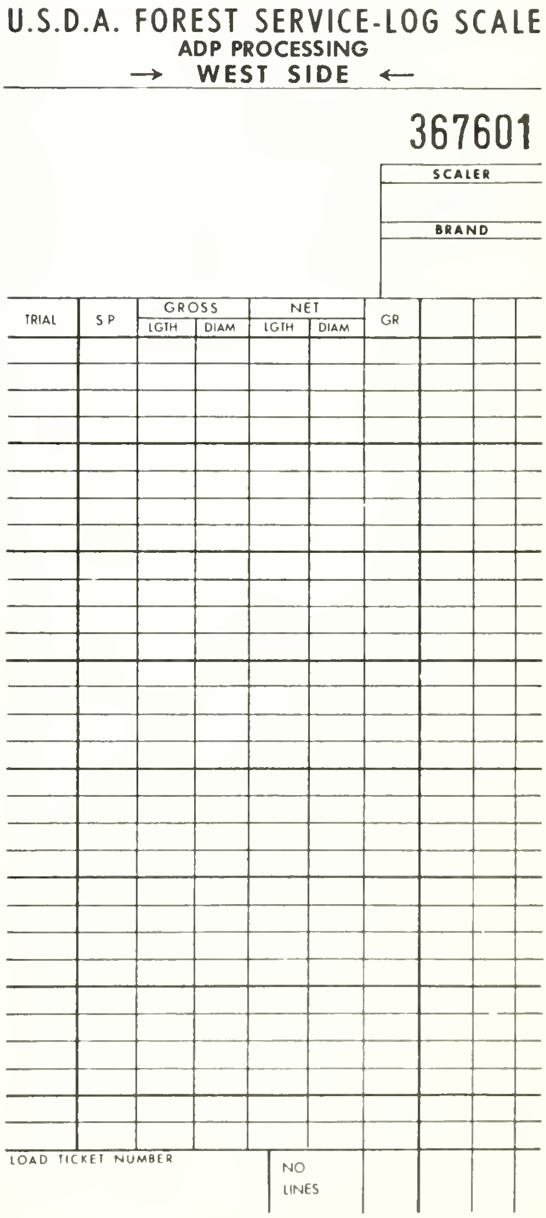
b: Water

c: Truck

Figure 5.--Log scaling conditions

Scribner by scaling bureau rules and others are scaled net or gross Brereton. Since about a billion board feet are exported, there is considerable familiarity with Brereton scaling procedures. The use of weighing has already been mentioned. Even though weight scale might seem to be an ideal way to pay for log hauling, one operator who tried it stated that truckers wanted to know how many board feet they were hauling.

Total net scale is seldom accepted as a full measure of value. Either the detailed scale bill is examined, a sample of logs is inspected, or both (Figure 6). Thus, knowledge of how the logs run is an important part of the valuation process. Range of diameters and lengths, kind and variability of defect, and whether the logs are high or low within grades are all important considerations in establishing value. Knowledge of source locality and past experience with logs from the area also help in log valuation.



U.S.D.A. FOREST SERVICE-LOG SCALE
ADP PROCESSING
→ WEST SIDE ←

367601

SCALER

BRAND

TRIAL	S P	GROSS		NET		GR			
		LGTH	DIAM	LGTH	DIAM				

LOAD TICKET NUMBER

NO LINES

Figure 6.--Type of log scale bill used with automatic data processing.

PRODUCT STUDIES

Studies relating product output to log input are made for various reasons. These can be classed as operating efficiency studies, batch studies, and individual log studies. The most frequent and least accurate of these studies is the comparison of weekly or monthly records of input and output for management control. Operating efficiency of a mill is judged on estimates of volume and value of log input compared with volume and value of product output.

Somewhat better controlled are batch studies run for a day, a shift, or part of a shift. In these, there is usually little question of the input and output not representing identical logs – all logs going into the mill are scaled – and the green chain or chipbin is cleared before and after the run. However, these studies usually consider only total input and total output by green grade and dimension or, if chips, by dry weight. Grade recovery of lumber and veneer may be studied by assembling logs of a single grade, and usually of a limited diameter and length range, in batches large enough to keep the mill operating for the duration of the study.

The most refined studies are those in which each log is numbered and its products are measured individually. This is a more expensive study to make, and may slow mill operations and challenge sawyers to maximize output. Sometimes, dimensions of the products are prescribed and are not identical with those produced in normal mill operation. For these reasons, results of such studies are sometimes not considered representative of regular mill operations. However, such studies have provided the clearest insights into the important effect of log size on production costs and of log dimensions and grade on product volume and grade. These studies provide the basis for some operation research analyses and sometimes, in conjunction with the results of batch studies, are part of the basis for appraising timber values.

In periodic control studies and batch studies, the usual estimate of input is number of board feet, Scribner Decimal C. In sawmills, this is compared with green chain lumber tally. The difference is overrun or underrun. As long as overrun remains fairly constant, the production process is considered to be under control. The amount of variation in overrun that causes concern varies tremendously. In some mills, large deviations for several months will be expected to average out before the year is over. In others, a change of less than 5 percent for a 2-week period has to be examined and explained to be sure operating efficiency has not changed. These varying standards are partly a result of differences in tightness of control of measurement of logs into the mill; differences in defect, grade, and size of logs processed; and dimensions of lumber produced. A mill that can stick to a uniform grade mix and constant average log diameter is expected to have more uniform overrun than a mill with frequent changes in average log quality and size. Mill experience usually suggests the overrun typical of log source localities. When new sources are tapped, a batch of logs may be run through the mill to get an idea of what overrun to expect.

Veneer mills appear to use a similar control process, although most use as their control the ratio of number of square feet of 3/8-inch plywood to a board foot, log scale. Ratios ranging from 2.2 to 2.9 were mentioned.

Larger industries have used operation research studies to analyze their production. Some plywood plants use the grade mix in their order file to control log input to the mill and log inventory. Advantages of minimizing inventories of logs or finished plywood of unneeded grades are obvious. This type of study can be based on grade recovery studies of large batches of logs. Another application of operations research is the determination of product mix that maximizes profit when operating capacities of mill equipment and potential sales volume of various dimensions and grades of plywood are imposed as constraints. A study of this kind can be based on average grade and size of log input in the recent past.

To determine the most profitable use of logs by grade and size, more detailed recovery studies are required. In these studies, the board-foot Scribner volume estimate for the log by itself is practically useless. Important variables are diameter, length, taper, quality; and defect of the log. Some recovery studies suggest that present methods of estimating quality and defect are inadequate. These findings should not surprise mill operators who feel that the No. 2 sawmill grade is too broad or who have observed that product recovery often has a more constant relation to gross scale than to net scale. In using the results of such recovery studies, an integrated industry can consider several alternatives for logs – saw, peel, chip, or sell. A single-product industry has a simpler alternative – process or sell logs.

Accurate studies of product recovery require different applications of basic log dimensions and different defect deductions for various products. Pulp yield is based on the cubic volume and density of wood in the log. The only defect deductions are for missing or rotten wood. (Possibly volume of knots and compression wood should be considered, but no studies were found that did this.) Veneer yield is related to small-end diameter, amount of necessary round-off, effect of taper on fishtail production, and core diameter. Core diameter may be determined by chuck size, core market, or log characteristics. The standard saw-log defect deductions are not appropriate for veneer, with some defects being more severe and some less severe for veneer. The value of logs for poles and piling depends on small-end diameter, taper, length, and defect. Lumber yields also are related to small-end diameter, taper, length, and defect. Published results of some lumber recovery studies using Scribner log rule estimates show high overrun for small diameters, a minimum overrun at 28 or 30 inches, and increasing overrun for larger logs. These studies usually eliminate effect of length on overrun by limiting the range of log length in the study. Where defective logs are separated from sound logs, overrun usually is greater for defective logs. These studies also demonstrate that each mill must make its own product recovery studies because overrun varies so greatly among mills (Figure 7).

No studies were encountered that tested the three basic units – length, surface area, and cubic volume – suggested by L. R. Grosenbaugh in the Davis report[6] on allowable cut. Limited tests at the Pacific Northwest Forest and Range Experiment Station show that these basic units are effective estimators of lumber and veneer volume production. However, this trio of units is no better than the basic log dimensions from which they were derived. Their advantage lies in the ease with which they are measured and cumulated in standing trees.

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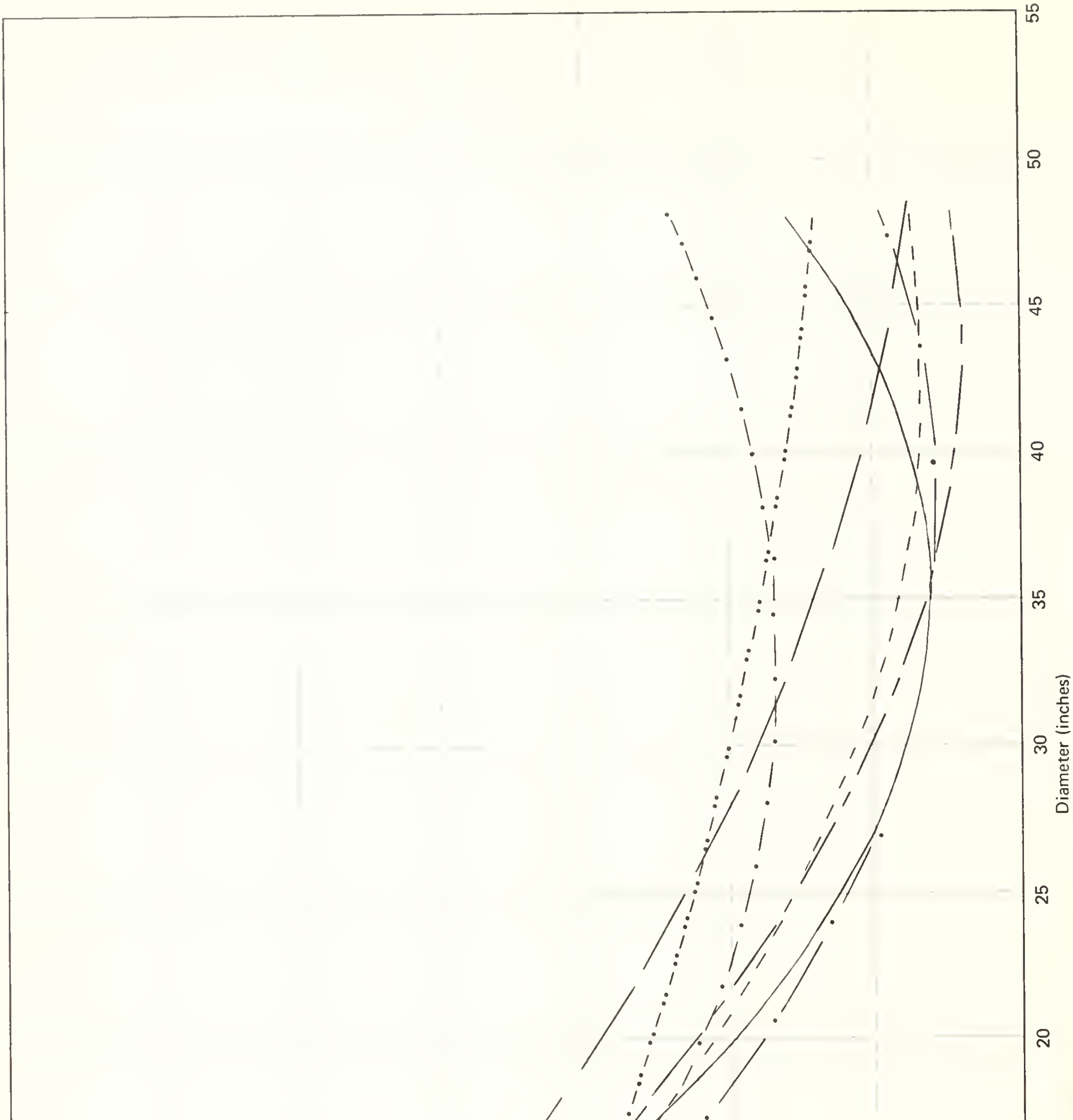
[6] *Davis, Kenneth P., Briegleb, Philip A., Fedkiw, John, and Grosenbaugh, Lewis R. Determination of allowable annual timber cut on forty-two western National Forests. Rep. Board Rev., U.S. Forest Serv., Washington, D.C., M-1299, 38 pp., 2 tables. 1962.*


Overrun (percent)
0
20
40
60
80
100
20
Diameter (inches)
0
10
15
20
25
30
35
40
45
50
55

There may be advantages in cumulating them for batches of logs, but these have not been demonstrated. Apparently, no tests have been made in the Northwest of the utility and accuracy of log weight and length as cumulated measures for batches of logs to estimate product recovery. However, the operator of a dimension mill reported that the closest way to estimate lumber yield is to weigh logs. On the basis of 10 loads of 30-percent defective Douglas-fir, he found that he got 1 board foot of lumber for each 6.3 pounds of logs. He used this factor for a year with good results.

SOURCES OF TIMBER MEASUREMENT PROBLEMS

There are several ways measurement problems can be classified. Consideration of problem source is important because some measurement problems will remain to annoy all concerned, no matter how many changes are made or refinements added to the present systems. Measurement problems typical of old-growth timber will disappear in time. However, others are generated by the way records are kept or sales are made and can be reduced only by changing record keeping or sales procedures, not by adjusting measurement systems.

Figure 8.--Defective logs.

DEFECTIVE TREES

Defect is a major source of problems, particularly in the approximately 500 billion board feet of old-growth timber in the Douglas-fir region. Since high-value old growth will be with us in commercial amounts for 30 to 50 years, any system for measuring timber in the Douglas-fir region must be adapted to good defect estimation. In standing trees, external indicators of defect must be used; those high in the tree are hard to see, and many defects have no external indicators. After trees have been bucked, the cut sections give samples of the inside of the tree (Figure 8) and external indicators can sometimes be examined closely. However, if logs must be measured on trucks or in decks, these external indicators may be hidden. It is generally agreed that unless the cruiser or scaler frequently has watched logs being sawed or peeled he cannot interpret defect indicators correctly under current scaling rules. Some studies suggest that to get the same accuracy, sampling rates in defective timber must be several times greater for net-volume estimates than for gross-volume estimates.

SHAPE OF LOGS AND TREES

Many measurement problems would disappear if trees were circular in section and tapered uniformly. Since neither of these conditions is often found in nature, there are problems of diameter measurement and variations in rules for making diameter measurements on logs. A common rule is to measure the greatest diameter and one at right angles to it. Because of shape and abnormal swellings or knots, it is often unlikely that two scalers will agree on either direction or magnitude of the greatest diameter.

Accurate estimates of cubic-foot volume are easy to make on logs with uniform taper. However, Brereton scale, which assumes there are 12 board feet in each cubic foot, is usually more than 1 percent low when the small end is less than 70 percent of the diameter of the large end. If nominal rather than actual length is used, there will be an additional low bias averaging about 2 percent. Scribner scale neglects taper and becomes progressively more biased as either taper or length increases. The amount of bias usually is expressed as overrun. Nonuniform taper and butt swell present many problems in determining cubic-foot and Brereton scale, whereas long-log Scribner scaling ignores the existence of these problems. Nonuniform taper also creates problems of form-class estimation in cruising and in selecting appropriate conversion factors after logs have been scaled in any unit.

HUMAN ERRORS

Human errors will be present as long as timber is measured. If the errors due to carelessness and lack of experience in determination of length, diameter, and defect of trees and logs were reduced to a minimum, there would still be other errors in the measurement systems. These include selection of inappropriate volume tables or equations, incorrect determination of form class or utilization limits, wrong choice of breakage deduction, use of incorrect conversion factors, selection of inadequate sampling intensity for high variable populations, and a host of other erroneous decisions.

VARIATION IN LOG AND TREE SIZE AND VALUE

The Douglas-fir region may have the distinction of having the greatest average variation in log and tree size and value of any part of the United States. Single logs scaling 6,000 board feet are still cut (and larger could be, except for highway weight limits and capacity of logging equipment). Obviously, cruising and scaling systems, geared to recognizing value of No. 1 peelers, are too expensive for low-grade material. Variation in value requires flexibility in measurements; it can define the acceptable accuracy of weight scaling and sample scaling and cruising. Change in size of logs and trees causes variation in product recovery ratios and reduces accuracy of converting factors.

COST OF MEASUREMENT

Since measurement itself adds nothing to the intrinsic value of the product, costs of measurement should be held to a minimum. This could result in choice of conditions for measurement that minimizes measurement costs but adds to other production costs such as truck delays at scaling ramps. On the other hand, attempts to minimize effect of measurement on other production costs could result in scaling conditions that don't permit accurate measurement, such as in large storage decks.

VARIABLE LENGTH LOG EXTRACTION

Cutting logs in variable lengths appears to be the most efficient way to get timber from the forest to the mill. However, in truck scaling, accurate determination of volume is easier when logs or bolts are uniform in length. Long logs have more hidden defect than short logs. Butt swell on long butt logs causes trouble in cubic-foot or Brereton scaling and in taper determination for board-foot segment scaling. Cruisers can't predict exactly where trees will be bucked and, under present systems, can't estimate accurately what the aggregate scale of the logs will be.

MULTIPRODUCT UTILIZATION

The value of a log depends on the products that can be made from it. Many people seek accurate factors for converting from one way of expressing volume of logs to other ways so that they can determine the most profitable use of the logs. Another approach is to seek more efficient means of estimating product potentials of each log than catalogs of conversion factors. Other measurement problems attributed to the multiproduct potential of logs are that defects affect usable volume differently for various products and that log lengths and trim requirements differ for each process. Also, minimum diameter limits of merchantability vary among products, making it difficult for cruisers to predict how much of each tree will be used.

CHANGING PRODUCTION TECHNOLOGY AND CONSUMER DEMAND

Changes in production technology include development of new products as well as changes in processes or equipment in making timber products. The measuring system should provide information on volume or raw material available and also accurate estimates of product output. An example of change is the recent expansion of chipping facilities. Several observers reported that after chippers were installed in sawmills, the production of No. 4 lumber and hence overrun was reduced.

Another area where changing technology and consumer demand generate perplexing problems is in allowable cut calculations. These calculations are based on even flow of timber products. This even flow should be susceptible to measurement. But the term is not well defined – no one proposes even flow of masts for sailing ships, yet historically this was once the most valuable product of American forests. More recent problems in assaying even flow are those generated by diminishing use of logs for lumber and increasing use of mill residues in pulpmills.

USE OF LOGS IN TIMBER VALUATION

The intermediate step of valuing logs is so deeply entrenched in the way timber business is conducted in the Douglas-fir region that it may seem natural or necessary. However, there are those who point out that timberland produces trees, that timberland owners sell trees, and that the value of trees is determined by the useful products into which they can be converted. From this point of view, log measurements and log values should be considered only if they are useful in establishing the value of trees. This, in theory, is what is done in lump sum sales. However, the way things work today, the check of accuracy of a timber cruise applied in practice is the log scale. It already has been noted that sampling error of the cruise is not the same as accuracy measured by this means.

Another problem related to use of logs in timber valuation is the implicit requirement that some or all of the logs be scaled, which is a cost of doing business. Also, where the sale contract requires log measurement, it is possible that utilization practices in the woods may be poorer because payment is made only for logs scaled as merchantable, whereas in lump-sum sales the purchaser can use as much of the tree as is profitable at no extra cost.

USE OF A SINGLE UNIT OF ESTIMATE FOR CONTROL

Although volumes of trees and logs are estimated in various units, accountants insist that only one unit be used in the financial records of each business. When production costs are being studied, it is helpful to use a unit that is related to the physical job of harvesting, transporting, and processing wood. However, studies of product recovery and logging and milling costs all show that except for chips a single unit of volume does not serve. Almost all such studies show the important effect of log size—often as indicated by scaling diameter. Accountants who insist on a single unit readily accept a limited classification scheme (i.e., different dollar values for different grades and species). All these things suggest that a single unit of volume does not really serve the needs of the timber processing industry. The problem is how to supplement it to get the information needed for business control.

CONVERSION FACTORS AND AN ALTERNATIVE

Industry's request for development of more accurate conversion factors suggests two obvious things. The first is that modern industry is interested in accurate estimates of varied product potentials of trees and logs. The second is that existing conversion factors do not serve this interest. When a conversion factor is stated, the statement should show the conditions under which it was developed and mention sources of difference that will reduce its accuracy. For product converting factors, these conditions include methods and equipment in the manufacturing plant and species and size of logs. Other variables that may affect conversion accuracy are bark thickness, taper, and amount and kind of defect.

Although variation in manufacturing methods and equipment must be considered somehow, there appear to be two approaches to solving the conversion problem. One is to accumulate long lists of converting factors suitably qualified so that one appropriate for each occasion can be found. The other is to develop a means of recording and cumulating information about the size and shape of batches of trees or logs that can be used to estimate recovery of any product or probable scale by any rule. This latter approach is not so extreme as it may seem, for there would be no particular problem in keeping track of both volume (in any unit) and length of all logs in a batch. These two totals give an estimate of average volume per unit length, which describes average log size. Whether additional derived units should be cumulated or some measure of the range and variability of the log dimensions would be more useful is open for study.

Results of product recovery studies, expressed as equations showing either change in overrun or in percent of log volume converted to the product as a function of log diameter, can be considered continuously varying conversion factors. However, this concept can be applied only to certain special equation forms; many other predicting equations can be viewed only as direct estimates of product recovery based on measured log dimensions.

CRITERIA FOR MEASUREMENT SYSTEMS

Throughout the discussions of measurements, statements were made that explicitly or implicitly set up standards of performance and accuracy deemed desirable. Some of these were mentioned by most of those interviewed, others by but a few. Because this study was not an opinion poll, the relative popularity of most criteria will not be discussed.

UNIFORMITY

Nearly everyone mentioned uniformity as the outstanding desirable characteristic of measurement systems. Uniform systems are wanted that can be applied consistently to all trees and logs.

STABILITY

Measurement systems should not be subject to frequent minor changes. People want to know by experience how the systems work.

ECONOMY

Costs of measurement should be appropriate to value of the trees or logs and to degree of accuracy needed for efficient business operation.

UNDERSTANDABILITY

Dimensions, volume, quality, and defect should be expressed in terms understandable to both buyers and sellers of logs or trees and to others concerned with timber measurement.

OBJECTIVITY

The systems should avoid so far as possible all subjective individual judgment. This implies maximum use of direct linear measurements and counts and detailed specific instructions for each part of the determination of dimensions, quality, or defect.

CONVERTIBILITY

Accurate converting factors are wanted – from one unit of volume to another – and from any measure of raw material to any end product.

REPRODUCIBILITY

Each part of the system should be designed so that two or more people will get the same result. This makes possible direct checks on accuracy of application.

PRECISION

Various standards of precision were mentioned. Generally, in the measurement of 100 pieces or 100,000 board feet, acceptable standards 95 times out of 100 are: value or net volume of trees, 5 to 10 percent; value or net volume of logs, 5 percent; and gross volume of logs, 2 percent.

LACK OF BIAS

Precise measurements are not necessarily accurate. Measures of precision test reproducibility of measurement with a given instrument and by a specified method. Accuracy requires lack of bias in both instrument and method.

COMPLETENESS

Measurements should include examination or sampling of all dimensions and indicators of quality and defect needed to determine values of trees or logs for each product. The measurements should be adaptable to changes in technology of wood processing.

ADDITIVITY

Additivity affects many parts of the measurement systems. It should be possible to deplete inventories of standing trees by records of logs measured and logging residue. It should be possible to deplete records of storage inventory by simple measurements of logs into the mill. The sum of log and chunk volumes should equal tree volume, and this should not vary with bucking lengths. The tree and log measures should be linearly related to product quantities of major interest, so that when scale and resulting product of two or more batches are added, the sums stay in constant proportion.

HOW PRESENT DOUGLAS-FIR REGION TIMBER MEASUREMENT SYSTEMS MEET THE CRITERIA

Rather than to test all current timber measurement systems against all criteria, it seems more efficient to consider a few features common to most systems. There are at least six major headings here: systems of measurement, estimate, or exchange; rules of application for log measurement; grading rules; conditions of measurement; means of summarizing data; and possibilities of improvements that will better meet the criteria.

SYSTEMS OF MEASUREMENT, ESTIMATE, OR EXCHANGE

Six systems have been identified: Scribner log scale (board feet), Brereton log scale (board feet), cubic (feet), weight (pounds), linear (feet), and piece. Although the vast majority of logs are measured in Scribner, the use of other units violates the criterion of uniformity. These other units have been used long enough that none can be considered a recent minor change. They appear to be understandable to most buyers and sellers, but not necessarily to others interested in timber measurements. None of the units are directly convertible to estimates of product recovery without more information, particularly about diameter of logs. Most of the units may be generally additive, although they are not linearly related to all product quantities. However, the Scribner rule, because it does not allow for taper, cannot be considered additive. Overrun, and hence bias, may vary from 0 to 100 percent for the Scribner rule as applied here. Also, because it assigns no volume to 5-inch logs and relatively little to other small logs, it is not easily convertible to other units of estimated volume or to product yields of small logs.

RULES OF APPLICATION FOR LOG MEASUREMENT

As already noted, the log scaling and grading rules of the scaling bureaus and the Forest Service are quite uniform, but the supplemental instructions to scalers are said to be somewhat less so. Individual application of these rules and instructions can be erratic. Part of this trouble can be traced back to the rules which are so written that subjective judgment is a requisite of scaling and grading. Wherever subjective judgment is called upon, reproducibility is lowered. Apparently, the rules are stable because many persons commented on how difficult it is to get the rules changed.

Defect deductions appear to be not additive, because lumber recovery or overrun is usually greater for defective than for sound logs. However, scaling logs up to 40 feet without taper allowance appears to be the biggest source of failure of the rules of application to meet the criteria. There is lack of uniformity both because Bureau of Land Management uses short-log scaling and because east-side and California logs are used in the Douglas-fir region. Data on board feet from the Douglas-fir region based on Scribner long logs cannot be added to board-foot estimates from other parts of the United States and cannot be compared directly with lumber production records. The results of long-log scaling are understandable to buyers and sellers but apparently not to many others interested in the timber industry. Long-log scaling without taper allowance is neither complete nor additive and requires knowledge of log length and taper before accurate converting factors can be found.

GRADING RULES

Grading rules are not uniform. Diameter limits and other characteristics vary among species. This makes grading rules difficult to understand. Practically all these rules require subjective judgment of what grades of products the log will produce. This reduces reproducibility of grades for individual logs. They appear to be quite stable, since names, indicative of former utilization, have lingered on after manufacturing technology has made these names obsolete.

CONDITIONS OF MEASUREMENT

Because conditions of measurement are not uniform, measurements are not necessarily reproducible and bias and accuracy may vary. Where parts of logs are hidden during measurement, subjective judgment is inevitable. Only occasionally do conditions make complete measurements possible, although they are not required by most present scaling rules.

MEANS OF SUMMARIZING DATA

Some log and tree measurement data still are worked up by hand and use of log scale or the volume tables – others are summarized on electronic computers. Hand calculation is less accurate, once records have been edited, than electronic, is more expensive, and leads to omission of much detail that can be summarized cheaply on electronic computers. This suggests that hand computation prevents the completeness of record that is available today and that can be used to get good estimates of multiproduct potential yields. However, many machine programs have been written merely to replace rather than to improve hand summaries.

POSSIBILITIES OF IMPROVEMENT

In view of the failure of present measurement systems to fully satisfy the standards of performance, it is pertinent to ask if systems can be improved so that they will. It is obvious that some criteria call for performance limited by other standards. For example, there must be a balance between economy and precision. However, the criteria are compatible and present knowledge is sufficient to supply many of the parts of measurement systems that would meet these standards. However, there are still difficult questions of objective assessment of grade, defect, and accurate and additive estimates of product recovery standing as obstacles to completely satisfactory measurement systems. Some research has been done on these questions but more is needed.

DISCUSSION

Present timber measurement systems in the Douglas-fir region have developed gradually in the last century. Most logs are measured by the Scribner log rule without taper allowance for logs up to 40 feet long. This rule probably gave reasonably good estimates of lumber recovery when mills cut nothing smaller than 12-inch logs and considered low-grade lumber unmerchantable. However, with current sawmill utilization it gives high overrun, and when average log size varies it gives highly variable overrun. Use of Scribner long-log scale creates difficult converting factor problems for the half of the logs that are not used in sawmills.

Although most buyers and some sellers seem satisfied to use Scribner long-log scale as the basis for sale and purchase of trees and logs, the standards of accuracy for 100-piece lots suggest the acceptance of large errors in individual log measurements. If errors were random, 5 percent in 100 pieces would be equivalent to 50 percent in each individual. If all errors were in the same direction (bias), the average individual error would be 5 percent. Actually, the 5 percent in 100 pieces is partly an allowance for random variation and partly for bias. Although great variation in piece measurements is recognized, it is usually claimed that these fluctuations average out and that estimates of experienced cruisers or scalers agree quite well. This undoubtedly is true for small and uniform-value logs, but is somewhat questionable for large logs with highly variable defect. It is this latter kind of logs that requires greatest accuracy in measurement. A scaling bias of 5 percent on a 2-million-foot sale at $40 a thousand costs $4,000. A major source of complaint and dissatisfaction among users of the present systems is the employment of inexperienced cruisers or scalers – and most recognized the need for training.

Despite the familiarity of buyers and sellers with the measurement systems, these systems are certainly not well understood by those not active in the timber market. Outstanding sources of confusion are differences between long- and short-log scale, between net and gross scale, and between scale and product recovery. Even amongst insiders there appear to be some misconceptions, such as an assumed independence of log price from the scaling and grading procedures. However, the greatest weakness in current systems is implied by the remark that even an experienced man could "lose his shirt" if he tried to enter a market 200 miles from the area in which he gained experience. The weakness is obviously in recognition of quality and defect, not in log dimensions. The requirement that cruisers and scalers gain experience by watching logs being sawed or peeled is further evidence of the local and subjective nature of grades and defects in present systems.

SUMMARY

Many problems in timber measurement in the Douglas-fir region have been discussed. A problem of great concern to many forest managers is lack of understanding of the measurement systems by those not active in the timber market. This is not strictly a measurement problem. However, some specific measurement problems can be noted:

1. The Scribner rule, which assigns little volume to small trees or logs, is not well adapted to estimation of value of second-growth stands.
2. Long-log scaling without taper allowance makes conversions to any other unit of volume inaccurate unless lengths and tapers of logs are known.
3. Estimation of grade and defect is based to a large extent on subjective judgment.
4. Different defects reduce yields of various products to a different degree.
5. Most volume estimates for standing trees depend on volume tables that have undetermined bias and unspecified error of estimate.
6. When cruising standing trees, sellers cannot predict accurately the utilization and bucking lengths and, hence, the probable scale.

An additional problem is the present need for the timber industry to be able to accurately determine the value of each log for alternative products. This requires either a large catalog of precise converting factors or good means of estimating potential yields of each log – information not furnished by present systems.

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Volume and Taper Tables For Red Alder

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INTRODUCTION

Red alder is a species of increasing importance in the Pacific Northwest. Interest in improved volume tables for the species resulted in publication of the 1949 volume tables (Johnson et al. 1949; Skinner 1959). More recently, Browne (1962) published cubic-foot-volume tables for red alder in British Columbia, and Hoyer (1966) presented tarif access tables, based on the 1949 tables, for use with the general tarif tables of Turnbull et al. (1963).

This paper presents new volume and taper tables for red alder. These form a unified system, permitting computation of cubic- and board-foot volumes for alternative assumed scaling practices and limits of merchantability.

DATA

Basic data used in construction of these tables consisted of (1) tree measurement data from Oregon, Washington, and British Columbia used in construction of the 1949 tables; (2) additional tree measurement data from Washington and Oregon contributed by Weyerhaeuser Co.; and (3) tree measurement data originally used for the volume tables published by Johnson et al. in 1926. After elimination of trees lacking measurements of upper stem diameters to less than 10 inches, having low forks or other gross abnormalities or apparent errors in recording of data, a total of 473 trees were available for the analysis (table 1).

METHODS

A report on the method of data analysis is planned for separate publication. Therefore, only an outline of the approach used is given in this paper.

Basically, the method consisted in deriving from the pooled tree measurement data an equation expressing squared diameter inside bark — (d.i.b.)^2 — as a function of the relative height at point of measurement, diameter outside bark at breast height (d.b.h.) and total height (H) of the tree.[1]

Cubic volumes (CV) were then estimated by integration of the resulting equation. Estimates of upper stem diameter were obtained as the square root of the estimated (d.i.b.)^2. Board-foot volumes were estimated by applying assumed merchantability and scaling standards to the estimates of upper stem diameters. Equations were then developed for conversion of total cubic volume to merchantable cubic- and board-foot volumes.

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[1] Since the principal intended use of the equation was in estimation of volume, using the relationship
cubic volume $= k \int (\text{d.i.b.})^2 dH$,
(d.i.b.)^2 rather than d.i.b. was considered the variable of primary interest.

RESULTS

CUBIC-VOLUME TABLE

Table 2 gives estimates of average cubic volume of red alder trees of specified d.b.h. and total height. Volumes are inside bark, from a stump of height in feet equal to [½ + (½)(d.b.h./12)],[2] to the indicated inside bark (i.b.) top diameter limits of 12.0, 10.0, 8.0, 6.0, 4.0, and 0.0 inches. No trim allowance is made.

These estimates were obtained by integration of the estimating equation for $(d.i.b)^2$ from assumed stump height to heights corresponding to the indicated diameter limits.

TAPER TABLE

Table 3 gives estimated diameters inside bark of red alder trees of specified d.b.h. and total height, at intervals of 4.125 feet above stump height. Values given are square roots of the values of $(d.i.b.)^2$ predicted by the estimating equation. The height interval used provides trim allowance of 0.50 foot per 16 feet of bole.

VOLUME TABLES IN BOARD FEET

Tables 4, 5, and 6 give estimated average tree volume in board feet Scribner (SV) for stated assumed scaling lengths (8 and 16 feet), top diameter limits (12.0, 10.0, 8.0, and 6.0 inches i.b.), and diameter measurement practice ("nearest inch" versus rounding of fractional diameters to next lower exact inch). Volumes were obtained by applying the formula Scribner log rule (Bruce 1925) to estimated upper stem diameters (table 3), with trim allowance of 0.50 foot per 16 feet of merchantable stem and using, for top logs, estimated length (unrounded) to the stated top d.i.b. limit.

Use of formula rule rather than scale stick values eliminates the arbitrary and illogical jumps which result from rounding and the diagraming process. Volumes for measurement to "nearest inch" were obtained by using estimated top d.i.b. in the formula; volumes for measurement "rounding down" were obtained by using (d.i.b. — ½) as the diameter in the formula. Since volume tables represent the means of many trees, smoothed values are appropriate.

Table 7, which gives estimated Scribner volumes by d.b.h. class and number of 16-foot logs, was prepared by graphical interpolation from values shown in tables 3 and 5.

Table 8 gives estimated tree volumes in board feet by International ¼-inch rule, with the same assumed measurement practices used in table 4.

CHOICE OF TOP DIAMETER LIMIT

In application of either board-foot or merchantable cubic-volume tables, the choice of minimum top d.i.b. limit should be based on the user's estimate of the top d.i.b. to which average trees of the size under consideration can actually be utilized. This limit will vary with tree size, because of excessive branching in the tops of large trees. Thus, board-foot volume to a 6-inch top in a tree 24 inches d.b.h. is not a realistic estimate of the volume of material actually utilizable as sawtimber, even though smaller trees may be utilized to this limit.

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[2] An arbitrary rule, which approximates average height of stumps as cut.

COMPARISON OF "ACTUAL" AND ESTIMATED VOLUMES

"Actual" cubic volume of sample trees was calculated by Smalian's formula (except with butt section treated as a neiloid) and the differences $|CV_{estimate} - CV_{actual}|$, where estimated volume was CVT as shown in table 2, were expressed as percentages of estimated volume. The mean percentage difference, excluding 131 trees for which stump diameter had not been recorded, was −1 percent with standard deviation of 9 percent.

For a portion (139) of the sample trees, differences between estimated Scribner volume (SV8 in table 6) and "actual" Scribner volume were calculated. These, when expressed as percentages of estimated volume, had a mean of −0.8 percent and standard deviation of 15 percent.

TARIF ACCESS CURVES

Those wishing to use the tarif system for volume computation (Turnbull et al. 1963) can readily use table 2 as the basis for a tarif access table by means of the relationship

$$\text{tarif number} = \frac{0.913(\text{CV4})}{(\text{basal area} - 0.087)}$$

given by Turnbull and Hoyer (1965).

Figure 1 is such an access table in graphical form.

COMPUTING EQUATIONS

The equations given below may be used for calculations on automatic data processing equipment.

1. Diameters inside bark may be estimated by the following equation, which is the basis of table 3.

$$\text{d.i.b.}_{\text{est}} = (\text{d.b.h.})\sqrt{\left[\frac{(\text{d.i.b.})^2}{(\text{d.b.h.})^2}\right]_{\text{est}}}$$

where

$$\left[\frac{(\text{d.i.b.})^2}{(\text{d.b.h.})^2}\right]_{\text{est}} = 0.91274(x)^{1.5} - 1.9758(x^{1.5}-x^3)(\text{d.b.h.})(10^{-2})$$
$$+ 8.2375(x^{1.5}-x^3)(H)(10^{-3}) - 4.964(x^{1.5}-x^{32})(H)(\text{d.b.h.})(10^{-5})$$
$$+ 3.773(x^{1.5}-x^{32})(H)^{0.5}(10^{-3}) - 7.417(x^{1.5}-x^{40})(H)^2(10^{-6})$$

in which

H = total height of tree,

d.b.h. = diameter outside bark at breast height,

and

$$x = \frac{(\text{distance from tip to estimated d.i.b.})}{(H-4.5)}$$

The ratio $(\text{d.i.b.})^2/(\text{d.b.h.})^2$ has a standard error of estimate of approximately 0.07.

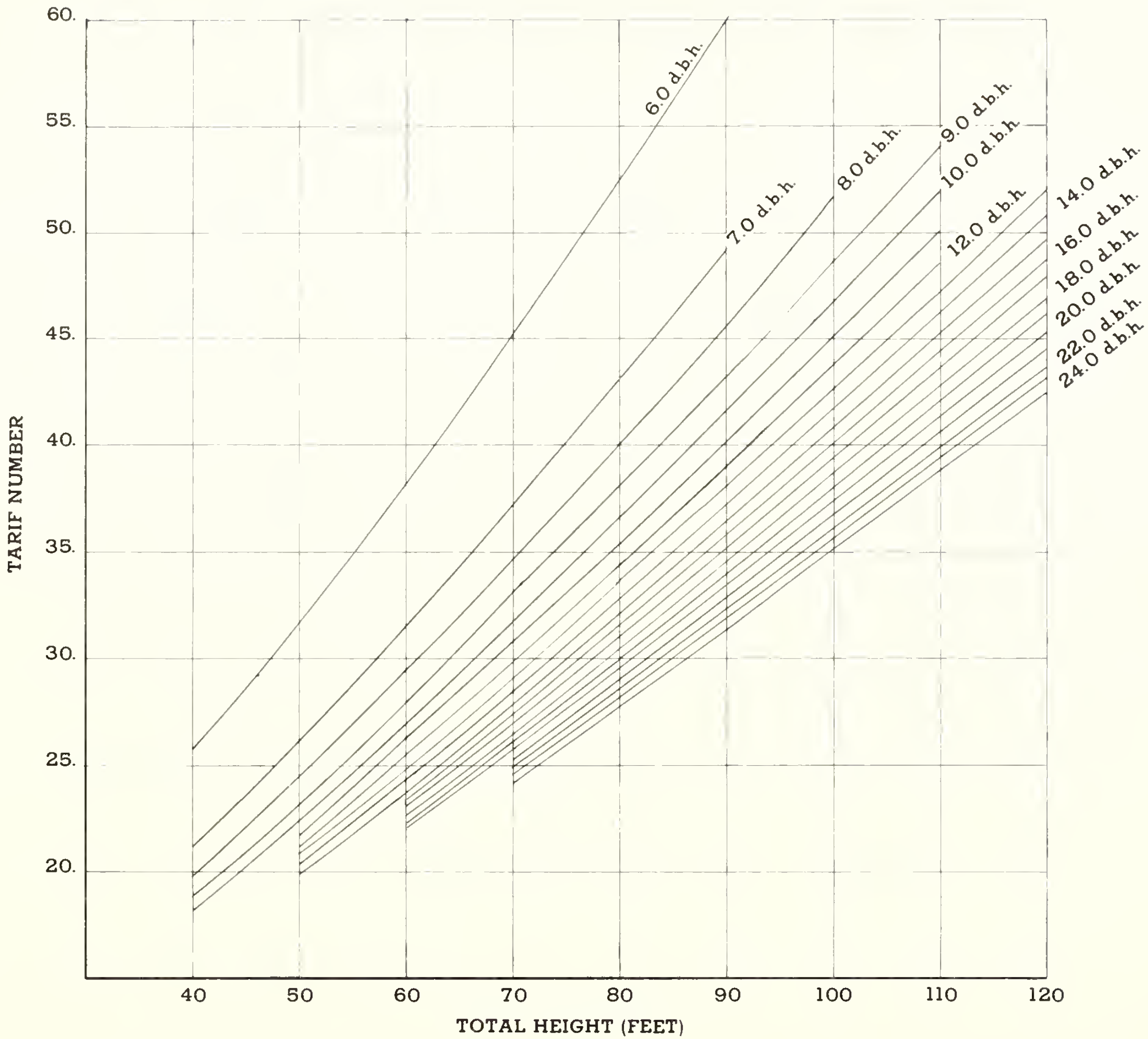

Figure 1. —Graph for estimating tarif number of red alder from d.b.h. and total height.

2. The basic equation for total cubic volume above stump (CVT), derived from (1), is:

$$CVT = 0.00545415\ (d.b.h.)^2(H-4.5)\ (F)$$

where[3]

$$\begin{aligned} F = {} & 0.36510(Z)^{2.5} - 7.9032(Z)^{2.5}(d.b.h.)(10^{-3}) + 3.2950(Z)^{2.5}(H)(10^{-3}) \\ & - 1.9856(Z)^{2.5}(H)(d.b.h.)(10^{-5}) - 2.9668\ (Z)^{2.5}(H)^2(10^{-6}) \\ & + 1.5092(Z)^{2.5}(H)^{0.5}(10^{-3}) + 4.9395(Z)^4(d.b.h.)(10^{-3}) \\ & - 2.05937(Z)^4(H)(10^{-3}) + 1.5042(Z)^{33}(H)(d.b.h.)(10^{-6}) \\ & - 1.1433(Z)^{33}(H)^{0.5}(10^{-4}) + 1.8090(Z)^{41}(H)^2(10^{-7}) \end{aligned}$$

in which

$$Z = \frac{(H - \tfrac{1}{2} - (d.b.h.)/24)}{(H-4.5)} = \frac{(\text{total height above stump in feet})}{(\text{total height above b.h. in feet})}$$

3. The estimates of total cubic volume (CVT) for trees of specified d.b.h. and height (H) given by equation 2 above may be converted to merchantable cubic volumes to top diameters of 4, 6, 8, 10, and 12 inches i.b. (CV4, CV6, CV8, CV10, CV12) by multiplying estimated total cubic volume by the following conversion factors:

$$\frac{CV4}{CVT} = 0.99875 - \frac{43.336}{(d.b.h.)^3} - \frac{124.717}{(d.b.h.)^4} + \frac{0.193437(H)}{(d.b.h.)^3} + \frac{479.83}{(d.b.h.)^3(H)}$$

$$\frac{CV6}{CVT} = 1.00081 - \frac{1614.44}{(d.b.h.)^4} + \frac{2.86121(H)}{(d.b.h.)^4} + \frac{1686.7}{(H)^3} - \frac{21.7181}{(d.b.h.)(H)} + \frac{1.1028(10^5)}{(d.b.h.)^5(H)}$$

$$\frac{CV8}{CVT} = 1.03361 - \frac{1.59234}{(d.b.h.)} - \frac{4667.04}{(d.b.h.)^4} + \frac{0.104498(H)}{(d.b.h.)^2} + \frac{5322.16}{(d.b.h.)^3(H)}$$

$$\frac{CV10}{CVT} = 1.02328 - \frac{43.4570}{(d.b.h.)^2} - \frac{7626.29}{(d.b.h.)^4} + \frac{76.7229(H)}{(d.b.h.)^4} - \frac{9954.576(H)}{(d.b.h.)^6} + \frac{116766.}{(d.b.h.)^4(H)}$$

$$\frac{CV12}{CVT} = 1.21396 - \frac{10.24325}{(d.b.h.)} + \frac{6.54920}{(H)} + \frac{12.2606(H)}{(d.b.h.)^3} - \frac{46116.8(H)}{(d.b.h.)^6} - \frac{1145.61}{(d.b.h.)^2(H)}$$

A similar set of conversion factors, some what less accurate but based on d.b.h. only, is given by the curves shown in figure 2.

These cubic-volume conversion factors, and the board-foot volume conversion factors of following sections, should of course *not* be applied to trees of dimensions too small to contain merchantable volume to the specified top diameter limit.

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[3] "F" is $\int_0^Z \left[\frac{(d.i.b.)}{(d.b.h.)}\right]^2 dx$, which is a form factor based on a cylinder of diameter equal to d.b.h. and height equal to (H—4.5).

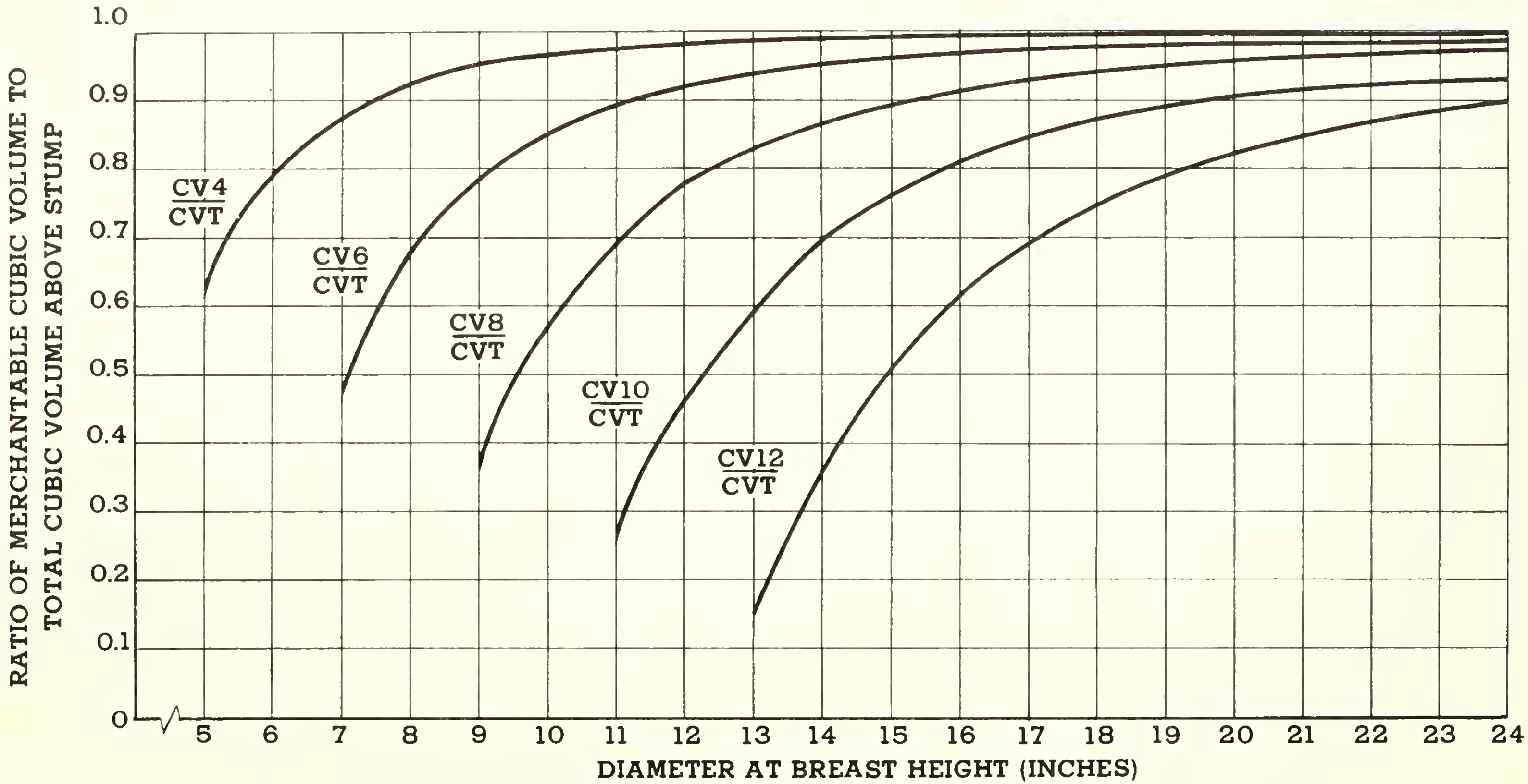

Figure 2.—Relationship of ratios of (merchantable cubic volume)/CVT to tree d.b.h.

4. Total cubic-volume estimates (CVT) for saw-log size trees of specified d.b.h. and H may be converted to board feet, Scribner, by multiplying by the conversion factors given below. Ratios are for board-foot volumes to tops of 6, 8, 10, and 12 inches i.b. (SV6, SV8, SV10, and SV12). Scaling is assumed to be in 16-foot logs, with fractional diameters rounded down to next lower exact inch, since this most nearly approximates current commercial practice.

$$\frac{SV6}{CVT} = 8.36001 - \frac{30.3982}{D} - \frac{205.532}{H} - \frac{152.004}{D^2} + \frac{1674.00}{D^4} + \frac{1227.84}{DH}$$

$$\frac{CV8}{CVT} = 8.11342 - \frac{398.033}{D^2} - \frac{218.418}{H} + \frac{76702.1}{H^3} - \frac{0.05208(H)}{D} + \frac{11337.8}{D^2H} - \frac{2.46759(10^7)}{D^6H}$$

$$\frac{SV10}{CVT} = 7.76152 - \frac{16.6331}{(d.b.h.)} - \frac{156.070}{(H)} - \frac{5845.33}{(d.b.h.)^3} + \frac{2.29172(10^5)}{(d.b.h.)^3(H)} - \frac{2.43897(10^8)}{(d.b.h.)^8}$$

$$\frac{SV12}{CVT} = 7.34627 - \frac{129.986}{(H)} - \frac{2.20502(H)(10^5)}{(d.b.h.)^6} + \frac{7465.72}{(H)^2} - \frac{4082.55}{(d.b.h.)(H)} + \frac{2.97332(10^6)}{(d.b.h.)^4(H)}$$

Total cubic-volume estimates (CVT) for saw-log-size trees of specified d.b.h. and H may be converted to board feet, International ¼-inch rule, by multiplying by the conversion factors given below. Ratios are for board-foot volumes to tops of 6, 8, 10, and 12 inches i.b. (IV6, IV8, IV10, and IV12). Scaling is assumed to be in 16-foot logs, with fractional diameters rounded to the nearest inch.

$$\frac{IV6}{CVT} = 8.22987 - \frac{189.164}{D^2} - \frac{5631.3}{D^4} - \frac{179.256}{H} + \frac{7977.6}{D^2H} + \frac{143.04(H)}{D^5}$$

$$\frac{IV8}{CVT} = 8.30882 - \frac{190.146}{D^2} - \frac{21960.}{D^4} - \frac{191.413}{H} - \frac{1.211(10^6)}{H^4} + \frac{11281.}{D^2H}$$

$$\frac{IV10}{CVT} = 8.24035 - \frac{7034.29}{D^3} - \frac{4.22367(10^8)}{D^8} - \frac{178.007}{H} + \frac{2.49955(10^5)}{D^3H}$$

$$\frac{IV12}{CVT} = 7.84957 - \frac{51936.7}{D^2H} + \frac{398559.}{D^3H} - \frac{2.45274(10^5)(H)}{D^6} - \frac{130.245}{H} + \frac{7.299(10^6)}{H^4}$$

TABLE 1.--DISTRIBUTION OF SAMPLE TREES BY DIAMETER AND HEIGHT CLASSES.

DBH	TOTAL HEIGHT IN FEET											TOTAL FOR DBH CLASS
	20	30	40	50	60	70	80	90	100	110	120	
2	1	4	2	-	-	-	-	-	-	-	-	7
3	-	1	6	3	-	-	-	-	-	-	-	10
4	-	1	3	1	1	-	-	-	-	-	-	6
5	-	-	1	-	2	2	-	-	-	-	-	5
6	-	-	-	1	-	2	5	2	-	-	-	10
7	-	-	-	-	1	4	12	5	-	-	-	22
8	-	-	-	-	-	1	14	9	-	-	-	24
9	-	-	-	-	4	3	14	11	1	-	-	33
10	-	-	-	-	-	2	18	12	4	-	-	36
11	-	-	-	-	2	5	9	13	3	-	-	32
12	-	-	-	-	2	7	15	23	4	1	-	52
13	-	-	-	-	-	2	7	14	4	-	-	27
14	-	-	-	-	-	2	15	18	16	1	-	52
15	-	-	-	-	-	2	12	14	10	1	-	39
16	-	-	-	-	-	1	13	14	13	4	-	45
17	-	-	-	-	-	-	4	5	6	4	-	19
18	-	-	-	-	-	-	8	4	2	2	-	16
19	-	-	-	-	-	1	2	4	7	-	1	15
20	-	-	-	-	-	-	2	2	4	-	-	8
21	-	-	-	-	-	-	-	2	1	1	-	4
22	-	-	-	-	-	-	-	-	2	-	-	2
23	-	-	-	-	-	1	1	-	1	-	1	4
24	-	-	-	-	-	-	1	2	-	2	-	5
TOTAL FOR HT CLASS	1	6	12	5	12	35	152	154	78	16	2	TOTAL NO. 473

TABLE 2.--VOLUME OF RED ALDER TREES IN CUBIC FEET INSIDE BARK (CV), FROM STUMP TO SPECIFIED MINIMUM TOP DIAMETER INSIDE BARK (DIB). STUMP HEIGHT = 0.5 FOOT + 0.5 x DBH. MERCHANTABLE VOLUMES OMITTED FOR TREES LESS THAN 6 INCHES DBH OR HAVING LESS THAN 8 LINEAL FEET OF MERCHANTABLE BOLE.

DBH	TOTAL HT	MINIMUM TOP DIB - INCHES					
		12.0 CV12	10.0 CV10	8.0 CV8	6.0 CV6	4.0 CV4	0.0 CVT
2	20	-	-	-	-	-	.216
2	30	-	-	-	-	-	.307
2	40	-	-	-	-	-	.404
3	20	-	-	-	-	-	.510
3	30	-	-	-	-	-	.690
3	40	-	-	-	-	-	.902
3	50	-	-	-	-	-	1.12
4	30	-	-	-	-	-	1.22
4	40	-	-	-	-	-	1.59
4	50	-	-	-	-	-	1.98
4	60	-	-	-	-	-	2.39
5	30	-	-	-	-	-	1.91
5	40	-	-	-	-	-	2.47
5	50	-	-	-	-	-	3.07
5	60	-	-	-	-	-	3.70
5	70	-	-	-	-	-	4.35
6	40	-	-	-	-	2.81	3.54
6	50	-	-	-	-	3.47	4.39
6	60	-	-	-	-	4.18	5.28
6	70	-	-	-	-	4.94	6.20
6	80	-	-	-	-	5.72	7.15
6	90	-	-	-	-	6.54	8.12
7	40	-	-	-	2.30	4.20	4.78
7	50	-	-	-	2.72	5.20	5.92
7	60	-	-	-	3.17	6.26	7.12
7	70	-	-	-	3.66	7.37	8.36
7	80	-	-	-	4.19	8.52	9.64
7	90	-	-	-	4.74	9.71	10.9

TABLE 2 (continued)

DBH	TOTAL HT	MINIMUM TOP DIB - INCHES					
		12.0 CV12	10.0 CV10	8.0 CV8	6.0 CV6	4.0 CV4	0.0 CVT
8	40	-	-	-	4.20	5.71	6.20
8	50	-	-	-	5.13	7.06	7.67
8	60	-	-	-	6.15	8.50	9.21
8	70	-	-	-	7.23	9.99	10.8
8	80	-	-	-	8.38	11.5	12
8	90	-	-	-	9.59	13.1	14.1
8	100	-	-	-	10.8	14.8	15.8
9	40	-	-	-	6.11	7.37	7.78
9	50	-	-	3.49	7.51	9.10	9.62
9	60	-	-	3.91	9.02	10.9	11.6
9	70	-	-	4.33	10.6	12.9	13.6
9	80	-	-	4.72	12.3	14.8	15.6
9	90	-	-	5.05	14.0	16.8	17.7
9	100	-	-	5.26	15.8	18.9	19.8
9	110	-	-	5.27	17.6	21.0	22.0
10	40	-	-	5.58	8.08	9.17	9.53
10	50	-	-	6.69	9.96	11.3	11.8
10	60	-	-	7.91	12.0	13.6	14.1
10	70	-	-	9.23	14.1	16.0	16.6
10	80	-	-	10.6	16.3	18.4	19.1
10	90	-	-	12.1	18.5	20.9	21.6
10	100	-	-	13.6	20.8	23.4	24.2
10	110	-	-	15.2	23.2	26.0	26.9
11	50	-	-	9.74	12.5	13.7	14.1
11	60	-	-	11.6	15.0	16.5	16.9
11	70	-	-	13.7	17.7	19.3	19.8
11	80	-	-	15.8	20.4	22.2	22.8
11	90	-	-	18.0	23.2	25.2	25.9
11	100	-	-	20.3	26.1	28.3	29.0
11	110	-	-	22.7	29.0	31.4	32.2
12	50	-	8.08	12.8	15.2	16.3	16.6
12	60	-	9.37	15.3	18.3	19.5	19.9
12	70	-	10.8	18.0	21.4	22.9	23.4
12	80	-	12.2	20.8	24.7	26.4	26.9
12	90	-	13.7	23.7	28.1	29.9	30.5
12	100	-	15.2	26.7	31.5	33.5	34.1
12	110	-	16.7	29.8	35.0	37.1	37.8

TABLE 2 (continued)

DBH	TOTAL HT	MINIMUM TOP DIB - INCHES 12.0 CV12	10.0 CV10	8.0 CV8	6.0 CV6	4.0 CV4	0.0 CVT
13	50	-	11.8	15.9	18.1	19.0	19.3
13	60	-	14.0	19.1	21.7	22.8	23.2
13	70	-	16.3	22.4	25.4	26.7	27.1
13	80	-	18.7	25.8	29.3	30.7	31.2
13	90	-	21.3	29.4	33.2	34.8	35.4
13	100	-	23.9	33.1	37.3	39.0	39.6
13	110	-	26.7	36.8	41.4	43.2	43.9
13	120	-	29.4	40.6	45.5	47.5	48.2
14	50	9.28	15.4	19.1	21.0	21.9	22.2
14	60	10.5	18.4	22.9	25.2	26.2	26.6
14	70	11.7	21.6	26.9	29.6	30.8	31.1
14	80	12.9	24.9	31.0	34.0	35.4	35.8
14	90	14.0	28.3	35.2	38.6	40.1	40.6
14	100	14.8	31.8	39.6	43.3	44.9	45.4
14	110	15.4	35.5	44.0	48.0	49.7	50.3
14	120	15.4	39.2	48.4	52.8	54.6	55.2
15	50	13.6	19.1	22.4	24.2	25.0	25.2
15	60	15.9	22.8	26.8	29.0	29.9	30.2
15	70	18.3	26.7	31.5	33.9	35.0	35.4
15	80	20.9	30.8	36.3	39.0	40.2	40.7
15	90	23.5	35.1	41.2	44.3	45.6	46.0
15	100	26.1	39.5	46.2	49.6	51.0	51.5
15	110	28.8	43.9	51.3	55.0	56.5	57.0
15	120	31.5	48.5	56.5	60.4	62.0	62.6
16	60	21.1	27.3	30.9	32.8	33.7	34.0
16	70	24.5	32.0	36.2	38.5	39.5	39.8
16	80	28.2	36.8	41.7	44.3	45.4	45.8
16	90	31.9	41.9	47.3	50.2	51.4	51.8
16	100	35.8	47.1	53.1	56.1	57.5	57.9
16	110	39.8	52.3	58.9	62.2	63.6	64.1
16	120	43.8	57.6	64.7	68.3	69.8	70.3
17	60	26.2	31.8	35.1	36.9	37.7	38.0
17	70	30.6	37.2	41.1	43.2	44.1	44.4
17	80	35.2	42.9	47.3	49.7	50.7	51.1
17	90	39.9	48.7	53.7	56.3	57.4	57.8
17	100	44.8	54.7	60.1	63.0	64.2	64.6
17	110	49.8	60.7	66.7	69.7	71.0	71.5
17	120	54.9	66.8	73.2	76.5	77.9	78.4

TABLE 2 (continued)

DBH	TOTAL HT	MINIMUM TOP DIB - INCHES 12.0 CV12	10.0 CV10	8.0 CV8	6.0 CV6	4.0 CV4	0.0 CVT
18	60	31.2	36.3	39.6	41.1	41.9	42.1
18	70	36.5	42.6	46.2	48.1	49.0	49.3
18	80	42.0	49.0	53.1	55.3	56.3	56.6
18	90	47.7	55.6	60.2	62.6	63.7	64.0
18	100	53.6	62.4	67.4	70.0	71.2	71.6
18	110	59.5	69.2	74.7	77.5	78.7	79.1
18	120	65.5	76.1	82.0	85.0	86.3	86.8
19	60	36.3	41.0	43.9	45.5	46.2	46.4
19	70	42.4	48.0	51.4	53.2	54.0	54.3
19	80	48.9	55.3	59.1	61.1	62.0	62.3
19	90	55.5	62.7	66.9	69.2	70.2	70.5
19	100	62.2	70.2	74.9	77.3	78.4	78.8
19	110	69.1	77.9	82.9	85.5	86.7	87.1
19	120	76.0	85.5	90.9	93.8	95.0	95.4
20	60	41.4	45.8	48.5	50.0	50.7	50.9
20	70	48.4	53.6	56.7	58.4	59.2	59.5
20	80	55.7	61.6	65.2	67.1	68.0	68.2
20	90	63.2	69.9	73.8	75.9	76.8	77.2
20	100	70.8	78.2	82.5	84.8	85.8	86.2
20	110	78.6	86.6	91.3	93.8	94.9	95.2
20	120	86.4	95.1	100.	103.	104.	104.
21	70	54.4	59.3	62.2	63.8	64.6	64.8
21	80	62.6	68.1	71.4	73.3	74.1	74.4
21	90	70.9	77.2	80.8	82.8	83.7	84.0
21	100	79.5	86.3	90.4	92.5	93.5	93.8
21	110	88.1	95.6	99.9	102.	103.	104.
21	120	96.8	105.	110.	112.	113.	113.
22	70	60.5	65.0	67.8	69.4	70.0	70.3
22	80	69.5	74.7	77.9	79.6	80.3	80.6
22	90	78.8	84.6	88.1	89.9	90.8	91.1
22	100	88.2	94.6	98.4	100.	101.	102.
22	110	97.6	105.	109.	111.	112.	112.
22	120	107.	115.	119.	121.	122.	123.
23	70	66.6	70.9	73.6	75.0	75.7	75.9
23	80	76.5	81.4	84.4	86.0	86.8	87.0
23	90	86.6	92.1	95.4	97.2	98.0	98.3
23	100	96.9	103.	107.	108.	109.	110.
23	110	107.	114.	118.	120.	121.	121.
23	120	118.	125.	129.	131.	132.	132.

TABLE 2 (continued)

DBH	TOTAL HT	MINIMUM TOP DIB - INCHES 12.0 CV12	10.0 CV10	8.0 CV8	6.0 CV6	4.0 CV4	0.0 CVT
24	70	72.8	76.9	79.4	80.8	81.4	81.7
24	80	83.6	88.2	91.1	92.6	93.3	93.6
24	90	94.6	99.8	103.	105.	105.	106.
24	100	106.	111.	115.	117.	118.	119.
24	110	117.	123.	127.	129.	130.	130.
24	120	128.	135.	139.	141.	142.	142.

TABLE 3.--TAPER TABLE FOR RED ALDER, BASED ON DIAMETER OUTSIDE BARK AT BREAST HEIGHT (DBH) AND TOTAL HEIGHT. VALUES ARE DIAMETERS INSIDE BARK IN INCHES, AT INDICATED HEIGHT ABOVE STUMP. STUMP HEIGHT = 0.5 foot + 0.5 x DBH. VALUES LESS THAN 4.0 OMITTED.

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
6	0.00	7.1	6.8	6.6	6.6	6.5	6.5	-	-	-
6	4.13	5.7	5.7	5.7	5.7	5.7	5.7	-	-	-
6	8.25	5.3	5.4	5.5	5.5	5.5	5.5	-	-	-
6	12.38	4.8	5.1	5.2	5.3	5.4	5.4	-	-	-
6	16.50	4.3	4.7	5.0	5.1	5.2	5.3	-	-	-
6	20.63	-	4.3	4.7	4.9	5.1	5.2	-	-	-
6	24.75	-	-	4.4	4.7	4.9	5.0	-	-	-
6	28.88	-	-	4.0	4.4	4.7	4.9	-	-	-
6	33.00	-	-	-	4.1	4.5	4.7	-	-	-
6	37.13	-	-	-	-	4.2	4.5	-	-	-
6	41.25	-	-	-	-	4.0	4.3	-	-	-
6	45.38	-	-	-	-	-	4.1	-	-	-
7	0.00	8.3	7.9	7.8	7.7	7.6	7.6	-	-	-
7	4.13	6.6	6.6	6.6	6.6	6.6	6.6	-	-	-
7	8.25	6.1	6.3	6.4	6.4	6.4	6.4	-	-	-
7	12.38	5.6	5.9	6.1	6.2	6.2	6.2	-	-	-
7	16.50	5.0	5.5	5.8	6.0	6.1	6.2	-	-	-
7	20.63	4.4	5.1	5.4	5.7	5.9	6.0	-	-	-
7	24.75	-	4.5	5.1	5.4	5.7	5.8	-	-	-
7	28.88	-	4.0	4.7	5.1	5.4	5.7	-	-	-
7	33.00	-	-	4.2	4.8	5.2	5.4	-	-	-
7	37.13	-	-	-	4.4	4.9	5.2	-	-	-
7	41.25	-	-	-	4.0	4.6	5.0	-	-	-
7	45.38	-	-	-	-	4.3	4.7	-	-	-
7	49.50	-	-	-	-	4.4	4.4	-	-	-
7	53.63	-	-	-	-	4.1	4.1	-	-	-
8	0.00	9.6	9.1	8.9	8.8	8.8	8.7	8.7	-	-
8	4.13	7.6	7.6	7.6	7.6	7.6	7.6	7.6	-	-
8	8.25	7.0	7.2	7.2	7.3	7.3	7.3	7.3	-	-
8	12.38	6.4	6.7	6.9	7.0	7.1	7.2	7.2	-	-
8	16.50	5.7	6.2	6.6	6.8	6.9	7.0	7.1	-	-
8	20.63	5.0	5.7	6.2	6.5	6.7	6.8	6.9	-	-
8	24.75	4.1	5.2	5.8	6.2	6.4	6.6	6.8	-	-
8	28.88	-	4.5	5.3	5.8	6.2	6.4	6.6	-	-
8	33.00	-	-	4.8	5.4	5.9	6.2	6.4	-	-
8	37.13	-	-	4.3	5.0	5.6	5.9	6.2	-	-
8	41.25	-	-	-	4.6	5.2	5.6	6.0	-	-
8	45.38	-	-	-	4.1	4.8	5.4	5.7	-	-

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
8	49.50	-	-	-	-	4.4	5.0	5.5	-	-
8	53.63	-	-	-	-	4.0	4.7	5.2	-	-
8	57.75	-	-	-	-	-	4.3	4.9	-	-
8	61.88	-	-	-	-	-	-	4.6	-	-
8	66.00	-	-	-	-	-	-	4.2	-	-
9	0.00	10.9	10.4	10.1	10.0	9.9	9.8	9.8	9.8	-
9	4.13	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	-
9	8.25	7.8	8.0	8.1	8.2	8.2	8.2	8.2	8.2	-
9	12.38	7.1	7.5	7.8	7.9	8.0	8.0	8.0	8.0	-
9	16.50	6.4	7.0	7.4	7.6	7.7	7.8	7.9	.79	-
9	20.63	5.5	6.4	6.9	7.3	7.5	7.6	7.8	7.8	-
9	24.75	4.6	5.7	6.4	6.9	7.2	7.4	7.6	7.7	-
9	28.88	-	5.1	5.9	6.5	6.9	7.2	7.4	7.5	-
9	33.00	-	4.3	5.4	6.1	6.6	6.9	7.2	7.4	-
9	37.13	-	-	4.8	5.6	6.2	6.6	6.9	7.2	-
9	41.25	-	-	4.1	5.1	5.8	6.3	6.7	7.0	-
9	45.38	-	-	-	4.6	5.4	6.0	6.4	6.8	-
9	49.50	-	-	-	4.0	4.9	5.6	6.1	6.5	-
9	53.63	-	-	-	-	4.5	5.2	5.8	6.2	-
9	57.75	-	-	-	-	-	4.8	5.5	6.0	-
9	61.88	-	-	-	-	-	4.4	5.1	5.7	-
9	66.00	-	-	-	-	-	-	4.7	5.3	-
9	70.13	-	-	-	-	-	-	4.3	5.0	-
9	74.25	-	-	-	-	-	-	-	4.6	-
9	78.38	-	-	-	-	-	-	-	4.3	-
10	0.00	12.2	11.6	11.3	11.1	11.0	11.0	10.9	10.9	-
10	4.13	9.4	9.5	9.5	9.5	9.5	9.5	9.5	9.4	-
10	8.25	8.7	8.9	9.0	9.0	9.1	9.1	9.1	9.0	-
10	12.38	7.9	8.3	8.6	8.7	8.8	8.9	8.9	8.9	-
10	16.50	7.0	7.7	8.1	8.4	8.6	8.7	8.7	8.8	-
10	20.63	6.1	7.0	7.6	8.0	8.3	8.5	8.6	8.6	-
10	24.75	5.1	6.3	7.1	7.6	8.0	8.2	8.4	8.5	-
10	28.88	4.0	5.6	6.5	7.2	7.6	7.9	8.2	8.3	-
10	33.00	-	4.7	5.9	6.7	7.2	7.6	7.9	8.1	-
10	37.13	-	-	5.2	6.2	6.8	7.3	7.7	7.9	-
10	41.25	-	-	4.5	5.6	6.4	7.0	7.4	7.7	-
10	45.38	-	-	-	5.0	5.9	6.6	7.1	7.4	-
10	49.50	-	-	-	4.4	5.4	6.2	6.8	7.2	-
10	53.63	-	-	-	-	4.9	5.8	6.4	6.9	-
10	57.75	-	-	-	-	4.3	5.3	6.0	6.6	-

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
10	61.88	-	-	-	-	-	4.8	5.6	6.2	-
10	66.00	-	-	-	-	-	4.3	5.2	5.9	-
10	70.13	-	-	-	-	-	-	4.7	5.5	-
10	74.25	-	-	-	-	-	-	4.3	5.1	-
10	78.38	-	-	-	-	-	-	-	4.7	-
10	82.50	-	-	-	-	-	-	-	4.2	-
11	0.00	-	12.8	12.4	12.3	12.2	12.1	12.1	12.1	-
11	4.13	-	10.4	10.4	10.4	10.4	10.4	10.4	10.4	-
11	8.25	-	9.7	9.9	9.9	10.0	10.0	9.9	9.9	-
11	12.38	-	9.1	9.4	9.6	9.7	9.7	9.7	9.7	-
11	16.50	-	8.4	8.9	9.2	9.4	9.5	9.6	9.6	-
11	20.63	-	7.7	8.3	8.8	9.1	9.2	9.4	9.5	-
11	24.75	-	6.9	7.8	8.3	8.7	9.0	9.2	9.3	-
11	28.88	-	6.1	7.1	7.8	8.3	8.7	8.9	9.1	-
11	33.00	-	5.2	6.4	7.3	7.9	8.3	8.7	8.9	-
11	37.13	-	4.2	5.7	6.7	7.5	8.0	8.4	8.7	-
11	41.25	-	-	4.9	6.1	7.0	7.6	8.1	8.4	-
11	45.38	-	-	4.1	5.5	6.5	7.2	7.7	8.1	-
11	49.50	-	-	-	4.8	5.9	6.8	7.4	7.8	-
11	53.63	-	-	-	4.0	5.3	6.3	7.0	7.5	-
11	57.75	-	-	-	-	4.7	5.8	6.6	7.2	-
11	61.88	-	-	-	-	4.0	5.2	6.1	6.8	-
11	66.00	-	-	-	-	-	4.7	5.7	6.4	-
11	70.13	-	-	-	-	-	4.1	5.2	6.0	-
11	74.25	-	-	-	-	-	-	4.6	5.6	-
11	78.38	-	-	-	-	-	-	4.1	5.1	-
11	82.50	-	-	-	-	-	-	-	4.6	-
11	86.63	-	-	-	-	-	-	-	4.1	-
12	0.00	-	14.0	13.6	13.4	13.3	13.2	13.2	13.2	-
12	4.13	-	11.3	11.3	11.3	11.3	11.3	11.3	11.3	-
12	8.25	-	10.6	10.7	10.8	10.8	10.8	10.8	10.8	-
12	12.38	-	9.9	10.2	10.4	10.5	10.6	10.6	10.6	-
12	16.50	-	9.1	9.6	10.0	10.2	10.3	10.4	10.4	-
12	20.63	-	8.3	9.0	9.5	9.8	10.0	10.2	10.3	-
12	24.75	-	7.4	8.4	9.0	9.4	9.7	9.9	10.1	-
12	28.88	-	6.6	7.7	8.5	9.0	9.4	9.7	9.9	-
12	33.00	-	5.6	7.0	7.9	8.6	9.0	9.4	9.6	-
12	37.13	-	4.5	6.2	7.3	8.1	8.7	9.1	9.4	-
12	41.25	-	-	5.3	6.6	7.6	8.2	8.7	9.1	-
12	45.38	-	-	4.4	5.9	7.0	7.8	8.4	8.8	-
12	49.50	-	-	-	5.2	6.4	7.3	8.0	8.5	-

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
12	53.63	-	-	-	4.4	5.8	6.8	7.6	8.1	-
12	57.75	-	-	-	-	5.1	6.2	7.1	7.8	-
12	61.88	-	-	-	-	4.4	5.7	6.6	7.4	-
12	66.00	-	-	-	-	-	5.0	6.1	7.0	-
12	70.13	-	-	-	-	-	4.4	5.6	6.5	-
12	74.25	-	-	-	-	-	-	5.0	6.0	-
12	78.38	-	-	-	-	-	-	4.4	5.5	-
12	82.50	-	-	-	-	-	-	-	5.0	-
12	86.63	-	-	-	-	-	-	-	4.4	-
13	0.00	-	15.3	14.8	14.6	14.4	14.4	14.3	14.3	14.3
13	4.13	-	12.2	12.2	12.2	12.2	12.2	12.2	12.2	12.2
13	8.25	-	11.4	11.6	11.6	11.7	11.7	11.7	11.6	11.6
13	12.38	-	10.7	11.0	11.2	11.3	11.4	11.4	11.4	11.4
13	16.50	-	9.8	10.4	10.7	11.0	11.1	11.2	11.2	11.2
13	20.63	-	9.0	9.7	10.2	10.6	10.8	11.0	11.0	11.1
13	24.75	-	8.0	9.0	9.7	10.2	10.5	10.7	10.9	10.9
13	28.88	-	7.0	8.3	9.1	9.7	10.1	10.4	10.6	10.8
13	33.00	-	6.0	7.5	8.5	9.2	9.7	10.1	10.4	10.6
13	37.13	-	4.8	6.6	7.8	8.7	9.3	9.8	10.1	10.4
13	41.25	-	-	5.7	7.1	8.1	8.8	9.4	9.8	10.1
13	45.38	-	-	4.7	6.4	7.5	8.4	9.0	9.5	9.8
13	49.50	-	-	-	5.6	6.9	7.8	8.6	9.1	9.6
13	53.63	-	-	-	4.7	6.2	7.3	8.1	8.8	9.2
13	57.75	-	-	-	-	5.5	6.7	7.6	8.3	8.9
13	61.88	-	-	-	-	4.7	6.1	7.1	7.9	8.6
13	66.00	-	-	-	-	-	5.4	6.6	7.5	8.2
13	70.13	-	-	-	-	-	4.7	6.0	7.0	7.8
13	74.25	-	-	-	-	-	-	5.4	6.5	7.3
13	78.38	-	-	-	-	-	-	4.7	5.9	6.9
13	82.50	-	-	-	-	-	-	4.0	5.4	6.4
13	82.50	-	-	-	-	-	-	-	4.8	5.9
13	90.75	-	-	-	-	-	-	-	4.1	5.4
13	94.88	-	-	-	-	-	-	-	-	4.8
13	99.00	-	-	-	-	-	-	-	-	4.2
14	0.00	-	16.5	16.0	15.8	15.6	15.5	15.5	15.4	15.4
14	4.13	-	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1
14	8.25	-	12.3	12.4	12.5	12.5	12.5	12.5	12.5	12.4
14	12.38	-	11.4	11.8	12.0	12.2	12.2	12.2	12.2	12.2
14	16.50	-	10.5	11.1	11.5	11.8	11.9	12.0	12.0	12.0
14	20.63	-	9.6	10.4	11.0	11.3	11.6	11.7	11.8	11.9
14	24.75	-	8.6	9.7	10.4	10.9	11.2	11.5	11.6	11.7

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
14	28.88	-	7.5	8.9	9.8	10.4	10.8	11.2	11.4	11.5
14	33.00	-	6.3	8.0	9.1	9.8	10.4	10.8	11.1	11.3
14	37.13	-	5.1	7.1	8.4	9.3	10.0	10.4	10.8	11.1
14	41.25	-	-	6.1	7.6	8.7	9.5	10.0	10.5	10.8
14	45.38	-	-	5.0	6.8	8.0	8.9	9.6	10.1	10.5
14	49.50	-	-	-	5.9	7.3	8.4	9.2	9.8	10.2
14	53.63	-	-	-	5.0	6.6	7.8	8.7	9.4	9.9
14	57.75	-	-	-	4.0	5.8	7.2	8.2	8.9	9.5
14	61.88	-	-	-	-	5.0	6.5	7.6	8.5	9.1
14	66.00	-	-	-	-	4.1	5.8	7.0	8.0	8.7
14	70.13	-	-	-	-	-	5.0	6.4	7.5	8.3
14	74.25	-	-	-	-	-	4.2	5.7	6.9	7.8
14	78.38	-	-	-	-	-	-	5.0	6.3	7.4
14	82.50	-	-	-	-	-	-	4.3	5.7	6.8
14	86.63	-	-	-	-	-	-	-	5.1	6.3
14	90.75	-	-	-	-	-	-	-	4.4	5.7
14	94.88	-	-	-	-	-	-	-	-	5.1
14	99.00	-	-	-	-	-	-	-	-	4.5
15	0.00	-	17.7	17.2	16.9	16.8	16.7	16.6	16.6	16.6
15	4.13	-	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
15	8.25	-	13.1	13.3	13.4	13.4	13.4	13.4	13.3	13.3
15	12.38	-	12.2	12.6	12.8	13.0	13.0	13.0	13.0	13.0
15	16.50	-	11.2	11.9	12.3	12.5	12.7	12.8	12.8	12.8
15	20.63	-	10.2	11.1	11.7	12.1	12.3	12.5	12.6	12.7
15	24.75	-	9.1	10.3	11.0	11.6	12.0	12.2	12.4	12.5
15	28.88	-	8.0	9.4	10.4	11.0	11.5	11.9	12.1	12.3
15	33.00	-	6.7	8.5	9.7	10.5	11.1	11.5	11.8	12.0
15	37.13	-	5.4	7.5	8.9	9.9	10.6	11.1	11.5	11.8
15	41.25	-	-	6.4	8.1	9.2	10.1	10.7	11.2	11.5
15	45.38	-	-	5.3	7.2	8.5	9.5	10.2	10.8	11.2
15	49.50	-	-	4.1	6.3	7.8	8.9	9.7	10.4	10.9
15	53.63	-	-	-	5.3	7.0	8.3	9.2	9.9	10.5
15	57.75	-	-	-	4.2	6.2	7.6	8.7	9.5	10.1
15	61.88	-	-	-	-	5.3	6.9	8.1	9.0	9.7
15	66.00	-	-	-	-	4.3	6.1	7.4	8.5	9.3
15	70.13	-	-	-	-	-	5.3	6.8	7.9	8.8
15	74.25	-	-	-	-	-	4.4	6.1	7.3	8.3
15	78.38	-	-	-	-	-	-	5.3	6.7	7.8
15	82.50	-	-	-	-	-	-	4.5	6.1	7.3
15	86.63	-	-	-	-	-	-	-	5.4	6.7
15	90.75	-	-	-	-	-	-	-	4.6	6.1

TABLE 3 (continued)

BH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
5	94.88	-	-	-	-	-	-	-	-	5.4
5	99.00	-	-	-	-	-	-	-	-	4.7
5	103.13	-	-	-	-	-	-	-	-	4.0
6	0.00	-	-	18.4	18.1	17.9	17.8	17.7	17.7	17.7
6	4.13	-	-	15.0	15.0	15.0	15.0	15.0	15.0	15.0
6	8.25	-	-	14.1	14.2	14.2	14.2	14.2	14.2	14.1
6	12.38	-	-	13.4	13.6	13.8	13.8	13.9	13.8	13.8
6	16.50	-	-	12.6	13.0	13.3	13.5	13.6	13.6	13.6
6	20.63	-	-	11.7	12.4	12.8	13.1	13.3	13.4	13.4
6	24.75	-	-	10.9	11.7	12.3	12.7	12.9	13.1	13.2
6	28.88	-	-	10.0	11.0	11.7	12.2	12.6	12.8	13.0
6	33.00	-	-	9.0	10.2	11.1	11.7	12.2	12.5	12.8
6	37.13	-	-	7.9	9.4	10.4	11.2	11.8	12.2	12.5
6	41.25	-	-	6.8	8.5	9.8	10.6	11.3	11.8	12.2
6	45.38	-	-	5.6	7.6	9.0	10.0	10.8	11.4	11.9
6	49.50	-	-	4.3	6.6	8.2	9.4	10.3	11.0	11.5
6	53.63	-	-	-	5.6	7.4	8.7	9.7	10.5	11.1
6	57.75	-	-	-	4.4	6.5	8.0	9.2	10.0	10.7
6	61.88	-	-	-	-	5.6	7.3	8.5	9.5	10.3
6	66.00	-	-	-	-	4.6	6.5	7.9	9.0	9.8
6	70.13	-	-	-	-	-	5.6	7.2	8.4	9.3
6	74.25	-	-	-	-	-	4.7	6.4	7.8	8.8
6	78.38	-	-	-	-	-	-	5.6	7.1	8.3
6	82.50	-	-	-	-	-	-	4.8	6.4	7.7
6	86.63	-	-	-	-	-	-	-	5.7	7.1
6	90.75	-	-	-	-	-	-	-	4.9	6.4
6	94.88	-	-	-	-	-	-	-	4.1	5.7
6	99.00	-	-	-	-	-	-	-	-	5.0
6	103.13	-	-	-	-	-	-	-	-	4.2
7	0.00	-	-	19.6	19.3	19.1	18.9	18.9	18.8	18.8
7	4.13	-	-	15.9	15.9	15.9	15.9	15.9	15.9	15.9
7	8.25	-	-	14.9	15.0	15.1	15.1	15.0	15.0	14.9
7	12.38	-	-	14.1	14.4	14.6	14.6	14.7	14.6	14.6
7	16.50	-	-	13.3	13.8	14.1	14.2	14.3	14.4	14.4
7	20.63	-	-	12.4	13.1	13.5	13.8	14.0	14.1	14.2
7	24.75	-	-	11.5	12.3	13.0	13.4	13.7	13.9	14.0
7	28.88	-	-	10.5	11.6	12.3	12.9	13.3	13.6	13.7
7	33.00	-	-	9.4	10.8	11.7	12.4	12.9	13.2	13.5
7	37.13	-	-	8.3	9.9	11.0	11.8	12.4	12.8	13.2
7	41.25	-	-	7.1	9.0	10.3	11.2	11.9	12.5	12.9
7	45.38	-	-	5.9	8.0	9.5	10.6	11.4	12.0	12.5

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
17	49.50	-	-	4.5	7.0	8.7	9.9	10.8	11.6	12.1
17	53.63	-	-	-	5.8	7.8	9.2	10.3	11.1	11.7
17	57.75	-	-	-	4.6	6.9	8.4	9.6	10.6	11.3
17	61.88	-	-	-	-	5.9	7.6	9.0	10.0	10.8
17	66.00	-	-	-	-	4.8	6.8	8.3	9.4	10.3
17	70.13	-	-	-	-	-	5.9	7.6	8.8	9.8
17	74.25	-	-	-	-	-	4.9	6.8	8.2	9.3
17	78.38	-	-	-	-	-	-	5.9	7.5	8.7
17	82.50	-	-	-	-	-	-	5.0	6.8	8.1
17	86.63	-	-	-	-	-	-	4.1	6.0	7.4
17	90.75	-	-	-	-	-	-	-	5.2	6.8
17	94.88	-	-	-	-	-	-	-	4.3	6.0
17	99.00	-	-	-	-	-	-	-	-	5.3
17	103.13	-	-	-	-	-	-	-	-	4.4
18	0.00	-	-	20.8	20.4	20.2	20.1	20.0	20.0	19.9
18	4.13	-	-	16.8	16.8	16.8	16.8	16.8	16.8	16.8
18	8.25	-	-	15.7	15.9	15.9	15.9	15.9	15.8	15.7
18	12.38	-	-	14.9	15.2	15.3	15.4	15.5	15.4	15.4
18	16.50	-	-	14.0	14.5	14.8	15.0	15.1	15.1	15.1
18	20.63	-	-	13.0	13.8	14.2	14.6	14.8	14.9	14.9
18	24.75	-	-	12.0	13.0	13.6	14.1	14.4	14.6	14.7
18	28.88	-	-	11.0	12.2	13.0	13.6	14.0	14.3	14.4
18	33.00	-	-	9.9	11.3	12.3	13.0	13.5	13.9	14.2
18	37.13	-	-	8.7	10.4	11.6	12.4	13.0	13.5	13.8
18	41.25	-	-	7.5	9.4	10.8	11.8	12.5	13.1	13.5
18	45.38	-	-	6.1	8.4	10.0	11.1	12.0	12.6	13.1
18	49.50	-	-	4.7	7.3	9.1	10.4	11.4	12.2	12.7
18	53.63	-	-	-	6.1	8.2	9.6	10.8	11.6	12.3
18	57.75	-	-	-	4.8	7.2	8.9	10.1	11.1	11.8
18	61.88	-	-	-	-	6.1	8.0	9.4	10.5	11.4
18	66.00	-	-	-	-	5.0	7.1	8.7	9.9	10.8
18	70.13	-	-	-	-	-	6.2	7.9	9.2	10.3
18	74.25	-	-	-	-	-	5.1	7.1	8.6	9.7
18	78.38	-	-	-	-	-	4.0	6.2	7.8	9.1
18	82.50	-	-	-	-	-	-	5.3	7.1	8.5
18	86.63	-	-	-	-	-	-	4.2	6.3	7.8
18	90.75	-	-	-	-	-	-	-	5.4	7.1
18	94.88	-	-	-	-	-	-	-	-	6.3
18	99.00	-	-	-	-	-	-	-	-	5.5
18	103.13	-	-	-	-	-	-	-	-	4.6

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
19	0.00	-	-	22.0	21.6	21.4	21.2	21.1	21.1	21.1
19	4.13	-	-	17.7	17.7	17.7	17.7	17.7	17.7	17.7
19	8.25	-	-	16.6	16.7	16.7	16.7	16.7	16.6	16.6
19	12.38	-	-	15.6	15.9	16.1	16.2	16.2	16.2	16.1
19	16.50	-	-	14.7	15.2	15.5	15.8	15.9	15.9	15.9
19	20.63	-	-	13.7	14.4	14.9	15.3	15.5	15.6	15.7
19	24.75	-	-	12.6	13.6	14.3	14.8	15.1	15.3	15.4
19	28.88	-	-	11.5	12.7	13.6	14.2	14.6	14.9	15.1
19	33.00	-	-	10.3	11.8	12.9	13.6	14.2	14.6	14.8
19	37.13	-	-	9.1	10.9	12.1	13.0	13.7	14.2	14.5
19	41.25	-	-	7.8	9.8	11.3	12.3	13.1	13.7	14.2
19	45.38	-	-	6.4	8.8	10.4	11.6	12.5	13.2	13.8
19	49.50	-	-	4.9	7.6	9.5	10.9	11.9	12.7	13.3
19	53.63	-	-	-	6.4	8.5	10.1	11.3	12.2	12.9
19	57.75	-	-	-	5.0	7.5	9.3	10.6	11.6	12.4
19	61.88	-	-	-	-	6.4	8.4	9.8	11.0	11.9
19	66.00	-	-	-	-	5.2	7.4	9.1	10.4	11.4
19	70.13	-	-	-	-	-	6.4	8.3	9.7	10.8
19	74.25	-	-	-	-	-	5.4	7.4	9.0	10.2
19	78.38	-	-	-	-	-	4.2	6.5	8.2	9.5
19	82.50	-	-	-	-	-	-	5.5	7.4	8.9
19	86.63	-	-	-	-	-	-	4.4	6.5	8.2
19	90.75	-	-	-	-	-	-	-	5.6	7.4
19	94.88	-	-	-	-	-	-	-	4.7	6.6
19	99.00	-	-	-	-	-	-	-	-	5.8
19	103.10	-	-	-	-	-	-	-	-	4.8
20	0.00	-	-	23.2	22.8	22.5	22.4	22.2	22.2	22.2
20	4.13	-	-	18.6	18.6	18.6	18.6	18.6	18.6	18.6
20	8.25	-	-	17.4	17.5	17.5	17.5	17.5	17.4	17.4
20	12.38	-	-	16.4	16.7	16.9	17.0	17.0	17.0	16.9
20	16.50	-	-	15.3	15.9	16.3	16.5	16.6	16.6	16.6
20	20.63	-	-	14.3	15.1	15.6	16.0	16.2	16.3	16.4
20	24.75	-	-	13.2	14.2	14.9	15.4	15.8	16.0	16.1
20	28.88	-	-	12.0	13.3	14.2	14.8	15.3	15.6	15.8
20	33.00	-	-	10.8	12.3	13.4	14.2	14.8	15.2	15.5
20	37.13	-	-	9.5	11.3	12.6	13.6	14.3	14.8	15.2
20	41.25	-	-	8.1	10.3	11.8	12.9	13.7	14.3	14.8
20	45.38	-	-	6.6	9.1	10.9	12.1	13.1	13.8	14.4
20	49.50	-	-	5.0	7.9	9.9	11.3	12.4	13.3	13.9

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	12
20	53.63	-	-	-	6.6	8.9	10.5	11.8	12.7	13.
20	57.75	-	-	-	5.2	7.8	9.6	11.0	12.1	12.
20	61.88	-	-	-	-	6.6	8.7	10.3	11.5	12.
20	66.00	-	-	-	-	5.4	7.7	9.5	10.8	11.
20	70.13	-	-	-	-	4.0	6.7	8.6	10.1	11.
20	74.25	-	-	-	-	-	5.6	7.7	9.3	10.
20	78.38	-	-	-	-	-	4.3	6.8	8.5	9.
20	82.50	-	-	-	-	-	-	5.7	7.7	9.
20	86.63	-	-	-	-	-	-	4.6	6.8	8.
20	90.75	-	-	-	-	-	-	-	5.9	7.
20	94.88	-	-	-	-	-	-	-	4.8	6.
20	99.00	-	-	-	-	-	-	-	-	6.
20	103.13	-	-	-	-	-	-	-	-	5.
20	107.25	-	-	-	-	-	-	-	-	4.
21	0.00	-	-	-	24.0	23.7	23.5	23.4	23.4	23.
21	4.13	-	-	-	19.5	19.5	19.5	19.5	19.5	19.
21	8.25	-	-	-	18.3	18.4	18.4	18.3	18.2	18.
21	12.38	-	-	-	17.5	17.7	17.8	17.8	17.7	17.
21	16.50	-	-	-	16.6	17.0	17.2	17.3	17.4	17.
21	20.63	-	-	-	15.7	16.3	16.7	16.9	17.0	17.
21	24.75	-	-	-	14.8	15.6	16.1	16.5	16.7	16.
21	28.88	-	-	-	13.8	14.8	15.5	16.0	16.3	16.
21	33.00	-	-	-	12.8	14.0	14.8	15.4	15.9	16.
21	37.13	-	-	-	11.8	13.1	14.1	14.9	15.4	15.
21	41.25	-	-	-	10.7	12.2	13.4	14.3	14.9	15.
21	45.38	-	-	-	9.5	11.3	12.6	13.6	14.4	15.
21	49.50	-	-	-	8.2	10.3	11.8	12.9	13.8	14.
21	53.63	-	-	-	6.9	9.2	10.9	12.2	13.2	14.
21	57.75	-	-	-	5.4	8.1	10.0	11.5	12.6	13.
21	61.88	-	-	-	-	6.9	9.1	10.7	11.9	12.
21	66.00	-	-	-	-	5.6	8.0	9.8	11.2	12.
21	70.13	-	-	-	-	4.2	7.0	9.0	10.5	11.
21	74.25	-	-	-	-	-	5.8	8.0	9.7	11.
21	78.38	-	-	-	-	-	4.5	7.0	8.9	10.
21	82.50	-	-	-	-	-	-	5.9	8.0	9.
21	86.63	-	-	-	-	-	-	4.8	7.1	8.
21	90.75	-	-	-	-	-	-	-	6.1	8.
21	94.88	-	-	-	-	-	-	-	5.0	7.
21	99.00	-	-	-	-	-	-	-	-	6.
21	103.13	-	-	-	-	-	-	-	-	5.
21	107.25	-	-	-	-	-	-	-	-	4.

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
22	0.00	-	-	-	25.1	24.8	24.7	24.6	24.5	24.5
22	4.13	-	-	-	20.4	20.4	20.4	20.4	20.4	20.3
22	8.25	-	-	-	19.1	19.2	19.2	19.1	19.0	18.9
22	12.38	-	-	-	18.2	18.4	18.5	18.5	18.5	18.4
22	16.50	-	-	-	17.3	17.7	17.9	18.1	18.1	18.1
22	20.63	-	-	-	16.4	17.0	17.4	17.6	17.8	17.8
22	24.75	-	-	-	15.4	16.2	16.8	17.1	17.4	17.5
22	28.88	-	-	-	14.4	15.4	16.1	16.6	17.0	17.2
22	33.00	-	-	-	13.3	14.5	15.4	16.0	16.5	16.8
22	37.13	-	-	-	12.2	13.6	14.7	15.4	16.0	16.4
22	41.25	-	-	-	11.0	12.7	13.9	14.8	15.5	16.0
22	45.38	-	-	-	9.8	11.7	13.1	14.1	14.9	15.6
22	49.50	-	-	-	8.5	10.7	12.2	13.4	14.4	15.1
22	53.63	-	-	-	7.1	9.6	11.3	12.7	13.7	14.5
22	57.75	-	-	-	5.6	8.4	10.4	11.9	13.1	14.0
22	61.88	-	-	-	-	7.1	9.4	11.1	12.4	13.4
22	66.00	-	-	-	-	5.8	8.3	10.2	11.6	12.8
22	70.13	-	-	-	-	4.3	7.2	9.3	10.9	12.1
22	74.25	-	-	-	-	-	6.0	8.3	10.1	11.4
22	78.38	-	-	-	-	-	4.6	7.3	9.2	10.7
22	82.50	-	-	-	-	-	-	6.1	8.3	10.0
22	86.63	-	-	-	-	-	-	4.9	7.3	9.2
22	90.75	-	-	-	-	-	-	-	6.3	8.3
22	94.88	-	-	-	-	-	-	-	5.2	7.4
22	99.00	-	-	-	-	-	-	-	4.0	6.4
22	103.13	-	-	-	-	-	-	-	-	5.4
22	107.25	-	-	-	-	-	-	-	-	4.3
23	0.00	-	-	-	26.3	26.0	25.8	25.7	25.6	25.6
23	4.13	-	-	-	21.3	21.3	21.3	21.3	21.2	21.2
23	8.25	-	-	-	19.9	20.0	20.0	19.9	19.8	19.7
23	12.38	-	-	-	18.9	19.2	19.3	19.3	19.2	19.1
23	16.50	-	-	-	18.0	18.4	18.7	18.8	18.8	18.8
23	20.63	-	-	-	17.0	17.6	18.0	18.3	18.4	18.5
23	24.75	-	-	-	16.0	16.8	17.4	17.8	18.0	18.2
23	28.88	-	-	-	14.9	16.0	16.7	17.2	17.6	17.8
23	33.00	-	-	-	13.8	15.1	16.0	16.6	17.1	17.5
23	37.13	-	-	-	12.6	14.1	15.2	16.0	16.6	17.0
23	41.25	-	-	-	11.4	13.1	14.4	15.4	16.1	16.6
23	45.38	-	-	-	10.1	12.1	13.6	14.7	15.5	16.1
23	49.50	-	-	-	8.8	11.0	12.7	13.9	14.9	15.6
23	53.63	-	-	-	7.3	9.9	11.7	13.1	14.2	15.1
23	57.75	-	-	-	5.8	8.7	10.7	12.3	13.5	14.5

TABLE 3 (continued)

DBH	HEIGHT ABOVE STUMP	TOTAL HEIGHT OF TREE IN FEET								
		40	50	60	70	80	90	100	110	120
23	61.88	-	-	-	4.0	7.4	9.7	11.5	12.8	13.9
23	66.00	-	-	-	-	6.0	8.6	10.6	12.1	13.2
23	70.13	-	-	-	-	4.4	7.4	9.6	11.2	12.6
23	74.25	-	-	-	-	-	6.2	8.6	10.4	11.8
23	78.38	-	-	-	-	-	4.8	7.5	9.5	11.1
23	82.50	-	-	-	-	-	-	6.3	8.6	10.3
23	86.63	-	-	-	-	-	-	5.1	7.6	9.5
23	90.75	-	-	-	-	-	-	-	6.5	8.6
23	94.88	-	-	-	-	-	-	-	5.4	7.7
23	99.00	-	-	-	-	-	-	-	4.1	6.7
23	103.13	-	-	-	-	-	-	-	-	5.6
23	107.25	-	-	-	-	-	-	-	-	4.5
24	0.00	-	-	-	27.5	27.2	27.0	26.8	26.8	26.7
24	4.13	-	-	-	22.2	22.2	22.2	22.2	22.1	22.1
24	8.25	-	-	-	20.7	20.7	20.7	20.7	20.6	20.5
24	12.38	-	-	-	19.7	19.9	20.0	20.0	20.0	19.9
24	16.50	-	-	-	18.7	19.1	19.4	19.5	19.5	19.5
24	20.63	-	-	-	17.6	18.3	18.7	19.0	19.1	19.2
24	24.75	-	-	-	16.6	17.4	18.0	18.4	18.7	18.8
24	28.88	-	-	-	15.4	16.5	17.3	17.9	18.2	18.5
24	33.00	-	-	-	14.3	15.6	26.5	17.2	17.7	18.1
24	37.13	-	-	-	13.1	14.6	15.7	16.6	17.2	17.6
24	41.25	-	-	-	11.8	13.6	14.9	15.9	16.6	17.2
24	45.38	-	-	-	10.5	12.5	14.0	15.2	16.0	16.7
24	49.50	-	-	-	9.0	11.4	13.1	14.4	15.4	16.2
24	53.63	-	-	-	7.6	10.2	12.1	13.6	14.7	15.6
24	57.75	-	-	-	5.9	8.9	11.1	12.7	14.0	15.0
24	61.88	-	-	-	4.1	7.6	10.0	11.8	13.2	14.4
24	66.00	-	-	-	-	6.2	8.9	10.9	12.4	13.7
24	70.13	-	-	-	-	4.6	7.7	9.9	11.6	13.0
24	74.25	-	-	-	-	-	6.4	8.8	10.7	12.2
24	78.38	-	-	-	-	-	4.9	7.7	9.8	11.5
24	82.50	-	-	-	-	-	-	6.5	8.8	10.6
24	86.63	-	-	-	-	-	-	5.2	7.8	9.8
24	90.75	-	-	-	-	-	-	-	6.7	8.9
24	94.88	-	-	-	-	-	-	-	5.5	7.9
24	99.00	-	-	-	-	-	-	-	4.2	6.9
24	103.13	-	-	-	-	-	-	-	-	5.8
24	107.25	-	-	-	-	-	-	-	-	4.6

TABLE 4.--ESTIMATED TREE VOLUMES IN BOARD FEET SCRIBNER (SV), BY FORMULA RULE. BASED ON 16-FOOT SCALING LENGTH (EXCEPT TOP LOGS) AND ESTIMATED LOG TOP DIAMETERS INSIDE BARK (CORRESPONDING TO MEASUREMENT OF SCALING DIAMETERS TO "NEAREST INCH"). 6-INCH TRIM ALLOWANCE PER 16-FOOT LOG. VALUES OMITTED FOR TREES HAVING LESS THAN 8 FEET OF MERCHANTABLE BOLE.

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
8	40	-	-	-	11
8	50	-	-	-	16
8	60	-	-	-	21
8	70	-	-	-	26
8	80	-	-	-	31
8	90	-	-	-	37
8	100	-	-	-	43
9	40	-	-	-	17
9	50	-	-	16	26
9	60	-	-	18	33
9	70	-	-	20	40
9	80	-	-	22	50
9	90	-	-	24	58
9	100	-	-	25	66
9	110	-	-	25	76
10	40	-	-	22	24
10	50	-	-	27	35
10	60	-	-	34	44
10	70	-	-	43	57
10	80	-	-	51	69
10	90	-	-	59	80
10	100	-	-	67	94
10	110	-	-	76	105
11	50	-	-	40	45
11	60	-	-	53	59
11	70	-	-	65	75
11	80	-	-	76	88
11	90	-	-	90	106
11	100	-	-	104	122
11	110	-	-	117	138
12	50	-	39	54	55
12	60	-	46	70	74
12	70	-	54	84	93

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
12	80	-	65	103	112
12	90	-	75	121	133
12	100	-	85	137	152
12	110	-	94	158	174
13	50	-	52	68	65
13	60	-	69	86	91
13	70	-	86	108	113
13	80	-	102	131	138
13	90	-	119	151	161
13	100	-	134	176	186
13	110	-	152	199	211
13	120	-	170	221	236
14	50	50	70	82	78
14	60	57	93	102	109
14	70	65	114	132	133
14	80	73	133	158	164
14	90	80	157	185	191
14	100	85	181	214	222
14	110	90	204	240	250
14	120	90	228	270	282
15	50	68	89	95	93
15	60	82	115	123	127
15	70	100	139	157	156
15	80	120	168	185	192
15	90	138	198	220	223
15	100	156	225	252	260
15	110	173	256	286	292
15	120	191	286	320	330
16	60	111	136	144	146
16	70	137	166	181	181
16	80	162	203	216	221
16	90	186	236	256	259
16	100	213	270	292	300

TABLE 4 (continued)

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB 12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
16	110	242	308	333	338
16	120	269	341	370	379
17	60	140	156	166	165
17	70	171	196	207	207
17	80	200	237	249	252
17	90	234	273	293	295
17	100	270	318	335	341
17	110	304	358	382	386
17	120	338	400	423	431
18	60	166	176	188	186
18	70	201	226	233	234
18	80	239	271	282	283
18	90	283	316	331	334
18	100	323	365	380	384
18	110	363	409	431	435
18	120	408	460	480	485
19	60	192	200	211	207
19	70	230	256	259	262
19	80	281	304	317	316
19	90	329	359	370	373
19	100	372	412	427	428
19	110	425	464	482	486
19	120	474	520	539	541
20	60	216	226	234	228
20	70	263	286	286	290
20	80	322	338	352	349
20	90	373	402	409	413
20	100	428	460	474	473
20	110	486	521	533	539
20	120	538	581	598	598
21	70	298	317	316	319
21	80	361	376	388	383
21	90	417	446	450	455
21	100	483	507	523	520
21	110	545	578	586	593
21	120	605	642	659	659
22	70	333	347	347	349
22	80	400	415	424	419
22	90	463	490	494	498
22	100	537	558	572	569
22	110	603	636	643	648
22	120	675	703	721	721
23	70	368	377	378	380
23	80	439	454	461	455
23	90	513	535	538	541
23	100	591	611	622	619
23	110	661	694	701	704
23	120	743	769	784	784
24	70	402	408	410	411
24	80	477	494	499	492
24	90	562	579	584	585
24	100	645	665	673	670
24	110	725	752	760	762
24	120	811	836	848	848

TABLE 5.--ESTIMATED TREE VOLUMES IN BOARD FEET SCRIBNER (SV), BY FORMULA RULE. BASED ON 16-FOOT SCALING LENGTH (EXCEPT TOP LOGS), AND ESTIMATED LOG TOP DIAMETER INSIDE BARK MINUS 1/2 INCH (CORRESPONDING TO "ROUNDING DOWN" FRACTIONAL SCALING DIAMETERS TO NEXT LOWER EXACT INCH). 6-INCH TRIM ALLOWANCE PER 16-FOOT LOG. VALUES OMITTED FOR TREES HAVING LESS THAN 8 FEET OF MERCHANTABLE BOLE.

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
8	40	-	-	-	8
8	50	-	-	-	12
8	60	-	-	-	16
8	70	-	-	-	20
8	80	-	-	-	24
8	90	-	-	-	28
8	100	-	-	-	33
9	40	-	-	-	12
9	50	-	-	13	20
9	60	-	-	15	26
9	70	-	-	17	31
9	80	-	-	18	39
9	90	-	-	20	46
9	100	-	-	21	53
9	110	-	-	21	61
10	40	-	-	18	19
10	50	-	-	22	28
10	60	-	-	28	35
10	70	-	-	36	46
10	80	-	-	43	56
10	90	-	-	50	66
10	100	-	-	57	77
10	110	-	-	65	86
11	50	-	-	34	37
11	60	-	-	45	48
11	70	-	-	55	62
11	80	-	-	65	74
11	90	-	-	77	89
11	100	-	-	89	102
11	110	-	-	100	116
12	50	-	34	47	46
12	60	-	41	60	63

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
12	70	-	47	72	79
12	80	-	57	89	95
12	90	-	66	105	113
12	100	-	75	119	130
12	110	-	83	137	149
13	50	-	46	59	55
13	60	-	61	75	78
13	70	-	76	94	97
13	80	-	90	114	119
13	90	-	104	132	140
13	100	-	119	154	161
13	110	-	135	174	183
13	120	-	151	194	205
14	50	45	62	72	67
14	60	52	83	89	94
14	70	59	101	116	116
14	80	66	119	139	143
14	90	72	141	163	167
14	100	77	162	189	195
14	110	81	182	212	220
14	120	81	204	240	248
15	50	62	79	84	80
15	60	74	103	109	111
15	70	91	124	139	137
15	80	109	151	165	169
15	90	126	178	196	197
15	100	142	202	225	230
15	110	157	230	255	259
15	120	173	258	286	292
16	60	101	123	129	129
16	70	125	149	162	161
16	80	148	183	193	197

TABLE 5 (continued)

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
16	90	170	213	230	230
16	100	194	244	262	268
16	110	221	278	299	302
16	120	246	309	333	339
17	60	127	141	149	147
17	70	156	178	186	185
17	80	183	215	224	226
17	90	214	248	265	265
17	100	247	289	303	306
17	110	278	326	345	347
17	120	309	364	383	389
18	60	152	160	170	166
18	70	184	206	210	210
18	80	219	247	256	255
18	90	260	288	300	301
18	100	297	334	346	347
18	110	333	374	392	394
18	120	375	420	437	440
19	60	176	183	191	186
19	70	211	234	235	237
19	80	258	279	288	286
19	90	303	329	337	339
19	100	343	378	390	389
19	110	392	426	440	443
19	120	437	478	492	493
20	60	199	207	213	207
20	70	242	263	261	264
20	80	297	310	322	318

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
20	90	345	370	375	377
20	100	395	423	435	433
20	110	449	480	489	493
20	120	497	535	549	548
21	70	276	291	289	292
21	80	334	346	356	351
21	90	386	412	413	417
21	100	448	468	481	477
21	110	505	534	539	544
21	120	561	593	607	606
22	70	309	320	319	320
22	80	372	384	391	385
22	90	430	454	456	458
22	100	500	517	529	524
22	110	560	589	594	597
22	120	627	652	667	665
23	70	342	349	349	350
23	80	408	421	427	419
23	90	477	496	498	500
23	100	551	568	577	572
23	110	616	644	650	652
23	120	693	715	727	726
24	70	374	379	380	380
24	80	445	460	463	456
24	90	524	539	542	542
24	100	602	619	626	622
24	110	677	701	706	707
24	120	758	779	789	787

TABLE 6.--ESTIMATED TREE VOLUMES IN BOARD FEET SCRIBNER (SV), BY FORMULA RULE. BASED ON 8-FOOT SCALING LENGTH AND ESTIMATED LOG TOP DIAMETERS INSIDE BARK (CORRESPONDING TO MEASUREMENT OF SCALING DIAMETERS TO "NEAREST INCH"). 3-INCH TRIM PER 8-FOOT LOG. VALUES OMITTED FOR TREES HAVING LESS THAN 8 LINEAL FEET OF MERCHANTABLE BOLE.

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
8	40	-	-	-	15
8	50	-	-	-	20
8	60	-	-	-	24
8	70	-	-	-	29
8	80	-	-	-	35
8	90	-	-	-	40
8	100	-	-	-	46
9	40	-	-	-	23
9	50	-	-	16	31
9	60	-	-	18	39
9	70	-	-	21	46
9	80	-	-	23	55
9	90	-	-	25	64
9	100	-	-	26	72
9	110	-	-	26	81
10	40	-	-	26	33
10	50	-	-	32	43
10	60	-	-	39	54
10	70	-	-	47	65
10	80	-	-	54	77
10	90	-	-	63	89
10	100	-	-	71	101
10	110	-	-	80	114
11	50	-	-	48	57
11	60	-	-	59	71
11	70	-	-	71	85
11	80	-	-	83	101
11	90	-	-	97	117
11	100	-	-	110	133
11	110	-	-	124	149
12	50	-	43	64	71
12	60	-	52	80	89
12	70	-	60	96	108
12	80	-	69	113	127
12	90	-	79	131	147
12	100	-	88	148	167
12	110	-	97	167	187
13	50	-	63	80	86
13	60	-	78	101	109
13	70	-	93	122	132
13	80	-	109	143	156
13	90	-	125	166	180
13	100	-	142	189	204
13	110	-	159	212	229
13	120	-	176	235	254
14	50	52	84	99	103
14	60	61	104	123	130
14	70	70	125	149	157
14	80	77	146	176	185
14	90	84	169	203	214
14	100	90	191	230	243
14	110	94	215	258	273
14	120	93	239	286	302
15	50	78	105	118	121
15	60	93	130	147	153
15	70	110	156	177	185
15	80	128	184	209	217
15	90	145	212	241	251
15	100	163	241	274	285
15	110	181	271	307	319
15	120	199	300	340	354
16	60	125	157	172	176
16	70	149	188	208	214
16	80	174	222	244	252
16	90	200	256	281	290
16	100	226	291	319	329

TABLE 6 (continued)

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT-INCHES IB 12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
16	110	253	325	358	369
16	120	280	361	396	409
17	60	156	184	198	202
17	70	187	222	239	244
17	80	219	261	281	287
17	90	252	300	323	331
17	100	285	341	367	376
17	110	320	383	410	421
17	120	355	424	454	466
18	60	186	211	224	228
18	70	225	256	271	275
18	80	263	301	318	324
18	90	303	347	367	374
18	100	345	393	416	424
18	110	385	440	466	474
18	120	427	488	515	525
19	60	218	240	250	254
19	70	262	290	303	308
19	80	309	342	357	363
19	90	355	394	412	418
19	100	402	447	467	474
19	110	451	500	523	530
19	120	500	553	578	586
20	60	250	270	278	282
20	70	300	325	337	342
20	80	352	382	397	402
20	90	407	441	458	464
20	100	461	501	519	525
20	110	515	560	581	588
20	120	571	620	642	650
21	70	340	363	373	376
21	80	398	426	438	443
21	90	458	490	505	510
21	100	520	556	572	578
21	110	582	622	640	647
21	120	644	688	708	716
22	70	379	400	409	412
22	80	445	470	482	485
22	90	511	541	555	559
22	100	579	612	628	633
22	110	648	684	702	708
22	120	717	756	776	783
23	70	418	438	447	448
23	80	491	515	526	528
23	90	565	592	605	608
23	100	640	671	685	690
23	110	714	749	766	771
23	120	790	828	846	852
24	70	456	476	485	486
24	80	538	560	570	572
24	90	619	645	656	659
24	100	701	730	743	747
24	110	783	815	830	835
24	120	864	900	917	922

TABLE 7.--ESTIMATED TREE VOLUMES IN BOARD FEET SCRIBNER (SV) BY FORMULA RULE, BY TREE DBH AND MERCHANTABLE HEIGHT IN 16-FOOT LOGS. BASED ON 16-FOOT SCALING LENGTH AND ESTIMATED LOG TOP DIAMETER INSIDE BARK MINUS 1/2 INCH (CORRESPONDING TO "ROUNDING DOWN" FRACTIONAL SCALING DIAMETERS TO NEXT LOWER EXACT INCH). 6-INCH TRIM PER 16-FOOT LOG. TABLE DERIVED BY GRAPHICAL METHODS FROM TABLES 3 AND 5.

DBH	NO. 16.5-FOOT LOGS	TOP DIAMETER LIMIT - INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
8	1.	-	-	-	10
8	1.5	-	-	-	18
8	2.	-	-	-	25
9	0.5	-	-	12	-
9	1.	-	-	-	-
9	1.5	-	-	-	22
9	2.	-	-	-	30
9	2.5	-	-	-	42
9	3.	-	-	-	52
10	1.	-	-	26	-
10	1.5	-	-	44	25
10	2.	-	-	59	36
10	2.5	-	-	-	51
10	3.	-	-	-	64
10	3.5	-	-	-	77
11	1.5	-	-	49	-
11	2.	-	-	67	44
11	2.5	-	-	87	59
11	3.	-	-	-	76
11	3.5	-	-	-	93
11	4.	-	-	-	108
12	1.	-	48	-	-
12	1.5	-	-	53	-
12	2.	-	-	74	50
12	2.5	-	-	99	71
12	3.	-	-	120	90
12	3.5	-	-	-	109
12	4.	-	-	-	128
12	4.5	-	-	-	148
13	1.	-	50	-	-
13	1.5	-	84	59	-
13	2.	-	114	83	56
13	2.5	-	144	111	82
13	3.	-	-	137	104
13	3.5	-	-	164	127
13	4.	-	-	189	151
13	4.5	-	-	-	173
13	5.	-	-	-	195
14	1.	78	-	-	-
14	1.5	-	91	-	-
14	2.	-	124	89	-
14	2.5	-	160	123	93
14	3.	-	194	154	118
14	3.5	-	-	185	147
14	4.	-	-	214	173
14	4.5	-	-	-	201
14	5.	-	-	-	227
15	1.	79	-	-	-
15	1.5	128	96	-	-
15	2.	170	134	101	-
15	2.5	-	176	137	105
15	3.	-	214	171	134
15	3.5	-	254	207	166
15	4.	-	-	241	196
15	4.5	-	-	277	229
15	5.	-	-	-	258
15	5.5	-	-	-	291
16	1.5	135	-	-	-
16	2.	183	144	-	-
16	2.5	233	190	150	-
16	3.	-	234	189	152
16	3.5	-	278	231	187
16	4.	-	-	267	222
16	4.5	-	-	308	259
16	5.	-	-	-	293
16	5.5	-	-	-	329

TABLE 7 (continued)

DBH	NO. 16.5-FOOT LOGS	TOP DIAMETER LIMIT - INCHES IB				DBH	NO. 16.5-FOOT LOGS	TOP DIAMETER LIMIT - INCHES IB			
		12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6			12.0 SV12	10.0 SV10	8.0 SV8	6.0 SV6
17	1.5	143	-	-	-	21	2.5	325	-	-	-
17	2.	195	155	-	-	21	3.	399	340	287	-
17	2.5	253	207	164	-	21	3.5	475	413	356	304
17	3.	303	253	208	169	21	4.	545	479	413	362
17	3.5	-	303	253	209	21	4.5	-	551	484	424
17	4.	-	350	295	249	21	5.	-	-	540	480
17	4.5	-	-	341	289	21	5.5	-	-	609	543
17	5.	-	-	382	329	21	6.	-	-	-	607
17	5.5	-	-	-	369						
18	1.5	151	-	-	-	22	2.5	346	-	-	-
18	2.	208	162	-	-	22	3.	423	364	313	-
18	2.5	271	221	179	-	22	3.5	506	442	383	330
18	3.	326	276	227	187	22	4.	581	512	449	392
18	3.5	-	331	277	232	22	4.5	-	588	522	460
18	4.	-	380	325	276	22	5.	-	656	585	521
18	4.5	-	-	375	322	22	5.5	-	-	650	590
18	5.	-	-	423	366	22	6.	-	-	-	652
18	5.5	-	-	-	410						
19	2.	218	-	-	-	23	2.5	365	-	-	-
19	2.5	290	238	195	-	23	3.	450	388	-	-
19	3.	349	297	247	206	23	3.5	536	469	410	355
19	3.5	415	356	301	255	23	4.	616	549	482	421
19	4.	-	413	353	304	23	4.5	708	628	561	497
19	4.5	-	472	410	354	23	5.	-	711	633	564
19	5.	-	-	461	404	23	5.5	-	-	707	637
19	5.5	-	-	-	454	23	6.	-	-	-	707
20	2.	232	-	-	-	24	2.5	383	-	-	-
20	2.5	308	255	210	-	24	3.	474	411	-	-
20	3.	376	316	267	225	24	3.5	565	499	437	383
20	3.5	444	384	328	280	24	4.	656	584	517	454
20	4.	506	446	385	334	24	4.5	746	668	600	534
20	4.5	-	508	447	389	24	5.	-	751	677	609
20	5.	-	-	501	442	24	5.5	-	-	756	686
20	5.5	-	-	-	498	24	6.	-	-	-	759

TABLE 8.--ESTIMATED TREE VOLUMES IN BOARD FEET INTERNATIONAL 1/4-INCH RULE (IV), BASED ON 16-FOOT SCALING LENGTH (EXCEPT TOP LOGS) AND ESTIMATED LOG TOP DIAMETERS INSIDE BARK (CORRESPONDING TO MEASUREMENT OF SCALING DIAMETERS TO "NEAREST INCH"). 6-INCH TRIM ALLOWANCE PER 16-FOOT LOG. VALUES OMITTED FOR TREES HAVING LESS THAN 8 LINEAL FEET OF MERCHANTABLE BOLE.

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT -INCHES IB			
		12.0 IV12	10.0 IV10	8.0 IV8	6.0 IV6
8	40	-	-	-	17
8	50	-	-	-	23
8	60	-	-	-	30
8	70	-	-	-	37
8	80	-	-	-	45
8	90	-	-	-	52
8	100	-	-	-	59
9	40	-	-	-	24
9	50	-	-	18	34
9	60	-	-	21	44
9	70	-	-	24	55
9	80	-	-	26	66
9	90	-	-	30	77
9	100	-	-	32	89
9	110	-	-	32	101
10	40	-	-	26	32
10	50	-	-	34	46
10	60	-	-	42	59
10	70	-	-	52	74
10	80	-	-	61	88
10	90	-	-	72	104
10	100	-	-	83	120
10	110	-	-	94	136
11	50	-	-	48	58
11	60	-	-	63	75
11	70	-	-	77	94
11	80	-	-	93	112
11	90	-	-	108	132
11	100	-	-	125	153
11	110	-	-	142	172
12	50	-	43	64	70
12	60	-	54	83	92
12	70	-	64	102	114
12	80	-	74	122	138

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT -INCHES IB			
		12.0 IV12	10.0 IV10	8.0 IV8	6.0 IV6
12	90	-	85	143	162
12	100	-	96	165	186
12	110	-	107	186	212
13	50	-	61	80	81
13	60	-	79	103	110
13	70	-	97	126	137
13	80	-	116	153	165
13	90	-	136	179	195
13	100	-	154	205	223
13	110	-	174	232	252
13	120	-	194	260	282
14	50	53	80	95	96
14	60	62	104	121	130
14	70	74	128	153	159
14	80	82	153	185	194
14	90	90	178	214	227
14	100	97	206	247	261
14	110	101	234	279	296
14	120	101	259	312	330
15	50	77	100	110	111
15	60	92	130	143	149
15	70	111	159	180	184
15	80	132	189	214	224
15	90	151	223	252	261
15	100	172	256	291	302
15	110	194	288	327	341
15	120	214	323	366	382
16	60	122	152	165	169
16	70	150	187	207	210
16	80	179	226	246	255
16	90	208	267	292	298
16	100	236	303	333	344
16	110	267	345	377	389
16	120	298	385	422	435

TABLE 8 (continued)

DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT -INCHES IB 12.0 IV12	10.0 IV10	8.0 IV8	6.0 IV6	DBH	TREE TOTAL HEIGHT	TOP DIAMETER LIMIT -INCHES IB 12.0 IV12	10.0 IV10	8.0 IV8	6.0 IV6
17	60	152	177	188	190	21	70	325	347	351	355
17	70	187	219	236	237	21	80	393	413	428	427
17	80	222	264	281	287	21	90	456	489	498	504
17	90	258	307	331	336	21	100	525	558	576	577
17	100	296	354	378	388	21	110	592	632	647	656
17	110	338	402	430	438	21	120	659	705	726	729
17	120	374	446	478	491						
18	60	182	198	211	213						
18	70	223	251	263	266	22	70	361	379	383	387
18	80	263	300	317	322	22	80	434	454	466	464
18	90	309	351	373	377	22	90	504	535	543	548
18	100	354	405	426	434	22	100	581	610	628	628
18	110	400	456	482	491	22	110	656	693	706	714
18	120	447	509	537	548	22	120	732	769	790	794
19	60	209	223	235	235						
19	70	254	282	291	295	23	70	397	413	415	418
19	80	307	339	353	358	23	80	477	495	505	502
19	90	360	396	413	418	23	90	555	581	590	595
19	100	410	456	475	481	23	100	639	665	680	680
19	110	465	513	537	544	23	110	718	754	766	772
19	120	518	574	599	606	23	120	802	837	856	859
20	60	238	250	260	258						
20	70	289	315	320	325	24	70	432	445	449	451
20	80	349	374	390	391	24	80	518	537	544	541
20	90	410	442	455	461	24	90	606	630	637	641
20	100	467	507	524	528	24	100	695	720	733	734
20	110	530	572	592	599	24	110	783	814	827	832
20	120	589	638	661	666	24	120	875	906	922	926

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RE HAZARD FROM RECOMMERCIAL THINNING F PONDEROSA PINE

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PACIFIC NORTHWEST
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CONTENTS

INTRODUCTION

Precommercial thinning lately has become a major feature in management of ponderosa pine (*Pinus ponderosa* Laws.) on the National Forests in Oregon and Washington. Nearly 47,000 acres were thinned in 1966, up from 9,196 in 1959; and the upward trend appears certain to continue. Current practice is to cut the trees with a powersaw about a foot above the ground and let them lie as they fall. The slash, i.e., the felled trees, becomes a fire hazard as soon as it dries. It also obstructs access, provides a breeding place for certain insect pests (notably engraver beetles, *Ips* sp.), temporarily prevents use of forage by big game and livestock, and is esthetically offensive. On the other hand, thinning greatly increases timber growth and should prevent epidemics of mountain pine beetle (*Dendroctonus ponderosae* Hopk.). Protection by slash may permit forage to become established or recover from overuse. In any case, forage production increases severalfold, and habitat for wildlife is improved significantly. The thinned forest, after the slash deteriorates, is generally easier to protect and esthetically more pleasing than the unthinned.

Are the temporary effects of slash from precommercial thinning serious enough to require countermeasures, the cost of which will reduce the amount of thinning that can be accomplished? One point of view is that the additional fire hazard alone is of sufficient degree and duration to demand abatement in order to prevent loss of the investment in thinning and other values as well. Opposed is the opinion that the hazard, though initially high, is of sufficiently short duration to be tolerated, with appropriate adjustment in protection measures, so that maximum acreage can be thinned with the funds available. Both points of view have merit, and each probably is completely correct in some areas. The problem of reconciling them is the common one of optimizing allocation of expenditures to obtain maximum net gain in all forest products, tangible and intangible. This publication makes available means for gauging the fire hazard of slash more objectively than has been possible heretofore as a basis for deciding what action is required in specific situations.

Quantity of slash, expressed by ovendry weight per acre, by size class, is probably the best determinant, or indicator, of fire hazard, and certainly is the one on which the best information is available (Fahnestock 1960, Fahnestock and Dieterich 1962, Anderson et al. 1966). Information on quantity also should be useful in assessing the impact of thinning slash on other aspects of resource protection and management. This report draws on available knowledge of slash quantity to provide:

1. A basis for estimating the weight of slash produced by thinning operation.
2. General estimates of the weight of slash to be expected from thinning normal stands of known site and age to various spacings.
3. Inferences regarding flammability and difficulty of fire control for at least 5 years after thinning.
4. Suggestions as to general types of research and operational feedback needed to strengthen the scientific basis for deciding what to do about thinning slash.

QUANTITY OF SLASH

Weights of Individual Trees

The individual tree is the basic unit in computing slash weight per unit of area. In precommercial thinning, the entire tree becomes slash. The three main component parts are crown (foliage, branches, tip), wood (trunk only), and bark. Information on the three components comes from different sources, and continued separation of identities is necessary for interpretation.

Crowns.—Table 1 gives crown weights for ponderosa pine and its common associates up to a 16-inch d.b.h. Few pines larger than 6 inches are cut in precommercial thinning, but a few of the less valuable species sometimes are. The weights are for living material only and therefore are conservative. The data were adapted from tables developed for the Inland Empire and California (Fahnestock 1960; Chandler 1960). Measurements from 21 ponderosa pines and 13 incense-cedars (*Libocedrus decurrens* Torr.) on the Deschutes National Forest showed that crown weight estimates based on data collected elsewhere for these species could legitimately be used in eastern Oregon; the same was assumed to be true for the other four species.

Table 1.—*Individual crown weights of ponderosa pine and its principal associates by d.b.h. class*

D.b.h. class (inches)	Ponderosa pine [1]	Incense-cedar [2]	Douglas-fir [1]	Grand fir [1]	Lodgepole pine [1]	Western larch [1]
	Pounds, ovendry					
1	4	9	3	8	1	1
2	7	19	5	13	2	3
3	15	30	8	20	4	6
4	23	41	15	28	7	10
5	36	53	22	40	13	15
6	48	67	31	52	20	21
7	65	82	42	66	30	27
8	82	98	54	79	42	36
9	103	115	63	95	56	43
10	126	133	84	110	75	55
11	150	152	98	127	96	62
12	178	173	118	145	120	77
13	202	194	131	165	150	89
14	237	216	157	184	178	103
15	—	240	178	205	215	117
16	—	266	205	226	256	134

[1] Adapted from Fahnestock (1960).
[2] Adapted from Chandler (1960).

Boles.—Cubic volume tables are available for ponderosa pine and most of its common associates, the major exception being incense-cedar (Johnson 1955). Some of the tables do not include tree diameters smaller than 6 inches b.h., but reasonable estimates for the smaller sizes can be obtained by extrapolation and comparison with other species. Table 2 is a cubic-foot volume table for ponderosa pine through the range of sizes that are likely to be cut in thinning or dwarfmistletoe control. Values were obtained by entering a standard volume table with heights typical of their respective age-site classes (Meyer 1938). The diameter groupings are those used in available stand tables. The site and age classes cover the range likely to be thinned in Region 6. Weight of wood is volume times 25, the mean ovendry weight in pounds of a cubic foot of ponderosa pine (U.S. Forest Service 1955).

Bark.—Ponderosa pine bark volume consistently is about 23.5 percent of peeled wood volume.[1] Specific gravity of bark varies widely with growing conditions (Spalt and Reifsnyder 1962). In the absence of a figure for ponderosa pine, the best assumption seems to be that bark density approximates wood density. Therefore, weight of bark is 23.5 percent of the weight of wood in a particular tree bole.

[1] Personal communication with F. A. Johnson, Biometrician, Pacific Northwest Forest and Range Experiment Station.

Table 2.—*Cubic-foot volume of small ponderosa pines by age class, site index, and d.b.h.*

Age class (years)	D.b.h. (inches)					
	1	2-3	4-5	6-7	8-9	10-11
Site index 60:[1]						
20	0.05	0.25	0.95	2.25	—	—
40	.05	.35	1.25	2.90	5.30	9.05
60	.05	.40	1.50	3.30	6.25	10.71
80	.05	.45	1.65	3.30	7.20	12.50
Site index 80:[1]						
20	.05	.25	1.05	2.60	4.65	—
40	.05	.40	1.55	3.40	6.40	10.95
60	.05	.45	1.70	4.00	7.60	13.20
80	.05	.45	1.75	4.25	8.10	14.55
Site index 100:[1]						
20	.05	.35	1.25	2.85	5.20	—
40	.05	.45	1.75	4.10	7.60	13.00
60	.05	.45	1.90	4.50	8.50	15.20
80	—	.45	1.90	4.60	9.05	16.30

[1] Approximate equivalents are:
Site III = site index 85-98
Site IV = site index 71-84
Site V = site index 57-70.

Total Weight Per Acre

Two types of total-weight estimates have value for several purposes. Preliminary estimates, based on general characteristics of the stands to be thinned, can be used to determine the need for hazard reduction and/or other extra protection measures over large areas and can form a basis for scheduling thinning operations in patterns that will facilitate fire protection. Working estimates, based on specific measurements in stands scheduled for thinning, can pinpoint the location of hazard so that special protection measures, if needed, can be tailored to specific situations. Both types of estimates are obtained by summing the products of number of trees cut in each d.b.h. class times the respective tree weights; only the sources of tree numbers differ.

Preliminary estimates.—Normal yield tables (Meyer 1938) for ponderosa pine provide tree numbers for use in preliminary estimates. Prescribed spacing in the thinned stand determines how many crop trees per acre will be left. Number of trees to be cut is determined by subtraction; the best assumption as to size allocation is that the largest trees will be left. Table 3, constructed on this basis, shows estimated weights per acre to be expected when normal stands of pure ponderosa pine of four ages on three sites are thinned to various densities. Several considerations dictate the breakdown into size classes of material:

Table 3.—*Tons of slash per acre from thinning normal stands of ponderosa pine to various spacings*

Spacing (feet)	Type of material[1]	Site index 60, stand age—				Site index 80, stand age—				Site index 100, stand age—			
		20	40	60	80	20	40	60	80	20	40	60	80
8 by 8	Crowns	9	9	2	—	5	3	—	—	2	<1	—	—
	Bark	1	2	1	—	1	1	—	—	1	<1	—	—
	Trunks ≤ 7 inches	3	8	2	—	4	4	—	—	3	<1	—	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	13	19	5	—	10	8	—	—	6	1	—	—
10 by 10	Crowns	11	13	6	2	7	7	2	—	4	3	—	—
	Bark	1	3	2	<1	1	2	<1	—	1	1	—	—
	Trunks ≤ 7 inches	3	11	8	2	5	8	2	—	5	5	—	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	15	27	16	4	13	17	4	—	10	9	—	—
12 by 12	Crowns	11	15	8	4	7	10	5	1	6	7	2	—
	Bark	1	3	3	1	1	3	2	—	2	3	1	—
	Trunks ≤ 7 inches	4	14	12	6	6	13	8	1	8	11	4	—
	Trunks > 7 inches	—	—	—	—	—	—	—	—	—	—	—	—
	Total	16	32	23	11	14	26	15	2	16	21	7	—
14 by 14	Crowns	12	16	10	6	8	12	8	3	7	10	5	1
	Bark	1	3	4	2	2	4	3	1	2	3	2	1
	Trunks ≤ 7 inches	4	15	16	10	7	16	11	6	11	14	6	2
	Trunks > 7 inches	—	—	—	—	—	—	(2)	(<1)	—	(2)	(5)	(1)
	Total	17	34	30	18	17	32	22	10	20	27	13	4
16 by 16	Crowns	12	17	12	9	9	14	10	6	7	12	8	4
	Bark	1	3	4	2	2	4	3	1	3	3	2	1
	Trunks ≤ 7 inches	4	16	18	11	8	18	11	5	12	15	6	2
	Trunks > 7 inches	—	—	—	(3)	—	—	(8)	(7)	—	(8)	(12)	(9)
	Total	17	36	34	22	19	36	24	12	22	30	16	7
18 by 18	Crowns	12	17	13	10	9	15	12	8	8	14	10	7
	Bark	1	4	4	2	2	4	3	1	3	3	2	<1
	Trunks ≤ 7 inches	4	17	20	11	9	20	11	5	13	14	6	2
	Trunks > 7 inches	—	—	—	(6)	—	(<1)	(12)	(13)	—	(13)	(20)	(18)
	Total	17	38	37	23	20	39	26	14	24	31	18	10

[1] Crowns, all trees; bark, from trees ≤ 7 inches d.b.h.; trunks ≤ 7 inches d.b.h., wood only; trunks > 7 inches, bark and wood—weights are in parentheses and not included in totals because this material is potentially merchantable.

1. Crowns (foliage and branches) are the fine material that governs rate of fire spread and fire intensity. Crowns of all trees cut become slash.

2. Boles contribute mainly to resistance to control of fires; and in large quantities, mixed with fine material, they also affect rate of spread and fire intensity.

3. Nominally, 6 inches d.b.h. is the maximum size of trees to be cut in precommercial thinning of ponderosa pine, and 7 inches is the minimum size for merchantable pulpwood (U.S. Forest Service 1967). However, occasional trees larger than 6 inches are cut, especially when dwarf-mistletoe control is combined with thinning, when there is no immediate prospect of a market for pine pulpwood, and when 7-inch trees would probably be marketable only if a large volume, mainly in bigger trees, were available. Finally, as a practical matter, the normal yield tables lump 6- and 7-inch trees into a single class, giving no indication of the number of each. Therefore, the break at 7 inches is realistic and convenient for present purposes. Boles larger than a 7-inch d.b.h. are tabulated for the sake of completeness but not included in totals; little of this material would be cut unless it could be sold and removed from the woods.

4. Bark of 7-inch and smaller trees is shown separately; it is the first part of the trunk to become flammable and the part that contributes most to rate of fire spread. Larger trees presumably would be removed with the bark attached; therefore, the combined weights of wood and bark are given.

Stocking differs considerably from normality in most natural stands. The tabulated slash quantities can be multiplied by percent of normal stocking to adjust preliminary estimates for the actual density of stands to be thinned. Errors resulting from such adjustment are likely to be negative for understocked stands and positive for overstocked stands. The fewer trees cut in understocked stands would be larger because of greater growing space. The increase due to average weight of crown and bole would be greater than the loss due to reduction in numbers. The reverse is true for overstocked stands.

Working estimates.—Field tallies of sample plots can provide tree numbers for calculating weights of slash to be expected on specific areas. Such sampling probably need not be done intensively or frequently but should be useful as a training medium and occasional check on ocular estimates. The purposes are to gauge objectively the need for slash disposal or other fire protection measure, assign priorities for treatment, and select the most appropriate methods.

An example from the Deschutes National Forest illustrates the working estimate and provides a comparison of slash weight based on local measurements with weights derived from yield tables. Trees marked for cutting were tallied on twenty-two 1 50-acre plots on four Ranger Districts, selected to represent a wide range of stand characteristics.[2] Thinning was to about 14- by 14-foot spacing. The resulting slash weight estimates (table 4) may not be representative of large areas, but they do emphasize the wide range of variation that occurs.

[2] The author is indebted to personnel of the Deschutes National Forest for obtaining field tallies.

Table 4.—*Slash yields from sample thinning plots on the Deschutes National Forest*

Description of stand	Trees cut per acre	Mean d.b.h.	Weight[1]			
			Crown	Wood	Bark	Total
	Number	*Inches*	*Tons per acre*			
Pure ponderosa pine:						
Age 10-20, site III (1 plot)	7,750	1.2	17.5	7.5	1.8	26.8
Age 30-40, site III (1 plot)	3,700	2.7	22.1	26.8	6.3	55.2
Age 30-40, site IV (13 plots):						
Lightest plot	600	3.3	5.2	5.2	1.2	11.6
Heaviest plot	3,800	3.6	37.3	51.9	12.2	101.4
Mean	2,570	—	18.0	20.2	4.7	42.9
Mostly Douglas-fir (1 plot)	4,600	2.7	17.2	21.8	3.3	42.3
Half grand fir (1 plot)	2,250	2.4	13.8	12.2	1.8	27.8
Mostly lodgepole pine (5 plots):						
Lightest plot	450	2.6	.8	2.6	.4	3.8
Heaviest plot	1,950	3.3	5.2	20.2	3.0	28.4
Mean	1,150	—	3.7	8.6	1.3	13.6

[1] Does not include wood and bark of trees larger than 7-inch d.b.h., which occurred on 4 plots and averaged 1.4 tons per acre over all 22 plots.

Most of the Deschutes plots in pure ponderosa pine had slash weights slightly greater to much greater than those derived from yield tables for stands of the same age and site. The average for 13 plots in 30-to-40-year-old site IV stands is nearly one-third greater than the comparable value in table 3 for 40-year-old stands of site index 80. Stand density is responsible for the difference; the 13 Deschutes plots averaged more than twice the normal numbers of trees per acre, and the 10- to 20-year-old site III plot had about four times the normal number. Random or systematic sampling on a large scale almost unquestionably would reduce average weight based on field measurements, since the Deschutes plots represent only the range of stand densities, without reference to area in each density class. The significance of the few measurements made so far is to show the preliminary estimates based on normal yield tables do not exaggerate common field conditions.

FIRE HAZARD: NATURE AND DEGREE

Fuels and weather are the two main components of forest fire hazard; precommercial thinning strongly affects both. The fuel effect consists of suddenly placing tons of fine, small, and medium-sized material near the ground, where conditions are most favorable for ignition and spread of fire. The weather effect consists of exposing the fuels to stronger insolation and air movement as a result of drastically opening up the canopy. The increase in hazard has not been measured directly in young ponderosa pine stands, but a useful first estimate can be made by inference from relevant research findings and experience.

For about 30 years, the fuel component of hazard has been accounted for by means of fuel types defined in terms of expected rate of spread and resistance to control. Rate of spread is "the relative activity of a fire in extending its horizontal dimensions"; resistance to control is "the relative difficulty of constructing and holding a control line as affected by resistance to line construction and by fire behavior" (U.S. Forest Service 1956). "Low," "medium," "high," and "extreme" are the recognized type levels of both hazard components. Values assigned to the various levels are purely relative in the Pacific Northwest scheme: 1, 5, 25, and 125 for rate of spread; 1, 2, 4, and 8 for resistance to control.[3] The neighboring Northern Rocky Mountain Region uses absolute values for the levels of hazard, and these are not in the same ratios as the Pacific Northwest series.[4] [5] However, comparison of fuel-type photographs for the two Regions suggests that, with a little judgment, the two systems can be used interchangeably to characterize fuel types that occur in both Regions. The **extreme** rate-of-spread type for the Pacific Northwest includes the **flash** type that has been added to the original Northern Rocky Mountain series (Barrows 1951).

The existing concept of fuel type includes some influence of general weather, local weather, and microclimate. Ratings are for a specified level of fire danger and take into consideration exposure of the fuel to drying because of topographic aspect and density and height of dominant vegetation. Research during the past 30 years has developed some competent measures of the effects of individual factors on fire behavior separately, so as to evaluate conditions not specifically covered by the fuel-type system.

Rate of Spread

Rate of spread in uncut, young ponderosa pine stands is rated **medium** or **high** in the Northern Rocky Mountains, depending mainly on the amount and compactness of fine fuels—needles and herbage—on and near the ground (fig. 1).[6] No rating is available for the Pacific

3 U.S. Forest Service Region 6. Fuel-type mapping—original instructions (with some revisions). File designation F-PLANS-National Fire Planning (1959-Guidelines), 23 pp. (On file at Pacific Northwest Forest and Range Exp. Sta., Seattle, Wash.)

4 Hornby, L. G. Instructions for fuel-type mapping. Developed in cooperation with U.S. Forest Service Region 1, Office of Operation, 28 pp., June 26, 1933. (On file at Pacific Northwest Forest and Range Exp. Sta., Seattle, Wash.)

5 U.S. Forest Service Region 1. Fuel type standards 1936. (On file in Division of Fire Control, Missoula, Mont.)

6 See footnote 5.

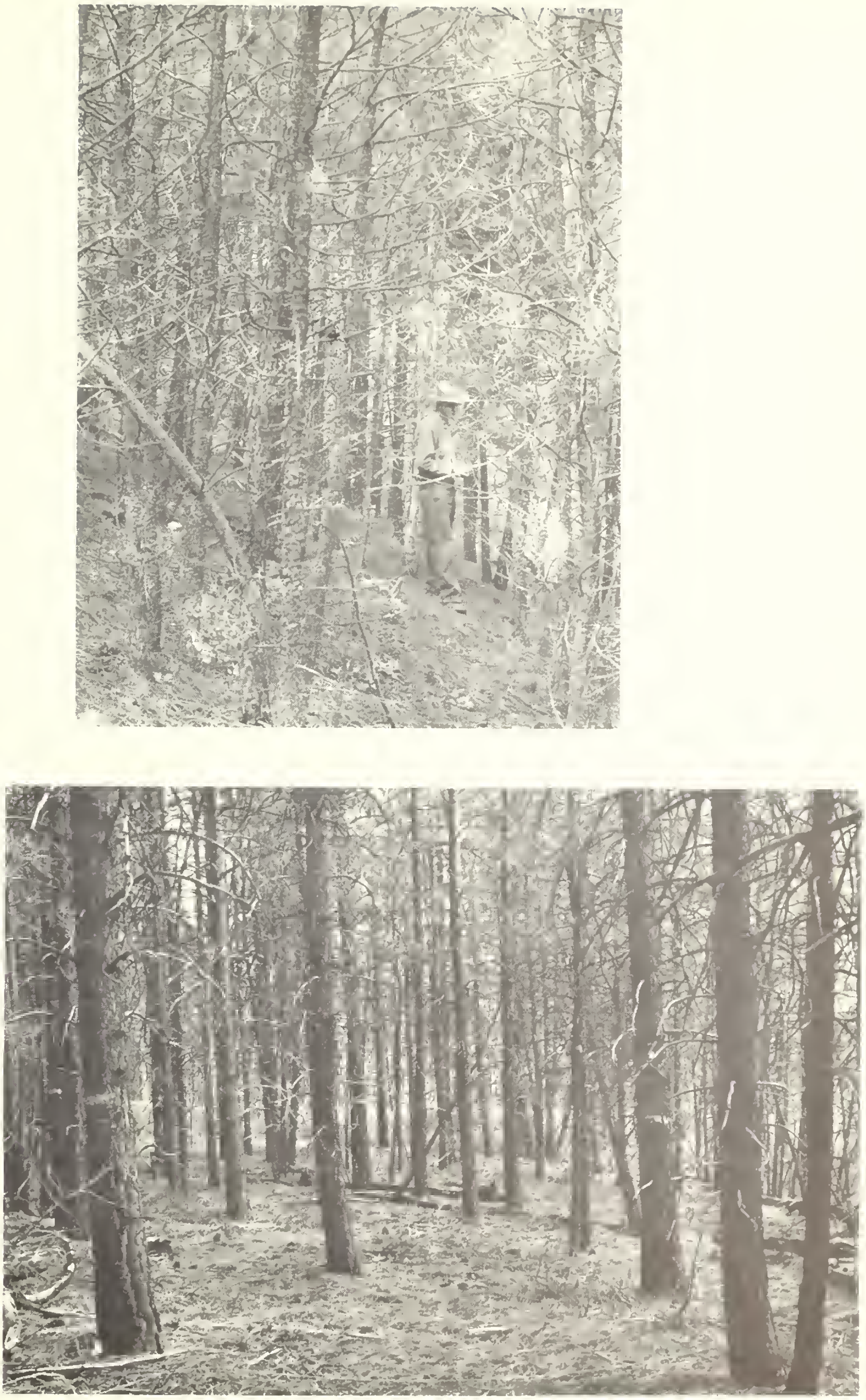

Figure 1.—Unthinned young ponderoso pine stands. Upper, U.S. Forest Service Region 1 fuel-type standard, ***high-low;*** *lower, experimental plot on Pringle Falls Experimental Forest, Oregon, before thinning, that would have the same rating.*

Northwest, but stands in the two Regions are quite similar.

Effects of slash. — Experimental burning of small plots of lopped ponderosa pine slash has provided the only objective measurements indicative of probable fire behavior in thinning slash (Fahnestock 1960; Fahnestock and Dieterich 1962). Tonnages of slash in which measured rate of spread would equal **high** and **extreme** levels were found to be as follows:

	Rate of Spread	
	High (Tons)	Extreme (Tons)
Year of cutting	3-12	>12
1 year after cutting	4-22	>22
5 years after cutting	>22	—

These estimates took into account adjustment of the weather factor to midafternoon level and allowance for natural fuel already present. Obviously, from table 3, any intensity of thinning likely to be employed results in at least a **high** rate-of-spread fuel during the year of cutting (i.e., prior to the first winter after cutting) and the next year. (At least 25 percent of the wood in $\leq$ 7-inch-d.b.h. trees is less than 4 inches in diameter, the maximum size accepted in the slash burning experiments).

Dead foliage is the main component of slash that supports high rate of spread. Ponderosa pine slash may retain a noticeable quantity of needles as long as 7 years. Field observation on the Deschutes National Forest indicated substantial needle loss during the 4th year after cutting. Four-year-old slash retained at least 25 percent of its needles, 5-year-old slash only a scattered few. Thus, the rate-of-spread rating for slash from present precommercial thinning would appear to change little during the 1st to 4th years after cutting. Figures 2 and 3 compare available photographs and suggested rate-of-spread ratings for thinning slash with Region 6 standard ratings for slash from commercial cutting.

Loss of needles greatly reduces the influence of slash on rate of spread during the 5th year after cutting. Nevertheless, available indications are that thinning to 14- by 14-foot spacing produces enough slash for a **high** rating in 40-year-old stands with site indexes of 100 or less and also in 60-year-old stands with indexes of 80 or less. Loss of many twigs and smaller branches would be required to further reduce the rating in such heavy concentrations of slash; amount of loss and time involved are not known. Table 5 shows the combinations of age, site index, and thinning intensity that would produce at least a **high** rate-of-spread rating in normal stands after the 1st year.

The results of experimental burning probably underestimate rate of spread in ponderosa pine slash. Spread was somewhat slower than expected from the appearance of the slash. The reason appeared to be relatively high moisture content in the branchwood, which was generally larger in diameter than that of other species. Large material ordinarily would dry better on typical ponderosa pine sites, with rainfall typically close to 20 inches a year, than in the experimental area, with about 30 inches (U.S. Department of Agriculture 1941).

The rate-of-spread ratings based on experimental burning are conservative for the slash created in precommercial thinning because of differences in fuel arrangement. The experimental slash was lopped; it averaged less than 1.4 feet deep when freshly placed on plots, and much of it was in contact with the ground. Thinning slash consists of entire trees, and much of it is supported several feet above the ground. The fine material is more exposed to drying influences than in the experimental plots, and more wind affects a fire, once started. Consequently, thinning slash would support higher rate of spread, pound for pound, both initially and after 5 years, than the experimental slash.

Table 5.—*Occurrence of* **high** *and* **extreme** *rate-of-spread ratings in normal stands as related to stand characteristics, spacing of "leave" trees, and time since thinning*[1]

Spacing (feet)	Site index 60, stand age—				Site index 80, stand age—				Site index 100, stand age—			
	20	40	60	80	20	40	60	80	20	40	60	80
1- to 4-year-old slash:												
8 by 8	E	E	H	—	H	H	—	—	H	—	—	—
10 by 10	E	E	E	H	E	E	H	—	H	H	—	—
12 by 12	E	E	E	H	E	E	E	—	E	E	H	—
14 by 14	E	E	E	E	E	E	E	H	E	E	E	H
16 by 16	E	E	E	E	E	E	E	H	E	E	E	H
18 by 18	E	E	E	E	E	E	E	E	E	E	E	H
5-year-old slash:												
8 by 8	—	—	—	—	—	—	—	—	—	—	—	—
10 by 10	—	H	—	—	—	—	—	—	—	—	—	—
12 by 12	—	H	—	—	—	H	—	—	—	—	—	—
14 by 14	—	H	H	—	—	H	H	—	—	H	—	—
16 by 16	—	H	H	—	—	H	H	—	H	H	—	—
18 by 18	—	H	H	H	—	H	H	—	H	H	—	—

[1] H = **high**
E = **extreme** (Region 1 standard).

Figure 2.—Precommercial thinning slash at three ages, with suggested fuel ratings. Upper—fresh, ***extreme-high****; middle —3 years old,* ***high-medium*** *(would be* ***high-high*** *in stand as dense as that shown in upper and lower photos); lower— 7 years old,* ***high-medium****.*

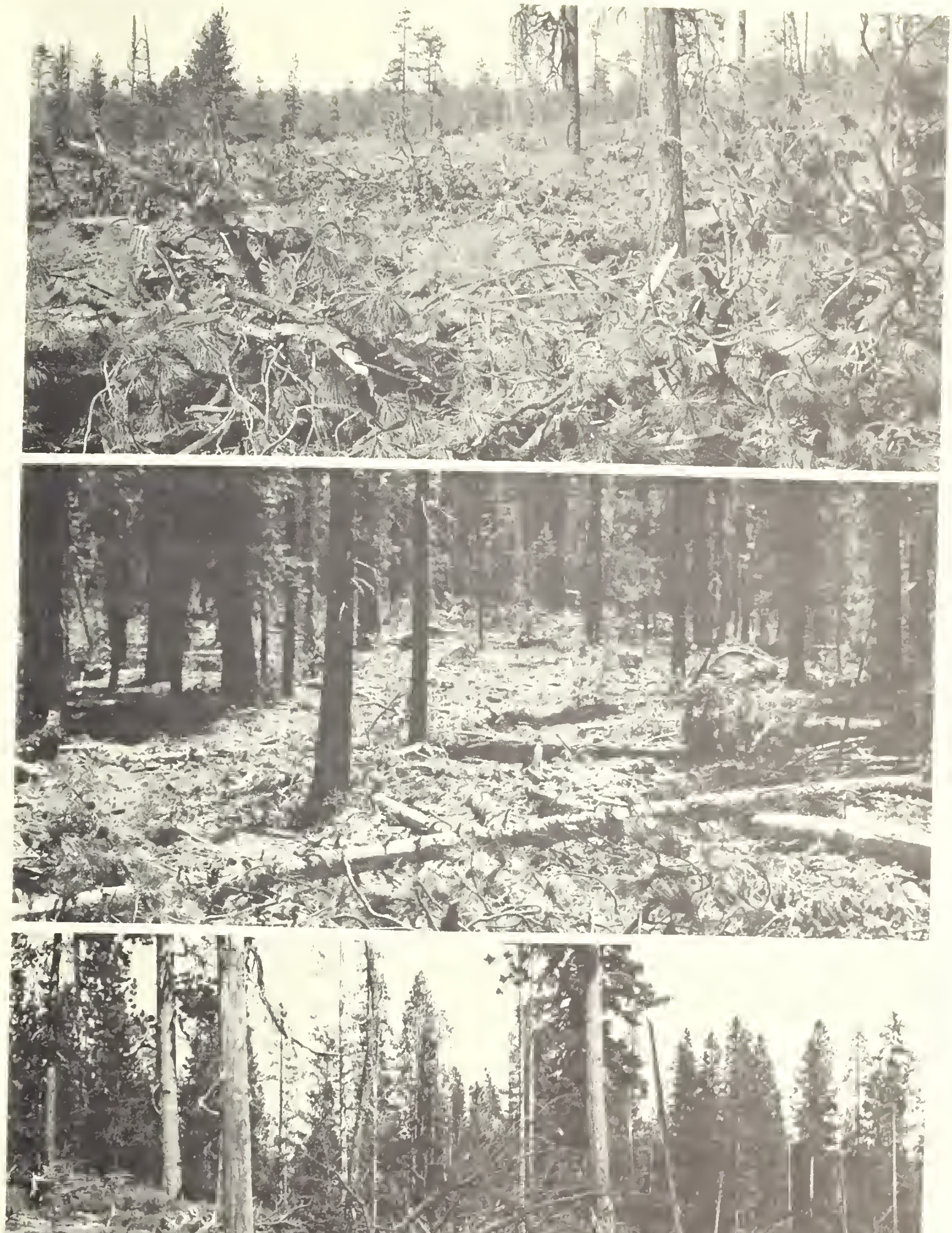

Figure 3.—Some examples of ponderosa pine logging slash in the Pacific Northwest as rated by U.S. Forest Service Region 6 fuel-type standards. Upper—fresh, extreme-medium; middle—1 year old, high-high; lower—7 years old, high-medium.

Effects of weather and climate.—An increase in severity of the weather factors of fire danger accompanies the addition of fuels when stands are thinned. Opening up a stand of trees allows more air movement and stronger insolation. Air and fuel temperatures rise, and, in response, relative humidity and fuel moisture content fall. Lowered fuel moisture content facilitates ignition by small firebrands, an important consideration where human use is heavy. Clearcutting a stand of pole-size ponderosa pine increases potential rate of spread 4.5 times (Fons 1940 Countryman 1956). Inference from measurements in partially cut Douglas-fir stands suggests that cutting 35 percent of the original volume, roughly equivalent to thinning a normal 40-year-old, site IV stand to 13- by 13-foot spacing, raises the general level of fire danger about 50 percent (Morris 1941). Probably the increase in average hours per day and days per year with high fire danger is even more important. Average number of critical fire days increases four times when a mature stand in the western white pine type is cut back to half its original volume (Jemison 1934). The change may be somewhat less, but still should be considerable, in the drier ponderosa pine type.

Composite effect.—There is no way to calculate the true relation of rate of spread to slash weight in thinning slash by adjusting the experimentally determined rates for differences in arrangement and weather. With all factors considered, however, judgment suggests that any fresh slash situation rated **extreme** in table 4 probably would still rate **high** 5 years later. Based on this assumption, the following tabulation indicates the closest spacing that will result in a **high** rating after 5 years when fully stocked stands are thinned:

Stand age	*Site index* 60 (Feet)	80 (Feet)	100 (Feet)
20	12 by 12	14 by 14	12 by 12
40	8 by 8	10 by 10	12 by 12
60	12 by 12	14 by 14	16 by 16
80	14 by 14	18 by 18	18 by 18

Since most stands do not have normal stocking, weight of slash per acre is a more versatile guide than the tabulation. A tentative rule of thumb is that *rate-of-spread rating will remain* ***high*** *for at least 5 years when total weight of slash from trees* $\leq$ *7-inch d.b.h. exceeds 15 tons per acre.* The one Region 6 fuel type containing old ponderosa pine slash (7 years) is rated **high**; slash in originally dense stands that have been heavily thinned looks as bad as the fuel-type-standard photograph[7/] after 5 years (figs. 2 and 3).

Resistance to Control

Resistance-to-control ratings integrate the effects of all factors that obstruct efforts to control fires. Fuels obstruct control efforts by imposing a physical barrier to fireline construction, burning with such intensity as to prevent close enough approach to do effective work, and supporting or contributing to violent fire behavior phenomena such as crowning and spotting. Ponderosa pine thinning slash contributes to resistance to control in all three ways.

Resistance to control is rated **low** by Region 1 in uncut, young ponderosa pine stands. Region 6 has no ratings of uncut stands but gives six examples consisting mainly of slash from commercial logging of ponderosa pine and associated species. Resistance to control is rated **high** for one example each of fresh and 1-year-old slash, **medium** for one example each of fresh, 1-year-old, and 7-year-old, and **low** for one example of 2-year-old. Resistance to line construction as evidenced by quantity of logs on the ground seems to be the main criterion for differentiating. In comparison with the fuel-type photographs, heavy concentrations of precommercial thinning slash appear to contain enough stems to offer **high** resistance to line construction. The stems are much smaller than those that remain after commercial cutting, but they are extremely numerous and interlaced so as to be mutually reinforcing. The original degree of physical resistance should persist until decay significantly weakens the wood.

Fresh, dry slash of any species makes a high-intensity, unapproachable fire. A fire started in dry, fresh slash can become uncontrollable in seconds.[8/]

7/ See footnote 3.

8/ Personal observation by the author.

Intensity declines after the needles fall, but it remains much higher than that produced by burning the fuels usually found near the ground in unthinned stands. When burned experimentally, ponderosa pine gave the second highest intensity of the five species of fresh slash recorded. Five years brought a 65-percent reduction, proportionately the least reduction of any species. Potential for spotting approximately parallels intensity; elevated fine fuel, mainly needles, both supplies firebrands and supports the rapid evolution of heat to carry them considerable distances.

Young natural stands of ponderosa pine tend to be somewhat patchy, with intervening open strips and patches that usually contain little fuel other than needle litter. Occurrence of openings that are sufficiently wide and numerous materially reduces resistance to control in thinned stands by making it unnecessary to construct and hold firelines through the slash. Openings of any appreciable width greatly facilitate line construction, but they need to be at least ½-chain wide to give much help with line holding, especially if slash is on both sides. The degree to which openings can be used effectively depends also on their orientation with respect to prevailing winds and on policy as to maximum acceptable fire size.

Resistance to control cannot be rated objectively or reliably with knowledge currently available. Total weight of slash per acre may be a helpful criterion in fresh slash; weight of boles, in 5-year-old slash. The sum of the squared or cubed diameters of cut trees could be a useful criterion, perhaps the best for resistance to line construction. The following weight limits are suggested for the **high** resistance-to-control rating until objective determinations can be made:

	Tons of slash per acre	
Condition	*Fresh* (Total weight)	*5-year-old* (Boles)
Lines must be built through slash concentrations; openings infrequent or unsuitable	≥10	≥15
Lines can be built at will	≥20	≥25

The above guidelines refer only to the effect of the thinning slash itself on resistance to control. Slope, soil characteristics, subordinate vegetation, and preexisting dead fuels could cause lesser quantities of slash to have a **high** rating.

DISCUSSION

This paper consolidates and attempts to interpret available information that contributes to rating ponderosa pine thinning slash as a fire hazard. The tentative conclusion reached is that thinning well-stocked stands to wide spacings (12 feet by 12 feet and wider) commonly produces fuels that rate **high** in rate of spread and resistance to control for at least 5 years after cutting, and that would burn with relatively high intensity.

Drastic thinning is known to be desirable in stagnated ponderosa pine stands (Mowat 1953); diameter growth increases significantly with spacing up to 18 feet by 18 feet, height growth with spacing up to 13 feet by 13 feet (Barrett 1965). Therefore, heavier cuts are likely in the future, leaving fewer stems per acre than the former standard of 350 (Flora 1966) and producing a greater fire hazard than in the past.

Consideration of hazard must go beyond statement of ratings. Some dense young ponderosa pine stands are rated **high** as to rate of spread because of fluffy needles on the ground (fig. 1).[9] However, only a small amount of fuel is readily available to burn—probably not more than 2 or 3 tons of fine fuel per acre in most instances, with varying amounts of larger material scattered about. Instantaneous intensity, duration, and total heat output of surface fires are relatively low in both dense and open stands. Consequently, such fires tend to be easy to control and, in thinned or otherwise open stands, to do little damage. Slash in any quantity radically changes the picture. Available fine fuel may

[9] See footnote 5.

double or treble,[10] and the additional fuel is located off the ground, where it can burn rapidly and completely. Larger fuel components, when dry, prolong combustion and add proportionately to heat output. In fresh slash, the result inevitably is a high-intensity, hard-to-control, damaging fire. Instantaneous intensity declines as fine crown material falls to the ground, but the potential for high total heat output and consequent damage persists for an unknown length of time.

Really severe burning conditions can cause violent fire behavior in dense, young ponderosa pine stands regardless of designated fuel type. When conditions are dry and windy enough that thickets crown out readily, fire intensity in the flareups is bound to be high, and spotting may cause more rapid spread than would occur in slash. Men who vividly remember the spectacular flareups that occur when "dog-hair" thickets burn may conclude that thinned stands, even with slash present, are less hazardous than unthinned stands.[11] However, fuel in thinned stands dries more rapidly and becomes drier than in the uncut forest. Exposure to wind results in faster horizontal spread of fire. And fire spreads rapidly in slash even without wind. Consequently, year in and year out, the thinned forest that contains abundant slash up to 5 or more years old should be a considerably greater hazard than the unthinned. It appears significant that many large fires in Western United States have burned almost exclusively in slash. Some of these fires have stopped when they reached uncut timber;[12] none has come to attention that started in green timber and stopped when it reached a slash area.

In the long run, precommercial thinning greatly reduces the vulnerability of stands to fire (fig. 4). The crop trees are spaced widely, and crown fires therefore are unlikely to occur. Rate-of-spread rating may remain **high** or go to **extreme** because of increased growth of herbage; but after slash has deteriorated (or has been removed), fires are of short duration and low intensity. Resistance to control is **low**. The difficulty lies in making sure fire does not destroy large areas while slash is present.

[10] Material less than one-half inch in diameter constitutes about 40 percent of total crown weight (unpublished data on file at Pacific Northwest Forest and Range Exp. Sta.).

[11] Harmon, W. H., memorandum to H. G. Hopkins, 2470 Silvicultural practices, May 1, 1967.

[12] E.g., Merton Creek Fire, St. Joe National Forest, Idaho, ca. 1953; Raft River Fire, Quinault Indian Reservation, Washington, July 1967.

It has been pointed out that the trees cut in precommercial thinning would die anyway over a rotation and would accumulate as fuel.[13] However, as a fuel, this gradual accumulation of scattered dead trees never compares with the result of cutting the same trees all at once. In fact, calling attention to the hazard of slowly accumulating and deteriorating fuels only serves to emphasize the much greater hazard of a large volume of fuel created all at once.

The conclusion is inescapable that precommercial thinning to present and prospective standards in ponderosa pine stands of near-normal density seriously increases fire hazard for at least 5 years. The years of extra hazard cannot be averaged against the remaining life of the stand during which hazard is less than it was before thinning. Expectation of better times does not reduce present problems, but it may lead to a false sense of security.

In general, fire occurrence rates and fire losses mount as fuel becomes more hazardous (Barrows 1951). However, such a generalization is not sufficient basis for evaluating the impact of precommercial thinning on the difficulty of fire control.

It is necessary to learn as specifically as possible what changes to expect in fire occurrence rate, fire behavior, cost of control, and damages as a result of the presence of the slash. Only when this information is in hand can an effective fire control system be designed and optimum division of expenditures be made between thinning and protection. The following brief but intensive investigative program should supply the missing answers:

1. *Analyze fire experience.* Compare fire cause, occurrence rate, final size, suppression cost, and damage on areas of undisposed slash with the same statistics for uncut areas and logged areas on which slash was treated. Use mass statistics and case histories as appropriate.

2. *Measure hazard experimentally.* Develop hypotheses as to rate of spread, resistance to control, and intensity of fires in relation to initial quantity, distribution, and age of slash. Test hypotheses by experimental burning and line building in thinned and unthinned areas. Do experimental burning over a range of fire danger levels, including those high enough that dense reproduction could be expected to crown. Develop relative and, if possible, absolute ratings or measurements of hazard.

[13] Harmon, W. H., memorandum to "The Record," 2470 Silvicultural practices (thinning slash analysis), June 21, 1967.

*Figure 4.—Naturally open and thinned stands without slash. Upper—natural pole stand, rated **medium-low** by U.S. Forest Service Region 6 fuel-type standards. Lower—heavily thinned sapling stand after slash disposal, suggested rating **low-low**. (But rate of spread can be anything in such stands, depending on density of grass.)*

3. *Inventory the fuel created by precommercial thinning.* "Cruise" slash experimentally before cutting, using the best crown and stem weight information available. Confirm cruise figures and develop adjustment factors by sampling after trees are cut. Measure deterioration by sampling areas thinned 1 to 10 years ago; special photography may be the most efficient method. Map slash distribution in relation to stand characteristics. Calculate areas in the several significant hazard classes.

4. *Determine appropriate action.* Develop alternative combinations of hazard-area dispersal, slash treatment, and fire control operations. Compare as to costs and benefits, taking into account compatibility with all uses of the forest.

The suggested investigations should require not more than 2 years. The cost would be only a small fraction of the cost of either a damaging fire in slash or an unjustified program of slash disposal.

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SOIL MOISTURE TENSION VARIATION ON CUTOVERS IN SOUTHWESTERN OREGON

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CONTENTS

INTRODUCTION

Soil moisture stress is often the cause of seedling mortality in regenerating mixed-conifer forests of southwestern Oregon. Also, moisture status is an important consideration in stand manipulation or fertilization for increasing timber production.

The tension at which moisture is held by the soil provides the best means for comparing moisture status of different kinds of soils and for indicating the availability of moisture at a particular location. For example, 15 atmospheres is considered to be the soil moisture tension at the permanent wilting point of plants (Richards and Weaver 1943; Shaw 1952, pp. 156-157),[1] and 3 atmospheres is the soil moisture tension at which the growth of some trees stops (Zahner and Whitmore 1960).

Soil moisture tension of field samples is usually determined by referring actual soil moisture content to a curve of soil moisture retention over tension constructed for the soil in question. The purposes of this paper are: (1) to report characteristics of soil moisture retention over tension curves for several southwestern Oregon forest soils; (2) to report variation in soil moisture at 15 atmospheres of tension in relation to parent material, aspect, depth, clay content, and between points 10 feet apart; (3) to compare soil moisture tension on cutovers with and without vegetation during the driest part of the growing season. Soil texture is also discussed to characterize the study soils.

Although this paper is written primarily for researchers concerned with forest soil moisture, practicing foresters may be particularly interested in the section, "Soil Moisture Tension Attained With and Without Vegetation," pages 13 to 15, and the discussion concerning the effects of vegetation on soil moisture tension, pages 16 and 17.

[1] *Names and dates in parentheses refer to Literature Cited, p. 18.*

METHODS

Soil samples were collected at three depths, at 69 sampling points, for a total of 207 sampling positions. At each position, two samples were collected during the driest portion of the summer before the first late summer rain. One sample was used for determining field moisture content and the other for determining soil moisture retention over tension curves and for textural analysis.

Study Areas

Three areas were chosen for study: Calf Creek, South Umpqua, and Dead Indian (fig. 1).

Calf Creek. — The first area, about 2 acres, is in a clearcut in the Calf Creek drainage of the North Umpqua River at latitude 43°16′ and longitude 122°36′. Elevation is 3,000 feet. Aspect varies from east to northeast and slope from 0 to about 20 percent. The soil is a loam at 6-inch depth and typically a clay loam at 18- and 36-inch depths. It is probably in the tentative Freezeout[2] series. Soil samples were collected at distances of ½, 1, 2, 3, 4, and 5 chains along four lines, approximately 1 chain apart, extending to the north into the clearcut from the east and west timber edges for a total of 24 sampling points. This study was originally designed to measure the effect of distance from clearcut edge on soil moisture content. However, unusually abundant rainfall during the summer of 1964 masked any effect this distance may have had on soil moisture levels. Data from this area are used primarily to show variation in soil moisture retention over tension curves and in soi texture within a small area.

South Umpqua. — The second area is in the South Umpqua drainage extending 11 miles east and west and 9 miles north and south from longitude 122°34′ to 122°49′ and latitude 43° to 43°7′. The northernmost samples were collected 10 miles due south of the Calf Creek area. Elevations ranged from 1,600 to 3,200 feet. Investigations included: (1) comparisons of soil moisture-tension relationships for soils derived from basaltic and rhyolitic parent material; (2) measurement of the effect of competing vegetation in cutovers on soil moisture tension; (3) comparisons of soil moisture-tension curves for points 10 feet apart; and (4) determination of relationship between clay content and characteristics of soil moisture retention over tension curves.

Sampling locations with three replications were selected on north-slope, south-slope, and level areas on clearcuts for each of the two parent materials (basalt and rhyolite), making a total of 18 locations. Clearcuts were chosen where slash had been burned several years previously but where vegetation was still predominantly herbaceous or grass species rather than shrubs. At each location, two stakes were driven 10 feet apart along a contour, thus making a total of 36 sampling points. One stake was randomly selected as the center of a 10- by 10-foot area from which all vegetation was removed with a hoe and mattock. Vegetation was left around the other stake. Vegetation was removed in late May and early June and again in late June.

North and south aspect plots varied from 45- to 90-percent slope, and level plots from

[2]*Richlen, E. M. Soil survey report of South Umpqua area of Umpqua National Forest. In-Service report, Region 6, U. S. Forest Serv. 1963.*

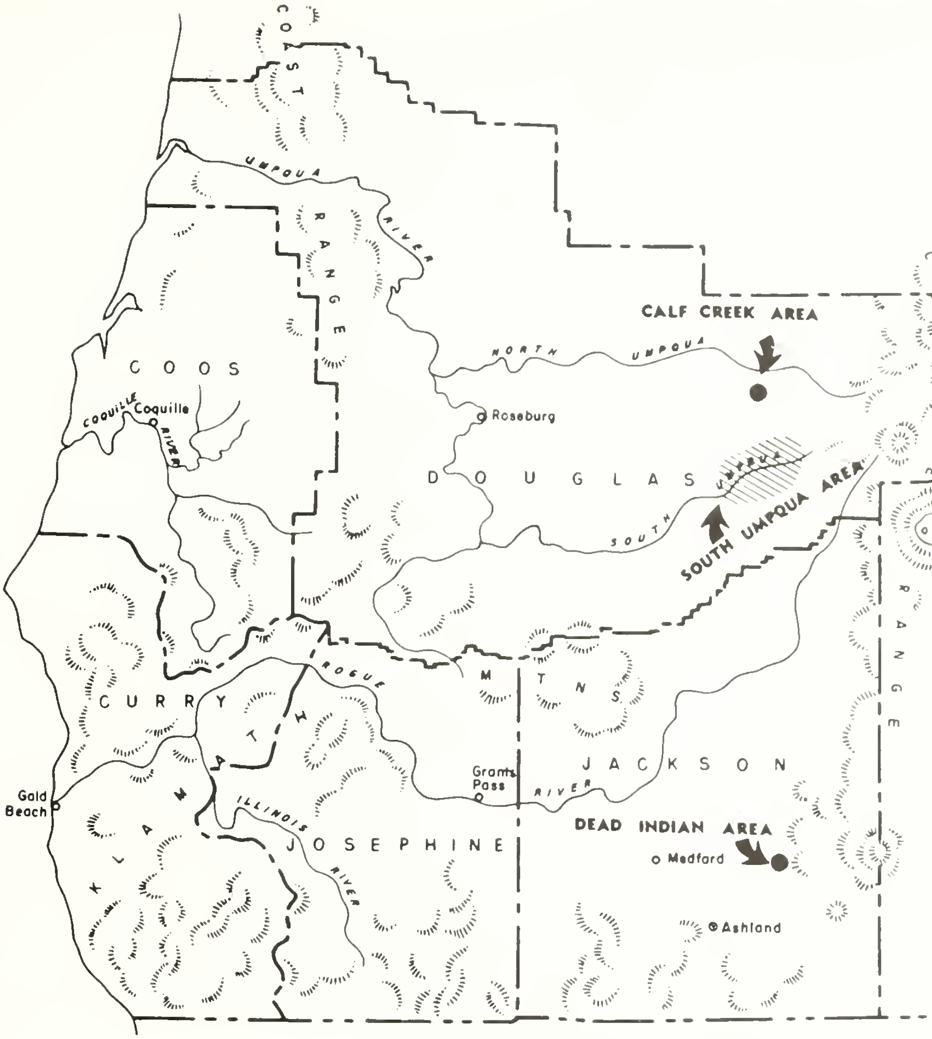

Figure 1. — Location of study areas.

to 20 percent. Vegetation coverage was estimated to the closest 10 percent on the basis of projection of live plant tissue to ground surface. Plant cover varied from 20 to 50 percent, with 30 percent being most prevalent. Although the percentages are low to medium, the vegetative cover density was subjectively considered medium to heavy. The more common plants[3] in order of abundance were: modest whipplea (*Whipplea modesta*), grass sp., grapeleaf California dewberry (*Rubus ursinus* var. *vitifolius*), salal (*Gaultheria shallon*) sedge (*Carex* spp.), Oregongrape (*Mahonia aquifolium*), western bracken (*Pteridium aquilinum* var. *pubescens*).

Soil derived from basaltic parent material is included in the tentative Coyota series, on steep slopes having both north and south aspects, and in the tentative Freezeout series on areas with level aspect.[4] Parent material at one north and one south aspect location was andesitic instead of basaltic. Coyota series are well-drained, medium-textured lithosols and intergrade to reddish-brown lateritic soils

[3] *Plant names from Kelsey and Dayton (1942).*

[4] *See footnote 2.*

developed from basic igneous parent material. The Freezeout series consists of well-drained, moderately fine-textured reddish-brown lateritic soils, also developed from basic igneous material. Soils derived from rhyolitic parent material are classed in the tentative Vena series on steep slopes and in the tentative Acker series on gentle to level areas. The Vena series are dark-brown or grayish-brown, well-drained, medium-textured lithosolic soils developed from acid igneous rock. The Acker series are well-drained, medium-textured, gray-brown Podzolic-like soils developed from acid igneous parent material.

Dead Indian. — The third area is a large cutover known locally as the Dead Indian area, northeast of Ashland in the Rogue River drainage at 122° 20′ longitude and 42° 18′ latitude. Three locations in a triangle approximately 20 to 25 chains on a side were selected on a gently sloping west-facing plateau. The slope is 5 to 15 percent at the sampling locations. The soil is a stony loam derived from andesitic parent material probably in the tentative Boze series.[5] The Boze series are brown, well-drained, medium-textured lithosolic soils developed from intermediate, igneous rock.

The purpose of this study was to determine whether moisture depletion by vegetation was great enough to be a factor in planted tree mortality. At each of the three locations, three points 15 to 25 feet apart were selected for a total of nine sampling points. Around one point, vegetation was removed with a hoe or mattock on an area about 10 feet square. Through the second point, a furrow 8 to 12 inches deep was made with a tractor-pulled plow. At the third point, the vegetation was left undisturbed. The vegetation was primarily grass species with a coverage of 20 to 30 percent.

Sample Collection

Two soil samples from each sampling position were collected — one for determination of moisture content and larger bulk sample for moisture tension and texture determinations. Samples were collected from a zone inches thick, centering on 6-inch, 18-inch, an 36-inch depths, except in South Umpqua are where the lower depth was 28 inches becaus of shallow soil on steeper slopes. Moistur determination samples were a composite fror three sides of a pit approximately 1 foo wide. Samples were put in metal cans, seale with masking tape, weighed the followin morning. Moisture content was determine gravimetrically. For the South Umpqua an Dead Indian areas, gravel, cobbles, and stone estimated to be over one-quarter inch wer picked out and discarded when the sample for field moisture content were collecte However, bulk samples at South Umpqua an Dead Indian areas included all material gravel, cobbles, stones, and soil — within th boundaries of the sample excavation in orde that percent of material over one-quarter inc could be estimated. Bulk sample size varie from 1,000 to 1,500 grams air-dry weight fo South Umpqua area and 3,000 to 18,000 gram for Dead Indian area. The Dead Indian sample were larger because of large stones. Calf Cree soil was relatively free of cobbles and stone and no attempt was made to estimate cobbl and stone content.

Both field moisture and bulk soil sample from Dead Indian area were collected the las week in July 1965, and from South Umpqu the first week in August 1965. Bulk sample and undisturbed cores in 100-cubi centimeter lucite rings were collected fro Calf Creek in October 1964.

Laboratory Analysis and Computations

Soil moisture at 1, 0.5, and 0.2 atmosphe of tension was determined for half of t undisturbed core samples from the Calf Cre area by the Oregon State University soils la oratory. Soil moisture retained at 3, 8, 1 and 25 atmospheres of tension was dete mined for soil from the bulk samples wi pressure membrane apparatus (Richar 1947) for each sampling position at all samp points.

Equations for estimating soil moisture te sions from measured field moisture conte were desired. However, with the equipme

[5] *See footnote 2.*

available (pressure membrane apparatus), tensions at which selected soil moisture contents are held cannot be determined. Rather, retained moisture for selected tensions must be determined. Thus, as selected tensions have no error, they must be used as an independent variable in regression analysis (Winsor 1946).

Therefore, it was necessary to calculate first for each sample a linear regression with the following equation:

$$\text{Log } y = A + B \log x$$

where

A and B = regression constants

y = soil moisture percent ovendry basis

and

x = atmospheres of tension.

Natural or Naperian logarithms were used. Then, the equations were reversed into the form

$$\text{Log } x = \frac{1}{B} \log y - \frac{A}{B}$$

and the soil moisture tension at the dry point of the summer was computed for each of the South Umpqua and Dead Indian samples.

Gravel particles, 2 mm. to ¼ inch, were left in samples for gravimetric moisture determination and for soil moisture retention determination in pressure membrane apparatus. These gravel particles were included because they contain or are associated with substantial amounts of moisture; also, they helped to avoid crushing soil aggregates 2 mm. to ¼ inch in size.

Percentage of (1) stones, cobbles, and medium and coarse gravel over one-quarter inch in size, and (2) fine gravel, 2 mm. to ¼ inch, was determined by screening and weighing when air dry. Particle-size distributions into sand, silt, and clay (6-hour settling) were made by the hydrometer method (Day 1956). Although particles over 2 mm. were screened out of samples used for texture analysis by the hydrometer method, final figures on particle size were recomputed to include fine gravel, 2 mm. to ¼ inch, because fine gravel was included in samples used for determination of moisture retention over tension and for field moisture content.

RESULTS

Texture

Rhyolitic soils were coarser textured than basaltic soils (tables 1, 2, 3). Rhyolitic soils contain, on the average, more stones, cobbles, gravel, and sand, whereas basaltic soils contain more silt and clay. However, the difference in clay content is not statistically significant (table 3). The Calf Creek soils (basaltic) are very similar in texture to basaltic soils found on level ground in South Umpqua (table 4). Texture of South Umpqua basaltic soils on north and level aspects is quite similar, whereas soils on south aspects are coarser. Rhyolitic soils on north aspect in the South Umpqua have similar texture to those on south aspect, but soils on level aspects are finer textured. Clay content for all soils sampled increased and sand decreased with depth (tables 1 and 3). The most consistent relationship was the larger amounts of silt for basaltic than for rhyolitic soils (tables 1, 2, 3).

Particle-size distribution varied greatly for any one depth, aspect, and soil (tables 2,4). Even on the Calf Creek area, covering less than 2 acres, the variation was quite evident. Occasionally, particle-size distribution differed greatly in two samples obtained only 10 feet apart. For example, in one pair of sampling points, clay content was 20 percent at one point and 47 percent for the other at the 28-inch depth; in another pair, gravel content was 23 percent at one point and 51 percent at the other at the 6-inch depth.

TABLE 1. – Particle-size distribution for South Umpqua samples – means[1] of six samples

(In percent)

BASALT AND ANDESITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Coyota series)			
6	9.8	30.7 (34.0)	38.5 (42.5)	21.0 (23.5)	14.6
18	5.8	22.8 (24.5)	40.8 (43.3)	30.5 (32.2)	21.4
28	6.8	19.8 (21.7)	36.7 (39.3)	36.7 (39.0)	14.3
		South aspect (Coyota series)			
6	18.3	34.3 (43.2)	27.8 (33.8)	19.5 (23.0)	46.5
18	15.5	33.0 (40.5)	29.2 (33.7)	22.3 (25.8)	36.8
28	17.3	34.2 (43.2)	27.3 (32.3)	21.2 (24.5)	37.7
		Level (Freezeout series)			
6	11.8	32.3 (36.5)	34.5 (39.0)	21.3 (24.5)	1.2
18	4.5	25.0 (26.0)	36.3 (38.2)	34.2 (35.8)	1.0
28	2.8	24.6 (25.4)	32.3 (33.3)	40.2 (41.3)	10.8
		All aspects			
6	13.3	32.4 (37.9)	33.6 (38.4)	20.6 (23.7)	20.8
18	8.6	26.9 (30.3)	35.4 (38.4)	29.0 (31.3)	19.8
28	9.0	26.2 (30.1)	32.1 (35.0)	32.7 (34.9)	20.9

RHYOLITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Vena series)			
6	23.8	36.5 (48.0)	20.0 (26.2)	19.7 (25.8)	35.3
18	37.3	33.5 (54.2)	12.5 (20.0)	16.3 (25.8)	60.0
28	38.3	31.3 (51.2)	11.5 (18.8)	18.3 (30.0)	54.8
		South aspect (Vena series)			
6	26.0	40.8 (56.1)	17.8 (23.7)	15.3 (20.2)	36.7
18	22.0	38.3 (49.7)	19.5 (24.7)	20.2 (25.6)	56.3
28	29.2	35.3 (51.0)	15.5 (21.7)	20.0 (27.3)	63.3
		Level (Acker series)			
6	16.2	32.7 (39.5)	29.5 (35.0)	21.7 (25.5)	16.7
18	8.3	28.2 (30.6)	31.7 (34.7)	31.8 (34.7)	12.4
28	8.5	27.2 (29.8)	31.0 (34.2)	33.3 (36.0)	14.8
		All aspects			
6	22.0	36.7 (47.9)	22.4 (28.3)	18.9 (23.8)	29.6
18	22.7	33.3 (44.8)	21.2 (26.5)	22.8 (28.7)	42.9
28	25.3	31.3 (44.0)	19.3 (24.9)	24.0 (31.1)	44.3

[1] *Percentages of particles over ¼ inch are for total sample but are excluded from sample for other particle-size percentages.*
Particles over 2 mm. are excluded from total for figures in parentheses.

TABLE 2. – Particle size[1] distribution for South Umpqua samples – range[2]

(In percent)

BASALT AND ANDESITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Coyota series)			
6	4-17	25-38	26-46	16-25	7-49
18	2-10	14-32	32-46	20-50	1-74
28	2-14	8-33	29-44	20-56	0-33
		South aspect (Coyota series)			
6	6-48	29-42	14-37	8-30	16-67
18	6-32	24-39	18-38	13-32	7-68
28	3-39	28-43	15-38	9-33	8-66
		Level (Freezeout series)			
6	1-20	27-37	27-41	18-26	0-2
18	0-11	20-29	32-43	23-43	0-2
28	0-8	21-29	24-42	33-48	0-43
		All aspects			
6	1-48	25-42	14-46	8-30	0-67
18	0-32	14-39	18-46	13-50	0-74
28	0-39	8-43	15-44	9-56	0-66

RHYOLITE

Depth (inches)	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
		North aspect (Vena series)			
6	20-31	29-48	16-29	11-32	18-55
18	33-47	29-40	9-17	11-23	49-74
28	29-52	26-37	8-16	9-25	34-65
		South aspect (Vena series)			
6	11-51	29-42	11-27	9-25	18-61
18	17-31	31-45	14-24	10-33	10-85
28	17-39	28-42	9-20	10-36	20-90
		Level (Acker series)			
6	2-25	31-37	25-33	17-32	0-37
18	2-15	26-29	28-34	27-37	0-25
28	2-15	22-37	28-32	20-40	0-33
		All aspects			
6	2-51	29-48	25-33	9-32	0-61
18	2-47	26-45	9-34	10-37	0-85
28	2-52	22-42	8-32	10-40	0-90

[1] *Percentages of particles over ¼ inch are for total sample – particles over ¼ inch excluded from sample for other particle-size percentages.*

[2] *6 samples for each range.*

TABLE 3. – F values for particle size,[1] South Umpqua samples

Source	Particles, 2 mm. to ¼ inch	Sand	Silt	Clay	Particles, ¼ + inch
Aspect	4.61*	6.78*	4.61*	(2)	6.98**
Soil	11.76**	7.78*	29.49**	(2)	5.14*
Aspect x soil	(2)	(2)	5.17*	(2)	(2)
Depth	(2)	8.54**	4.95*	17.02**	(2)
Depth x aspect	7.92**	(2)	(2)	3.21*	(2)
Depth x soil	5.60**	(2)	(2)	(2)	3.59*
Depth x aspect x soil	3.96**	(2)	(2)	(2)	(2)

[1] *Separate analysis for each particle size.*

[2] *Nonsignificant.*

* *Significant at 5-percent level.*
***Significant at 1-percent level.*

TABLE 4. – Particle-size distribution for Calf Creek samples, Freezeout soil series
(In percent)

Particle size	Means for 24 samples[1]			Range for 24 samples		
	6-inch depth	18-inch depth	36-inch depth	6-inch depth	18-inch depth	36-inch depth
2mm. to ¼ inch	9.9	5.2	3.2	2-22	1-13	0-11
Sand	29.6 (32.9)	26.1 (27.6)	22.0 (22.6)	23-34	17-31	10-34
Silt	39.4 (43.7)	42.3 (44.7)	39.2 (40.7)	33-48	36-48	30-45
Clay	21.1 (23.4)	26.4 (27.7)	35.6 (36.7)	15-32	21-36	22-56

[1] *Figures in parentheses: particles over 2 mm. excluded from total.*

Soil Moisture Tension

Soil Moisture Retention Curves

The calculated soil moisture retention curves (log soil moisture = A + B log tension in atmospheres) fit the data very well for the range 3 to 25 atmospheres of tension (figs. 2, 3, 4, 5, 6). Not a single one of 816 individual computed points deviated over 1 percent in soil moisture content from the measured value.

Data from Calf Creek show that soil moisture retained at tensions of 1 atmosphere and lower is less than would be expected from extrapolation of the linear logarithmic regressions computed for the range of 3 to 25 atmospheres.

Soil moisture at 0.2, 0.5, and 1.0 atmosphere for undisturbed samples from Calf Creek averaged 79.6, 88.2, and 96.3 percent,

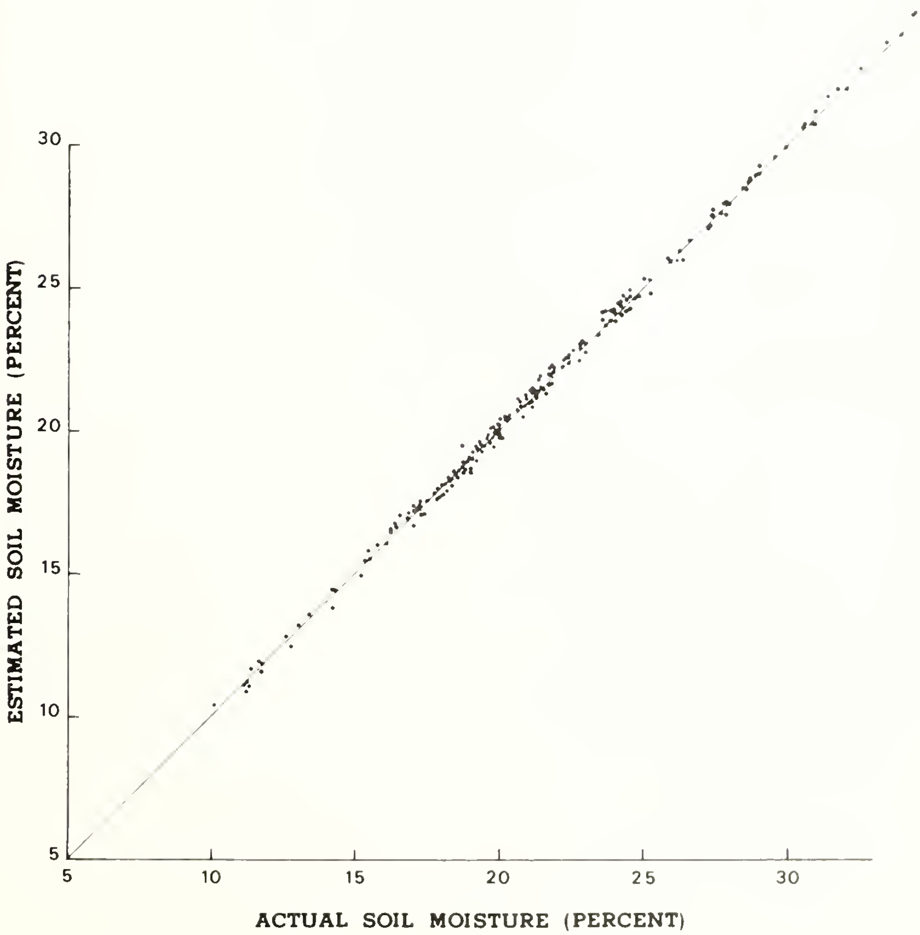

Figure 2. – Comparison of estimated and actual soil moisture percentages at 3 atmospheres for logarithmic soil moisture retention curves.

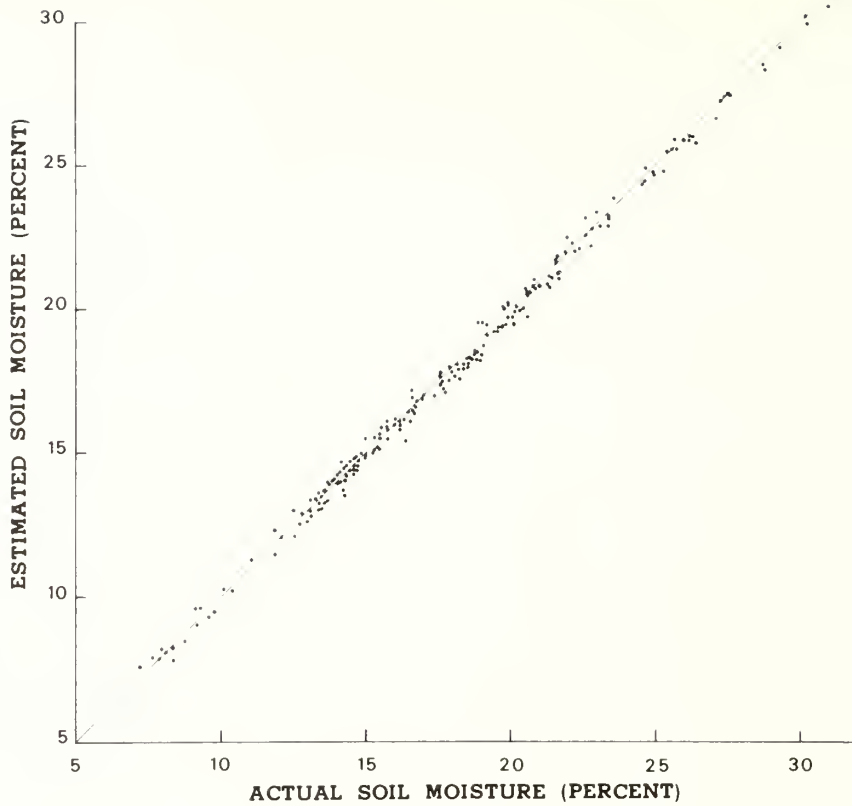

Figure 3. – Comparison of estimated and actual soil moisture percentages at 8 atmospheres for logarithmic soil moisture retention curves.

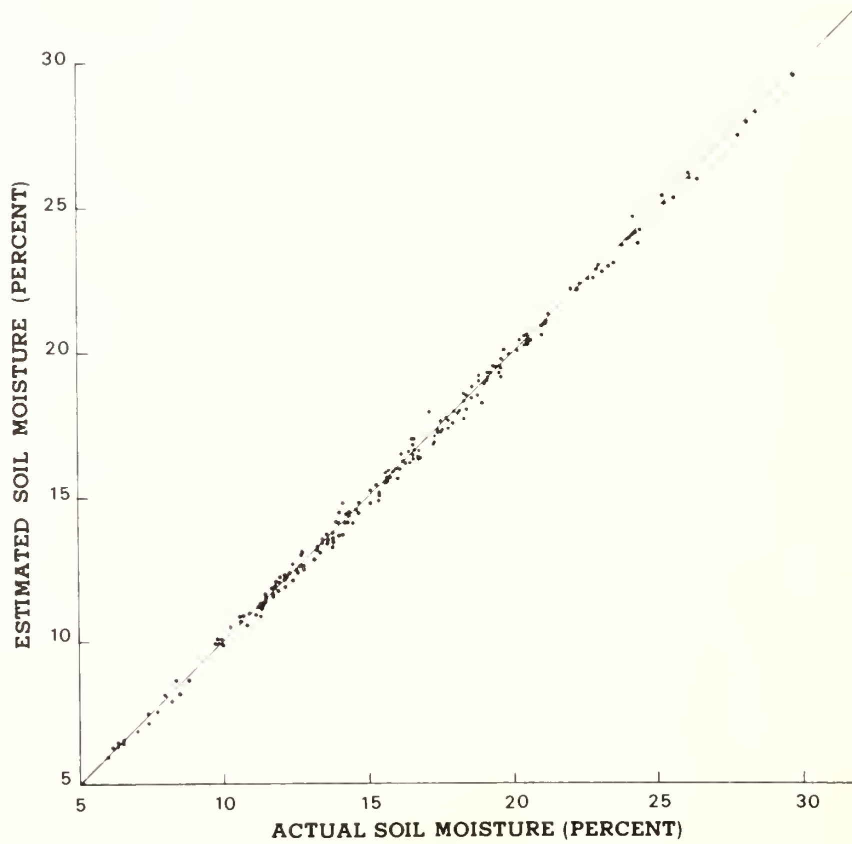

Figure 4. – Comparison of estimated and actual soil moisture percentages at 15 atmospheres for logarithmic soil moisture retention curves.

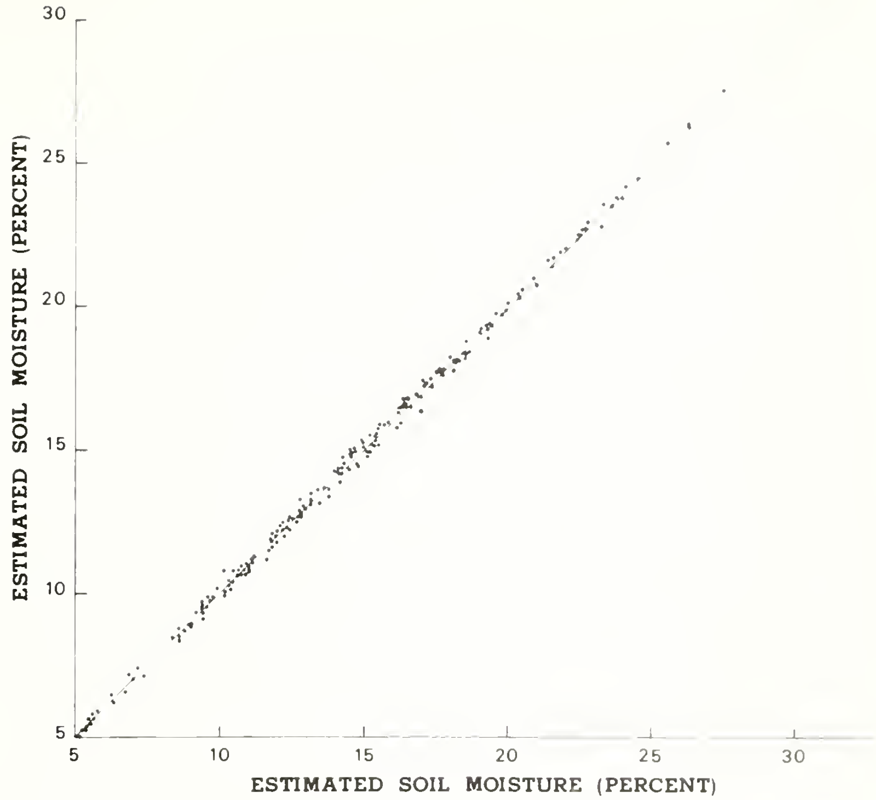

Figure 5. — Comparison of estimated and actual soil moisture percentages at 25 atmospheres for logarithmic soil moisture retention curves.

respectively, of the estimated values as computed from extrapolations of the 3- to 25-atmosphere soil moisture retention curves. However, percentages for individual samples varied greatly from these averages. For example, for 0.2 atmosphere of tension they ranged from 65.3 to 100.2 percent.

Soil Moisture at 15 Atmospheres

Soil moisture at 15 atmospheres of tension varied greatly — ranging from 10.0 to 29.7 percent for basaltic soil, and 6.0 to 21.2 for rhyolitic soil (table 5).

At Calf Creek, means and ranges were as follows:

Depth	Means	Range
(Inches)	(Percent)	(Percent)
6	13.2	11.0 to 18.2
18	14.7	12.1 to 21.2
36	18.9	15.4 to 25.2

The difference between the means for basaltic soil, 19.2, and rhyolitic soil, 12.6, was significant at the 5-percent level. At Calf Creek, soil moisture at 15 atmospheres increased with soil depth at every sampling point. At the South Umpqua area, there were a number of sampling points for basaltic and rhyolitic soils for which soil moisture at 15 atmospheres was approximately the same for all three depths. However, the average trend was increasing moisture content with increasing depth, and differences were significant at the 1-percent level.

The differences in soil moisture content at 15 atmospheres between points 10 feet apart varied from 0 to 7.9 percent of soil moisture and was greatest at the deepest depth (table 6). For example, at the maximum difference of 7.9 percent, the soil moisture content at one point was 18.3 percent and 26.2 percent at the other point.

Soil moisture level at 15 atmospheres tends to increase with increasing clay content (fig. 7). However, the spread of values is quite large.

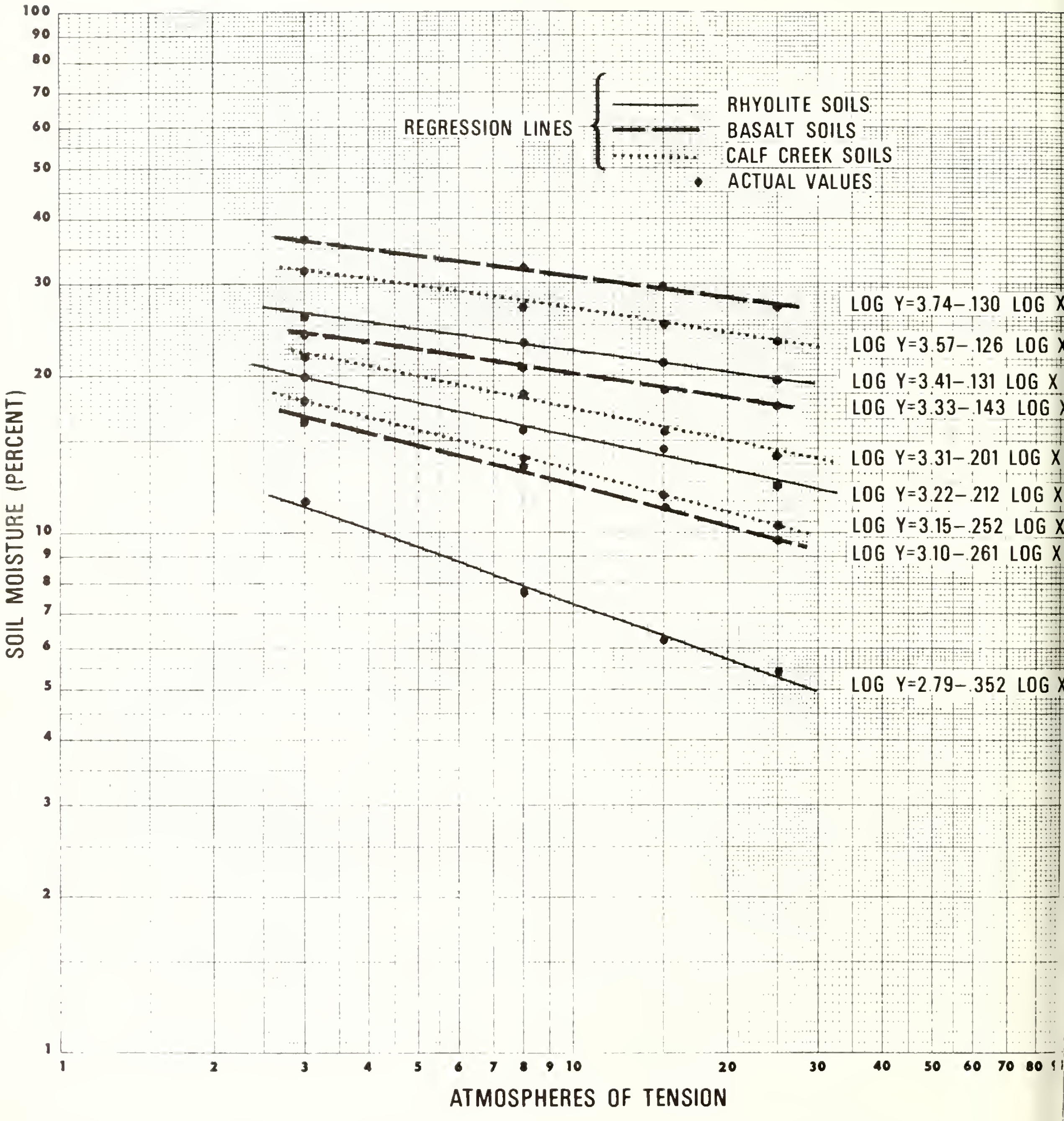

Figure 6. – Typical moisture retention curves (each regression line for a single sampling point and depth).

TABLE 5. – Soil moisture at 15 atmospheres of tension for basaltic and rhyolitic soils[1]
South Umpqua area
(In percent)

Depth (inches)	North aspect		South aspect		Level		All aspects	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
BASALT								
6	15.0	10.9-18.3	18.8	11.6-25.2	18.4	13.9-22.3	17.4	10.9-25.2
18	17.6	10.6-24.1	19.0	11.1-24.4	21.1	16.3-28.4	19.2	10.6-28.4
28	20.1	11.2-28.1	19.3	10.0-26.4	23.3	20.5-29.7	20.9	10.0-29.7
A11	17.6	10.6-28.1	19.1	10.0-26.4	21.0	13.9-29.7	19.2	10.0-29.7
RHYOLITE								
6	15.1	6.3-20.4	8.2	6.0-11.2	11.4	9.8-16.0	11.6	6.0-20.4
18	14.8	6.4-20.4	9.5	6.6-13.8	13.8	9.8-17.5	12.7	6.4-20.4
28	15.8	8.5-21.2	10.1	6.5-14.4	14.5	11.2-18.1	13.5	6.5-21.2
A11	15.2	6.3-21.2	9.2	6.0-14.4	13.2	9.8-18.1	12.6	6.0-21.2

[1] *Each mean and range (except for "A1 l aspects") based on 6 samples.*

Soil Moisture Tension Attained With and Without Vegetation

Vegetation very markedly depleted soil moisture during the summer. Soil moisture tensions reached at the dry point in the summer on the South Umpqua study area were many times higher on plots with vegetation than without at all soil depths (table 7). On 16 of the 18 plots with vegetation, the soil moisture tensions reached 15 atmospheres or more at the 6-inch depth; and at all depths at all locations, soil moisture tensions were several times greater for plots with than without vegetation.

Soil moisture tension reached on vegetated plots was much greater on south exposures than on north. On five of the six south exposure plots, tension was over 40 atmospheres at the 6-inch depth. Soil moisture tension decreased with depth at all sampling points.

Soil moisture tensions at 6 inches were greater at Dead Indian area than at South Umpqua for plots with vegetation (table 8). At the lower depths, tensions were less at Dead Indian area than at South Umpqua. The short time interval between collection of Dead Indian and South Umpqua samples should be of little concern as soil moisture content is changing very slowly in late July and early August (Hallin 1967).

TABLE 6. – Differences in soil moisture percent at 15 atmospheres of tension for points 10 feet apart

(In percent)

Depth (inches)	Basalt		Rhyolite	
	Means	Range	Means	Range
6	0.8	0.1 - 1.4	1.4	0.2 - 5.4
18	1.5	.3 - 3.3	1.4	0 - 3.0
28	2.3	0 - 7.9	2.8	.3 - 6.0

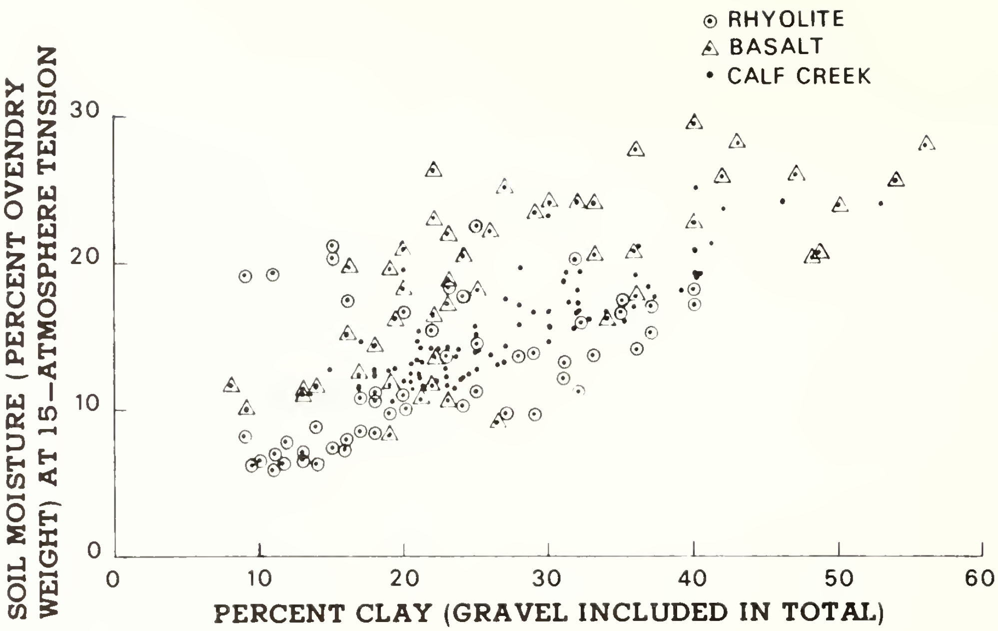

Figure 7. — Soil moisture at 15-atmosphere tension and clay content.

TABLE 7. – Soil moisture tension for basaltic and rhyolitic soils with and without vegetation a the approximate summer dry point,[1] South Umpqua area (means for three sample

Depth (inches)	North aspect		South aspect		Level aspect		All aspects	
	With vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation	Without vegetation	With vegetation	Without vegetatio
	Atmospheres							
BASALTIC SOIL								
6	23.2	2.7	53.5	13.1	22.2	2.7	33.0	6.1
18	12.7	1.2	13.9	1.9	9.5	1.0	12.0	1.4
28	6.0	1.1	8.7	.9	3.4	.6	6.0	.9
A11	14.0	1.6	25.3	5.3	11.7	1.4	17.0	2.8
RHYOLITIC SOIL								
6	17.9	5.4	85.0	6.3	25.1	3.6	42.7	5.1
18	9.8	1.8	31.1	4.3	10.0	2.4	17.0	2.8
28	5.3	1.4	20.2	2.8	7.6	1.6	11.1	2.0
A11	11.0	2.9	45.4	4.5	14.2	2.6	23.6	3.3

[1] *1st week in August 1965.*

TABLE 8. — Soil moisture tension at Dead Indian area for plots with vegetation, without vegetation, and with furrow at the approximate summer dry point[1] (means for three samples)

Depth (inches)	With vegetation	Without vegetation	Furrow[2]
	Atmospheres		
6	101.7	1.0	0.9
18	3.4	.5	.5
36	.6	.4	([3])

[1] *Last week in July 1965.*
[2] *Furrows 10 to 12 inches deep — depth measured from bottom of furrow.*
[3] *No sample at 36 inches.*

DISCUSSION AND CONCLUSIONS

Some results reported here may differ from those usually obtained because fine gravel (2 mm. to ¼ inch) has been included in samples for field moisture content, moisture retention over tension, and particle size distribution determination. Fine gravel was included because it holds or is associated with soil moisture and because soil aggregates would have been eliminated or crushed if soil particles between 2 mm. and ¼ inch had been screened out.

Although rhyolitic soil was distinctly coarser textured than basaltic soil, the large range and overlap in particle size between soils developed on these two parent materials are perhaps even more important. The high variation found at Calf Creek on an area of less than 2 acres and sometimes between points only 10 feet apart on the South Umpqua area emphasizes the conclusion that there is great variation in particle size distribution within the tentative soil series sampled. Sampling by soil horizons instead of fixed depths probably would have reduced the variation in particle size distribution somewhat, but not enough to alter the conclusion that there is large variation in texture within the tentative soil series sampled. Although there were trends in particle size distribution with depth, differences in texture between adjoining depth classes at a sampling point usually were not large. Furthermore, it is likely that a high percentage of samples from a given depth, aspect, and soil series would have come from the same soil horizon.

When tree growth and response to treatment are considered, the wide range in particle size distribution and in soil moisture at 15 atmospheres of tension for the soil series studied suggests the following questions: (1) Is particle size distribution more important than parent material? (2) Is coarse-textured basaltic soil more like rhyolitic soil than typical basaltic soil, or does the parent material impart other characteristics that overshadow the effect of texture? These and other questions that might be asked suggest that much more research is needed to determine what soil characteristics are important to tree growth and how these characteristics affect growth and respond to treatment. This information is needed in order to establish better criteria for classifying forest soils and to aid in improving management of forest land in southwestern Oregon.

As shown by the scatter diagrams of estimated over actual values, the linear logarithmic soil moisture retention equations (log soil moisture = A + B log tension) fit the data for each sample quite closely for each of the tensions (3, 8, 15, and 25 atmospheres) used in the regression analysis. Consequently, the inverted form (log of tension = $\frac{1}{B}$ log soil moisture - $\frac{A}{B}$) of these linear logarithmic equations is suitable for computing soil moisture tension from field moisture content for the soils studied through at least the range of 3 to 25 atmospheres and is likely to be appropriate for many similar soils.

Undisturbed soil samples or cores are needed to measure soil moisture retention for low tensions — 1 atmosphere and lower — as soil structure affects soil moisture retention at low tensions. Undisturbed cores are difficult or impossible to get in cobbly or stony soils. Furthermore, several cores may be needed to arrive at a meaningful average value for a given location. Consequently, it would be highly desirable to be able to accurately extrapolate the regression for moisture values of disturbed samples in the 3- to 25-atmosphere range in order to estimate values for tensions below 1 atmosphere. The data obtained from the Calf Creek soil cores show that actual soil moisture content for 1 atmosphere and lower is below values extrapolated from the regression equations for tensions ranging 3 to 25 atmospheres. This is not surprising when the nature of a logarithmic curve is considered. Theoretically, there should be a maximum soil moisture content when "0" tension is reached; however, there would be no maximum with a logarithmic curve because it approaches but never reaches zero. Plotting on double logarithmic paper shows that the regression for 3 to 25 atmospheres intersects the plotted line for low tensions at approximately 1½ atmospheres.

The variability in the relationship between soil moisture at low tensions for undisturbed Calf Creek samples and extrapolated values from equations for tensions ranging from 3 to 25 atmospheres may be due to lack of comparability of the samples. At each sampling point, only one undisturbed core was obtained, whereas the bulk sample was a composite of several samples spread over about 1 or 2 square feet. Perhaps additional research in which special care is taken to insure comparability of disturbed and undisturbed samples will uncover means by which soil moisture at low tensions can be estimated from extrapolated values for equations developed for higher tensions.

Other researchers (Nielsen and Shaw 1958) have shown that, for many soils, percentage of clay can be used for accurately estimating soil moisture at 15 atmospheres of tension. Although a relationship between soil moisture at 15 atmospheres and clay content was found for the Calf Creek and South Umpqua areas, the scatter of the data is much too great for accurate estimation of soil moisture content at 15 atmospheres from a single overall regression with percentage of clay.

Undoubtedly, the spread in the data would be less if fine gravel had been excluded from samples used for both soil moisture and texture determination. For small areas such as Calf Creek, or small groups of plots from the South Umpqua area, soil moisture at 15 atmospheres could be accurately estimated from percentage of clay. However, regressions would have to be tested for each relatively small area for which estimating equations are desired, and direct measurements of soil moisture at 15 atmospheres would undoubtedly be more economical.

Large differences in soil moisture retention at 15 atmospheres for points 10 feet apart indicate that samples for determining soil moisture retention curves should be taken as close as possible to the point where samples will be collected for soil moisture determination.

The much higher soil moisture tensions on plots with vegetation than on those without vegetation show the importance of vegetation in depleting soil moisture. Competing vegetation clearly is an important cause of new regeneration mortality. Soil moisture tensions during the dry period of the summer were 15 atmospheres (the permanent wilting point) or higher at the 6-inch depth for 19 out of the 21 locations with vegetation.

Obviously then, positive steps to counteract the moisture drain of competing vegetation must be taken in order to insure successful establishment of regeneration. Some possibilities are: (1) establishing regeneration promptly after harvest cutting before competing vegetation is fully established, and (2) controlling vegetation if and when present.

As soil moisture tension decreases with depth at all sampling points, use of planting stock with roots as long as can be economically planted is indicated.

SUMMARY

1. Although rhyolitic soils are coarser textured than basaltic soils, there was a wide range in particle size distribution within each group and considerable overlap between soils from the two parent materials.

2. Linear logarithmic regressions of the form "log soil moisture = A + B log tension" fit data from basaltic, rhyolitic, and andesitic soils at three locations in southwestern Oregon between 3 and 25 atmospheres of tension. In inverted form, these can be used for estimating soil moisture tension from soil moisture content.

3. Measured soil moisture in undisturbed cores for tensions 1 atmosphere and less are lower than values extrapolated from the linear logarithmic moisture retention curves for disturbed soil samples based on tensions ranging 3 to 25 atmospheres.

4. Soil moisture percent at 15 atmospheres of tension varied greatly even within a relatively uniform area as small as 2 acres and frequently between points only 10 feet apart. Therefore, samples used for preparing soil moisture retention curves should be collected as close as possible to the point from which samples for moisture determination and subsequent moisture tensions are to be determined.

5. Additional basic soils research to define more clearly soil characteristics important to tree growth and to determine effect on growth and response to silvicultural treatment is suggested in order to improve criteria for forest soils classification and timber production.

6. Soil moisture tension at 6-inch depth during the driest period of the summer on cutover areas with vegetation is much higher than where vegetation has been removed — usually 15 to 25 atmospheres or more compared to 2 to 8 atmospheres where vegetation has been removed. Therefore, positive steps are needed, such as planting or seeding as soon as possible after harvest cutting before vegetation becomes fully established, or removing or killing part of established vegetation before attempting to establish regeneration.

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EPEATED SPRAYING TO CONTROL

UTHWEST OREGON BRUSH SPECIES

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE
PORTLAND, OREGON
1968

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RESEARCH PAPER PNW-59

RATKOWSKI

INTRODUCTION

Reclamation and reforestation of brush-covered forest lands is a major concern of foresters throughout the Pacific Northwest, where dense brushfields occupy large areas of potentially productive commercial forest land. Herbicides are known to kill many of the brush species effectively and economically. Unfortunately, however, most brushfields are composed of a mixture of evergreen and deciduous shrubs, including many that are resistant to herbicides. Repeated applications of herbicides will be needed to attain a degree of control sufficient to allow reforestation of most brush-covered sites.

To make reliable estimates of rehabilitation costs, foresters must know the number of resprays that will be needed to attain acceptable degrees of control in different brush associations. This paper reports the effect of repeated midsummer applications of herbicides as foliage sprays on some of the most abundant brush species in southwestern Oregon.

MATERIALS AND METHODS

During 1955, selected formulations of herbicides were tested as midsummer foliage sprays on 13 of the most common shrubby brush species on forest lands in southwestern Oregon. Each herbicidal treatment was applied as a foliage spray to drip point on 20 separate shrubs in a completely randomized design. Four species proved highly susceptible to herbicides and were readily killed with one spray application, but nine species proved only moderately susceptible or resistant to the initial spray treatment.[1] Surviving shrubs of moderately susceptible and resistant species sprouted the following year from stems, roots, and/or burls; but many of the sprouts exhibited curling and necrosis indicating continued herbicidal activity.

In July 1957 and July 1959, resprouting shrubs in the moderately susceptible and resistant categories on these plots were again sprayed with the same formulations of herbicides with which they were treated in 1955. Only the most effective treatments from the 1955 tests were repeated in the respray treatments, which were designed to determine the cumulative degree of control attainable with repeated midsummer applications of herbicides as foliage sprays.

Herbicides used were low-volatile propylene glycol butyl ether esters of 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and dichlorprop or 2-(2,4-dichlorophenoxy)propionic acid. A fourth herbicide, 3-amino-1,2,4-triazole (amitrole), was a commercial preparation containing 50 percent active ingredient.[2] Either water or oil-in-water emulsions containing 5 percent black diesel oil by volume were used as carriers in a 3-gallon knapsack sprayer with nozzle adjusted to deliver a fine spray.

The three treatments were applied at 2-year intervals near the end of the period of active growth for brush species in southwestern Oregon. This delay between treatments provided enough time for each spray to attain its maximum effect before re-treatment.

Stage of growth is also important in application of herbicides. The period of stem elongation is generally regarded as the optimum time for applying herbicides as foliage sprays. When the initial sprays were applied on mature shrubs in 1955, stems were growing in length on all species except serviceberry and canyon live oak. Respray treatments in 1957 and 1959, however, were applied just after stem elongation had ended. This timing may have been a bit late for maximum effect on the resprouting shrubs, but it allowed treatments to attain their maximum effect and minimized recovery between treatments.

[1] Gratkowski, H. Effects of herbicides on some important brush species in southwestern Oregon. U.S. Forest Serv., Pacific Northwest Forest & Range Exp. Sta. Res. Paper 31, 33 pp., illus. 1959.

[2] Fresh supplies of the three phenoxy herbicides were provided by the Dow Chemical Company when needed. Amitrol was furnished by Amchem Products, Inc. This cooperation is sincerely appreciated.

RESULTS AND DISCUSSION

Results of the spray treatments allow classification of the 13 shrubby brush species[3] into five classes based on their susceptibility to repeated midsummer applications of herbicides as foliage sprays:

Class	*Species*
Highly susceptible (90 to 100 percent of the shrubs dead after one spraying)	Hairy manzanita Hoary manzanita Howell manzanita Deerbrush ceanothus
Moderately susceptible (90 to 100 percent of the shrubs dead after two sprayings)	Snowbrush ceanothus Varnishleaf ceanothus
Slightly resistant (90 to 100 percent of the shrubs dead after three sprayings)	Greenleaf manzanita Mountain whitehorn ceanothus
Moderately resistant (only one-third to two-thirds of the shrubs dead after three sprayings)	Golden chinkapin Golden evergreen-chinkapin Scrub tanoak Saskatoon serviceberry
Highly resistant (less than one-third of the shrubs dead after three sprayings)	Canyon live oak

Although the initial application of herbicides on mature shrubs in 1955 caused a nearly complete defoliation of all species, only one- to two-thirds of the crown was killed on shrubs in the moderately and highly resistant categories. This degree of control would probably serve to release young conifers from brush competition, but it would not be adequate for reclamation and reforestation of nonstocked brushfields. For release, the objective is not necessarily to kill the brush, but to increase the amount of light reaching young conifers and to decrease brush root competition for soil moisture and nutrients. One need only obtain a high percentage of defoliation, a fair amount of top-kill, and a minimum of resprouting. For brushfield reclamation, however, a high percentage of the shrubs must be killed and resprouting must be limited in amount and vigor, or the recovering shrubs will soon overtop coniferous seedlings, limit their survival, and the site will again revert to brush.

Results of these tests show, however, that repeated spraying can control even resistant species to a degree that seems adequate for reforestation. High percentages of kill can be attained on species in the three most susceptible categories. And, although an appreciable percentage of shrubs in the more resistant categories were still alive after three sprayings, almost all of the crowns were dead and only limited numbers of sprouts had been produced by the remaining live plants. Competitive potential of these shrubs appeared greatly reduced and site conditions much more favorable for survival of interplanted young coniferous trees.

Resprouting shrubs proved much easier to kill than full-crowned mature plants (table 1). For example, although the first application of herbicides on mature plants did not kill any shrubs of species in the moderately resistant category, the first respray on sprouts killed as many as 40 percent of the shrubs. When the surviving shrubs sprouted again, a second respray increased the percentage of shrubs killed to as much as 60 percent. Repeated sprays are effective, advisable, and worthwhile on sites where resistant brush species are abundant.

Effect on Individual Species

Four highly susceptible species, **hairy manzanita** (*Arctostaphylos columbiana* Piper), **hoary manzanita** (*A. canescens* Eastw.), **Howell manzanita** (*A. hispidula* Howell), and **deerbrush ceanothus** (*Ceanothus integerrimus* Hook & Arn.) were readily killed with one application of 2,4-D as a foliage spray. Effects of various formulations of herbicides applied as foliage sprays on these and other species are listed in table 1.

Snowbrush ceanothus (*Ceanothus velutinus* Dougl.) required two sprayings to kill a high percentage of the shrubs. In resprays, as in the initial treatments, 2,4,5-T proved more effective than 2,4-D on snowbrush; and a 4-aehg[4] formulation of 2,4,5-T in an emulsion carrier was more effective than a 2-aehg formulation when applied as a midsummer foliage spray with

[3] Common and botanical names are those listed in "Standardized Plant Names," 2d ed., 1942, by Harlan P. Kelsey and William A. Dayton, except for golden chinkapin, which is in accordance with "Check List of Native and Naturalized Trees of the United States (including Alaska)," U.S. Dept. Agr. Handb. 41, 1953, by Elbert L. Little, Jr. Latin names and authorities are given in the section of this paper entitled "Effect on Individual Species."

[4] Pounds acid equivalent per 100 gallons of spray.

Table 1—*Cumulative percentage[1] of shrubs killed by repeated midsummer foliage sprays of herbicides on mature (1955) and resprouting (1957 and1959) shrubby brush species*

Species and herbicide	Concentration	Carrier	1955	1957	1959
	Aehg[2]				
Hairy manzanita					
2,4-D	1	Water	100	(3)	(3)
2,4,5-T	1	Water	90	(3)	(3)
2,4,5-T	2	Water	100	(3)	(3)
Hoary manzanita					
2,4-D	1	Water	100	(3)	(3)
2,4,5-T	1	Water	85	(3)	(3)
2,4,5-T	2	Water	100	(3)	(3)
Howell manzanita					
2,4-D	2	Water	95	(3)	(3)
2,4-D	2	Emulsion	100	(3)	(3)
2,4,5-T	2	Water	85	(3)	(3)
Deerbrush ceanothus					
2,4-D	2	Water	90	(3)	(3)
2,4-D	2	Emulsion	80	(3)	(3)
2,4,5-T	2	Water	85	(3)	(3)
Snowbrush ceanothus					
2,4-D	2	Emulsion	20	65	(3)
2,4,5-T	2	Emulsion	30	80	(3)
2,4,5-T	4	Emulsion	40	95	(3)
2,4-DP +	2				
amitrole	2	Water	70	90	(3)
Varnishleaf ceanothus					
2,4-D	2	Emulsion	45	60	(3)
2,4,5-T	2	Emulsion	65	95	(3)
2,4,5-T	4	Emulsion	85	100	(3)
Mountain whitethorn ceanothus					
2,4-D	2	Water	5	20	55
2,4,5-T	2	Water	20	65	90
Greenleaf manzanita					
2,4-D	2	Water	15	45	90
2,4-D	2	Emulsion	20	30	80
Golden chinkapin					
2,4-D	2	Emulsion	0	15	25
2,4,5-T	2	Emulsion	0	25	55
Amitrole	4	Water	0	20	60
2,4-DP +	2				
amitrole	2	Water	10	30	50
Golden evergreenchinkapin					
2,4-D	2	Emulsion	0	20	30
2,4,5-T	2	Emulsion	0	15	55
Amitrole	4	Water	0	40	60
Scrub tanoak					
2,4-D	2	Emulsion	0	35	55
2,4,5-T	2	Emulsion	0	20	60
Serviceberry					
2,4-D	½	Water	0	40	50
2,4-D	2	Water	0	40	58
Canyon live oak					
2,4-D	2	Emulsion	0	0	5
2,4-D	4	Emulsion	0	0	5

1/ 1955 and 1957 sprays were rated just before the next respray was applied. The 1959 treatments were rated in autumn, 1960.

2/ Pounds acid equivalent per 100 gallons. For amitrole, read aihg (active ingredient per 100 gallons).

3/ Not resprayed.

ground spray equipment. The increased cost of chemicals for this treatment would be offset by a saving in time and labor costs required to attain a similar degree of control with a 2-aehg spray mixture. The less concentrated spray solution would necessitate a third spray application and take at least one more year to attain a similar degree of control. For economy in spraying individual shrubs, two applications of 3-aehg 2,4,5-T in an emulsion carrier are recommended for snowbrush ceanothus (table 2). This should produce an acceptable degree of control.

Varnishleaf ceanothus (*Ceanothus velutinus* var. *laevigatus* T. & G.) also was best controlled with 2,4,5-T. One treatment of mature shrubs with a 4-aehg concentration of 2,4,5-T killed 85 percent of the shrubs (table 1), and aerial parts of the remaining plants were dead to ground level. Therefore, one thorough spraying with 4-aehg 2,4,5-T in an emulsion carrier is suggested as the least expensive treatment for controlling varnishleaf ceanothus (table 2).

Mountain whitethorn ceanothus (*Ceanothus cordulatus* Kell.) was also more susceptible to 2,4,5-T than to 2,4-D, but this species required three midsummer applications of 2,4,5-T in water to produce a high percentage of kill. The initial application on mature plants in 1955 killed all aerial parts, but vigorous resprouting threatened to nullify this degree of control within a year or two. Of the treatments tested, a 2-aehg concentration of 2,4,5-T in water was most effective.

Almost complete control of **greenleaf manzanita** (*Arctostaphylos patula* Greene) was obtained with three applications of 2-aehg 2,4-D in water. Although the first spray treatment in 1955 killed almost all aerial portions of the mature plants, most shrubs resprouted vigorously from burls at the soil surface. The sprouts were small but vigorous, and large numbers of sprouts were produced by each burl. Therefore, although one application of 2-aehg 2,4-D in a water carrier can be expected to provide increased light for established young conifers

Table 2.—*Foliage spray formulations for midsummer application on individual shrubs*

Common name	Chemical	Concentration	Carrier [1]	Comments [2]
		Aehg		
Manzanita, hairy	2,4-D	2	Emulsion	Good control with one treatment
Manzanita, hoary	2,4-D	2	Water	Good control with one treatment
Manzanita, Howell	2,4-D	2	Emulsion	Good control with one treatment
Manzanita, greenleaf	2,4-D	2	Water	Good control after three treatments
Ceanothus, deerbrush	2,4-D	2	Water	Good control with one treatment
Ceanothus, snowbrush	2,4,5-T	3	Emulsion	Good control after two treatments
Ceanothus, varnishleaf	2,4,5-T	4	Emulsion	Good control with one treatment
Ceanothus, mountain whitethorn	2,4,5-T	2	Water	Good control after three treatments
Chinkapin, golden	2,4,5-T	2	Emulsion	Fair control after three treatments
Evergreenchinkapin, golden	2,4,5-T	2	Emulsion	Fair control after three treatments
Tanoak, scrub	2,4-D	2	Emulsion	Fair control after three treatments
Serviceberry, saskatoon	2,4-D	1	Water	Fair control after three treatments
Oak, canyon live	2,4-D	2	Emulsion	Poor control after three treatments; aerial parts almost all dead; limited sprouting

1/ Emulsions suggested are oil-in-water, containing 2 percent black diesel oil by volume.

2/ "Good control" indicates 80 percent or more of the shrubs dead and the remaining shrubs killed back.
"Fair control" indicates 50 to 80 percent dead and the remaining shrubs killed back.
"Poor control" indicates less than 50 percent of the shrubs dead after high-volume foliage spraying with ground spray equipment.

beneath a greenleaf manzanita canopy, competition for soil moisture and nutrients may not be appreciably reduced. In both conifer release and brushfield reclamation projects, respray treatments are deemed desirable on sites where greenleaf manzanita is abundant.

The respray tests show that 2,4,5-T is the most economical herbicide tested on **golden chinkapin** (*Castanopsis chrysophylla* (Dougl.) A. DC.) The initial application of 2-aehg 2,4,5-T on mature shrubs killed none of the plants,[5] and the degree of control achieved was of questionable value even for releasing established young conifers from competition of chinkapin. After the third spraying, however, 55 percent of the shrubs were dead, aerial portions of the original crowns were dead to ground level on almost all remaining shrubs, and the living plants supported an average of only one 12-inch sprout per 6 square feet of original crown area. Of treatments tested, 2-aehg 2,4,5-T in an emulsion carrier is considered most useful for golden chinkapin.

Response of **golden evergreenchinkapin** (*Castanopsis chrysophylla* var. *minor* (Benth.) A. DC.) to herbicides is almost exactly like that of golden chinkapin. As for the latter, a 2-aehg concentration of 2,4,5-T in an emulsion carrier seems an effective and economical treatment for golden evergreenchinkapin. After three successive applications, 55 percent of the shrubs were dead, aerial portions of all original crowns were dead to ground level, and the shrubs supported an average of only one 7-inch sprout per 2 square feet of original crown area.

On **scrub tanoak** (*Lithocarpus densiflorus* var. *echinoides* (R. Br.) Abrams), 2,4-D was as effective as 2,4,5-T. Both herbicides killed similar numbers of shrubs in three treatments. Although sprouts were more numerous and slightly taller in shrubs sprayed with 2,4-D, the difference was not enough to be of practical significance. A 2-aehg concentration of 2,4-D in an emulsion carrier is suggested as most economical for foliage spraying of scrub tanoak.

On **saskatoon serviceberry** (*Amelanchier alnifolia* (Nutt.) Nutt.) a weak ½-aehg formulation of 2,4-D in water produced as good a degree of control as a stronger 2-aehg formulation. Only a few sprouts developed after these treatments (average one sprout per 5 to 8 square feet of original crown area); and in both treatments, the sprouts were similar in size (10 inches tall) and equal in vigor. A high percentage of kill was not achieved even with three successive sprayings of serviceberry. However, after the second application, all of the original crowns were dead and resprouting was so limited that the competitive potential of the shrubs was considered negligible. A 1-aehg formulation of 2,4-D in water is recommended for midsummer foliage application on serviceberry with ground spray equipment (table 2).

Midsummer foliage sprays on resprouting **canyon live oak** (*Quercus chrysolepis* Liebm.) were as ineffective as the initial sprays on mature shrubs in southwestern Oregon. After three successive treatments, only 5 percent of the shrubs were dead. Although all original crowns were killed, the remaining live plants had produced an average of two healthy 8-inch sprouts for each 3 square feet of original crown area. This degree of control would be sufficient for release of established conifers, but the developing sprouts might provide an undesirable amount of competition for new plantations of conifers in reclamation projects on sites where canyon live oak is abundant. Of treatments tested, 2-aehg 2,4-D in an emulsion carrier was as effective as any other on canyon oak.

Comparison With Aerial Spraying

Since aerial spraying is the usual method for application of herbicides on forest lands in the Pacific Northwest, foresters may wonder how these results of ground spray tests may be interpreted in terms of aerial spraying. Results of an aerial brush control project in the Siskiyou Mountains[6] provide some leads for such interpretation.

Two brushfields were aerially sprayed with herbicides during July 1955, burned in September 1956, and resprayed in June 1958 and August 1959. Although the initial treatments on the two areas were different, both were resprayed each time with 3 pounds acid equivalent of low-volatile esters of 2,4-D per acre in oil-in-water emulsions containing 1.5 gallons of black diesel oil per acre. Total spray volume in each application was 8 gallons per acre. Estimates of degree of control obtained by aerial spraying (table 3) are based upon abundance of each species on sample plots in the sprayed and

[5] See footnote 1.

[6] Gratkowski, H. J., and Philbrick, J. R. Repeated aerial spraying and burning to control sclerophyllous brush. J. Forest. 63: 919-923, illus. 1965.

burned areas as compared to abundance on plots in unsprayed brush surrounding the areas.

Table 3.—*Estimated percentage of shrubs dead after three aerial applications of herbicides on brushfields in southwestern Oregon*

Species	Year sprayed		
	1955 [1]	1958	1959
Mountain whitethorn ceanothus	0	28	44
Greenleaf manzanita	15	59	88
Scrub tanoak	0	—	42
Canyon live oak	0	21	30

[1] Both brushfields were burned in 1956, one year after the initial application of herbicides on mature shrubs. Degree of control listed was determined before burning.

Kill obtained by repeated aerial spraying of mountain whitethorn ceanothus, greenleaf manzanita, and scrub tanoak was similar to that obtained with ground spray equipment. On canyon live oak, however, aerial spraying appears to have been more effective. This comparison indicates that aerial spraying can be expected to kill percentages of shrubs similar to those killed in the screening tests on individual shrubs described earlier.

CONCLUSION

Most brushfields on forest land in the Pacific Northwest include species that are somewhat resistant to herbicides. Where such species are abundant, repeated treatments will be needed to kill a high percentage of the shrubs. Results of both the screening tests and aerial spraying presented here indicate that respray treatments on such sites are effective, advisable, and worthwhile. Respray treatments in both cases were effective in killing resprouting shrubs, even in species that were somewhat resistant to foliage sprays on healthy, full-crowned, mature shrubs.

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CONE PRODUCTION BY
PPER-SLOPE CONIFERS

rry F. Franklin

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CONTENTS

INTRODUCTION

Seed supply and seedling survival are the two key features of any silvicultural system utilizing natural regeneration. Infrequent occurrence of good crops could restrict the potential for natural regeneration or necessitate cutting methods which provide seed over a long timespan.

Investigation of seed supply in upper-slope, true fir-hemlock forests of the Pacific Northwest began in 1961 with establishment of a long-term cone production study. Since then, annual cone counts have been made of mature specimens of noble fir *(Abies procera)*, Pacific silver fir *(A. amabilis)*, mountain hemlock *(Tsuga mertensiana)*, and western white pine *(Pinus monticola)* throughout the mountains of western Oregon and Washington. More limited observations of cone production by subalpine fir *(Abies lasiocarpa)*, grand fir *(A. grandis)*, Shasta red fir *(A. magnifica* var. *shastensis)*,[1] and Engelmann spruce *(Picea engelmannii)* have also been obtained.

This paper is a progress report on cone-bearing habits of these upper-slope tree species. Some silvicultural implications of the data are also provided.

[1] Shasta red fir in southern Oregon is a morphologically variable complex sometimes referred to as noble fir. Populations may constitute hybrid swarms resulting from mingling of noble and California red firs *(Abies magnifica)*, in which case none of the present taxonomic designations are correct. However, because of ecological differences between the southern Oregon true fir and the noble fir found in Washington and northern Oregon, and until the identity of the former has been satisfactorily established by taxonomic study, the southern Oregon true fir will be referred to as Shasta red fir.

THE STUDY

A total of 47 plots have been established and studied since 1961, the majority now providing a 6-year record of cone production. The location and elevation of these plots, characteristics of the sample trees, and period of observation are listed in table 1. The geographic distribution of study plots is illustrated in figure 1. The majority of plots are for key upper-slope species: Pacific silver fir (12 plots), noble fir (eight plots), mountain hemlock (seven plots), and western white pine (nine plots, one of which was lost to mountain pine beetle 2 years after establishment). The remainder are divided between grand, Shasta red, and subalpine firs and Engelmann spruce. In several instances, "plots" are located in the same stand, e.g., grand fir, subalpine fir, western white pine, and Engelmann spruce at Big Meadows Creek. No records of cone production by upper-slope Douglas-fir and western hemlock were taken.

Field Methods

The study began with selection of relatively compact and mature stands of upper-slope species. To obtain a good cross section of yearly geographic variation in cone production, locales were selected throughout the western Oregon and Washington ranges of the major tree species. Most stands sampled were necessarily along stabilized clearcut boundaries or road rights-of-way to obtain good views of the crowns for counting purposes. Since the major purpose of the study was to observe yearly variation in cone production, edge effects were not considered important.

Table 1.--Location of the study plots, characteristics of the sample trees, and length of cone production record, as of 1967

Species	Locality	Ranger District and National Forest	Ecological province[1]	Elevation	Sample trees			
					Number	Average height	Average d.b.h.	Average age
				Feet		*Feet*	*Inches*	*Years*
Pacific silver fir	Glacier Creek No. 1	Glacier Mount Baker	Mount Baker	3,700	27	160	23.7	125
	Glacier Creek No. 2	Glacier, Mount Baker	Mount Baker	4,000	23	180	36.4	325
	Tunnel Creek	Skykomish, Snoqualmie	Mount Baker	2,750	21	185	45.0	250
	Stampede Pass	Cle Elum, Wenatchee	Mount Rainier	3,600	33	145	22.7	175
	Mosquito Lakes	Mount Adams, Gifford Pinchot	Mount Adams	3,900	21	130	27.3	200
	Spirit Lake	St. Helens, Gifford Pinchot	Mount Rainier	3,250	4	140	27.0	120
	Bare Mountain	St. Helens, Gifford Pinchot	Mount Rainier	4,000	22	125	25.8	325
	Timberline Road	Zigzag, Mount Hood	Mount Hood	4,500	17	110	27.0	250
	Santiam Pass	McKenzie, Willamette	Three Sisters	4.750	24	100	17.8	150
	Iron Mountain	Sweet Home, Willamette	Willamette	5,200	21	80	21.7	100
	Hunger Mountain	Sol Duc, Olympic	Olympic	3,000	22	185	38.6	175
	Bon Jon Pass	Quilcene, Olympic	Olympic	3,500	26	125	25.3	135
Noble fir	Tunnel Creek	Skykomish, Snoqualmie	Mount Baker	2,750	19	220	51.6	225
	Stampede Pass	Cle Elum, Wenatchee	Mount Rainier	3,600	22	155	31.3	175
	Willame Creek	Packwood, Gifford Pinchot	Mount Rainier	4,000	22	215	58.0	225
	Spirit Lake	St. Helens, Gifford Pinchot	Mount Rainier	3,250	31	155	32.0	115
	Sleeping Beauty	Mount Adams, Gifford Pinchot	Mount Adams	4,000	21	160	31.3	200
	North Wilson	Bear Springs, Mount Hood	Mount Hood	4,500	24	145	33.4	250
	Wildcat Mountain	McKenzie, Willamette	Willamette	4,250	20	170	42.4	115
	Marys Peak	Alsea, Siuslaw	Coast Ranges	3,700	30	150	46.7	175
Mountain hemlock	Heather Meadows	Glacier, Mount Baker	Mount Baker	3,850	17	80	24.3	250
	Stampede Pass	Cle Elum, Wenatchee	Mount Rainier	3,600	23	130	20.2	225
Mountain hemlock	Steamboat Mountain	Mount Adams, Gifford Pinchot	Mount Adams	5,000	18	50	18.5	175
	Deadman's Curve	Zigzag, Mount Hood	Mount Hood	4,500	19	100	21.6	250

[1] See Franklin (1965).

Table 1.--Location of the study plots, characteristics of the sample tree and length of cone production record, as of 1967--Continued

Species	Locality	Ranger District and National Forest	Ecological province[1]	Elevation	Sample trees				Years of record
					Number	Average height	Average d.b.h.	Average age	
				Feet		*Feet*	*Inches*	*Years*	
	Santiam Pass	McKenzie, Willamette	Three Sisters	4,750	20	105	22.4	200	6
	Carpenter Mountain	Blue River, Willamette	Willamette	5,300	21	85	23.0	125	6
	Windigo Pass	Diamond Lake, Umpqua	Crater Lake	5,250	21	125	19.8	225	6
tern white pine	Lake Wenatchee	Lake Wenatchee, Wenatchee	Wenatchee	2,400	0	210	34.2	175	2
	Big Meadows Creek	Lake Wenatchee, Wenatchee	Wenatchee	2,400	15	200	28.4	125	5
	Smithbrook	Lake Wenatchee, Wenatchee	Mount Baker	3,300	18	140	34.5	150	4
	Peterson Prairie	Mount Adams, Gifford Pinchot	Mount Adams	3,000	19	115	21.0	75	6
	Bear Paw	Bear Springs, Mount Hood	Mount Hood	2,350	25	95	15.2	75	6
	Santiam Pass	McKenzie, Willamette	Three Sisters	4,750	20	115	29.0	110	6
	Lost Prairie	Sweet Home, Willamette	Willamette	3,325	7	160	32.0	105	5
	Windigo Pass	Diamond Lake, Umpqua	Crater Lake	5,250	21	135	26.1	250	6
	Bessie Rock	Prospect, Rogue River	Crater Lake	5,400	15	140	25.4	225	2
alpine fir	Big Meadows Creek	Lake Wenatchee, Wenatchee	Wenatchee	2,400	18	165	24.4	150	5
	Smithbrook	Lake Wenatchee, Wenatchee	Mount Baker	3,300	24	115	30.0	125	4
	Steamboat Mountain	Mount Adams, Gifford Pinchot	Mount Adams	5,300	25	85	19.7	150	6
	Sand Mountain	McKenzie, Willamette	Three Sisters	5,200	30	40	8.7	50	6
nd fir	Big Meadows Creek	Lake Wenatchee, Wenatchee	Wenatchee	2,400	20	160	31.2	150	5
	Peterson Prairie	Mount Adams, Gifford Pinchot	Mount Adams	3,000	23	75	23.0	125	5
	Lost Prairie	Sweet Home, Willamette	Willamette	3,325	20	155	31.1	120	5
ta red fir	Windigo Pass	Diamond Lake, Umpqua	Three Sisters	5,250	21	135	29.1	250	6
	Bessie Rock	Prospect, Rogue River	Three Sisters	5,400	30	150	32.9	225	2
elmann spruce	Big Meadows Creek	Lake Wenatchee, Wenatchee	Wenatchee	2,400	16	165	30.5	150	5
	Lost Lake Creek	McKenzie, Willamette	Three Sisters	4,250	20	140	31.8	125	5

Franklin (1965).

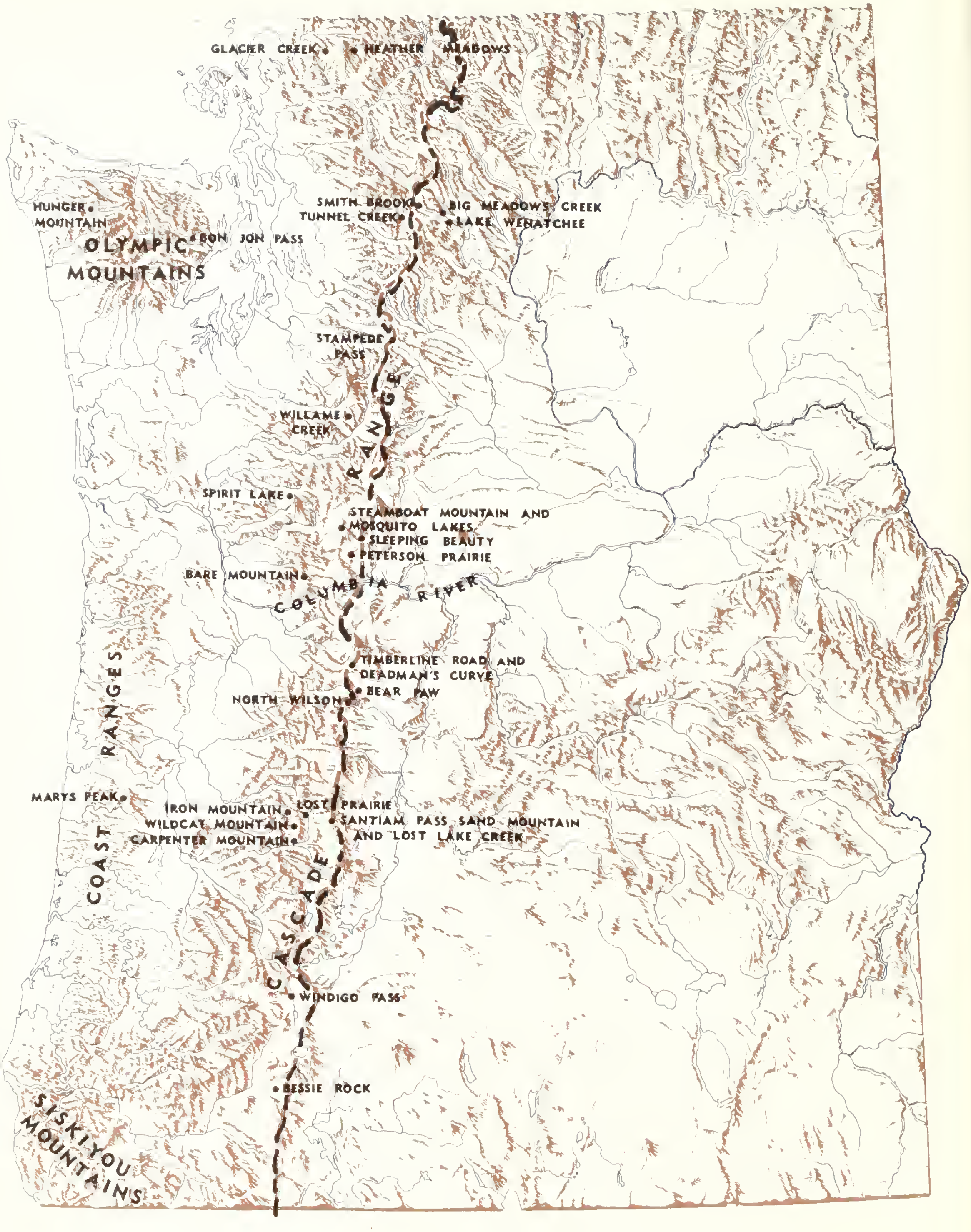

Figure 1.–Geographic distribution of cone production study plots.

Differences in cone production between trees on the stand edge and within the stand were not observed.

Once a suitable stand was located, usually 15 to 30 trees of each species being sampled were selected. Sample trees were dominants with an undamaged upper crown, one side of which was readily observable for cone counting purposes. Only dominant trees were used since many studies have shown that these are the trees that produce three-fourths or more of all cones (Fowells and Schubert 1956; Haig et al. 1941).[2] Each tree was tagged, measured, and marked with a large spray-painted number for identification from a distance. At the same time, observation or counting points were selected for each tree, and adjacent logs, stumps, or trees were marked with paint. A sketch map aided in relocation of these counting points in later years.

Using binoculars or a variable 15- to 60-power spotting scope, we counted yearly all visible cones from the identical, single counting point selected for the tree. Binoculars were used during the first 3 years of the study (1961-63), and the spotting scope has usually been used since. A small-scale test revealed no consistent differences in counts between the binoculars and spotting scope, but it was easier and faster to obtain accurate counts using the scope. The author made approximately two-thirds of the cone counts himself. Observations by four others, who assisted in the study, were checked against those of the author, but they did not differ consistently nor by more than ± 5 percent. An observer correction factor was, therefore, not used.

[2] Names and dates in parentheses refer to Literature Cited, p. 21.

Two problems were encountered in counting mountain hemlock cones. First, it was difficult to obtain accurate counts of the abundant, densely clustered, relatively small cones during years of heavy production. Observers sometimes had to count individual branches and multiply these values by number of similarly laden branches to obtain total counts. Second, some mountain hemlock cones are retained in tree crowns for at least 2 or 3 years after shedding their seed. Counts must be made while new cones are still tightly closed and distinctive from the old cones, yet not so early that the new cones are too small to be readily and accurately counted.

Presentation of Data

Data reported are based on the number of cones counted from a single and constant observation point for each tree. Total cone production was greater as many cones are hidden by foliage, limbs, or the main stem. Fowells and Schubert (1956) used a factor of 1.5 to convert individual cone counts of sugar and ponderosa pines and white fir from a single observation point to total cone production. Two-thirds of the crown was assumed to be visible from a single point. By counting cones before and after felling, Wenger (1953), Hoekstra (1960), and Garman (1951) found a cone count conversion factor of around 2 was needed for the species they worked with – loblolly pine, slash pine, and Douglas-fir, respectively. Converting factors are presently being developed for the upper-slope species under study. Total cone production may be calculated by the following tentatively suggested factors, based on available data and size and position of the cones in the crown:

Noble and Shasta red firs and western white pine	1.5
Pacific silver, grand, and subalpine firs	1.7
Mountain hemlock and Engelmann spruce	2.0

In tabulations of data and rating of cone crops, median cone counts for plots are emphasized, although the plot means and the range of individual tree counts on each plot are also given. The median observation is the middle one when cone counts are arranged in order of magnitude. Half of the counts are less than this value and half are greater (except in the case of zero median values). Medians are used because they are considered more representative of cone production by the "typical" study tree than the mean cone count for the plot. Production of large numbers of cones by one or two trees on a plot in a generally poor year results in relatively large average plot values, even if a majority of trees experienced a failure or very light crops.

It is convenient in discussing cone data to use general categories for cone production – failures, medium crops, very heavy crops, etc. A cone crop rating system based on the median cone count was developed to put the terms used on a quantitative basis (table 2). Considerations of number of seeds per cone and the range in cone production commonly encountered resulted in differences between species in rating definition. The reader should note the system is based on median cone counts of a sample of dominant trees. It can be applied as well to individual trees, however.

RESULTS AND DISCUSSION

Cone Production by Species

Noble fir.--Noble fir proved to be a prolific cone producer on most of the study plots (table 3). According to the "Woody-Plant Seed Manual" (U.S. Forest Service 1948), noble fir produces good crops at infrequent intervals and some seed every year. This statement is accurate when all plots are considered together. However, one stand (Willame Creek) mustered heavy or very heavy crops 4 years out of 6 and another (North Wilson) produced a single medium crop during 6 years of observation. The relatively high cone production a Tunnel Creek is noteworthy since this plo is near the northern limits of noble fir.

Variation in cone production betwee localities during a given year was consider able. The year 1962 was generally goo and 1964 was universally poor. In 1965, o the other hand, four plots produced ver heavy crops and the other four almost n cones.

Cone failures the year after a heavy very heavy crop were not universal. A analysis of 48 years of Douglas-fir co crop records showed that abundant yea were always followed by failures or lig crops (Lowry 1966). The seven records very heavy noble fir crops (e.g., Tunn Creek in 1962) were succeeded by failur three times but by very light, ligl medium, and heavy crops (Willame Cre in 1966) in the other four instances.

Table 2.--Cone crop rating system based on median count of a sample of dominant trees, cone counts to be made from a single observation point per tree

Species	Crop rating	Median number of cones per tree
Noble, Pacific silver, and Shasta red firs and western white pine	Failure	0
	Very light	1-4
	Light	5-9
	Medium	10-19
	Heavy	20-49
	Very heavy	50+
Grand and subalpine firs	Failure	0
	Very light	1-9
	Light	10-19
	Medium	20-49
	Heavy	50-99
	Very heavy	100+
Engelmann spruce and mountain hemlock	Failure	0-10
	Very light	11-49
	Light	50-99
	Medium	100-199
	Heavy	200-299
	Very heavy	300+

Table 3.--Noble fir cone counts by location and year[1]

Year	Tunnel Creek	Stampede Pass	Willame Creek	Sleeping Beauty	Spirit Lake	North Wilson	Wildcat Mountain	Marys Peak	Average
	Number[2]								
1961	21	32	–	–	–	–	–	–	26.5
1962	270	15	47	16	–	1	83	76	72.6
1963	0	0	24	0	4	0	10	0	4.8
1964	5	2	2	0	0	0	3	1	1.6
1965	1	0	184	0	77	0	172	112	68.3
1966	24	0	40	16	8	0	0	4	11.5
1967	0	6	2	0	0	12	10	4	4.2
Average, 1961-67	45.9	7.9	49.8	5.3	17.8	2.6	46.3	32.8	
	Number and range[3]								
1961	61 (0-286)	41 (6-36)	–	–	–	–	–	–	51.0
1962	343 (90-850)	19 (0-78)	67 (0-300)	24 (4-56)	–	4 (1-15)	98 (24-316)	92 (28-413)	91.0
1963	1 (0-12)	0 (0-2)	41 (0-354)	0 (0-0)	8 (0-57)	0 (0-0)	18 (0-118)	6 (0-44)	9.3
1964	14 (0-55)	8 (0-51)	6 (0-29)	2 (0-11)	7 (0-77)	1 (0-6)	7 (0-39)	3 (0-21)	6.0
1965	15 (0-92)	0 (0-0)	200 (48-465)	1 (0-11)	91 (18-313)	0 (0-0)	222 (50-784)	174 (36-960)	87.9
1966	83 (0-630)	5 (0-95)	56 (6-290)	28 (7-137)	12 (0-119)	1 (0-11)	0 (0-0)	8 (0-41)	24.1
1967	2 (0-23)	17 (0-86)	3 (0-14)	2 (0-13)	3 (0-27)	19 (0-109)	24 (0-147)	11 (0-117)	
Average, 1961-67	74.1	12.8	62.2	9.5	24.2	4.2	61.5	49.0	

[1] "–" means no measurements were taken.

[2] Median number of cones counted per tree. The number is the middle observation when cone counts are arranged in order of magnitude.

[3] Average number and range (figures in parentheses) of cones counted per tree.

important unknown factor, however, is the quality of the seed in the succeeding crop which could be very low due to a buildup of cone insects.

Individual noble firs have produced very large numbers of cones in a given year. The present record holder is a 53-inch-d.b.h. tree at Marys Peak which produced an estimated 1,440 cones in 1965 (count x 1.5). On a basis of 500 seeds per cone,[3] we can assume about 720,000 seeds (nearly 50 pounds) were produced in a single year by this one tree! Other noteworthy trees are two at Tunnel Creek, which produced estimated totals of 1,275 and 1,080 cones, respectively, in 1962, and a 58-inch specimen at Wildcat Mountain, which produced 1,176 cones in 1965.

Pacific silver fir.--Cone production by Pacific silver fir has been nearly universally poor during the last 6 years (table 4). Two stands (Iron Mountain and Timberline Road) produced two heavy or very heavy cone crops and experienced three failures during 6 years of observation. They were the exception, however, and in most stands a single medium crop was the best recorded. These observations do not agree with the suggestion that Pacific silver fir produces good crops at 2- to 3-year intervals and light crops in intervening years (U.S. Forest Service 1948).

There has been relatively little variation between locales (table 4). All stands produced crops in 1962, although crop size varied tremendously. All locales failed completely in 1963 (except for Hunger Mountain), 1964, and 1966. Cones were recorded on all study plots in 1965, even though the crop was rated as a failure (median cone count of 0) at three of the 12 locations.

The record count for a single Pacific silver fir was 254 cones on a 22-inch specimen at Iron Mountain in 1965. With a factor of 1.7 to convert to total cones and 400 seeds per cone,[4] we can assume a production of about 173,000 seeds (15 pounds).

Mountain hemlock.--During the last 6 years, mountain hemlock has not proved so prolific a seeder as generally believed (Fowells 1965) (table 5). All plots did have at least one good year in 1962, however, with crops rated from medium at Steamboat Mountain (median count 195 – nearly a heavy rating) to very heavy in the majority of stands. Two plots (Stampede and Santiam Passes) failed to produce even a medium crop during the following 4 years, although the remainder have each produced one other crop rated as medium or better.

Some years there was little variation between localities in cone crop rating, but in others it was considerable. From 1962 to 1964 and in 1967, there was very little variation – all stands did well in 1962 and all failed the other three years. In 1965, although all plots had cones, crops were rated as medium to very heavy at four locations and very light on the remainder. Crops were failures at four localities in 1966 and light to medium at three.

Individual mountain hemlock trees produced massive quantities of cones, " . . . cones so numerous as to weigh down the branchlets and almost cover them" (Fowells 1965). The largest number of cones counted was 1,700 on a 20-inch tree

[3] Unpublished data, on file at Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, indicate 500 seeds per cone is a conservative estimate for noble fir.

[4] Unpublished data on file at the Forestry Sciences Laboratory, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, indicate 400 seeds per cone is a conservative estimate for Pacific silver fir.

Table 4.--Pacific silver fir cone counts by location and year[1]

Year	Glacier Creek No. 1	Glacier Creek No. 2	Tunnel Creek	Stampede Pass	Mosquito Lakes	Spirit Lake	Bare Mountain	Timber-line Road	Santiam Pass	Iron Mountain	Hunger Mountain	Bon Jon Pass	Average
	Number[2]												
1961	17	–	–	–	–	–	–	–	–	–	–	–	17.0
1962	10	–	–	3	14	–	17	43	12	65	9	14	20.7
1963	0	0	0	0	0	0	0	0	0	0	10	0	.9
1964	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	2	18	18	0	0	92	2	63	1	115	40	0	29.2
1966	0	0	0	0	0	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	2	0	1	0	0	.6
Average, 1961-67	4.1	3.6	3.6	.5	2.3	18.4	3.2	18.0	2.2	30.2	9.8	2.3	
	Number and range[3]												
1961	15 (1-36)	–	–	–	–	–	–	–	–	–	–	–	15.0
1962	10 (1-25)	–	–	10 (0-52)	15 (1-34)	–	20 (0-59)	52 (11-106)	15 (2-53)	67 (10-182)	27 (0-226)	17 (0-64)	25.9
1963	0 (0-3)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	17 (0-42)	0 (0-3)	1.4
1964	0 (0-2)	0 (0-2)	0 (0-4)	0 (0-4)	2 (0-22)	0 (0-2)	1 (0-11)	2 (0-17)	0 (0-0)	3 (0-35)	0 (0-2)	0 (0-0)	.7
1965	4 (0-29)	31 (0-126)	24 (2-60)	2 (0-17)	3 (0-39)	89 (0-191)	6 (0-52)	58 (12-117)	4 (0-32)	132 (35-254)	49 (1-104)	7 (0-76)	34.1
1966	0 (0-4)	0 (0-3)	0 (0-1)	1 (0-6)	1 (0-4)	0 (0-0)	0 (0-2)	0 (0-0)	0 (0-2)	0 (0-0)	0 (0-3)	0 (0-7)	.2
1967	0 (0-0)	0 (0-0)	0 (0-5)	0 (0-1)	0 (0-3)	0 (0-0)	0 (0-3)	4 (0-24)	0 (0-4)	5 (0-28)	0 (0-0)	0 (0-0)	.8
Average, 1961-67	4.1	6.2	4.8	2.2	3.5	17.8	4.5	19.3	3.2	34.5	15.5	4.0	

[1] "–" means no measurements were taken.

[2] Median number of cones counted per tree. The number is the middle observation when cone counts are arranged in order of magnitude.

[3] Average number and range (figures in parentheses) of cones counted per tree.

Table 5.--Mountain hemlock cone counts by location and year

Year	Heather Meadows	Stampede Pass	Steamboat Mountain	Deadman's Curve	Santiam Pass	Carpenter Mountain	Windigo Pass	Average
	Number[1]							
1962	350	260	195	265	600	380	300	335.7
1963	0	0	0	0	0	0	0	0
1964	4	0	0	0	0	3	0	1.0
1965	37	30	198	250	28	420	150	159.0
1966	120	95	96	7	8	1	0	46.7
1967	0	0	0	0	0	0	0	0
Average, 1962-67	85.2	64.2	81.5	87.0	106.0	134.0	75.0	
	Number and range[2]							
1962	400 (100-1,000)	293 (20-1,190)	224 (45-700)	402 (10-1,140)	740 (200-1,700)	471 (90-1,500)	263 (0-600)	399.0
1963	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0
1964	10 (0-40)	3 (0-16)	0 (0-4)	1 (0-10)	0 (0-0)	6 (0-34)	67 (0-300)	12.4
1965	72 (0-460)	40 (0-130)	311 (55-780)	320 (30-1,440)	76 (5-465)	401 (80-1,080)	174 (40-580)	199.1
1966	168 (14-600)	121 (8-350)	96 (0-225)	13 (0-91)	17 (0-66)	2 (0-8)	1 (0-10)	59.7
1967	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-5)	0
Average, 1962-67	110.0	76.2	105.2	122.7	138.8	146.7	84.2	

[1] Median number of cones counted per tree. The number is the middle observation when cone counts are arranged in order of magnitude.

[2] Average number and range (figures in parentheses) of cones counted per tree.

located at Santiam Pass in 1962. This represents production of about 350,000 seeds (3 pounds) if we assume a conversion factor of 2.0 and 100 seeds per cone. Over 1,000 cones were counted on many other trees during the 5-year study period.

Western white pine.--Western white pine has been a consistent cone producer (table 6). Complete failures have been rare except on two plots located in the Wenatchee Province (Franklin 1965) – Lake Wenatchee and Big Meadows Creek. Five other stands, for which there is a 5- or 6-year record available, have produced at least one heavy crop; three have always produced at least a very light crop.

A general pattern of cone periodicity ties most of the plots together – good crops in 1962, 1964 and 1967, poor ones in 1963 and 1966, and a fair crop in 1965. There are still exceptions, however, particularly at the Wenatchee plots already noted and in the extreme southern Oregon Cascade Range and Siskiyou Mountains. Only one plot record is available for the latter area (Bessie Rock), but supplemental observations showed heavy western white pine crops were general in the southern Cascade Range and eastern Siskiyou Mountains in 1963 and 1966.

The maximum count for a single western white pine is 400 cones – counted in 1964 on a 36-inch specimen at Big Meadows Creek. Using 1.5 for a count conversion factor and 120 seeds per cone (Haig et al. 1941), we can assume about 72,000 or 27 pounds of seed. This record white pine cone count is identical with that reported by Haig et al. (1941) from northern Idaho.

Other species.--Limited records of cone production by subalpine fir, grand fir, Shasta red fir, and Engelmann spruce have been obtained (table 7). All four subalpine fir plots produced at least one medium crop during the last 4 years, and trees at Big Meadows Creek have produced both heavy and very heavy crops. Thus far there appears to be little yearly correlation between plots except that all three studied in 1963 had cone failures and all four failed or nearly so in 1967. A maximum count of 510 cones was produced by a 25-inch-d.b.h. tree growing at Big Meadows Creek in 1963.

For the last 5 years, grand fir has been a fairly prolific cone producer in the three areas studied. Two plots had two very heavy crops and three failures or very light crops. The third, Lost Prairie, had medium and heavy crops in 2 of 5 years of observation. Cone production on the Washington plots has shown an identical pattern with good years in 1964 and 1966 and poor ones in 1963, 1965, and 1967. Lost Prairie differed with a medium crop in 1965 and light crops in 1966 and 1967. A maximum count of 580 cones was made on a 31-inch-d.b.h. tree at Big Meadows Creek in 1964.

Engelmann spruce also seems to produce large cone crops at frequent intervals. At Big Meadows Creek, medium to very heavy cone crops have been produced in 3 out of 5 years; heavy and very heavy crops have been produced at Lost Creek in 2 of 5 years.

Yearly periodicity of the two plots shows almost no correlation; indeed, the reverse is suggested – spruce at one locale produce a good crop at the same time cone production fails at the other.

Variation in Cone Production Within Plots

Individual dominant specimens of the same species at the same locale varied significantly in cone-producing capacity

Table 6.--Western white pine cone counts by location and year[1]

Year	Lake Wenatchee	Big Meadows Creek	Smithbrook	Peterson Prairie	Bear Paw	Santiam Pass	Lost Prairie	Windigo Pass	Bessie Rock	Average
					Number[2]					
1962	0	–	–	50	34	41	–	58	–	36.6
1963	0	0	–	3	2	12	6	0	–	3.3
1964	–	126	8	110	77	54	8	38	–	60.1
1965	–	0	10	10	13	11	35	34	–	16.1
1966	–	0	9	16	2	2	0	2	59	11.2
1967	–	0	0	90	13	54	21	5	9	24.0
Average, 1962-67	0.0	25.2	6.8	46.5	23.5	29.0	14.0	22.8	34.0	
					Number and range[3]					
1962	3 (0-3)	–	–	55 (19-127)	42 (6-127)	50 (5-105)	–	74 (0-225)	–	44.8
1963	1 (0-9)	0 (0-2)	–	14 (0-62)	6 (0-24)	16 (0-44)	18 (0-60)	4 (0-44)	–	8.4
1964	–	142 (16-400)	37 (0-165)	122 (55-259)	76 (0-206)	64 (3-267)	39 (2-148)	53 (0-144)	–	76.1
1965	–	5 (0-61)	25 (0-189)	19 (0-76)	30 (0-198)	12 (0-40)	36 (3-78)	49 (0-157)	–	25.1
1966	–	1 (0-10)	26 (0-105)	19 (0-46)	6 (0-26)	5 (0-16)	4 (0-18)	4 (0-25)	70 (0-228)	16.9
1967	–	2 (0-29)	7 (0-41)	85 (6-210)	22 (0-111)	75 (0-165)	23 (0-100)	8 (0-42)	11 (0-30)	29.1
Average, 1962-67	2.0	30.0	23.8	52.3	30.3	37.0	24.0	32.0	40.5	

1 "–" means no measurements were taken.

2 Median number of cones counted per tree. The number is the middle observation when cone counts are arranged in order of magnitude.

3 Average number and range (figures in parentheses) of cones counted per tree.

Table 7.–Subalpine fir, grand fir, Shasta red fir, and Engelmann spruce cone counts by location and year[1]

Year	Subalpine fir					Grand fir				Shasta red fir			Engelmann spruce		
	Smith-brook	Big Meadows Creek	Steamboat Mountain	Sand Mountain	Average	Big Meadows Creek	Peterson Prairie	Lost Prairie	Average	Windigo Pass	Bessie Rock	Average	Big Meadows Creek	Lost Creek	Average
	Number[2]														
1962	–	–	53	15	34.0	–	–	–	–	6	–	6.0	–	–	–
1963	–	0	0	0	0.0	0	1	0	0.3	0	–	0.0	0	285	142.5
1964	50	140	3	0	48.2	340	150	50	180.0	8	–	8.0	480	0	240.0
1965	10	0	28	44	20.5	0	2	36	12.7	25	–	25.0	115	570	342.5
1966	0	63	3	0	17.2	265	300	16	193.7	0	0	0.0	120	25	72.5
1967	0	0	1	0	0.2	0	0	11	3.7	0	6	3.0	0	160	80.0
Average, 1962-67	15.0	40.6	14.7	9.8		121.0	91.2	22.6		6.5	3.0		143.0	208.0	
	Number and range[3]														
1962	–	–	61 (1-150)	31 (0-104)	46.0	–	–	–	–	12 (0-59)	–	12.0	–	–	–
1963	–	1 (0-18)	0 (0-0)	0 (0-0)	0.3	3 (0-28)	4 (0-20)	3 (0-15)	3.7	1 (0-5)	–	1.0	23 (0-200)	462 (0-2,570)	242.5
1964	47 (0-152)	151 (0-510)	10 (0-50)	8 (0-71)	54.0	311 (65-580)	186 (40-448)	53 (18-95)	183.3	10 (0-42)	–	10.0	542 (25-1,360)	2 (0-20)	272.0
1965	13 (0-48)	0 (0-7)	40 (0-136)	50 (0-160)	25.8	0 (0-0)	2 (0-11)	38 (2-110)	10.0	24 (0-76)	–	24.0	215 (20-3,100)	809 (20-2,580)	512.0
1966	0 (0-1)	95 (10-280)	13 (0-72)	0 (0-0)	27.0	274 (74-560)	291 (79-600)	24 (0-86)	196.3	0 (0-0)	0 (0-0)	0.0	374 (10-3,200)	75 (0-400)	224.5
1967	3 (0-20)	5 (0-54)	7 (0-89)	0 (0-0)	3.8	0 (0-0)	0 (0-0)	15 (0-59)	5.0	3 (0-15)	13 (0-64)	8.0	4 (0-40)	271 (0-1,290)	137.5
Average, 1962-67	15.8	50.4	21.8	14.8		117.6	96.6	26.6		8.3	6.5		231.6	323.8	

[1] "–" means no measurements were taken.

[2] Median number of cones counted per tree. The number is the middle observation when cone counts are arranged in order of magnitude.

[3] Average number and range (figures in parentheses) of cones counted per tree.

Statistical analyses were conducted on data from 33 of the cone plots, including at least one of each species, which had 2 or more years of light or better cone crops.[5] Variability between trees was significant or highly significant on 20 of these plots and approached significance on several of the others.

Regression analyses of cone production on tree diameter were then conducted on the 20 plots which showed significant variability between trees. On six, tree diameter and cone production were significantly related; i.e., diameter accounted for part of the variation in cone production between individual trees. However, this generally occurred on plots with a wide variation in diameter of the study trees; e.g., tree diameter on the Peterson Prairie white pine plot (one on which diameter and cone production are related) ranges from 14 to 45 inches, although all study trees are dominants. The normal range of tree diameters on study plots is 10 to 15 inches; under this condition, diameter was generally not significantly correlated with cone production.

In general and for the species under study, some trees apparently have an inherent capacity to produce more cones than other trees of the same species, and this is not accounted for by diameter differences in most even-aged stands. This finding is not surprising since geneticists and horticulturists have recognized inherent differences in flowering ability for many years. But it does have important implications in the selection of seed trees.

Do all trees of a given species at a locale show the same pattern of periodicity or rhythm of cone production? It was not possible to test this tree-year interaction statistically. Inspection of the data suggests that individual trees may occasionally be out of phase with the bulk of the population. This seems to be particularly common in years with intermediate levels of cone production.

SILVICULTURAL IMPLICATIONS

Frequency of Cone Crops

Six years of data are too few to allow predictions regarding frequency with which individual species will produce large cone crops. There are indications that western white pine and noble fir, in most localities, are fairly dependable cone producers. Engelmann spruce and grand fir have also produced large cone crops at frequent intervals, although observations have been made in only a few stands and for only 5 years. Mountain hemlock has not proved so prolific as previously believed.

Pacific silver fir has thus far been a disappointing cone producer at most locations. If this proves to be the general situation, silvicultural systems for natural regeneration of Pacific silver fir will have to provide a seed source over a considerable period of time, as in shelterwood or selective cutting. The necessity for these systems is emphasized when the short dissemination distance for silver fir seed is

[5] Statistical theory required rejection of years of record in which most trees had 0 cones.

considered along with its apparent low cone-bearing capacity. Hetherington (1965) showed most silver fir seed on Vancouver Island falls within 50 to 100 feet from the edge of the cutting area.

Available data do indicate the forester can expect some seed from at least one upper-slope species almost every year (table 8). This is important since most upper-slope stands are composed of mixtures of several species. The forester is, therefore, not dependent on cone production by a single species, unless he specifically desires regeneration of that species.

There are some years in which all species in a locale fail to produce cones. This happened in 1963 when almost no cones were produced by any species studied in Washington and northern Oregon, and again in 1966 in Oregon and in 1967 in northern Washington (table 8). More commonly, however, when some species are experiencing cone failures, others are producing crops. See, for example, the Mount Adams area in 1962 and 1964 through 1967 and the Santiam Pass and Willamette Province areas from 1962 through 1965 and in 1967 (table 8). Other upper-slope species, particularly Douglas-fir and western hemlock, will also contribute seed, and their pattern of cone production is not necessarily in phase with the species included in this study. For example, in 1966, upper-slope Douglas-fir and western hemlock were observed to produce better-than-average crops of cones in many localities in Oregon while associated true firs and mountain hemlock were experiencing failures.

The observation that species growing in mixed stands are often out of phase with one another in level of cone production is confirmed by other studies. Haig et al. (1941) concluded that "little consistency between species is evident" when he compared cone crops of western white pine, western larch, Douglas-fir, grand fir, western redcedar, and western hemlock in northern Idaho. Even in the poorest year he recorded, two of the six species had fair crops. Similarly, ponderosa pine, sugar pine, and white fir cone crops failed simultaneously in only 4 out of 16 years of record in a portion of the Sierra Nevada (Fowells and Schubert 1956).

Selection of Leave Trees

In selecting leave trees on partial cuttings, an important objective is to leave the most prolific seed producers. Highly significant differences in cone bearing between dominant full-crowned specimens in a single locale were demonstrated for all species included in this study. It is not the occurrence but the magnitude of the differences which are surprising.

The importance of care in selection of leave trees for maximum seed production, even when all are dominants, is illustrated in tables 9 and 10. For selected plots, trees were grouped by three criteria: (1) those most productive of cones over the period of record; (2) those largest in diameter; and (3) those of average cone productivity for the plot, presumably approximating what might be obtained from a random selection of dominant trees. Ten trees (table 9) simulates the number of dominants which might be left on an acre after heavy shelterwood cutting. Two trees per acre (table 10) is typical of a seed tree cutting.

If a forester selected, through some happy circumstance, the 10 trees most productive of cones, he might expect about twice as much seed over 4 or 5 years as would be produced by a random selection of dominants (table 9). On the study plots,

Table 8.--Yearly comparison of cone crop ratings between species as observed in the same general locality[1]

Locality and species[2]	1962	1963	1964	1965	1966	1967
Mount Baker:						
Pacific silver fir (Glacier Creek)	3	0	0	3	0	0
Mountain hemlock (Heather Meadows)	5	0	0	1	3	0
Stevens Pass:						
Noble fir (Tunnel Creek)	5	0	2	1	4	0
Pacific silver fir (Tunnel Creek)	–	0	0	3	0	0
Western white pine (Smithbrook)	–	–	2	3	2	0
Subalpine fir (Smithbrook)	–	–	4	2	0	0
Big Meadows Creek:						
Western white pine	0	0	5	0	0	0
Subalpine fir	–	0	5	2	0	0
Grand fir	–	0	5	0	5	0
Engelmann spruce	–	0	5	3	3	0
Stampede Pass:						
Noble fir	3	0	1	0	0	2
Pacific silver fir	1	0	0	0	0	0
Mountain hemlock	4	0	0	1	2	0
Mount Adams:						
Noble fir (Sleeping Beauty)	3	0	0	0	3	3
Pacific silver fir (Mosquito Lakes)	3	0	0	0	0	0
Mountain hemlock (Steamboat Mountain)	3	0	0	3	2	0
Western white pine (Peterson Prairie)	5	1	5	3	3	5
Grand fir (Peterson Prairie)	–	1	5	1	5	0
Subalpine fir (Steamboat Mountain)	4	0	1	3	1	1
Mount Hood:						
Noble fir (North Wilson)	1	0	0	0	0	3
Pacific silver fir (Timberline Road)	4	0	0	5	0	1
Mountain hemlock (Deadman's Curve)	4	0	0	4	0	0
Western white pine (Bear Paw)	4	1	5	3	1	3
Santiam Pass:						
Pacific silver fir	3	0	0	1	0	0
Mountain hemlock	5	0	0	1	0	0
Western white pine	4	3	5	3	1	5
Subalpine fir (Sand Mountain)	2	0	0	3	0	0
Engelmann spruce (Lost Lake Creek)	–	4	0	5	1	3
Willamette Province:						
Pacific silver fir (Wildcat Mountain)	5	0	0	5	0	1
Noble fir (Iron Mountain)	5	3	1	5	0	3
Mountain hemlock (Carpenter Mountain)	5	0	0	5	0	0
Western white pine (Lost Prairie)	–	2	2	4	0	4
Grand fir (Lost Prairie)	–	0	4	3	2	2
Windigo Pass:						
Shasta red fir	2	0	2	4	0	0
Mountain hemlock	5	0	0	3	0	0
Western white pine	5	0	4	4	1	2

[1] Crop ratings are 0 = failure, 1 = very light, 2 = light, 3 = medium, 4 = heavy, and 5 = very heavy.

[2] Where the plot name is different from the locality designation, it is given in parentheses.

Table 9.--Estimated total production of viable seed[1] on some plots by groups of 10 study trees selected by three different criteria

Species and plot[2]	Best cone producers	Largest d.b.h. trees	Average cone producers	Largest d.b.h. trees	Average cone producers
	Thousands of seed			*Percent of best producers*	
Noble fir, Willame Creek	994	817	575	82	58
Noble fir, Wildcat Mountain	879	813	472	92	54
Pacific silver fir, Timberline Road	201	168	133	84	66
Pacific silver fir, Iron Mountain	430	401	268	93	62
Mountain hemlock, Deadman's Curve	1,090	700	465	64	43
Western white pine, Windigo Pass	164	112	73	68	44
Subalpine fir, Steamboat Mountain	178	125	113	70	64
Grand fir, Big Meadows Creek	743	575	584	77	79

[1] Calculation of viable seed based on cone counts x conversion factor (to total cone production) x number of seeds per cone x percent viable seed according to the "Woody-Plant Seed Manual" (U.S. Forest Service 1948). Factors used were:

Species	*Conversion factor*	*Seeds per cone*	*Percent viable seed*
Noble fir	1.5	500	24
Pacific silver fir	1.7	400	22
Subalpine fir	1.7	150	38
Grand fir	1.7	200	28
Western white pine	1.5	120	48
Mountain hemlock	2.0	100	47

[2] Grand fir and western white pine data include a 4-year period; the remainder, a 5-year span.

Table 10.--Estimated total production of viable seed[1] on some plots by groups of two study trees selected by three different criteria

Species and plot[2]	Best cone producers	Largest d.b.h. trees	Average cone producers	Largest d.b.h. trees	Average cone producers
	Thousands of seed			*Percent of best producers*	
Noble fir, Willame Creek	269	156	115	58	43
Noble fir, Wildcat Mountain	329	268	94	81	29
Pacific silver fir, Timberline Road	51	34	27	67	52
Pacific silver fir, Iron Mountain	115	96	54	84	47
Mountain hemlock, Deadman's Curve	428	134	93	31	22
Western white pine, Windigo Pass	46	13	14	28	32
Subalpine fir, Steamboat Mountain	54	18	23	14	42
Grand fir, Big Meadows Creek	206	102	117	50	57

[1] Calculation of viable seed based on cone counts x conversion factor (to total cone production) x number of seeds per cone x percent viable seed according to the "Woody-Plant Seed Manual" (U.S. Forest Service 1948). Factors used were:

Species	*Conversion factor*	*Seeds per cone*	*Percent viable seed*
Noble fir	1.5	500	24
Pacific silver fir	1.7	400	22
Subalpine fir	1.7	150	38
Grand fir	1.7	200	28
Western white pine	1.5	120	48
Mountain hemlock	2.0	100	47

[2] Grand fir and western white pine data include a 4-year period; the remainder, a 5-year span.

selection of the 10 largest trees would have improved seed yields significantly over a random selection of trees (except in the case of grand fir at Big Meadows Creek). Cone production by the 10 largest noble and Pacific silver firs approached 80 to 90 percent of the yield of the most productive group of 10 trees.

With only two trees per acre left as a reserve, selection of the best seed producers was critical (table 10). Seed yields of the average producers were only 22 to 57 percent of the two most productive trees. Because the two biggest trees were not necessarily the most prolific, their selection as leave trees would have resulted in seed yields only slightly better than, or even inferior to, those obtained from a random selection of trees -- the average producers.

How can the forester identify the best cone producers when selecting leave trees in partial cuttings? The following guidelines may be helpful:

1. Select only dominant full-crowned trees. Specimens of other crown classes may provide shelter but will produce little or no seed.

2. If trees are being marked during a good seed year, select those with the greatest abundance of cones. With a few exceptions, trees that produced large numbers of cones during a good seed year were consistently top-ranking producers over the long run.

3. If marking is going on during a poor seed year, use other indicators of cone productivity -- spikes left from previous cone crops in crowns of true firs, old cones left in crowns of mountain hemlock, and old cones around the bases of white pines.

4. When marking for a shelterwood cutting, with 10 or more dominants as leave trees, a selection of the largest specimens will usually include a high proportion of the best cone producers. However, when only two leave trees per acre are required, use of diameter as a criterion of cone production may be a risky one and a poor substitute for carefully searching out the most prolific trees.

With care in selection of leave trees, the forester can greatly increase seedfall on his partial cuttings. This could greatly improve the chances for rapid natural regeneration.

CONCLUDING NOTE

Plans are to continue this study for many more years to strengthen information on cone crop periodicity of upper-slope species. Other aspects of seed supply under investigation are yearly variation in viable seed and damaging agents, total seed production of selected stands, and timing, distance, and direction of seed dispersal on cutover areas. Results of these studies will be related to fluctuations in cone crop levels found in this study.

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WILDERNESS USERS IN THE PACIFIC NORTHWEST - THEIR CHARACTERISTICS, VALUES, AND MANAGEMENT PREFERENCES

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Three general conclusions to be drawn from this study are:

(1) Respondents who were more wilderness-purist in their orientation, as measured by the wildernism attitude scale, often differed significantly in their attitudes from the attitudes expressed by other respondents. We suggest that the views of these purists represent the opinions of the group of people most perceptive of wilderness values and should receive added consideration, where appropriate, to prevent contemporary change in a resource legally established to endure for all time.

(2) There was little variation among the attitudes of visitors to the three different areas studied, despite alleged differences in the type of user characteristic of each area (one-day hikers, backpackers, and horse users, respectively). Our study thus indicated little support for different management policies in different areas, other than that necessary to adapt to obvious local conditions, such as terrain, access and weather.

(3) Many users indicated preferences for facilities and development that are essentially prohibited under the terms of the Wilderness Act. These desires, combined with the rapid increase in wilderness use and the implications of our data for continued increases in use, suggest the presence of a major problem. Use may eventually exceed the carrying capacity of classified Wilderness resources (particularly in specific locations), yet a great percentage of the users will not be seeking wilderness in the pure and precise sense defined in the Wilderness Act. This may indicate a need for additional back-country recreation areas that could be managed as semiwilderness, thereby reducing the pressure of overuse on classified wilderness and facilitating its protection. Such areas would permit more intensive management to provide for heavier use than can be allowed on legally classified Wilderness and would better satisfy the needs of the less wilderness-purist users. Provision for such areas would also provide for proper management of many controversial areas which are considered too small or are now used too intensely to be consistent with the objectives of protection under the Wilderness Act. It would provide an alternative in these cases where the choice is often popularly conceived as either Wilderness or multiple use classification in a mutually exclusive sense.

Cover:
We found that more than one-half of all wilderness use takes place in small family groups, and most of the remaining use is by small groups of close friends. Seventy percent of the users reported taking their first wilderness trip before they were 15 years old.

Contents

There are more than 4 million acres of classified and de facto wilderness on National Forest lands in Washington and Oregon, plus two National Parks with thousands of acres that may soon be classified as wilderness. This view is looking northwest up the Entiat River into the Glacier Peak Wilderness.

Introduction

The Need for Insight into Wilderness Users' Tastes and Preferences

Washington and Oregon contain 2,100,000 acres of National Forest land legally designated as Wilderness under the Wilderness Act of 1964 and approximately 2,000,000 additional acres of undeveloped back country. There are two National Parks within the State of Washington that include large undeveloped areas that may soon be legally classified as Wilderness. All of these areas are managed to preserve their natural conditions and to provide wilderness-type recreation opportunities for the public.

Officials charged with administering these areas are confronted with many problems. They must protect the physical resources from the effects of recreational use without altering the many esthetic dimensions of the wilderness environment. To carry out this responsibility, they must be sensitive to the aspects of wilderness valued by wilderness users, to their informal rules and customs, and to the reactions of these people to protective management measures.

This paper presents the results of a study to find out what kinds of persons visit wilderness, the values and codes of behavior they associate with wilderness use, and their feelings about some hypothetical policies and guidelines that might be used in the management of these areas. Long questionnaires concerning these issues were sent to a sample of 1,950 recorded wilderness users. An attitude scale included in the questionnaires was used to classify respondents on an attitude continuum, ranging theoretically from the wilderness-purists to those who were urban or convenience oriented. Respondents' attitude scores were then related to the rest of the questionnaire data to determine the extent to which wilderness-purists differed from other users. Not everyone who visits wilderness is a purist, and there are probably no wilderness users who are urban oriented in an absolute sense. But, there are relative differences in such orientations among wilderness users, and they are related to other differences in characteristics, behavior, and management preferences.

Wilderness Management--
Not A Majority Vote Problem

The Wilderness Act of 1964 defines management goals for areas classified by law as Wilderness. Provisions of the Act permit certain activities and prohibit others in the protection of these areas. To meet the preservation goals stated in the Act, some management latitude is allowed and the sound judgment of administrators is essential. To be effective, of course, wilderness managers' judgment must be based on thorough and accurate knowledge of the resources they manage, including the impact of various kinds and amounts of use on those resources. The soundness of management practices must ultimately be assessed in terms of consequences, not just good intentions. To be valid and effective, management decisions must consider the probable reactions of users to various efforts to channel their behavior in one way or another. Thus, wise wilderness management requires adequate and accurate information about the characteristics, tastes, and preferences of wilderness users.

It goes without saying that there are ecological and other considerations, including legal provisions and constraints, which have to be taken into account in prescribing wilderness management policy. Accordingly, **information about user behavior and attitudes does not operate in a vacuum and is not the sole or ultimate criterion with which to shape wilderness management decisions.** It must be seen in perspective, yet it must not be neglected.

The purpose of this bulletin is to provide useful information, and not in any sense to imply that wilderness management can or should be reduced to a popularity contest. Two points back up this fairly obvious criterion. First, as pointed out by Mills,[1] "needs and desires must be tempered by the ecological capability of the land." Second, to quote Burch (1966), "the forest camping system is like an omnibus – the seats are often full but occupied by different persons as they adjust to the flow of time." As these points suggest, the use of popular preference to guide wilderness management is limited by physical constraints and might lead to contemporary changes if emphasis is not given to purist versus popular points of view.

We thus qualified all of the data on user management preferences by using analytic techniques to identify differences between the attitudes of passionately devoted wilderness-purists and other visitors who may not be as devoted to wilderness values.

In addition, we isolated response by the different areas from which visitors were sampled to guard against generalizing about visitor reactions, which might have varied according to the characteristics of the areas.

The Outdoor Recreation Resources Review Commission (1962) discussed frequency of use as a measure of wilderness commitment and related some of their findings to this measure. We considered relating differences in user attitudes about wilderness behavior and management policies to a similar measure of wilderness experience. However, this would have introduced several methodological problems, such as accounting for the relationship between age and use; i.e., older users would have had more opportunity to accumulate wilderness experience than would younger users, although both might hold purist attitudes and values. In addition, the opportunity for wilderness experience is affected by income, vacation time, etc.

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[1] *Mills, Archie U. Back country and the hand of man. Paper presented at the national meeting of the American Society of Range Management, Seattle, Wash., February 1967.*

Figure 1. – Location of the three wilderness areas studied. A sample of visitors to these areas were asked to complete questionnaires regarding their wilderness experiences.

Visitors to Three Areas Were Studied

Three wilderness areas (fig. 1) were selected for the study, and questionnaires were sent to a sample of known visitors during the summer of 1965. The Glacier Peak Wilderness in Washington and the Eagle Cap Wilderness and the Three Sisters Wilderness in Oregon were chosen because they were the three most heavily used wilderness areas in the Pacific Northwest and each was reportedly dominated in use by a different type of visitor: backpackers, horseback riders, and 1-day hikers, respectively.[2]

The names and addresses of visitors who were to receive questionnaires were obtained

[2] *The designation of each area as characteristic of one type of use more than others was prompted by the frequent reference of administrators to such a classification and the results of an earlier study of visitors to the Three Sisters Wilderness (Burch 1964). However, our study indicated few instances where this classification accounted for variation in attitudes among users that was consistent with this perceived trend.*

Self-registration of all users is now required on all Forest Service wilderness and primitive areas in Washington and Oregon. The self-registration system provides better estimates of use and contributes to the safety of users. This study is based on a sample of 2,000 visitors drawn from self-registrations in the Eagle Cap, Glacier Peak, and Three Sisters Wilderness Areas.

from a random sample of cards deposited at the 76 self-registration stations located within the three areas. Tests of the effectiveness and representativeness of the self-registration system suggest that about 75 percent of all wilderness visitors register, with the nonresponse concentrated among horseback riders, fishermen, hunters, solitary visitors, and frequent or long-time visitors to the area (Wenger 1964a; Wenger and Gregersen 1964). Conversion factors have been computed to account for the under-representation of such visitors when compiling estimates of use. However, such adjustments are not possible in a questionnaire study and returns thus represent a sample of a sample.

The Glacier Peak Wilderness – A Backpacker's Favorite

The Glacier Peak Wilderness straddles the Cascade Range, approximately 100 miles northeast of Seattle, in the Mount Baker and Wenatchee National Forests of Washington. It is within 2 hours' driving time for the 1½ million persons living in the Puget Sound Basin.

Glacier Peak, the fourth highest peak in Washington, dominates the area, rising 10,528 feet above sea level. More than 30 other peaks rise from 5,000 to 8,800 feet above intervening valleys. Most of the higher peaks contain icefields, and more than 90 glaciers can be found in the area. The area includes timber types and plant communities characteristic of both the humid west side of the Cascade Range and the drier east side.

The 452,020-acre Glacier Peak Wilderness was formally established by the Secretary of Agriculture on September 6, 1960. When the Wilderness Act (Public Law 88-577) was passed by Congress and became effective on September 3, 1964, the Glacier Peak Wilderness was incorporated into the National Wilderness Preservation System.

There is access into the area on all sides from approximately 25 trails. Forest Service officials estimate that, in 1956, 2,875 persons visited the Glacier Peak area. Their estimates for 1958 indicated an increase to 3,200 visitors. In 1965, 25 self-registration stations were erected on trails inside the area. Adjusted data from visitor registrations at these stations indicated that 6,100 persons on foot and 1,300 horseback riders visited the area in 1965, for a total of 7,400 visits and almost 400,000 man-hours of use.[3] Thus, most but not all of the visitors to Glacier Peak are backpackers.

[3] U. S. Forest Service memorandum and accompanying tables, dated March 14, 1966, from George A. James to Philip L. Heaton, Assistant Regional Forester, Pacific Northwest Region, transmitting results of wilderness self-registration data for Washington and Oregon adjusted to account for known bias trends. For a discussion of self-registration bias, see Wenger (1964a) and Wenger and Gregersen (1964). A brief summary of their work is found in Morse (1966).

Looking northwest up the Napeequa River into the Glacier Peak Wilderness. Glacier Peak in the center, Clark Mountain on the left.

The rugged Glacier Peak Wilderness is particularly attractive for backpackers.

The North, Middle, and South Sisters dominate the north half of the Three Sisters Wilderness in central Oregon.

The Three Sisters Wilderness — A Day-Hiker's Area

The Three Sisters Wilderness straddles the Oregon Cascades, about 75 miles east of Eugene and 40 miles west of Bend, Oregon, on the Willamette and Deschutes National Forests. Its boundaries are within 3 hours' driving time of Portland, placing the area within easy reach of the city's approximately 600,000 people.

The main attractions of the area are three volcanic mountains known as the North, Middle, and South Sisters. All three exceed 10,000 feet in elevation and lie in a north-south line to form a portion of the Cascade divide. Another peak, Broken Top, is over 9,000 feet in elevation. The Wilderness contains 2,200 acres of glacier fields, the most extensive glaciers this far south in North America. Volcanic cinder cones are also scattered throughout the area. Lodgepole pine is the most extensive timber type, although both east-side and west-side vegetation and their subalpine plant associations are found in abundance.

The 196,708-acre Three Sisters Wilderness was established by the Secretary of Agriculture in 1957, after several years of study. The area is now included in the National Wilderness Preservation System under the Wilderness Act of 1964.

Access to the area is relatively easy, since its north boundary lies along the McKenzie

An earlier study found that the Three Sisters Wilderness was used predominately by 1-day hikers who lived within a few hours' drive.

Pass highway and numerous trails lead into the interior. A study of visitors to the area in 1962 indicated that almost 80 percent of the visitors stayed less than 1 day, about 90 percent of the registrants were from Oregon, and almost 60 percent lived within 60 miles of the area (Wenger 1964a and 1964b, Burch 1964).

In 1965, 35 self-registration stations were located within the area. Adjusted data from these self-registrations indicated that 10,800 hikers and 1,900 horseback riders visited the area – 12,700 visits accounting for approximately 400,000 man-hours of use. Wenger's study of the Three Sisters Wilderness indicated that in 1962, there were 20,000 visitors. Few persons would agree that use of the area is decreasing. The discrepancy may be due to incomplete administration of the registration system, which was introduced for the first time on a Region-wide scale in 1965. James points out, in his summary of 1965 use figures,[4] "the use estimates shown are undoubtedly low. Exactly how much low is not possible to determine. As an admittedly wild guess, I would say that the estimates might average 25 percent too low." The foregoing data and the stated opinions of administrators are the basis for our characterizing the Three Sisters Wilderness as a predominantly day-hiker area.

[4] *Ibid., footnote 3.*

Looking northwest over the Eagle Cap Wilderness. Left to right: Upper Lake, Lostine River Valley, Mirror Lake, Moccasin Lake, and Hurricane Creek Valley.

The Eagle Cap Wilderness – Favored by Horse Users

The Eagle Cap Wilderness lies in the Wallowa-Whitman National Forest in northeastern Oregon, about 75 miles southeast of Pendleton. The area is about a 6-hour drive from Portland, 3 hours from Boise, Idaho, and about 200 miles south of Spokane, Washington.

The Wallowa Mountains, where the area lies, are characterized by high alpine lakes and meadows, bare granite peaks and ridges, and U-shaped glaciated valleys with thick stands of timber. Elevation varies from 5,000 to almost 10,000 feet, Matterhorn Peak being the tallest at 9,845 feet. Nine peaks in the area are more than 9,000 feet in elevation. There are extensive stands of western larch and Engelmann spruce, although most of the area either is covered by subalpine timber types and grass or is barren.

In 1940, the Eagle Cap Primitive Area was reclassified by the Secretary of Agriculture as the Eagle Cap Wilderness. The 216,250-acre Wilderness is now part of the National Wilderness Preservation System under the Wilderness Act of 1964.

More visitors use horses (30 percent) in the Eagle Cap Wilderness than in any other in Washington or Oregon, but the opinions of most users from this area were no more favorable toward horses than those of users from the Glacier Peak or Three Sisters Wilderness.

Over 40 access trails lead into the area, but approximately 50 percent of the visitors enter from the Wallowa Lake trailheads. The Eagle Cap Wilderness is renowned for its horse users. We suspected that user opinions from this area would be markedly different as a result, but we found that they were not. There are no reliable use figures for the Eagle Cap Wilderness prior to 1965.

In 1965, 16 self-registration stations were established in the area. Data for that year indicated that 4,700 hikers and 2,300 horseback riders entered the area – 7,000 visits accounting for approximately 315,000 man-hours of use. The registration data indicate that in 1965 more persons used horses in this Wilderness than in any other Wilderness in the Pacific Northwest. In addition, administrators report that many of the hiking parties used packhorses. Thus, questionnaire responses by visitors to Eagle Cap might logically reflect horse-user sentiment and response of hikers to horse use more than responses from visitors to other Wilderness Areas, although to actually classify the Eagle Cap as a predominantly horse-users' area would be incorrect.

Questionnaires--
The Basic Research Tool

Data on the characteristics, attitudes, and management preferences with which this study is concerned were solicited by means of an eight-page questionnaire. The questionnaire called for response to 150 individual items. In spite of the length, **70.9 percent of the questionnaires were returned** with but one followup post card being sent. This is an exceptionally high rate of return, but typical of many outdoor recreation user studies. **It testifies to the interest, concern, and involvement of wilderness users with the management of these areas.**

Some other studies experiencing high rates of questionnaire return from wilderness users are: Sommarstrom,[5] 75-percent return with no followup post card from a sample of Olympic National Park back-country users; Burch and Wenger (1967), 89.7-percent return of a seven-page questionnaire from a sample of visitors to the Three Sisters Wilderness and adjacent auto campgrounds with two followup post cards; Hendee,[6] 60-percent return of a 13-page questionnaire sent to visitors recorded in two National Park back-country and three National Forest wilderness areas in western Washington, with no followup post card; and Lucas (1964a), 79-percent return of forms left on parked cars adjacent to the Boundary Waters Canoe Area.

The questionnaire used in this study was composed of six separate parts, all included in a 7- by 8½-inch booklet, eight pages in length. Part I contained a list of 20 possible features that might or might not exist in "remote back country of wilderness character." Part II was a list of 20 activities in which users might or might not expect to engage in wilderness-type areas. Part III listed 20 alleged benefits that might or might not be anticipated by wilderness users. In each of these sections, respondents were asked to indicate the degree of rejection or acceptance of each item by circling a number from -4 to +4.

Part IV listed 22 statements about rules and customs that wilderness users might feel obligated to observe in remote back country. Part V was a series of 53 statements suggesting policy and management guidelines relating to the administration of wilderness areas. In these latter two parts, respondents were asked to indicate their attitudes by circling symbols (SA, A, N, D, SD), which showed how strongly they agreed or disagreed with the questionnaire statements. Part VI requested extensive background information.

A total of 1,964 questionnaires were mailed to a random sample of individuals registering at the three areas – 1,348 questionnaires were completed and returned. Only 62 were returned unopened due to incomplete or nonexistent addresses. This low number of "duds" testifies to the reliability of the self-registrations. A total of 514 returns were received from individuals who were recorded in the Three Sisters Wilderness, 490 from visitors to Glacier Peak, and 344 from registrations in the Eagle Cap Wilderness. The percentage of returns was approximately the same from visitors to each of the three separate areas.

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[5] *Sommarstrom, Allan Ralph. The impact of human use o[n] recreational quality: the example of the Olympic Nation[al] Park back country user. 1966. (Unpublished master's thes[is] on file at Univ. Wash., Seattle.)*

[6] *Hendee, John C. Recreation clientele – the attributes o[f] recreationists preferring different management agencies, c[ar] campgrounds, or wilderness in the Pacific Northwest. 196[7]. (Unpublished doctoral dissertation on file at College of Fo[r]est Resources Library, Univ. Wash., Seattle.)*

Part I

Demographic Characteristics of the Wilderness Users

Data were collected on a number of background attributes of wilderness users: age, education, marital status, number of children, environment of upbringing, voluntary association with conservation groups or outdoor clubs, amount of back-country recreation experience during the previous year, age at time of first trip into a wilderness-type area, and the number of close friends who also are wilderness users. This information can be important to planners and managers who must try to project increases in use and infer wilderness user expectations. The data also indicate which segments of society are motivated to participate in wilderness recreation and suggest some trends in the pattern of individuals sharing these qualities.

Age

The persons responding to the questionnaire were individuals registering as heads of the parties at the self-registration stations. The age distribution of these respondents is given in table 1 and compared with the United States population. It was not surprising that **wilderness users were mainly young to middle-aged adults, although all age groups were represented.** The majority were between 25 and 54 years old, but the 16- to 18- and

Wilderness users are typically young to middle-aged adults, but older users are frequently encountered. Hikers near Cascade Pass in the Glacier Peak Wilderness.

Table 1. – Age distribution of visitors to the Glacier Peak, Three Sisters, and Eagle Cap Wilderness Areas during 1965 compared with U. S. population

Item	Age groups (years)							
	0-15	16-18	19-24	25-34	35-54	55-64	65+	Total
	Percent							
Wilderness users	3.1	6.7	12.1	24.4	46.2	5.7	1.7	100
U.S population (1960)[1]	32.8	3.7	7.8	12.8	24.0	8.7	9.2	100

[1] *U. S. Bureau of the Census 1964; figures for the three youngest categories were interpolated to fit appropriate age designations.*

This distribution is comparable with results of other studies of wilderness users (Outdoor Recreation Resources Review Commission 1962; Burch 1966; Hendee, see text footnote 6, p. 10).

19- to 24-year age classes were also overrepresented when compared with the United States population. It should be noted that 36.5 percent of the United States population in 1960 had not yet reached 19 years old, which is the age when wilderness participation significantly increases, and 32.8 percent had not yet reached 15 years. This suggests a substantial increase in the numbers of persons in the age groups containing potential wilderness users within the next decade.

Education

Wilderness users have been found to be a special group in that most of them are highly educated, more so than other recreationists. This pattern prevailed among the wilderness visitors responding to our questionnaire. Table 2 gives the distribution by educational attainment of wilderness users for this study and also for several other studies. These data indicate quite convincingly that people who have had at least some college experience are far more likely to be wilderness users than are persons with but a high school education or less, and persons with postgraduate educations are even more likely to visit wilderness. In fact, a composite review of table 2 indicates that **more than 60 percent of the respondents included in these wilderness-user studies come from less than the top 10 percent of the U. S. population in terms of educational attainment.** The growing number of persons moving into upper educational levels may account, in part, for the fact that wilderness use is increasing at much faster rates than other types of outdoor recreation.

Another proposition is that appreciation of wilderness values is diffusing downward in society, also accounting for part of the increase in use. A trend of lower education levels among wilderness users would support this proposition. The two oldest studies reported in table 2 date back only to 1960-61, but they do indicate a higher percentage of college-educated users than dc more recent studies.

We do not feel this clearly substantiate: the proposition because many intervenin factors could account for the pattern; e.g. differences in study methodology, geographi cal location, etc. However, it is a small piec of evidence of the kind researchers migh accumulate over time to determine if dowr ward diffusing values are associated with th increasing use of wilderness.

Table 2. – Comparison of educational attainment of national and regional populations and of wilderness users in several studies

Item	Educational attainment			
	High school or less	College graduate or some college	Postgraduate work	Total reporting
	Percent			*Number*
U. S. population, 1960[1]	92.3	7.7		—
Washington and Oregon population, 1960[2]	90.9	9.0		—
Eagle Cap Wilderness, Oregon[3]	37.9	38.0	24.1	343
Three Sisters Wilderness, Washington[3]	36.1	33.5	30.4	513
Glacier Peak Wilderness, Washington[3]	35.0	36.0	29.0	490
Eagle Cap, Three Sisters, and Glacier Peak Wilderness combined[3]	36.2	35.6	28.2	1,346
High Sierra Wilderness, California, 1960[4]	18.0	49.0	33.0	179
Boundary Waters Canoe Area, 1960-61[5]	21.0	54.0	24.0	—
Three Sisters Wilderness and Mountain Lakes Wild Area, 1962[6]	35.9	32.7	31.4	474
National Forest Wilderness users, 1966[7]	34.6	35.4	30.0	848

[1] *U. S. Bureau of the Census (1964).*
[2] *U. S. Bureau of the Census (1962a, 1962b).*
[3] *From study reported in this paper.*
[4] *Outdoor Recreation Resources Review Commission (1962).*
[5] *Includes data for paddling canoeists only as opposed to motor canoeists, auto and boat campers, resort guests, private cabin and day users. Paddling canoeists are inferred to be wilderness users comparable to those classified as wilderness-purists in our study (Lucas 1964b).*
[6] *Data are for respondents classified on the basis of their previous 5-year camping experience as remote (only) campers and combination remote and easy-access campers (Burch and Wenger 1967).*
[7] *Data from sample of persons recorded in three National Forests and two National Parks in western Washington, who specified National Forest wilderness as their preferred camping environment (see text footnote 6, p. 10).*

About one-half of all wilderness use is by small family groups. Couples with children are overrepresented among wilderness users, compared with the censused population. Here, the author's family takes a rest on a trail in the Glacier Peak Wilderness.

Marital Status and Number of Children

Nearly one-fourth of the respondents were single, 75.3 percent were married, and the remaining 1.9 percent were separated, widowed, or divorced. These figures are comparable with the ORRRC (1962) study and a more recent study that included wilderness users from three areas in Washington State (see footnote 6, p. 10).

Of the married respondents, 15.2 percent had no children, 34.5 percent had one child, 41.0 percent had two or three, 7.7 percent had four or five, and 1.7 percent had six or more. This distribution is consistent with the inference made in an earlier study by Burch (1966) that "parents who adopt . . . the more demanding camping styles may very likely have young children." Even though preferences may shift, as Burch suggested, from remote camping to easy-access camping (or a combination of the two) and subsequently back to remote camping as families progress through the stages of the family life cycle, it is clear from both his study and ours that **couples with children visit wilderness far more frequently than childless couples**. Childless couples are very much underrepresented among wilderness users (table 3) compared to the censused population of Washington and Oregon while couples with one and two or three children are overrepresented.

Table 3. – Number of children for married wilderness users and Washington and Oregon population by study areas

Item	Number of children					
	None	1	2-3	4-5	6+	Total
	Percent of total					*Number*
Glacier Peak, Eagle Cap, and Three Sisters Wilderness users	15.2	34.5	41.0	7.7	1.7	877
Three Sisters Wilderness users, 1962[1]	14.5	11.7	52.0	19.6	2.1	469
National Forest Wilderness users, self-designated, 1966[2]	19.3	11.4	48.1	18.5	2.8	608
1960 census Oregon population[3]	36.6	19.6	32.5	11.4		459,812
1960 census Washington population[4]	35.1	20.0	33.2	11.6		724,685

[1]*Burch (1966; see table 3, p. 608). Data from this study are for respondents designated on the basis of their previous 5-year camping patterns as remote-only campers and combination remote and easy-access campers.*

[2]*See text footnote 6, p10.*

[3]*U. S. Bureau of the Census (1962a).*

[4]*U. S. Bureau of the Census (1962b).*

Favored Company

The questionnaire also revealed that 47.6 percent of the users usually engaged in wilderness recreation with their families only, 38 percent usually visited wilderness with their friends, 7.7 percent with organized groups, and only 6.6 percent commonly went into the wilderness alone. Together, the foregoing items indicate that **about one-half of all wilderness use is by small family groups, and much of the remainder is by small clusters of friends.** Thus, it can be said that the **wilderness experience is typically sought in the company of a few intimates.** A partial explanation from this phenomenon may be the benefits stemming from the simplified role playing, reduced status seeking, and interpersonal competition prevailing in such a group and the resulting feeling of solidarity among group members as they meet the challenge of distance, time, terrain, and weather (McKinley 1966).

The intimate composition of the typical wilderness party was identified by Stone and Taves (1956) as a potential source of therapeutic values from wilderness. They observed that "Among many psychiatrists and social psychologists, mental health is apprehended as a function of one's interpersonal relations. The family and the friendship (group) are crucial interpersonal relations in this respect.

Visits by organized groups make up less than 10 percent of all wilderness visits in the Pacific Northwest. Here, Trail Riders of the Wilderness cross meadows in Cloudy Pass in the Glacier Peak Wilderness.

Consequently, to strengthen such groupings – which sociologists find to have been weakened by the impact of industrialization and city living – may be . . . important for therapy and even the prevention of mental disturbance . . . certainly the wilderness experience extends the opportunity for strengthening intimate social bonds . . . ." This aspect of wilderness visitation deserves serious study by competent researchers.

Environment of Upbringing

Respondents were asked where they were mainly brought up: "a city," "a small town," or "a rural area," and their collective responses are given in table 4. The respondents were given no clues as to what constituted the three categories.

The ORRRC (1962) study of wilderness users revealed that visitors to such areas tended to be both city bred and more likely to reside in urban areas, although Burch and Wenger (1967) found childhood residence and camping style unrelated. We do not have data on the current residence of users in our study, and our data on environment of upbringing do not reveal as sharp a trend toward urban upbringing. We can conclude, on the basis of our data, only that wilderness use is about equally common among persons of either rural, small town, or urban upbringing. What is significant is that our increasingly urban culture produces persons motivated to use wilderness. Later in this report, we introduce evidence that wilderness users reared in urban areas tend to be more wilderness-purist in outlook than do those reared in rural areas.

Wilderness trips offer unique opportunities for strengthening bonds between family and friendship groups.

Table 4. — Environment of upbringing of wilderness users

Wilderness area	Childhood residence		
	Rural	Small town	City
	Percent of respondents		
Eagle Cap	32.1	42.1	25.9
Three Sisters	29.6	36.6	33.8
Glacier Peak	30.6	37.7	31.5
All three areas	30.6	38.5	30.9

Age of First Exposure to Wilderness-Type Recreation and Number of Close Friends Who Are Also Wilderness Users

Respondents were asked how old they were at the time of their first trip to a back-country area. **Nearly 70 percent indicated their first trip was before they were 15 years old. Forty-four percent of the respondents also indicated that three or more of their five closest friends participated**, at least occasionally, **in wilderness-type recreation.** This evidence suggests that **wilderness values tend to be developed early in life and continue to be reinforced through social behavior later in life.**

Lucas (1964a), in his study of visitors to the Boundary Waters Canoe Area, found 38 groups containing persons who had come to that area in their youth as campers at one of the nearby organizations of private camps, and that two-thirds of these groups were paddling canoeists. All of the camps stress paddling canoe trips. The fact that two-thirds of these persons returned to the area for the same type of experience is an example of the strength of early learned values concerning wilderness. The ORRRC study (1962) found that the greater the social reinforcement through family and friends, the greater the commitment to wilderness use. The strong socialization of wilderness values may explain the intense involvement of wilderness users in preservation issues concerning such areas and their tendency to affiliate themselves with organized groups dedicated to common goals.

The data from our study take on added meaning when compared with recent findings of Burch and Wenger (1967). They found that persons who did not begin to enjoy the out of doors before they were 19 were most likely to be easy-access campers rather than remote or combination (remote and easy access) campers. Persons in their sample with childhood hiking experience were more likely to be remote or combination (remote and easy access) campers rather than exclusively easy access campers. They concluded from this and other evidence that recreationists tend to continue in the patterns learned in childhood. Our data clearly confirm this trend.

In summary, most wilderness use is by small family groups who are more likely to have children than the censused population. Nearly 70 percent of all visitors took their first wilderness trip before they were 15 years old; other studies suggest that **recreation patterns of adults are clearly linked with childhood experiences.** These findings combine to suggest, perhaps more clearly than any other, that **increases in wilderness visitation will continue as current wilderness users cultivate another generation with primitive camping tastes.**

The most common method of wilderness travel in the Pacific Northwest is by foot. Here, travelers nurse blisters from a day's hike in the Glacier Peak Wilderness.

Membership in Conservationist Groups and Outdoor Clubs

When respondents were asked if they belonged to any conservationist organizations or outdoor clubs, **30 percent reported that they belonged to at least one.** One of the interesting results was the wide variety of organizations that were perceived by respondents to fall under the heading of conservationist organizations or outdoor clubs. Membership in **80 different groups was reported under the heading of "conservationist organizations," and membership in 154 different groups was reported under "outdoor clubs."** Many groups were reported under both headings, but, amazingly, **218 different groups were mentioned by the 408 persons who were members.**

Table 5 gives the percentage of respondents reporting membership in conservationist organizations and outdoor clubs for each of the three areas studied. Readers should be aware that the percentage of all wilderness users who belong to such groups is probably less than reflected in table 5. Members of conservation groups were, no doubt, more likely to respond to the questionnaire than were nonmembers and were possibly overrepresented in the trail registrations to which questionnaires were sent.

Two other studies have reported somewhat higher percentages of wilderness-user membership in conservation groups. In the ORRRC (1962) study of visitors to the High Sierra Wilderness during 1960, 35 percent of the persons interviewed reported membership in "outdoor clubs or conservation organizations." In Merriam and Ammons' (1967) study of Montana wilderness users, 28 of the 77 persons (36 percent) interviewed in the Bob Marshall Wilderness and the Mission Mountains Primitive Area belonged to what they classified as fish, game, and wildlife groups or to four specific groups that we would classify as conservationist organizations.

Table 6 indicates the 13 most frequently mentioned groups, number of times membership in each was reported under the heading of conservationist organization," number of times reported under the heading of "outdoor club," and total number of wilderness visitors reporting membership in a group, irrespective of the heading under which it appeared. The latter figure is adjusted downward to account for the number of times identical respondents reported membership in the group under both "conservationist organization" and "outdoor club" headings.

Table 6 indicates that the nationally known groups were more frequently mentioned than regional or local groups. In fact,

Table 5. – Wilderness-user membership in conservationist organizations and outdoor clubs, by wilderness areas[1]

Areas where respondents were recorded	Membership in conservationist organization	Membership in outdoor club	Membership in either conservationist organization or outdoor club
	Percent		
Eagle Cap Wilderness	13.7	20.6	25.3
Three Sisters Wilderness	19.3	25.7	32.3
Glacier Peak Wilderness	17.6	29.0	31.8
All three areas	17.2	25.6	30.3

[1] *Total number of respondents = 1,348.*

about 40 percent of the members (almost 12 percent of our respondents) belonged to the national groups logically perceived as conservationist organizations (Sierra Club, Wilderness Society, Natl. Wildlife Federation, Izaak Walton League, National Parks and Recreation Association, Audubon Society). However, membership in all of these national groups combined made up less than one-quarter of all memberships reported since many respondents belonged to more than one group. Members of regional groups were recorded most in the area closest to their headquarters; i.e., Mountaineers and North Cascade Conservation Council members were found in the Glacier Peak Wilderness, Mazamas in the Three Sisters Wilderness, etc.

The fact that membership in conservation groups was concentrated among smaller regional and local activity-oriented groups rather than larger politically powerful national groups may be significant. It is

Table 6, – Wilderness-user membership in the most frequently mentioned groups reported as conservationist organizations or outdoor clubs

Name of group	Member of conservationist organization	Member of outdoor club	Member of either conservationist group or outdoor club
	Number	*Number*	*Number*
Mountaineers	18	54	57
Sierra Club	40	42	49
Boy Scouts of America	17	43	42
Wilderness Society	37	4	39
North Cascades Conservation Council	36	2	34
Mazamas	13	34	33
National Wildlife Federation	32	1	30
Federation of Western Outdoor Clubs	21	9	24
Izaak Walton League	11	8	16
National Rifle Association	5	13	15
Obsidians	1	13	12
National Parks and Recreation Association	11	0	11
Audubon Society	11	4	11
295 other groups	107	237	309
Total memberships	253	464	682

[1] *Based on 408 respondents who reported belonging to such groups out of sample of 1,348 wilderness users.*

unlikely that membership in the national groups occurs spontaneously. Such memberships may stem from a steppingstone type of process, whereby persons first join an activity-oriented local group, learn the appropriate values, and subsequently expand their involvement in the conservation movement by joining one of the larger national organizations. If such a steppingstone proposition is plausible, then membership in the larger groups is likely to expand greatly in the future, since the smaller activity-oriented groups now encompass a majority of the persons affiliated with organized groups. This topic deserves serious study considering its implications for wild-land management.

Further analysis of the data indicated that predominantly urban bred residents belong to "conservationist organizations" or "outdoor clubs." Compared with other wilderness users, members also make more wilderness visits and longer visits. They are more likely to visit wilderness with organized groups than are nonmembers and are also more likely to have close friends who are wilderness users. They are also slightly better educated. They were also found to have a more wilderness-purist orientation toward wild-land recreation than nonmembers.

Average Number of Trips and Average Length of Trips

Table 7 indicates the average number of trips into remote back country of wilderness character and the average length of stay during 1965 by respondents recorded in each of the three areas.

The average respondent participated in wilderness-type recreation about 6.3 times in 1965 for approximately 2.3 days each trip, accounting for an average of 14.5 man-days of use per respondent. This is a considerable amount of time to spend on such an activity, particularly since almost all of it must be spent during the summer months. The wilderness-use figures may be affected somewhat by nonresponse bias, since we might logically assume that the 70 percent of the persons who responded are the most frequent and dedicated users. The figures might also be subject to a prestige bias, since these users are normally anxious to credit themselves with experience. However, even if one assumes some bias, it is clear that wilderness use in the Pacific Northwest takes place in several short trips rather than one or two long trips. In addition, if we assume that respondents are more frequently visitors to the specific areas in which they were sampled, the Glacier Peak and Three Sisters Wilderness areas, respectively, seem to be used for more numerous short trips than does the more isolated Eagle Cap Wilderness.

The pattern of short frequent trips revealed in our study is also supported by other studies. We have already mentioned that almost 80 percent of the visitors to the Three Sisters Wilderness in 1962 were found to hike in and out of the area the same day (Wenger 1964b). A recent questionnaire study of wilderness users and car campers sampled in two

Table 7. – Average number of trips into wilderness-type areas in 1965 and length of stay by respondents from three areas

Area where respondents were recorded	Average number of trips	Average length of trips	Number of respondents
		Days	
Eagle Cap Wilderness	5.2	3.0	343
Three Sisters Wilderness	6.2	2.2	504
Glacier Peak Wilderness	7.1	2.2	485
All three areas	6.3	2.3	1,332

National Parks and three National Forests in Washington State revealed that the 1,300 respondents stating a preference for wilderness-type recreation averaged 4.8 trips for 2.3 days per trip in such areas during 1966 (see footnote 6, p. 10). It would be dangerous to generalize these findings to other areas of the country, but on the basis of these three studies, **wilderness visits in the Pacific Northwest appear to be more frequent and of less duration than previously anticipated.**

Merriam and Ammons (1967) found a somewhat different pattern in interviews with 108 visitors to the Bob Marshall Wilderness, the Mission Mountain Primitive Area, and back country in Glacier National Park. Visitors to the Bob Marshall stayed an average of 8 days, those to the Mission Mountain Primitive Area and Glacier National Park 2 days and 4 days, respectively. No data were cited concerning the number of trips. They attributed differences in the length of stay to variation in the size and accessibility of the areas.

Stone and Taves (1956) found the mean, median, and modal length of trips in the Boundary Waters Canoe Area to be 6½ days in an informal study of 21 camping parties. Several years later, in a much more systematic study of the Boundary Waters Canoe Area, Lucas (1964a) found the average length of stay to be about 1.75 days, compared with an estimate of 5.0 days by Forest Service officials.

Studies such as we have cited provide wilderness-use information at one moment in time for only a few areas. Such data may help managers make better estimates where there are no provisions for measuring use. Proof of this are wide discrepancies that have been found between estimates of use based on study samples and previous intuitive estimates of wilderness managers. Decisions involving the protection, management, and even the allocation of wilderness-type areas depend on accurate estimates of use, and the previously relied upon intuitive methods are no longer adequate. We urge resource managers to conscientiously utilize some type of system to measure use, such as self-registration stations, for all wilderness-type areas. The information is basic to management of the wilderness recreation resource just as scaling logs is to the management of the timber resource.

A Summary of Wilderness-User Characteristics and Their Implications

The foregoing information on the demographic characteristics of wilderness users indicates that they tend to be young to middle-aged adults and highly educated, with more than 60 percent coming from less than the top 10 percent of the U. S. population in terms of educational attainment. Three-fourths of them were married and most of these had children. About one-half of all wilderness use appears to be by small family groups and much of the remainder by small clusters of friends. Wilderness use appears to be about equally common among persons raised in cities, small towns, or rural areas, but the most wilderness-purist respondents were more likely to have been raised in urban settings than in rural areas. More than 65 percent of our respondents reported taking their first wilderness trip before they were 15 years old. Nearly half of our sample reported that three or more of their five closest friends were also wilderness users. This clearly suggests that wilderness values are developed early in life and continue to be reinforced through social behavior later in life.

Thirty percent of our respondents reported belonging to at least one conservationist organization or outdoor club and, amazingly, membership in 218 different groups was reported. Despite the fact that about 40 percent of the members belonged to conservationist organizations national in scope, membership in these groups made up only about one-quarter of all memberships reported since it was common for persons to belong to more than one group. **Wilderness users belonging to organized groups were more likely to be urban bred, to make more wilderness visits and longer visits, to be better educated, and to have a more wilderness-purist point of view.**

The average respondent participated in wilderness type recreation about 6.3 times in 1965 for approximately 2.3 days each trip. This and evidence from other studies clearly indicate that **wilderness use in the Pacific Northwest is characterized by several short trips rather than one or two long trips per year.**

These findings suggest that **wilderness visitation will continue to increase** because: (1) wilderness users typically have those characteristics becoming more common in our society; (2) users tend to be married, with children; (3) wilderness visitation is a continuation of patterns learned in childhood; e.g., nearly 70 percent took their first wilderness trip before they were 15 years old. We should emphasize that the anticipated increase will be a continuation of recent trends and a realization of former projections rather than a new development (Lucas 1966a, The North Cascades Study Team 1965, ORRRC 1962). The problem is one of accommodating increased use on limited resources while preventing declines in quality from overuse. This will be a challenging task for wilderness managers.

Part II

Differentiating Wilderness Users By Their Attitudes

The demographic characteristics of users identified in the foregoing section are important because they enable us to better predict future wilderness use. They also allow us to infer certain visitor expectations based on the characteristics of these persons. But there is another more subtle characteristic of such users that is even more vital in explaining their behavior and expectations; that is, the shared value system governing their attitudes and motivation to visit wilderness. If recreation users can be differentiated as to the degree they possess wilderness-oriented values, as well as by their characteristics, then the possibility of predicting reactions to management policies and inferring tastes and preferences is greatly enhanced. For this reason, we attempted to measure the wilderness-purist tendencies of the respondents in this study by using an attitude scale.

Using the scaling technique subsequently described, we were able to identify a hierarchy of wilderness users ranging from wilderness-purists to those more urban or convenience oriented. In developing such a classification of users, we had a very practical purpose in mind. We wanted to be able to correlate a person's wilderness-purist tendencies with his reactions to the suggested management policies and behavior norms that were included in the questionnaire. We also wanted to find out to what degree some of the demographic characteristics of users were actually related to wilderness-oriented attitudes and to try to get some better insights into the value system underlying wilderness use.

Our development of a classification of wilderness users is unique only in the sense that we specifically designed an attitude scale with which to build our hierarchy. Several researchers have used their results, and sometimes their intuition, to infer categories of wilderness users which they felt to hold certain values in common. The work of these persons will be reviewed, but only after presenting our method and its results so that meaningful comparisons can be made.

Development of a Wildernism-Urbanism Testing Instrument

Through discussion and pretesting, we devised a set of 60 short questions relating to wild-land recreation values that might be held more intensely by persons with wilderness-purist tendencies than by persons who, although they visited wilderness, held less extreme concepts of such values or held different values. The questions suggested **20 hypothetical liked or disliked features of wilderness-type areas, 20 activities deemed appropriate or inappropriate to wilderness-type areas, and 20 benefits that might or might not be obtained from recreation in remote back country of wilderness character.**

It was necessary to use the cumbersome phrase, "remote back country of wilderness character," throughout the questionnaire to avoid implying that the researchers in any way contemplated nonconforming uses of legally designated wilderness areas. In this report, the term "wilderness-type area" is used interchangeably with "remote back-country recreational area," "remote back country of wilderness character," etc. The necessity of using such a phrase was unfortunate in that some misunderstanding or bias may have resulted.

The items called for response on a 9-point scale, ranging from "strongly dislike" (-4) to "strongly favor" (+4). To simplify computations, these numerical responses were later translated so that they ranged from +1 to +9. The questionnaire items were selected so that those persons with the most extreme wilderness-purist concepts would respond extremely positively or extremely negatively, depending on the item. Conversely, those persons with extreme urban - or convenience - oriented concepts would respond at the opposite end of the scale for each item. The responses could then be cumulatively scored, the total score indicating the relative degree to which respondents were wilderness-purist or urban oriented. We designated those persons with wilderness-purist tendencies as "wildernists" (a contraction of the term "wilderness-purist") and urban- or convenience-oriented respondents as "urbanists." These contractions led us to refer to our attitude scale as the wildernism-urbanism scale because of the polar extremes of the attitude continuum being measured. Henceforth in this report, **when we refer to the "more wildernist respondents," we mean those who were more wilderness-purist because they had high wildernism scores.**

Although there were 60 items in the questionnaire that suggested features, activities, and potential benefits to be derived from wilderness use, we found, of course, that some of the items were far more effective in differentiating wildernists from urbanists. We related responses to each item to the cumulatively scored responses for all of the items using a statistical measure of association called gamma.[7]

Gamma might be compared, for simplicity's sake, to a squared correlation coefficient. It varies between -1.0 and +1.0 and indicates the proportional reduction in error one could achieve in predicting rank order variation in wildernism scores from knowledge of response to one scale item over the errors one would make in trying to predict total scores without knowledge of response to that item (Goodman and Kruskal 1954, Costner 1965). We eliminated all items which achieved a gamma statistic of less than ± 0.50 and thus reduced our wildernism testing instrument from 60 to 30 items. Listed below are the 30 items in our shortened and improved scale and the gamma statistics indicating their degree of association with scores compiled from the original 60 wildernism items. They are arranged in order from the highest positive gamma to the lowest negative gamma which indicates the relative degree of acceptance or rejection of the items.[8]

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[7] *We used "gamma statistics" rather than the more complex "item analysis" because of limitations in the computer program and the fact that gamma indicates the degree to which prediction errors can be reduced by virtue of the association between the two variables being considered; i.e., responses to individual items and total scores (Costner 1965).*

[8] *Readers, wishing to score themselves on the wildernism scale, should assign the numbers 1, 2, 3. . . 9 to -4, -3, -2 . . . +4, respectively, for the positively correlated items and assign the numbers 9, 8, 7. . . 1 to -4, -3, -2 . . . +4, respectively, for the negatively correlated items. Add the assigned numbers for all of the appropriately marked responses, divide by 30 or the number answered, and multiply by 10 to determine the total wildernism score. Refer to table 8 to see how the score compared with respondents sampled in this study.*

Wildernism-Urbanism Attitude Test

For each item in the following list of possible features, activities or benefits associated with wilderness-type recreation, circle one number that best expresses your attitude – how positive or how negative you feel toward having that feature, participating in that activity or receiving that alleged benefit from such experience.

Gamma statistic	Questionnaire item	Strongly dislike			Neutral			Strongly favor		
.75	Camping (backpacking)	-4	-3	-2	-1	0	1	2	3	4
.68	Tranquility	-4	-3	-2	-1	0	1	2	3	4
.68	Sleeping outdoors	-4	-3	-2	-1	0	1	2	3	4
.68	Hiking	-4	-3	-2	-1	0	1	2	3	4
.67	Solitude	-4	-3	-2	-1	0	1	2	3	4
.65	Enjoyment of nature	-4	-3	-2	-1	0	1	2	3	4
.65	Awareness of beauty	-4	-3	-2	-1	0	1	2	3	4
.64	Alpine meadows	-4	-3	-2	-1	0	1	2	3	4
.63	Absence of manmade features	-4	-3	-2	-1	0	1	2	3	4
.64	Drinking mountain water	-4	-3	-2	-1	0	1	2	3	4
.60	Virgin forest	-4	-3	-2	-1	0	1	2	3	4
.56	Lakes (natural)	-4	-3	-2	-1	0	1	2	3	4
.56	Timberline vegetation	-4	-3	-2	-1	0	1	2	3	4
.56	Vast area and enormous vistas	-4	-3	-2	-1	0	1	2	3	4
.54	Physical exercise	-4	-3	-2	-1	0	1	2	3	4
.53	Rugged topography	-4	-3	-2	-1	0	1	2	3	4
.53	Native wild animals	-4	-3	-2	-1	0	1	2	3	4
.53	Looking at scenery	-4	-3	-2	-1	0	1	2	3	4
.52	Emotional satisfaction	-4	-3	-2	-1	0	1	2	3	4
-.54	Cutting Christmas tree	-4	-3	-2	-1	0	1	2	3	4
-.58	Camps for organizations	-4	-3	-2	-1	0	1	2	3	4
-.59	Gravel roads	-4	-3	-2	-1	0	1	2	3	4
-.66	Private cottages	-4	-3	-2	-1	0	1	2	3	4
-.66	Purchasing souvenirs	-4	-3	-2	-1	0	1	2	3	4
-.66	Camping (with car)	-4	-3	-2	-1	0	1	2	3	4
-.69	Equipped bathing beaches	-4	-3	-2	-1	0	1	2	3	4
-.69	Automobile touring	-4	-3	-2	-1	0	1	2	3	4
-.71	Powerboating	-4	-3	-2	-1	0	1	2	3	4
-.71	Campsites with plumbing	-4	-3	-2	-1	0	1	2	3	4
-.71	Developed resort facilities	-4	-3	-2	-1	0	1	2	3	4

The foregoing 30 items were used to calculate the wildernism scores used in this publication. The 30 questionnaire items that were not as strongly associated with total scores (those achieving gamma statistics of less than ±.50) are tabulated below.

Questionnaire Items From the Wildernism-Urbanism Scale Which Were Dropped Because They Did Not Contribute Enough to Total Scores (Gamma Statistics Less Than ±.50)

Wilderness features		Strongly dislike			Neutral			Strongly favor	
Unchanged natural coastlines	-4	-3	-2	-1	0	1	2	3	4
Reservoirs (manmade)	-4	-3	-2	-1	0	1	2	3	4
Waterfalls and rapids	-4	-3	-2	-1	0	1	2	3	4
Campsites with outhouses	-4	-3	-2	-1	0	1	2	3	4
Remoteness from cities	-4	-3	-2	-1	0	1	2	3	4
Absence of people	-4	-3	-2	-1	0	1	2	3	4
Canoeing	-4	-3	-2	-1	0	1	2	3	4
Picking wildflowers	-4	-3	-2	-1	0	1	2	3	4
Taking pictures	-4	-3	-2	-1	0	1	2	3	4
Mountain climbing	-4	-3	-2	-1	0	1	2	3	4
Hearing naturalist talks	-4	-3	-2	-1	0	1	2	3	4
Talking with tourists	-4	-3	-2	-1	0	1	2	3	4
Viewing naturalist exhibits	-4	-3	-2	-1	0	1	2	3	4
Breathing fresh air	-4	-3	-2	-1	0	1	2	3	4
Getting physically tired	-4	-3	-2	-1	0	1	2	3	4
Studying pioneer history	-4	-3	-2	-1	0	1	2	3	4
Low-cost outdoor recreation	-4	-3	-2	-1	0	1	2	3	4
Learn to lead simple life	-4	-3	-2	-1	0	1	2	3	4
Chance to acquire knowledge	-4	-3	-2	-1	0	1	2	3	4
Chance to stumble onto wealth	-4	-3	-2	-1	0	1	2	3	4
Adventure	-4	-3	-2	-1	0	1	2	3	4
Sense of personal importance	-4	-3	-2	-1	0	1	2	3	4
Improve physical health	-4	-3	-2	-1	0	1	2	3	4
Recapture pioneer spirit	-4	-3	-2	-1	0	1	2	3	4
Relieve tensions	-4	-3	-2	-1	0	1	2	3	4
Attain new perspectives	-4	-3	-2	-1	0	1	2	3	4
Chance to boast	-4	-3	-2	-1	0	1	2	3	4
Sense of humility	-4	-3	-2	-1	0	1	2	3	4
Family solidarity	-4	-3	-2	-1	0	1	2	3	4
Chance for noble thoughts	-4	-3	-2	-1	0	1	2	3	4

Results of the Wildernism-Urbanism Attitude Test

Table 8 indicates the distribution of wildernism scores. As expected, most of the scores are grouped near the top of the scale, indicating that almost all respondents were somewhat "wildernist." Few outright urbanists were found. Since all of the respondents were actual wilderness users, to some extent, they all shared attitudes oriented toward wilderness-purist concepts. In another study, we used the wildernism scale (with minor modifications) on a large population of National Forest and National Park car campers and wilderness users and found that car campers were less wildernist than were wilderness users (footnote 6, p. 10). This implies a certain degree of external validity for the scale.

To further test the external validity of the scale, we administered the test to members of two conservation groups; the Friends of the Three Sisters Wilderness, July 1966, at Quaking Aspen Swamp in the central Oregon Cascades during their annual trek and the Wilderness Society, August 1966, during an extended trail ride in the North Cascades of Washington State. The scale was also administered to an introductory sociology class at the University of Washington on November 8, 1967. The distributions of wildernism scores from these groups are also given in table 8. They indicate, in general, that persons who might be expected to be wilderness-purist were indeed scored that way by our wildernism measuring instrument. Likewise, those persons from the sociology class and, in particular, those who had not visited wilderness during the past 2 years tended to be scored as more urbanist or neutral.[9]

[9] *Five of the sociology students had not visited wilderness during the past 10 years but had gone car camping, but only two of them had not visited wilderness or gone car camping during the last 10 years.*

Table 8. – Distribution of wildernism scores of visitors to three different wilderness areas, members of two conservation groups, and a sociology class

Item	Wildernism scores and assigned categories					
	Urbanists, 10-54	Neutralists, 55-64	Weak wildernists, 65-74	Moderate wildernists, 75-84	Strong wildernists, 85-90	Total
	Percent					*Number*
Eagle Cap Wilderness	1.5	9.8	34.6	34.3	19.8	338
Glacier Peak Wilderness	.6	6.0	27.3	41.3	24.8	487
Three Sisters Wilderness	.2	8.8	33.1	37.6	20.3	498
All three	.7	7.9	31.4	38.1	21.9	1,323
Friends of the Three Sisters (conservation group)	—	—	8.3	50.0	41.7	12
Wilderness Society (conservation group)	—	—	5.3	42.1	52.6	19
Introductory sociology class, University of Washington	8.0	46.0	38.0	8.0	—	50
Persons in class who had not visited wilderness during last 2 years	7.1	92.9	—	—	—	14

Characteristics of Wilderness-Purists

When we related the wildernism attitude scores to the background characteristics of the respondents, we found the following trends. **The more wilderness-purist (wildernist) users were more likely to have been raised in urban areas, were highly educated, had more close friends who also participated in wilderness-type recreation, and were more likely to belong to one or more conservationist organizations or outdoor clubs.** As table 8 indicates, those persons with little or no wilderness experience had lower wildernism scores, but when we related total wilderness experience during the past 2 years to each respondent's score, we found the relationship to be more subtle. Some wilderness experience appeared necessary to attain a wildernism score near the median; but those respondents with the most experience were not always the most wildernist. As indicated in subsequent sections of this report, wildernism scores and reactions to suggested behavior norms and management policies were frequently related. Not surprisingly, the more wildernist respondents opposed behavior and policies violating the complete naturalness of wilderness more than did the average respondent.

Patterns of Response to the Wildernism Items

We developed the wildernism scale to differentiate between the reactions of users to suggested wilderness management policies and behavior norms on the basis of their measured wilderness-purist tendencies. We wanted to identify the degree to which the more wildernist respondents differed in their preferences from those persons who were not so wilderness-purist or maybe even urban oriented in their outlook. This information is important to help qualify and interpret what might otherwise appear to be merely a problem of consensus or popular vote on subsequent items concerning how wilderness should be managed or how people should behave in such settings. However, the patterns of response to the 60 wildernism items may also reveal basic information concerning motivation to use wilderness, certainly some useful data on the attitude dimensions measured by the scale, and more detail on how the more wilderness-purist users differ from others. Following are the results of a factor analysis we conducted to identify clusters of items about which most of the wilderness users felt the same. These clusters of items indicate several different attitude dimensions apparently measured by the wildernism scale.

We classified our respondents according to their wilderness-purist tendencies, using an attitude scale. The purists were more likely than other users to have been raised in urban areas, to have higher educations, and to belong to conservation groups or outdoor clubs. Here, a wilderness visitor views (left to right) Plummer Peak and Fortress Mountain from Miners Ridge in the Glacier Peak Wilderness.

Ten mathematically independent factors were extracted in a factor analysis computer routine. By rotating these to simple structure, we were able to identify seven clearly interpretable clusters of items about which the wilderness users had similar feelings. The factors were exceptionally clear cut in that the combination of items they included suggested logical, implicit meaning. The individual items had high factor loadings and the factors were quite strong, as indicated by their relatively high eigenvalues.[10]

We labeled each of the strongest seven factors with a term expressing what we felt to be the underlying meaning implicit in that group of items. The factors are given in the following tabulations with the names we assigned to them, the items included in each cluster with their appropriate factor loadings, and our interpretation of the underlying meaning implicit in the group of items making up each factor.[11] They are presented in order of their relative strength as indicated by the eigenvalues calculated for each factor. Each factor is designated as positive or negative, depending on the direction in which the more wilderness-purist persons tended to respond. The cutoff points of the factor loadings, determining which items would be included, were selected for each cluster of items where the factor loadings appeared to drop abruptly.

Factor I. Spartanism – eigenvalue 7.35
(Positive response by wilderness-purists)

	Factor loading
Improve physical health	0.65
Adventure	.59
Recapture pioneer spirit	.58
Physical exercise	.55
Chance to acquire knowledge	.55
Learn to lead simple life	.51
Relieve tensions	.43
Attain new perspectives	.42
Breathing fresh air	.42
Emotional satisfaction	.40
Getting physically tired	.39

Spartanism was the strongest factor in that it had the highest eigenvalue, indicating that it contained items with the most consistent pattern of similar response. We designated it "Spartanism" because respondents who strongly endorsed items such as "improve physical health," "adventure," "recapture pioneer spirit," "physical exercise," and "learn to lead simple life" seem to be endorsing a Spartan way of life and an ethic of able-bodiedness, fortitude, and dauntlessness. One should note, however, that some of the items in the cluster also suggest rejuvenation-oriented values such as "relieve tensions," "emotional satisfaction," and "attain new perspectives." **The implication is that the strongest dimension of shared feelings among wilderness users in our study centered around the emotionally refreshing Spartan-like type of existence implicit in wilderness use.**

Factor II. Antiartifactualism – eigenvalue 3.39
(Negative response by wilderness-purists)

	Factor loading
Campsites with plumbing	0.80
Equipped bathing beaches	.78
Developed resort facilities	.74
Gravel roads	.70
Camping with car	.70
Automobile touring	.70
Camps for organizations	.68
Private cottages	.65
Powerboating	.60
Reservoirs (manmade)	.59
Campsites with outhouses	.57
Purchasing souvenirs	.45
Cutting Christmas trees	.41
Viewing naturalist exhibits	.40

This factor was second only to Spartanism in terms of consistently shared response. Respondents who strongly endorsed these items seem to be favoring human "improvements" and the installation of, or provision for, facilities and artifacts to provide for

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[10] *The magnitude of the factor eigenvalues indicates the relative strength of the groups of items in terms of the variance accounted for by clustering. Although several of the factors appear to be conceptually related, they are mathematically independent in an orthogonal factor analysis (Horst 1965).*

[11] *The factor loadings should be viewed as intercorrelation coefficients expressing the relationship between response to each of the items and the other items in the cluster.*

creature comforts and stimulation. The more wildernist users obviously rejected the presence of such facilities and artifacts. **The implication is that wilderness use is strongly based on a rejection of man's permanent presence in the natural environment.**

Factor III. Primevalism – eigenvalue 3.05
(Positive response by wilderness-purists)

	Factor loading
Waterfalls and rapids	0.70
Alpine meadows	.61
Timberline vegetation	.60
Lakes (natural)	.58
Virgin forest	.56
Rugged topography	.54
Unchanged natural coastlines	.50
Native wild animals	.47
Vast area and enormous vistas	.44

The general implication of primevalism factor is that **strongly motivated wilderness users seem devoted to satisfactions obtained from perceiving the undisturbed natural environment.** Persons who strongly reject such items seem to be repelled by, or at least not attracted to, primeval scenes. This cluster of items has some conceptual resemblance to factor II, antiartifactualism, in that a rejection of man's dominance over nature is implicit in a preference for primeval scenes.

Factor IV. Humility – eigenvalue 2.23
(Negative response by wilderness-purists)

	Factor loading
Chance to boast	0.66
Sense of personal importance	.56
Chance to stumble onto wealth	.54
Picking wild flowers	.47
Cutting Christmas trees	.40

The more wilderness-purist users rejected the items in this factor which implies (as did the antiartifactualism and primevalism factors) a desire for humility in man's relation to the natural environment. On the contrary, urbanist respondents showed a greater tendency to endorse such items which seems to express a wish to assert their personal dominance over the natural environment.

Factor V. Outdoorsmanship – eigenvalue 2.07
(Positive response by wilderness-purists)

	Factor loading
Camping (backpacking)	0.64
Hiking	.63
Mountain climbing	.63
Canoeing	.57
Sleeping outdoors	.44

This group of items suggests that **certain craft aspects of wilderness visits and life in the natural environment are valued by users in addition to the endurance or Spartan-like aspects which have been asserted in previous factors.** The more urban-oriented persons who rejected these items evidently regard these activities as onerous and are not as strongly attracted to wilderness use.

Factor VI. Aversion to social interaction – eigenvalue 1.92
(Negative response by wilderness-purists)

	Factor loading
Hearing naturalist talks	0.78
Viewing naturalist exhibits	.74
Studying pioneer history	.61
Talking with tourists	.52

The more wildernist respondents rejected these items, which suggests that they are averse to deliberate information-exchange embellishments of outdoor recreation. This aversion appears to be a dimension of wildernism, though most wilderness-purists are informed persons and learning does occur in conjunction with wilderness recreation. **We strongly suspect that the suggested techniques of information exchange (hearing, viewing, talking), all of which involve impersonal social interaction and perhaps developed facilities, are behind the rejection of these items.**

Factor VII. Escapism – eigenvalue 1.66
(Positive response by wilderness-purists)

	Factor loading
Absence of people	0.78
Remoteness from cities	.60
Absence of manmade features	.55
Solitude	.48
Vast areas and enormous vistas	.44
Tranquility	.39

Table 9. – Number of items falling into each factor of wildernism in the shortened scale compared with total number of items clustered in each factor from the original 60 items and their rank

Factor	Number of items in improved scale	Number of items in original scale	Ratio	Rank order of importance in improved scale
I. Spartanism	2	11	0.18	6
II. Antiartifactualism	10	14	.71	1
III. Primevalism	6	9	.67	2
IV. Humility	1	5	.20	7
V. Outdoorsmanship	3	5	.60	5
VI. Aversion to social interaction	0	4	.00	8
VII. Escapism	4	6	.67	3.5
Items not appearing in any factor	4	6	.67	3.5
Totals	30	60	—	—

The more wilderness-purist respondents endorsed these items, implying that they are averse to involvement with modern, impersonal, human aggregations or evidence thereof. This is not to suggest that wilderness users are actively antisocial. We interpret these items as merely a desire to seek temporary respite from human involvement, with values being placed on benefits from such experience. The fact that most wilderness use is by family or friendship groups suggests that **this factor reflects an aversion only to the kind of depersonalized human encounters so common to modern life.** Social interaction with intimates such as family or close friends is, in fact, reinforced by wilderness recreation, according to other evidence appearing in our study.

It is interesting to note that escapism is the seventh factor extracted. It has a lower eigenvalue and accounted for less variance than did the six other clusters of items in the wildernism scale. Escape from civilization has long been cited by observers as a dominant reason for wilderness use. Our data do not refute this but indicate that there are six factors or clusters of items in our attitude scale about which wilderness users more consistently had similar feelings. The escape from civilization theme is also implicit in Spartanism, antiartifactualism, and primevalism – the three strongest factors in the wildernism scale – suggesting that **the escape from civilization theme underlies many aspects of wilderness appeal but, by itself, is overshadowed.**

Dimensions of the Wildernism Scale That Best Differentiate Wilderness-Purists From Urbanists

The factor analysis reported above included all 60 of the wildernism items in the questionnaire. When we shortened the scale to include only the 30 items best differentiating wilderness-purists from urbanists, we found that the items included did not equally represent all of the factors described. Some of the clusters of items or dimensions of the wildernism scale we identified in the factor analysis were underrepresented and others were overrepresented in the new scale. The new scale contains only the 30 items most highly correlated with wildernism scores. Thus, **the factors or clusters of items prominent in the improved scale logically represent the dimensions of wildernism which most efficiently differentiate wilderness-purists from urbanists.**

Table 9 compares the number of items in the improved scale which fell into each factor with the total number of items clustered in that factor during analysis of the original 60 items.

Table 9 indicates that 20 of the 30 items in the improved scale are grouped, respectively, under antiartifactualism, primevalism, and escapism. **This suggests wildernists are best differentiated from urbanists in terms of their more positive affinity for natural environments devoid of human influence.** This is generally consistent with the ORRRC (1962) finding that "exit civilization" and "esthetic-religious" dimensions predominate in the appeal of wilderness.

Specifically, the more wilderness-purist respondents express more zeal than urbanists for tranquility, solitude, alpine meadows, absence of manmade features, virgin forest, lakes (natural), timberline vegetation, vast areas and enormous vistas, rugged topography, and native wild animals. They are more averse than urbanists to camps for organizations, gravel roads, private cottages, purchasing souvenirs, camping (with car), equipped bathing beaches, automobile touring, powerboating, campsites with plumbing, and developed resort facilities. Moreover, these more wildernist respondents appear more willing to adapt themselves to natural environment conditions, as indicated by their greater endorsement of three items from the outdoorsmanship factor that appear in the refined scale: camping (backpacking), sleeping outdoors, and hiking.

The Spartanism factor, despite its dominant rating in the analysis of all 60 items, contributed only two items to the refined scale (physical exercise and emotional satisfaction). The humility factor contributed only one (dislike for Christmas tree cutting).

The factor, aversion to social interaction, contributed no items to the abbreviated scale, indicating that this dimension of wildernism is not very important in differentiating wildernists from urbanists.

It is important to keep in mind that we are considering here only those items and their appropriate factors which best differentiate between the more wilderness-purist and other users. The items about which all wilderness users felt the same did not differentiate and were thus excluded from the refined scale.

Other Research Classifying Wilderness Users

As we mentioned earlier, our study is not the first attempt by researchers to categorize wilderness users on the basis of the intensity with which they hold certain values. It is the first attempt that we are aware of to use attitude scaling techniques in approaching the problem.

The ORRRC (1962, page 135) study of wilderness users included an analysis of the inveterate wilderness user, using frequency of use as a "rough and admittedly partial measure of commitment." In their analysis, they tested a number of propositions and found that wilderness commitment, as measured by frequency of use, is greater among males, among those introduced to camping early in their youth, and among those whose interest in wilderness is reinforced by family and friends. Age was related to wilderness commitment only among older users, there was no consistent relationship between income and frequency of use, and those raised in urban areas were more likely to be committed users than those raised in rural areas.

In many respects, the inveterate wilderness user identified in the ORRRC study approximates the strong wilderness-purist identified by our wildernism attitude scale. However, amount of use does not explain much variation in wildernism scores except between nonusers and users. For example, among those who do visit wilderness, amount of wilderness experience does not indicate how wilderness-purist they are, as measured by the wildernism scale. Our data indicate that habitual or inveterate users are often no more wilderness-purist than those who visit such areas in moderation. This curvilinear relationship between wildernism scores and amount of use could be identified statistically and would prove interesting, but such an endeavor is beyond the scope of this study.

Another interesting comparison between the inveterate wilderness users identified in the ORRRC study and the wilderness-purists of our study is that both types were more likely to have been raised in urban areas. This is consistent with a recent study of visitors to National Park and National Forest wilderness and car camping areas in Washington, which also found urban-bred recreationists to be more wilderness-purist, more preservation oriented, and more inclined to differentiate the natural environment as a place with certain appropriate behavior than were those who were rural bred (see footnote 6, p. 10). The findings suggest that nature-oriented attitudes do thrive among those raised in urban set- and that continued urbanization of our society is likely to increase, not decrease, the preference of many for wilderness-type recreation. Burch and Wenger (1967) found, however, that although city dwellers were more likely to be forest campers, rural residents were more likely to be remote campers. This evidence conflicts somewhat with our findings and the two other studies.[12]

The tendency to identify hierarchies of users along a continuum ranging from wilderness-purist to urban oriented extends to virtually all researchers who have studied wilderness use. For example, Stone and Taves (1956) related previous camping experience to several items in an early study in the Boundary Waters Canoe Area and found that the more experienced users traveled in smaller parties and took longer trips. Bultena and Taves (1961) and Taves et al. (1960) found that canoeists in the Boundary Waters Canoe Area sought greater isolation, desired fewer improvements, and were more inclined toward preserving the area in a true wilderness state than were other campers. Lucas (1964b), in his study of visitors to the Boundary Waters Canoe Area, also found paddling canoeists to be more wilderness-purist in that they were attracted to the area more by its wilderness qualities, they perceived less area as real wilderness, considered the wilderness overcrowded at much lower levels, and distinguished more sharply between sorts of groups met than did motor canoeists, day users, auto campers, boat campers, resort guests, or private cabin users. Merriam and Ammons (1967), in their study of visitors to wilderness in three Montana areas, also describe a gradation in users' wilderness concepts, ranging from the mountaineer to the roadside camper whose wilderness travel is, at best, a day's hike in and out of the area.

In summary, **the insights of wilderness researchers inevitably suggest a continuum of users that, in general, approximate what we suggest is a wilderness-purist to urban-oriented range of attitudes.** However, except for the easily identified canoeists in the Boundary Waters Canoe Area, wilderness researchers have not yet methodically and directly related the implied gradations in types of users to visitor attitudes toward wilderness management policies. In this respect, our exploration into wilderness-user attitudes differs, for one of our chief purposes in developing a wildernism-urbanism scale was to discover relations between users' orientation toward perceived wilderness values and their views on how administrators might manage the resource.

Studies of the Appeals of Wilderness

Our factor analysis revealed seven dimensions of common feelings among wilderness

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[12]*See also: Burch, William R., Jr. Nature as symbol and expression in American social life: a sociological exploration. 1964. (Unpublished doctoral dissertation on file at Univ. Minn., Minneapolis.)*

users as measured by our wildernism attitude scale. These seven dimensions are similar to the appeals of wilderness identified by other researchers. One section of the ORRRC Study Report 3 (1962) explored the appeals of wilderness and proposed five dimensions of motivation for entering wilderness. These dimensions were called exit-civilization, esthetic-religious, health, sociability, and the pioneer spirit. The ORRRC tested the relative importance of these dimensions of wilderness appeal against user response to 21 suggested reasons for wanting to be in the wilderness. By appropriately classifying each of the 21 stated reasons under their five dimensions of wilderness appeal and tabulating the number of persons ranking each reason as very important, some conclusions were evident as to the relative importance of each dimension. The ORRRC concluded that the two strongest motivations to visit wilderness are a wish to escape from the routines and crowds of daily life (exit-civilization) and a desire to enjoy the beauties of nature (esthetic-religious). The dimensions of health and sociability proved less salient as wilderness appeals in that order, and the pioneer spirit ranked last as a major reason for taking wilderness trips. Maintaining health seemed more important than restoring it, and older users were the ones likely to link this with wilderness use. The sociability motif was more important to middle-age and middle-income respondents, and the pioneer spirit was reflected most by persons from small towns. It was significant that the results were similar for three widely divergent types of wilderness, Mount Marcy in the Adirondacks, the Boundary Waters Canoe Area in Minnesota, and the High Sierra Wilderness in California. From this, the ORRRC concluded that the appeal of wilderness is a generic one, modified only slightly by differences in wilderness areas themselves.

The ORRRC study findings concerning the dimensions of wilderness appeal are related in some respects to the seven dimensions of wildernism that we identified by using factor analysis on responses to the items in our attitude scale. In making comparisons, however, one must remember that our factors were based on the similarity of response by wilderness users and that the ORRRC study dimensions of appeal were based on the rated importance of certain aspects of appeal to users. The exit-civilization motif might be compared to our escapism factor, as well as our antiartifactualism and Spartanism factors. Exit-civilization was the dominant appeal for wilderness in the ORRRC study, whereas Spartanism, antiartifactualism, and primevalism were foremost among the clusters of items in our study. The fact that escapism was the weakest cluster of items with common response in our study is puzzling at first glance. However, as we previously pointed out, the escape from civilization theme is implicit in our Spartanism, antiartifactualism, and primevalism factors, suggesting that the escapism motif underlies many aspects of wilderness appeal but by itself is overshadowed.

Our primevalism factor compares roughly with the esthetic-religious dimension and falls next in importance to the factors paralleling exit-civilization. Comparison of the factors we identified with the remaining three ORRRC dimensions of wilderness appeal becomes even more difficult at this point. One can only say that humility, outdoorsmanship, and aversion to social interaction are subordinate to other factors in terms of the common feelings of wilderness users, as were the rated importance of health and sociability as dimensions of wilderness appeal in the ORRRC study.

Bultena and Taves (1961) and Taves et al. (1960), in a study of visitors to the Boundary Waters Canoe Area, identified five primary images of the area which they interpreted as motives for visiting the wilderness. The classification they used had been developed earlier and used in a less formal study of wilderness users in the same area (Stone and Taves 1956). Their images included (1) wilderness as a locale for sport and play – a locale where one could engage in outdoor activities of a nature seldom pursued in their home communities; (2) wilderness as fascination – an opportunity to gain new experiences and realizations seldom found in the more artificial setting of the city; (3) wilderness as sanctuary – an opportunity to leave the impersonal, monotonous and otherwise "directed" mental and physical environment of the city; (4) wilderness as heritage – a chance to personally relive the glamorous experiences of fur traders, pioneers, and explorers; and (5) wilderness as personal gratification – a chance for emotional catharsis with a psychological culmination revitalizing them for return to the emotional pressures surrounding their everyday lives.[13] Their research indicated that "wilderness as fascination" was the most frequently held image of the area. In general, most users were drawn to the area by its primitiveness, naturalness, opportunity for adventure, and to escape from the cares associated with the directed environment of the workaday world. The authors observed that "in many respects, the users' initial image represents a temporary rejection of what is seen as the artificialities of the city. They envisage the Quetico-Superior as providing an opportunity to escape such artificiality . . . and to reduce life's complexities to what is basic and essential" (Bultena and Taves 1961, p. 169).

Lucas' (1964b) study of visitors to the Boundary Waters Canoe Area also suggested motives for wilderness use similar to the foregoing studies. He found that canoeists were most likely to be attracted by the wilderness qualities of the area and to classify these qualities as wild, uncommercialized, uncivilized, primitive, remote, quiet, peaceful, etc.

The significant point to be derived from review of these studies is that study of wilderness users by different researchers working in different areas turns up recurring similar themes underlying wilderness use. They suggest that wilderness visits are motivated in large part as an escape from artificiality of contemporary environments into natural settings, untarnished by civilization, where the necessity for primitive means of existence yields various emotional benefits to the participant.

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[13] *For a psychiatrist's discussion of this aspect, see McKinley (1963 and 1966).*

Part III

Wilderness-User Behavior and Attitudes Toward Management Policies

The data subsequently presented in this report concern the reactions of users to statements suggesting behavior for wilderness users and management policies for wilderness areas.

Qualification of the Survey Method

In reviewing the response to these statements concerning wilderness-user behavior and wilderness management, one should remember that none of us behave entirely as we say we would. There is a certain artificiality about questionnaire data in that behavior is not being observed or measured directly. Ask a hypothetical question and get a hypothetical answer is one way of expressing it. On the other hand, when questionnaire response patterns indicate that certain behavior is condemned or accepted by most users or that a certain management policy is accepted or rejected, we can generally assume that behavior surrounding the issue will tend to be more consistent with the expressed attitudes than inconsistent. People agreeing that "debris should be packed out of the wilderness" won't always do it, but the probability that they will is greater than if they said they didn't feel it should be packed out. More important, they will perhaps be more receptive to stimuli reinforcing the behavior they acknowledge as desirable.

We offer this explanation not in apology for our method but as encouragement to the reader to look beyond the surface expression of what users feel is desirable or undesirable to the underlying possibilities. **The following data indicate what wilderness is to the users through their reactions to behavior and management measures viewed as consistent or inconsistent with their concept of wilderness.** The data offer no black-and-white solutions and that is not their intent. But they do offer a basis for better insight into what the consequences of certain actions might be on the culturally derived concept of wilderness.

Informal Rules and Customs for Recreation in Wilderness-Type Areas

The questionnaire contained 22 normative statements suggesting informal rules and customs that might be observed when visiting wilderness-type areas. These statements called for response ranging from "strongly disagree" to "strongly agree" (SD = strongly disagree, D = disagree, N = neutral, A = agree, SA = strongly agree). For example, two statements that appeared in this section are:

One should camp wherever
he pleases in
remote back country SD D N A SA

Playing cards and reading
books are not appropriate
to back country
unless the weather is bad SD D N A SA

The 22 questionnaire statements referring to informal rules and customs for back-country use were factor analyzed to determine which statements clustered together with highly intercorrelated response patterns. We originally tried to group the statements, using our own insights as to which were related, but upon trying factor analysis, we found some relationships that were imperceptible to our casual observation, and the five factors identified appeared logically as well as statistically clustered. **They revealed, in other words, the statements about which wilderness users most nearly felt the same.** Five groups of such statements were identified and are presented in the following text. **They suggest the presence of norms among wilderness users, indicating an attitude of responsibility and equality, a rejection of external controls on behavior, withdrawal from symbols of civilization, support for some campsite maintenance behavior, and endorsement of certain campcraft skills.** In the following, each statement appears under its appropriate factor, with a statistical summary of the response it received, an interpretation of the response, and the "factor loading" indicating how strongly it was related to all statements in that group. One of the important designations to be noted following each statement is the "gamma statistic" which indicates the degree of association (correlation) between wildernism scores and response to the statement; i.e., a large gamma statistic (positive or negative) indicates relatively consistent response to that statement by the more wildernist (wilderness-purist) respondents.[14]

Factor I: A Wilderness Norm—Responsibility and Equality

This group of statements forms the strongest factor in that it accounted for the greatest reduction of response variance among the five factors identified. The five normative statements in this group appear to **imply a sense of equality among wilderness visitors and a sense of responsibility for maintaining the propriety of each other's behavior and for contributing to each other's welfare.** As one psychiatrist and ardent wilderness user has noted (McKinley 1963), "in the wilderness, competition and suspicion seem to fade . . . . Not competition, but cooperation is needed because of the forces of nature . . . "

It is interesting to note the overwhelming agreement among respondents to all of the statements and the relatively stronger endorsement of the more "wildernist" respondents. If we reflect on the escapism aspect of motivation previously discussed, yet observe the significant orientation of users toward interpersonal responsibility that is present in these statements, a new dimension of the "escape from civilization" aspect of wilderness use appears. Wilderness users, as a group, do not appear to reject social responsibilities despite their desire to escape to wilderness solitude where they can interact only with family or close friends.

Of more specific practical interest are the responses to the first three statements which indicate that: **Users feel obliged to say something to persons whose behavior in wilderness is improper.** They feel that **persons in trouble have first claim on the time and energy of everyone near.** They feel that **trash left by previous users should be removed by other users if possible.**

[14] *See page 71 of the Appendix for an explanation of the use of the statistic, gamma, to determine if correlation between questionnaire response and wildernism scores was strong, moderate, or slight. The terms "strong," "moderate," or "slight" do not refer in an absolute sense to explained variation in patterns of response due to wildernism scores but to the* relative *proportional reduction in error that is possible when wildernism scores are used to predict respondents' answers to the questionnaire statements about wilderness behavior and management (Costner 1965).*

Factor I	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	-----------	-----------	
I-1. If you see a person in a back-country recreational area doing something he shouldn't do, you should say something to him about it.	.65	80.6	15.7	3.7	G.22 + Moderate N = 1322

Eight out of ten persons felt that in wilderness-type areas *if you see a person doing something he shouldn't, you should say something to him about it,* and the more wildernist respondents were moderately more inclined to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
I-2. In an emergency, the person or party in trouble has first claim on the time and energy of everyone near, even if some cherished plans have to be abandoned.	.63	93.0	4.0	3.0	G.20 + Moderate N = 1324

More than nine out of 10 agreed that *in an emergency, the person or party in trouble has first claim on time and energy of everyone near,* and the more wildernist respondents were moderately more inclined to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
I-3. Trash left by previous back-country users should be removed by other users if they can do so.	.60	94.0	3.4	2.6	G.28 + Moderate N = 1329

More than nine out of 10 felt *trash left in remote back country should be removed by other users if they can do so.* The more wildernist respondents were moderately more inclined to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
I-4. Campfires should be no larger than necessary.	.55	95.6	2.5	1.9	G.26 + Moderate N = 1324

More than nine out of 10 felt *campfires should be no larger than necessary* and more wildernist respondents were moderately more likely to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
I-5. In the back country, formality should be put aside; everyone should be equal there.	.53	81.0	13.4	5.6	G.13 + Slight N = 1313

Eight out of ten felt *formality should be put aside and everyone should be equal in the back country* and the more wildernist respondents were slightly more inclined to feel this way.

Factor II: A Norm Suggesting Rejection of Controls on Behavior

Four out of five statements in factor II were worded so as to imply a rejection of controls on behavior. The fifth statement also referred to a measure of social control (fire permits), but response to it was negatively correlated with the other statements in the group.[15] This indicates that persons endorsing fire permits as a requirement tended to reject the other questionnaire statements that implied freedom from constraints on behavior. Expressed another way, users who did not feel fire permits should be required also felt they should be allowed to camp wherever they pleased, to shortcut trails, and cut brush, limbs, or wood. This suggests that **some wilderness users tend to consistently reject controls on behavior and others consistently find them acceptable.** This tendency does not appear to be related to respondents' wilderness-purist tendencies, since the correlation between wildernism scores and response to the items was negligible or slight in four of the five items. We feel, on the basis of response patterns appearing throughout the study, that the tendency to reject or accept reasonable controls on behavior is related to the respondents' knowledge of the necessity for such controls. It thus follows that **educational programs directed at reasons for constraints on behavior would greatly increase the likelihood that behavior controls would be successful.** We are suggesting that education is perhaps more important than enforcement in bringing about proper wilderness behavior.

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[15] *The negative factor loading (-.37) for the statement concerning fire permits indicates that people endorsing a fire permit requirement tended to disagree with the other statements.*

Factor II

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	-----------		
II-1. One should camp wherever he pleases in the remote back country.	.69	57.8	7.7	34.5	G.15 + Moderate N = 1326

Almost six out of 10 persons felt that they *should be allowed to camp wherever they please.* The more wildernist respondents were moderately more inclined to feel this way. The response patterns were more pronounced from visitors to the Eagle Cap Wilderness.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	-----------		
II-2. If a person sees a shorter route than the trailmakers used, he should have the right to decide whether to stay on the trail or not.	.65	32.2	14.9	52.9	G.00 Negligible N = 1323

About one-half of the visitors felt they *should stay on designated trails, but one out of three felt he should be able to shortcut trails if he wanted to.* The response pattern was nearly identical for the more wildernist respondents and other users.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	-----------		
II-3. In remote back-country recreational areas, nobody had better try to tell me what I should or shouldn't do.	.63	4.2	11.3	84.5	G-.02 Negligible N = 1323

Over eight out of 10 respondents did not feel that *"nobody had better try and tell them what to do."* Response was similar among the more wildernist respondents and others.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	----------	----------	
II-4. In the back country, a person should be free to cut brush or limbs for his bed or wood for his campfire.	.45	52.0	12.5	35.5	G-.10 Slight N = 1316

More than five out of 10 persons felt they *should be free to cut brush, limbs, or wood in the back country.* But the more wildernist users were slightly less inclined to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent	----------	----------	
II-5. Every back-country traveler (or party of travelers) should be required to obtain a fire permit from the administrative agency before entering an area.	-.37	63.7	18.7	17.6	G.01 Negligible N = 1329

More than six out of 10 respondents felt *all back-country travelers should be required to obtain fire permits before entering such areas.* The more wildernist respondents and other users felt alike on this item.

Factor III: A Norm Suggesting Withdrawal from Symbols of Civilization

The statements in factor III all refer to things or activities symbolizing civilization; e.g., radios, barking dogs, roads, etc. These symbols and activities are all described within the statements as being inappropriate to use of remote back country of wilderness character. The pattern of response to these statements indicates that **visitors vary in the intensity of their aversion to civilization reminders, such as radios, yelling people, etc., while traveling in the wilderness, but the more wildernist persons consistently oppose such things.** The pattern and the correlation with wildernism scores suggest that although people will not be clamoring for rules and regulations to control these kinds of behavior, reasonable rules and regulations to preserve primeval conditions and solitude would be acceptable where needed, particularly to the more wildernist users. Merriam and Ammons (1967) reported two findings related to our norm suggesting withdrawal from symbols of civilization. They reported that "roads were loudly opposed, though radio and, for some, television in the wilderness seemed less objectionable."

It is interesting to note the strong association between wildernism scores and response to most of these statements. **Wilderness-purists appear to strongly differentiate the wilderness environment as a place with appropriate and inappropriate behavior**; e.g., radios, barking dogs, and yelling people do not belong. Of specific interest to resource managers is the response to statement number 3 indicating that a road to a place takes most of the fun out of walking there, even if the trail follows a different route. This suggests a basic incompatibility between road access and trail access.

Factor III

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		---Percent-----------			
III-1. Radios should not be brought to the back country.	.64	30.9	35.9	33.2	G.39 + Strong N = 1323

About one out of three respondents felt that *radios should not be brought to the back country*, one-third were neutral, and one-third saw nothing wrong with such a practice. However, the more wildernist respondents strongly tended to agree that radios should not be brought into wilderness-type areas.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
III-2. Barking dogs, car horns, and yelling people do not belong in remote back-country recreational areas.	.62	92.1	5.0	2.9	G.55 + Strong N = 1326

More than nine out of 10 persons felt that *barking dogs and yelling people do not belong in wilderness-type areas,* and the more wildernist respondents strongly tended to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent ----------			
III-3. A road to a place takes most of the fun out of walking there even if the trail follows a different route.	.61	71.7	12.7	15.6	G.56 + Strong N = 1328

Seven out of 10 persons agreed that a *road to a place takes the fun out of hiking there even if the trail follows a different route,* and the more wildernist respondents strongly tended to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent -----------			
III-4. Playing cards and reading books are not appropriate to back country, unless the weather is bad.	.60	16.1	30.8	53.1	G.12 + Slight N = 1325

More than half the respondents disagreed that *playing cards and reading books are not appropriate in wilderness-type areas unless the weather is bad,* and almost three out of 10 persons were neutral. However, the more wildernist respondents were slightly more inclined to agree with the statement and thus oppose playing cards and reading unless the weather is bad.

Factor IV: A Norm Supporting Maintenance of Unpolluted Campsites

Factor IV contained the following three statements which seem to refer to maintenance of an unpolluted quality of campsites within the environment, the pattern of response indicates **a willingness on the part of the users to cooperate in achieving campsite quality and the presence of an informal code of conduct in this direction.** It might, therefore, be possible for managers to identify, publicize, and reinforce the site preservation benefits which result from other more subtle wilderness-user practices such as refraining from cutting limbs for beds, tying horses to trees near campsites, or making camps near the edges of lakes or streams.

Factor IV

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		---Percent----------			
IV-1. If a considerable quantity of wash water must be disposed of, a sump hole should be dug for it.	.68	78.3	11.5	10.2	G.01 Negligible N=1326

About eight out of 10 persons felt a *sump hole should be dug for disposing of considerable quantities of wash water.* Response was similar from the more wildernist users and other respondents.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent ----------			
IV-2. One should not wash his dishes, his clothes, or himself directly in streams or lakes.	.68	61.1	12.0	26.9	G.03 Negligible N = 1326

About six out of 10 felt *one should not wash dishes, clothes or himself directly in streams or lakes,* but almost three out of 10 disagreed. Similar response was received from the more wildernist users and others.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		--- Percent ----------			
IV-3. All evidence of use of an area should be removed when leaving a campsite.	.63	90.8	3.8	5.6	G.12 + Slight N = 1327

Nine out of 10 felt *all evidence of use should be removed when a campsite is left,* and the more wildernist respondents were slightly more inclined to feel this way.

Factor V: A Norm Supporting Campcraft Skills

The last group of statements with similar response referred to some aspects of campcraft. These data suggest that among wilderness users, there is a subculture that places value on certain knowledge, skills, and experience. **However, certain of these activities that many users now support or find acceptable may not be appropriate in a future era characterized by increasingly heavy use of wilderness-type areas.** Opportunities for individual burying of garbage may be exhausted in areas with shallow soil. Informal campsite improvement if carried to extremes could be inconsistent with wilderness preservation objectives, and particularly if carried out to suit the varying preferences of successive users. For example, Lucas (1964b) reported that a thousand or more campsites had been cleared by canoeists in the Boundary Waters Canoe Area. In areas of wood shortage, particularly at high elevations, cutting brush and limbs for fire or beds may soon exhaust the supply and deteriorate the environment. Even fires may have to be prohibited in areas where wood is very scarce. An example of such an area is found in portions of the proposed Enchantment Wilderness in Washington State where the only remaining firewood at some lakes is found in picturesque snags that give the area much of its charm (Hendee and Mills 1968). Note that statement 4, concerning the cutting of brush or wood, also appeared in factor II with the statements suggesting a rejection of constraints on behavior.

We suggest again that lack of knowledge as to the cumulative long-range consequences of their activity accounts for support by some wilderness users for practices that will ultimately result in the decline of wilderness quality. **The acceptance of constraints on wilderness behavior lies in communicating why such controls are necessary.**

Factor V

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		-------	Percent	-------	
V-1. Noncombustible trash (e.g., tin cans, aluminum foil, glass, unburned garbage) should be buried	.66	84.0	1.5	14.5	G.04 Negligible N = 1320

More than eight out of 10 felt *noncombustible trash should be buried* and there was no significant difference in the pattern of response from the more wildernist respondents.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		-------	Percent	-------	
V-2. Moderate improvement of a campsite by the camper is desirable (e.g., removing brush and limbs, putting nails in trees for utensils, simple box cupboards, etc.)	.65	29.2	14.3	56.5	G-.30 -Strong N = 1329

Between five and six out of 10 persons *did not agree that moderate camper improvement of a campsite is desirable,* but about three out of 10 respondents agreed. The more wildernist respondents displayed a strong tendency to oppose improvement of campsites by users.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		-------	Percent	-------	
V-3. Camping isn't complete without an evening campfire.	.63	73.8	16.9	9.3	G-.13 -Slight N = 1326

Over seven out of 10 persons felt that *camping isn't complete without an evening campfire* but the more wildernist campers were slightly less inclined to feel this way.

	Factor Loading	Agree	Neutral	Disagree	Correlation with wildernism scores
		-------	Percent	-------	
V-4. In the back country a person should be free to cut brush or limbs for his bed or wood for his campfire.	.55	52.0	12.5	35.5	G-.10 -Slight N = 1316

More than five out of 10 persons felt they *should be allowed to cut brush, limbs, or wood in the back country,* but strong wildernists were slightly less inclined to feel this way.

Two Items Not Appearing in the Factor Analysis

Two statements suggesting norms for behavior in wilderness-type areas did not turn out to have patterns of response highly associated with any other group of statements. The statements indicated that:

More than eight out of 10 persons felt that *a good rule to follow in wilderness-type areas is to take only pictures and leave only footprints,* and the more wildernist respondents were moderately more inclined to feel this way.

Almost nine out of 10 persons *did not feel that bringing more luxuries made for a better camping trip.* The more wildernist respondents were even more strongly inclined to feel this way.

Informal Rules and Customs for Wilderness Use Summarized

A summary of responses to all of the questionnaire statements referring to informal rules and customs for back-country use is included in the appendix. The responses are summarized for each of the areas in which visitors were recorded. This will give wilderness managers and other interested parties the opportunity to inspect response to each statement as it varied among visitors to the three different areas. In the appendix, the statements are arbitrarily grouped under three headings different from those designated in the foregoing section based on factor analysis of response. In the appendix, they are organized under: (1) statements concerning personal freedom, (2) statements concerning camping habits, and (3) statements concerning expected behavior in wilderness-type areas.

Twenty-two questionnaire statements suggested some informal rules and customs that might be observed in wilderness-type areas. A factor analysis of responses indicated five general groups of statements about which wilderness visitors felt pretty much the same. These groups of statements or factors indicate shared feelings about certain wilderness behavior. The first group of statements implied the presence of **a norm among wilderness users suggesting feelings of equality and a sense of responsibility for both maintaining the propriety of each other's behavior and contributing, when necessary, to each other's welfare**. The second factor implied the presence of **a norm suggesting a rejection of controls on behavior.** Some users consistently rejected the concept of behavior controls and others consistently endorsed such concepts. We feel the rejection of reasonable behavior controls is based on a lack of knowledge as to the undesirable consequences of the behavior and that **educational programs directed at reasons for restrictions will greatly increase their acceptability.**

The third factor contained items suggesting some activities reminiscent of civilization and revealed **a norm suggesting a rejection of symbols of civilization.** The more wildernist users tended to be more intolerant of reminders of civilization than other users. The fourth factor indicated **an informal code of behavior working to maintain campsite quality**. The fifth and last group of statements indicated the presence of **informal sanctions for certain campcraft skills, some of which are not consistent with wilderness preservation in areas of intensive use.** Two statements, not highly associated in response pattern to the five groups of statements, endorsed taking only pictures and leaving only footprints in wilderness-type areas and asserted that luxuries did not improve a camping trip.

In general, wilderness users are a responsible group. Educating them as to why some restrictions are needed usually wins their cooperation. Here, Forest Service wilderness patrolman talks with Girl Scouts in the Three Sisters Wilderness.

Part IV

Management Preferences for Wilderness-Type Areas

Fifty-three of the questionnaire statements suggested management practices, policies, or guidelines that might be implemented in remote back-country areas of wilderness character.[16] These statements called for responses using the symbols SD, D, N, A, SA to designate strongly disagree, disagree, neutral, agree, strongly agree, respectively. The preferences so indicated by each person were then correlated with their wildernism scores. This was to determine if the more wilderness-purist respondents reacted differently to suggested management policies than other users who were less perceptive of wilderness values, and the effect certain management policies might have on them. The statements concerning management preferences and their appropriate statistical data are included in the appendix under the same headings in which they are discussed in the following text.

The Need To Differentiate the Management Preferences of Wilderness-Purists From Other Users

It is extremely important that the preferences for certain management policies be related to the respondents' orientation toward wilderness-purist concepts. A certain policy might receive the endorsement of a majority of the wilderness users, yet, if the disagreeing minority are wilderness-purists, it may indicate that the policy, despite its popular support, would violate the long-standing wilderness values to which the more purist users are especially sensitive. **Wilderness-purists are more perceptive of wilderness values and their opinions should receive added consideration.**

In addition, some types of recreation use depend on wilderness, but other uses do not, despite the fact that they are enhanced by a wilderness setting. For example, backpacking featuring long treks and solitude depends on wilderness-type areas. Fishing, on the other hand, is enhanced for many by a wilderness setting but does not depend on such an environment. The point is that some people may visit wilderness incidental to other activity whereas others visit wilderness because such settings are prerequisite to their activity or satisfaction. The management preferences of these different types of users should be differentiated because there are closer alternatives available to the incidental users. **Wilderness management should not be as sensitive to the preferences of users whose activities do not depend exclusively on wilderness for their satisfaction.**

Another reason for differentiating among the preferences of users is that there may be management policies vital to the preservation of wilderness that are not fully understood or appreciated by wilderness users. **It is vital for wilderness managers to be aware of differences in sentiment among different types of users so that the appropriate public can be informed as to the necessity of a policy before it is implemented.** As Mills[17] pointed out, needs and preferences must be compro-

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[16] *Again, it is unfortunate that it was necessary to use the phrase "remote back country of wilderness character" to avoid implying that some policies which might violate the Wilderness Act were being contemplated for such areas. This may have biased response to some items by some persons.*

[17] *See footnote 1, p. 2.*

mised to fit the ecological capability of the land. In such cases, knowing what types of users endorse or reject the necessary policy may make it possible to direct specific information at the critical segment of users. A case in point is "burying noncombustible trash." In areas of intensive use or where the soil is shallow, such a practice is not consistent with long-range wilderness preservation, yet our data showed overwhelming approval of the practice. In educating wilderness users to "pack out their debris" and the necessity of such a practice, many of the more wildernist public can be reached through conservation groups and outdoor clubs, since the stronger wildernists tend to belong to such groups. Other means would be necessary to reach the more urbanist users who tend not to belong to organized groups. To reach these users might also require a different appeal.

Wilderness management is not an area where consensus of users should be controlling, yet their preferences should be considered. Our plea to wilderness managers is to **avoid drawing conclusions in a popular vote context without first looking for indications of different feeling among different types of users and the concerned public.**

In addition, the fact that part of our study deals with wilderness management preferences should not obscure the fact that many management alternatives are restricted by the Wilderness Act. Others are permissible only where necessary to protect the area from the effects of use. In both cases, the data are still valuable in that they reveal the sentiment of wilderness users surrounding such issues and thus further define the users' perception of wilderness. In addition, readers, managers, researchers, and users alike should remember that under the Wilderness Act, recreation use is subordinate to preserving for all an unaltered wilderness resource.

Organization of the Data

The following pages contain interpretations of response to the 53 questionnaire statements concerning management of wilderness-type areas. Following interpretation of each logical group of statements, the meaning and implications of the results are explored and summarized. The related statements have been assembled under the nine subject headings they concern.

The basic response data for the individual questionnaire statements are found in the appendix under similar headings. In the appendix, the data are summarized for each of the three areas included in the study – the

Wilderness users felt that administrators of such areas should be specially trained. Here, Forest Service officials discuss management problems at a wilderness workshop in the Glacier Peak Wilderness (August 19, 1967).

Eagle Cap, Three Sisters, and Glacier Peak Wilderness areas, respectively. The degree of correlation of response to each statement with wildernism scores is also indicated by the presence of a gamma statistic. The gamma statistics have, in turn, been classified as indicating relatively strong, moderate, or slight correlation between wildernism scores and reaction to the suggested management policies.

Wilderness-User Attitudes Toward Management Policies

I. User attitudes on administration of wilderness-type areas. – Four questionnaire statements were related to the administration of wilderness-type areas. Response to these statements indicated the following:

Three out of four persons felt that administrators of wilderness-type areas should be specially trained and their task recognized as different from administration of other types of wild land. Not surprisingly, the more wildernist respondents showed a stronger tendency to feel this way than did other users.

Almost eight out of 10 persons agreed that wilderness-type areas should be administered as units distinct from adjacent lands that may be devoted to harvesting timber and other resources. The more wildernist users showed a moderately stronger tendency to feel this way.

Sixty-five percent of the respondents disagreed with the statement, "it is not necessary to patrol wilderness-type areas regularly," with the more wildernist users displaying a slightly stronger tendency to feel this way. About two out of 10 persons didn't feel regular patrol was necessary, and 15 percent were neutral.

Six out of 10 persons did not feel that all cleanup duties in wilderness-type areas should be handled by employed personnel on regular schedules, but about two out of 10 persons supported "all cleanup by employed personnel," and the rest were neutral. The more wildernist respondents showed a slightly greater tendency to oppose "all cleanup by employed personnel" than did other users.

The response to these statements indicates that wilderness users in general, and particularly the more wilderness-purist, feel that **wilderness-type areas warrant management as administrative units distinct from adjacent**

Wilderness users endorsed the fact that regular patrol is necessary in such areas. Here, Forest Service wilderness patrolman travels with Girl Scout party in front of Broken Top in the Three Sisters Wilderness.

units, require regular patrol, and that **persons administering these areas should have special training for the task.** The responsible attitude of users is evident from the 60 percent who **did not feel that cleanup duties should be handled exclusively by employed personnel.** However, that the other 40 percent did **not** demonstrate this attitude toward cleanup clearly indicates the need for more education of users as to why a "pack it out yourself" program is necessary to maintain the quality of wilderness sites. As indicated in the section on wilderness behavior norms, **most wilderness users are exceptionally responsible in their attitudes. The minority who deviate from this accepted code, due to their background and lack of real interest in or understanding of the resource, must be reached.**

II. User attitudes concerning nature interpretation in wilderness-type areas. – Two questionnaire statements concerned possible means of providing more interpretation of natural features in wilderness-type areas. Response indicated that:

> Over six out of 10 people felt that a small book describing features observed along the trail, and designed to be carried in the backpack, should be sold by the administrative agency to enhance the pleasure of a back-country trip. Three out of 10 people were neutral, and less than 10 percent disagreed. However, the more wildernist respondents showed a slight tendency to disagree with the idea. It may be that these wilderness-purists have no need for such a guide because they already have the interpretive skills necessary to fully enjoy a wilderness trip or possess other interpretive material such as the books now being published by some conservation groups.
>
> Eight out of 10 persons felt that back-country rangers should be trained in public interpretation of the area's natural features, as well as in safety and trail techniques. The more wildernist respondents and others responded alike to this statement.

There seems to be support for interpretive booklets pertinent to wilderness-type areas and for more interpretive training of wilderness administrators, as witnessed in the response to the foregoing questionnaire statements. However, in a subsequent section of the questionnaire, less than one-third of the people favored descriptive signs giving interpretation of features of the area, and one-third opposed the idea, particularly the more wildernist users. It appears that **more interpretation is desired in wilderness-type areas, but the means of accomplishing it are crucial to acceptance of the idea. Interpretive signs constitute a defacement of wilderness; interpretive books in the users' packs do not.**

There are many advantages to be obtained from development of acceptable interpretive techniques for use in wilderness. Development of an appropriate interpretive booklet could raise the quality of the wilderness experience for many users, help disperse use to lesser known points within a wilderness, and impart appropriate rules and codes of behavior for such areas. Merriam and Ammons (1967) also concluded from their study of wilderness in Montana that "much could be done with adequate trail information or a published guide book which could be sold to users." Several excellent guidebooks, some including valuable interpretive material, have recently been produced by conservation groups, and reports indicate they sell extremely fast. As Merriam and Ammons (1967) point out, such books can help bridge the gap in understanding of wilderness between different types of users.

However, many of these books present information beyond the scope of interest or the geographical area of concern to the user and are expensive. They do not fill the need for an interpretive brochure which briefly presents material of interest or value to users of a specific area; e.g., geological, botanical, historical, archeological.[18]

III. Attitudes toward motorized equipment in wilderness-type areas. – Two questionnaire statements concerned the use of motorized

[18] *As a result of the findings reported in this publication, a Forest Service-sponsored study is now being carried out, under cooperative agreement with the University of Washington, to explore the desired dimensions of such booklets, the potential impact on wilderness use and users, and the possible means of distribution.*

equipment in the wilderness-type areas. Response indicated that:

> More than eight out of 10 persons felt that motorized trail bikes should be prohibited, and the more wildernist respondents tended even more strongly to oppose such vehicles.

> More than eight out of 10 persons opposed the idea that, if they can get them there, back-country users should be permitted to use powerboats on back-country waters. The more wildernist respondents opposed the idea more strongly than did the other respondents.

Response to the foregoing two statements indicates that wilderness users, and wilderness-purists in particular, overwhelmingly oppose the use of motorized trail bikes or powerboats in wilderness-type areas.

There appears to be a close relationship between our findings concerning the use of motorized trail bikes and powerboats in wilderness and the findings of Lucas (1964b, 1965) and Lucas and Priddle[19] in the study of the Boundary Waters Canoe Area. Lucas found that paddling canoeists were more exacting in the conditions they perceived as constituting wilderness and were particularly sensitive to the presence of motorboats, despite their common use in the area. The canoeists might be compared with the more wildernist respondents included in our study. Merriam and Ammons (1967) also found that motorboats and motor scooters were frowned upon by most persons interviewed in their study of visitors to the Bob Marshall Wilderness, the Mission Mountains Primitive Area, and back-country portions of Glacier National Park. They point out that "it is of interest to note that some users, two or three in each area, do not find scooters objectionable." Their sample for the three areas combined totaled 107 persons, indicating that something less than 10 percent of the users did not object to such vehicles. Our study revealed 9.9 percent who did not object to motor scooters and 7.3 percent who were neutral. The percent not objecting to motorboats in our study and theirs was nearly identical, 8.3 percent and 7.9 percent, respectively.

Less than 10 percent of the wilderness visitors felt the use of motorized trail bikes was appropriate to wilderness-type areas.

IV. Attitudes toward the use of helicopters. – Seven questionnaire statements concerned the use of helicopters in wilderness-type areas. Response indicated that:

> Almost everyone (96 percent) agreed that the use of helicopters is justified in wilderness-type areas for protection of the area (e.g., from fire).

> Almost everyone (98.6 percent) agreed that the use of helicopters is justified in wilderness-type areas for protection of human life.

> Over three out of four persons did not feel that the use of helicopters is justified in wilderness-type areas for visits by prominent people, and the more wildernist respondents tended more strongly to disagree with the idea.

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[19] *Lucas, Robert C., and Priddle, George B. Environmental perception: a comparison of two wilderness areas. Paper presented at annual meeting of Association of American Geographers, Syracuse, N. Y., March 31, 1964.*

The use of helicopters in wilderness-type areas was acceptable to a majority of users if such use helped preserve wilderness values; e.g., control of fire, eliminating overuse of trails by large pack strings, and wildlife protection. However, the more wilderness-purist users strongly opposed the use of helicopters.

About six out of 10 persons agreed that the use of helicopters is justified for routine administration and maintenance of wilderness-type areas, but one out of four (26.6 percent) disagreed. The more wildernist respondents displayed a strong tendency to oppose the idea.

Two out of three persons felt that the use of helicopters is justified in wilderness-type areas for bringing material and equipment to construction sites which otherwise would require large strings of pack animals, but almost two out of 10 persons disagreed. The more wildernist respondents displayed a moderate tendency to oppose the idea.

Fifty-six percent of the persons felt that the use of helicopters is justified in wilderness-type areas for bringing patrolmen to and from the area, but almost three out of 10 persons disagreed. The more wildernist respondents showed a strong tendency to oppose the idea.

More than 7 out of 10 persons felt that the use of helicopters is justified in wilderness-type areas for wildlife observation or control, but the more wildernist respondents showed a moderate tendency to disagree with the idea.

The collective response to all seven of the foregoing items suggests that almost all wilderness users **favor** the use of **helicopters for protection of the area from fire** and for **protection of human life** and **oppose** such use **for visits by prominent people**, with the more wilderness-purist users expressing stronger than average disapproval of the latter. A majority of the users accept the use of **helicopters for routine administration and maintenance, for bringing materials and equipment to construction sites where the alternative is to use large pack strings, bringing patrolmen to and from the area, and for wildlife observation and control.** But, those users with stronger wilderness-purist leanings tended to disagree with statements suggesting such uses of helicopters. **The use of helicopters for many purposes seems acceptable to a majority of wilderness visitors but apparently violates the ideals of the more wildernist visitors.**

Properly located trail skirting meadow at edge of timber is in good shape, despite heavy use.

Trails through the middle of meadows become muddy. Hikers and horses then move to one side. Soon multiple trails scar the landscape.

However, there was less opposition by the more wilderness-purist users where the issue was related to preservation of wilderness values (fire, overuse of trails by large pack strings, wildlife protection) than where the issue was related to routine management of such areas (e.g., routine administration and maintenance, bringing patrolmen to and from the area).

Merriam and Ammons (1967) found that a majority of respondents in their study of Glacier National Park back country and the Bob Marshall Wilderness felt airplanes (helicopters) were needed for emergency use or patrol, but they pointed out in their management recommendations that "it would be a good idea to restrict helicopter use, even in emergencies, to places not frequented by visitors."

We suggest that there may be advantages to the use of helicopters for many management purposes that would enhance the preservation of wilderness (Hendee and Mills 1968). However, the sight or sound of a helicopter is a repulsive thing to most users in a wilderness-type environment, and endorsement of the use of helicopters should not be construed as approval of their visual or audible effects on the environment.

V. Attitudes towards trails in wilderness-type areas. – Five questionnaire statements concerned the kinds of trails preferred by users in wilderness-type areas. Response indicated that:

> Three out of four persons disagreed that trails in the wilderness-type areas should be nonexistent, only blazed or marked routes.
>
> Almost everyone (86.6 percent) agreed that trails in wilderness-type areas should be developed and maintained consistent with volume of use.
>
> Three out of four persons felt that trails in wilderness-type areas should be of varied type and quality to different places, thus satisfying varied interests, but the more wildernist users showed a slight tendency to disagree.
>
> More than four out of five persons dis-

agreed that trails in the wilderness-type areas should be of high standard throughout the area, three out of 10 persons were neutral and only about one out of four agreed. However, the more wildernist respondents displayed a more moderate tendency than other users to oppose high-standard trails.

About eight out of 10 persons did not feel that trails in wilderness-type areas should be surfaced with sawdust or wood chips to keep dust down, with the more wildernist respondents strongly opposing such a practice.

Response to the foregoing items suggests that **trails should be developed and maintained appropriate for the use received – of varied quality** and **not of uniformly high standard throughout wilderness-type areas.** However, there appears to be only **little support for very low-standard trails** (e.g., blazed or marked routes) and **even less support for trails surfaced with sawdust or wood chips** to keep the dust down. These preferences seem quite consistent with a resolution adopted at a recent conservation group convention. The resolution asked that the Forest Service "when setting up standards of width and quality, and width of clearing, give more consideration to local terrain and anticipated use, and encourage the building of trails to blend into the hillsides and wind through the trees."[20]

VI. Signing preferences of wilderness users. – Ten questionnaire statements concerned wilderness-user preferences for signing.

Queries included preferences for construction materials, content, complexity, and location of signs. Response indicated the following:

A. Materials for signs

More than three out of four persons agreed that signs in wilderness-type areas should be of wood. Two other statements, suggesting enameled metal and stamped aluminum or stainless steel as sign materials, received only 8.2 percent and 16.0 percent agreement, respectively. There was a slight tendency for the more wildernist respondents to endorse wood signs and reject metal signs more than other users.

This statement illustrates how user preferences can conflict with management necessity. Metal signs have been used in back-country areas for many years because of reduced damage from bears, vandals, porcupines, and snowbreak, in addition to the smaller initial investment required. Wilderness managers must administer such areas with extremely limited funds, and the costs of meeting some preferences may greatly exceed the benefits. One inference that should be drawn, however, is that metal sign materials apparently are not consistent with most users' concept of wilderness. Their aversion to metal signs may be minimized through good taste on the part of the wilderness managers in the design, location, and intensity of metal signing where it is necessary.

B. Content of signs

About seven out of 10 persons felt that signs in wilderness-type areas should be directional only, giving distances to key points. An opposing item indicated only about three out of 10 persons felt that signs should be descriptive, giving interpretation of features of the area, but on the latter statement, another three out of 10 persons were neutral. The more wildernist respondents showed a moderate tendency to favor directional-only signs more than other users and a strong tendency to oppose interpretive signs more than other respondents.

C. Complexity of signs

A series of three statements dealt with the complexity of signs. The first indicated that four out of 10 persons agreed and about one out of four disagreed that signs should be simple, one item per sign, several signs per post. Respondent-agreement fell from about 40 percent to 15 percent and disagree-

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[20] *Federation of Western Outdoor Clubs, Resolution No. 33, 1967. Trail construction standards. Adopted at annual convention, Portland, Oregon, September 1967.*

Most wilderness users felt that signs in wilderness-type areas should be rustic and for directional purposes only, not for interpretive purposes.

Rustic wood signs, like these at a junction in the Glacier Peak Wilderness, fit the wilderness environment and were preferred by most users.

ment rose from about 27 percent to 42 percent on this statement when it was changed to specify signs should be simple, one item per sign, only one sign per post. Almost 50 percent of the users opposed the idea that signs should be elaborate, each sign large enough to include several items.

Between three and four out of 10 persons were neutral on these three items concerning signs, indicating confusion or a lack of clear-cut preference. The more wildernist respondents were slightly more inclined than other users to endorse simple signs, one item per sign, several signs per post, and to reject the same item when changed to specify only one sign per post. These more wilderness-purist users were also more opposed to elaborate signs with many items than were other users.

D. Location of signs

Five out of 10 persons agreed that signs should be placed at trail junctions only. Eight out of 10 respondents disagreed that signs should be grouped into a single directory of all routes emanating from one trailhead, with no further signs along the various trails. The more wildernist respondents showed a moderate tendency to favor signs at trail junctions more than other respondents, but all types of users alike tended to oppose single sign directories located at trailheads.

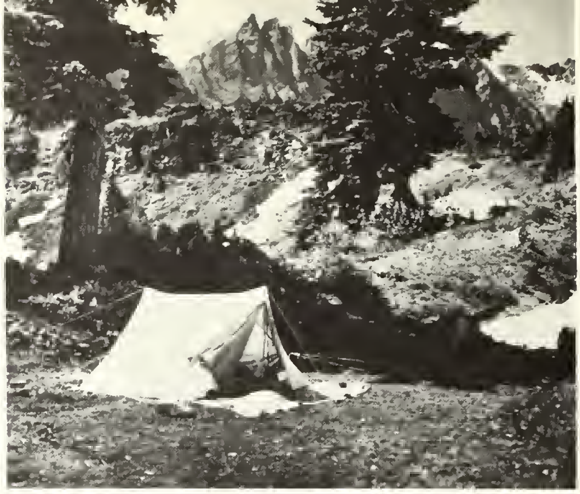
Response to the 10 questionnaire statements concerning signs indicated that **signs constructed of wood are overwhelmingly preferred over enameled metal, stamped aluminum, or stainless steel. A strong preference was indicated for signs giving directions only as opposed to signs interpreting features of the area. Preference was also given for simple sign design with one item per sign**, several signs per post. The concept of having elaborate signs large enough to include several items was rejected. The preferred location for signs was a trail junction rather than concentrating directions only at trailheads. The more wildernist respondents showed a slight tendency to support the preferences expressed by the largest percentage of other users. Between three and four out of 10 persons were neutral in their preferences on most of the statements, indicating a lack of clear-cut opinions concerning signs or, perhaps, some confusion over the questionnaire statements. The message for wilderness managers seems to be: **use wood signs where possible, keep them simple with directions only, and place them at trail junctions rather than concentrating them at trailheads.**

We neglected to include one important statement concerning signs in wilderness. This statement would have referred to the practice of designating trails by number rather than by name. Having no data on the preference of a sample of users concerning this issue, we can only give our opinion based on our personal preferences and the comments of many users with whom we have discussed our study. Our opinion is that this practice, at least in part, operates against the benefits to be derived by the user from a wilderness visit. We acknowledge the difficulties of transportation planning which extend even to wilderness-type areas, and there may be merit in the easier reference to numbered routes on maps. However, when hiking on a back-country trail, feeling satisfaction over having temporarily escaped the impersonal structuring of daily life, we are disappointed and offended at being greeted by a sign informing us that we are on Trail 1812b and Trail 1812c is a few miles ahead.

VII. Attitudes toward facilities and site improvements. – A total of eleven questionnaire statements dealt with facilities and site development. Two statements concerned toilet facilities, four sampled preferences for different types of tables and fireplaces, three related to protective developments facilitating horse use, and two referred to the construction of shelters in wilderness-type areas. The responses to these items are summarized in the following:

A. Attitudes toward toilet facilities

Five out of 10 persons agreed that outhouses are consistent with proper use of wilderness-type areas, and only about three out of 10 persons disagreed with the statement; however, the more wildernist respondents strongly tended to oppose the idea.



There were mixed feelings by respondents about facilities and site improvements. The more wilderness-purist users opposed them. Here is a backpacker's camp in the Glacier Peak Wilderness.

About one-third of the users felt that no toilet facilities whatever are consistent with proper use of wilderness-type areas, but almost 45 percent of the persons disagreed. The more wildernist respondents again tended to strongly oppose the presence of any toilet facilities in wilderness.

The Outdoor Recreation Resources Review Commission (1962) study also found 66 percent of their interviewed respondents endorsed primitive sanitary facilities, but in a postcamp questionnaire 53 percent indicated opposition to even rustic sanitary facilities. Bultena and Taves (1961) reported 78 percent of the canoeists interviewed in the Boundary Waters Canoe Area rated toilets as important. The response to our questionnaire statements concerning toilet facilities and the results of these other studies suggest some disagreement concerning the acceptability of outhouses in wilderness. In our study, wilderness-purists clearly opposed such facilities. This is another case where necessity and wilderness ideals appear to clash. A proper inference for wilderness managers would be to **use toilet facilities where necessary to protect the site but keep them as unobtrusive and rustic as possible.**

Movable rock fireplaces were endorsed by more users as being appropriate in wilderness-type areas than were permanent concrete fireplaces. Here, a freshly caught breakfast sizzles over a campfire in the Eagle Cap Wilderness.

Most users rejected the idea of plank tables in wilderness-type areas, but almost half of the respondents endorsed log or pole tables. Pictured here is a rustic, split-log table in the Railroad Creek drainage of the Glacier Peak Wilderness.

B. Attitudes toward tables and fireplaces

More than four out of 10 persons agreed that tables constructed of logs or poles are consistent with proper use of wilderness-type areas, but almost four out of 10 persons disagreed, including the more wildernist respondents who displayed a strong tendency to disagree.

Only one-fourth of the persons endorsed plank tables as being consistent with proper use of wilderness-type areas, but over one-half of the respondents disagreed. Again, the more wildernist respondents showed a strong tendency to disagree, even more so than they did for log or pole tables.

About six out of 10 persons disagreed with a statement suggesting that permanent (concrete) fireplaces are consistent with proper use of wilderness-type areas, and only about one out of four agreed. The more wildernist respondents strongly opposed the idea. As might be expected, almost five out of 10 persons endorsed movable rock fireplaces as being consistent with proper use of wilderness-type areas, with the more wildernist respondents showing a slight tendency to agree more than other users.

It is interesting to compare our findings concerning tables and fireplaces with some other studies. Bultena and Taves (1961) report that 60 percent of the canoeists rated fireplaces as important. Lucas (1964b), on the other hand, reported that canoeists more often asked that the picnic tables on back-country sites be removed than that more be added. He also reported that fire rings were preferred to iron and cement fireplaces. The ORRRC (1962) study found visitors to the large western wilderness areas, in general, opposed building "facilities," but that there was less resistance from respondents visiting eastern areas (Mount Marcy and Great Smoky) and the Boundary Waters Canoe Area than from those visiting the large western wilderness areas. Merriam and Ammons (1967) also found that simple campgrounds were desired.

With tables and fireplaces, as with toilet facilities, the message for managers seems to be **use only where necessary to protect the site, and keep them simple and rustic.** For campsite tables the rough-hewn table using split logs is an example, although another alternative might be to provide poles at campsites from which users could construct tables according to their need and preference

Pack strings are used by large parties of visitors and for many wilderness management tasks, but their use is exceedingly hard on trails, and pasture is often limited. In many locations, outfitters are required to carry food for their stock.

which could be dismantled when they left.

C. Attitudes toward developments facilitating horse use

More than one-half of the respondents did not feel that corrals for livestock are consistent with proper use of wilderness-type areas, and only two out of 10 agreed. The more wildernist respondents displayed a moderate tendency to oppose corrals more than did other users. Surprisingly, respondents from the Eagle Cap Wilderness, allegedly a horse-user area, showed no significantly greater acceptance of the idea than did visitors to other areas, but visitors to the Three Sisters Wilderness showed a little more opposition to such facilities.

About four out of 10 persons disagreed with an item suggesting that hitching racks or posts are consistent with proper use of wilderness-type areas, and less than three out of 10 supported such facilities. The more wildernist respondents were more likely to oppose such facilities. Again, respondents from the Three Sisters Wilderness Area were less likely to accept such facilities, and visitors to the Eagle Cap Wilderness showed no greater endorsement of hitching posts than users from all areas.

More than four out of 10 persons opposed drift fences for control of livestock as being consistent with proper use of wilderness-type areas, and a little over three out of 10 endorsed them.[21] The more wildernist respondents displayed a moderate tendency to oppose drift fences, but there was little difference in response from visitors to the different areas.

It seems obvious from the response to the several items concerning developments to facilitate horse use that there is mixed feeling on the part of users. This is probably related to whether or not they use horses. Conflicts between horse users and others are likely to increase as wilderness use increases. Horse use has already been prohibited in some areas where there is heavy foot travel. Snyder (1960, 1961, 1963), on the basis of 15 years of managing a large portion of the John Muir Wilderness (formerly the High Sierra Wilderness) in California, has frequently referred to the conflict between horse users and hikers. He indicates the belief that, where overuse is a problem, horses and mules should be the first to go as one 1,000-pound ironshod animal imposes

[21] *Drift fences also offer opportunities to the unskilled user to enclose stock in the locations where protection is sought by such fences. Reports of this are not uncommon among experienced wilderness managers. Thus, areas with such developments should be administered more intensely to guard against such an occurrence.*

Livestock corrals, hitching racks or posts, or drift fences – all developments to facilitate horse use – were opposed by most users and particularly by wilderness-purists. However, such facilities can make the presence of horses less offensive by keeping them away from other users and limiting their destructiveness to campsites and surrounding vegetation. Pictured here is a horse-worn campsite at Steamboat Lake in Eagle Cap Wilderness.

the wear and tear of several hikers. Bury (1967), in a recent article, suggests that zoning by time of year may also be an answer. The unfavorable reaction of many of our respondents to the suggestion of facilities to implement horse use probably stems in part from their dislike of horses. The manager should be aware of the potential of such facilities for making the presence of horses less obtrusive and minimizing their impact, esthetic and physical. **Horses should be kept away from hikers where possible.**

D. Attitudes toward permanently constructed shelters

Almost six out of 10 persons endorsed a statement suggesting that three-sided shelters for hikers are consistent with proper use of wilderness-type areas with about one-fourth of the users disagreeing. The more wildernist respondents showed a moderate tendency to oppose shelters for hikers, and visitors to the Eagle Cap Wilderness Area also opposed the idea 15 percent more than other wilderness users.

Response was evenly divided into thirds between those agreeing, neutral, and disagreeing that locked patrol cabins for official staff use only are consistent with proper use of wilderness type areas. The more wildernist respondents

Horses tied to this tree have damaged the roots.

A hitching post might have prevented the certain death of this tree, girdled by friction of halter ropes tied to it by horse users.

Horses have been turned loose to graze near the edge of a lake where they may do irreparable damage. A drift fence could prevent it.

showed a moderate tendency to oppose such facilities.

Merriam and Ammons (1967) found that nearly 80 percent of the 31 back-country visitors they interviewed in Glacier National Park favored trail shelters, but on the two National Forest areas included in their study, such facilities were not endorsed by a majority of the users. In a report devoted to the Glacier Park visitors, Merriam (1967) reported that "chalets already in place were accepted by the users as were primitive shelters. Shelters in classified wilderness are also a legal problem. Constructing shelters for users would be in the realm of convenience and comfort to the wilderness user, which violates current interpretation of the Wilderness Act under Forest Service policy, and shelters to facilitate administration of wilderness would set precedents for shelters by a host of other resource administrators; e.g., snow survey personnel, cattle grazers, miners, etc.

In summary, response to the foregoing statements concerning facilities and site improvements indicated that **about five out of 10 persons accept outhouses as being consistent with proper use of wilderness-type areas, but the more wildernist respondents oppose any kind of toilet facilities.**

More than one-half of the respondents reject the suggestion of plank tables in wilderness-type areas, but opinions are evenly

Locked patrol cabins for official use only were endorsed by only one-third of the users. Pictured is snow survey cabin in the Railroad Creek drainage of the Glacier Peak Wilderness.

Six out of 10 users endorsed three-sided shelters for hikers as consistent with proper use of wilderness-type areas.

Special horse camp near Image Lake in the Glacier Peak Wilderness keeps horses where they can do the least damage.

divided on log or pole tables. Not surprisingly, the more wildernist respondents tend to oppose any kind of tables.

Permanent concrete fireplaces are opposed, but movable rock fireplaces are endorsed as being appropriate to wilderness-type areas. The more wildernist respondents strongly oppose concrete fireplaces but show a slight tendency to accept movable rock fireplaces more than other users.

Corrals for livestock were rejected by most wilderness users and particularly the more wildernist respondents. More persons (four out of 10) opposed hitching racks or posts than endorsed them (three out of 10). And again, the more wildernist respondents were more likely to oppose such developments. Over four out of 10 persons, particularly the more wildernist respondents, opposed drift fences, whereas, only about three out of 10 persons endorsed them. It is worth noting that on the three statements relating to developments facilitating the use of recreation livestock, respondents from the Eagle Cap Wilderness, allegedly a horse-user area, did not differ significantly in their pattern of response from that for all areas. On the other hand, persons from the Three Sisters Wilderness displayed a greater aversion to corrals for livestock and hitching racks or posts than did visitors to the other areas.

Hiker shelters serve as attractive nuisances in wilderness-type areas, leading to overuse. Here is the memorial shelter at Image Lake in Glacier Peak Wilderness.

Three-sided shelters for hikers were endorsed by six out of 10 persons, but the more wildernist respondents and those from the Eagle Cap Wilderness were more likely to oppose the idea. Locked patrol cabins for official use only received evenly divided response between those endorsing such facilities, those neutral, and those disagreeing, but the more wildernist respondents were more likely to disagree.

It has been difficult to make direct comparisons between our data and the results from other studies concerning facilities to implement wilderness use. Questions are never phrased the same, and some studies have used very limited samples. As each item was considered, we related it to similar material from other studies and, where possible, gave our conclusion.

As a concluding observation on the results of the preceding items concerning facilities, we suggest that **facilities of any type in wilderness seem to offend users who have wilderness-purist attitudes**. This, in turn, reinforces the terms of the Wilderness Act which provides for facilities and improvements only where necessary to protect the area. As McClosky (1966) points out "the key management concept (under the Act) is minimization of man's influence on the environment." This leaves the decision of whether or not to provide facilities up to wilderness **managers who must decide when facilities are necessary and must also be aware that despite their necessity in certain places, the presence of any improvements will offend the sensitivities of wilderness-purists**. In addition, **they must be kept rustic and subtle to be compatible with most users' concept of wilderness.**

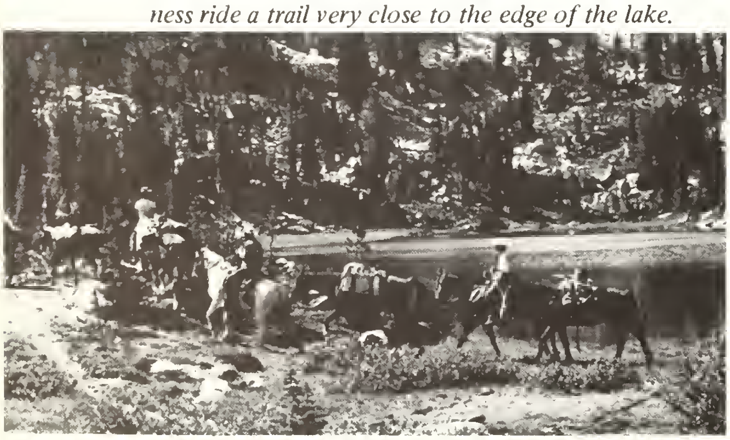
VIII. Attitudes toward restricting use or charging fees. – Three questionnaire statements concerned rationing of human use, restricting horse use, and charging for use, respectively. Response indicated the following.

> Almost five out of 10 persons did not feel that use of wilderness-type areas has to be restricted to limited numbers of people in a given area at a given time, and only three out of 10 agreed.

> Two out of three persons disagreed that the use of pack animals should be prohibited in wilderness-type areas since they do considerable damage to natural features. The more wildernist respondents displayed a moderate tendency to oppose pack animals more than did other users.

> It was interesting that visitors to the Eagle Cap Wilderness were more likely to oppose restriction of pack animals.

A party of horseback riders in the Eagle Cap Wilderness ride a trail very close to the edge of the lake.



This is the first evidence that has appeared indicating that visitors to the Eagle Cap Wilderness, allegedly a horse-user area, are more favorably disposed toward the presence of horses in wilderness.

> Only four out of 10 persons felt that costs of back-country administration and maintenance should be defrayed by some form of moderate charge with strong wildernists showing a slight tendency to oppose a charge for use more than other users.

Merriam (1964) reported that respondents in his study of the Bob Marshall Wilderness would be willing to pay an average of $3.60 for an annual license to visit wilderness. The ORRRC (1962, page 254) study also reported a willingness to pay on the part of users and concluded on the basis of extensive analysis that a user fee would substantially reduce use.

In summary, **most wilderness users do not seem to feel that human use of back-country areas needs to be restricted or that the use of pack animals needs to be restricted**. Strong wildernists were more likely to favor restricting packstock use, but respondents from the Eagle Cap Wilderness were more likely to oppose such a restriction. **More than four out of 10 persons favored a moderate charge for use of wilderness-type areas to defray costs of administration and maintenance, but one-third of the respondents, and particularly the stronger wildernists, opposed the idea.**

We cannot help but observe an inconsistency between users' responses to the possibility of restricting or rationing use and the realities of current trends. Wilderness use is increasing rapidly, and both the esthetic and biotic carrying capacities of some areas are being exceeded, or soon will be, beyond high-quality levels. Lucas (1964b) reports on the basis of his extensive study of the Boundary Waters Canoe Area that the "more pure users" (canoeists) are particularly sensitive to crowding and that the area they perceived as wilderness becomes substantially reduced with crowding. He points out in another paper (Lucas 1965) that "if there are truly diminishing returns in increasing use of the wilderness as the data seem to show, a serious problem lies ahead. Rationing recreational use, accepting lower quality experience, or expanding wilderness would be possible responses (solutions) singly or in many combinations." These are not unique observations, for virtually all scientists who have studied wilderness report alarm concerning problems of overuse in spots (Frissel and Duncan 1965; Snyder 1961, 1963, 1966). The potential for increasing carrying capacity by better distribution of use is not infinite, and attempts to control distribution have largely been unsuccessful. Grazing, timber cutting, or other resource uses are not allowed without restricting them to a sustained-yield basis. Use of recreation resources should be no different. Ultimately, the use of wilderness will need to be rationed by charging fees or by other means. This reality must be faced, and wilderness managers, despite the resistance of many users to the idea of restricted use, must soon begin the task of educating the public to this reality of wilderness preservation. Research must also bend to the task of determining physical and esthetic carrying capacities, consistent with preservation objectives, to serve as standards upon which to base rationing decisions (Wagar 1964, 1966; LaPage 1963).

IX. Attitude toward resource management practices. – A total of eight questionnaire statements concerned resource management practices, and, in particular, restrictions that might be placed on such activities in wilderness-type areas. Response indicated the following:

> Virtually everyone (97.9 percent) agreed that man-caused fires in wilderness-type areas, and outbreaks of nonnative insects and diseases, should be extinguished as soon as possible, with the more wildernist users concurring slightly more than others.
>
> About 9 out of 10 persons did not feel that lightning-caused fires, heavy infestations of native insects, and heavy infestations of forest diseases should be allowed to run their natural course. However, the more wildernist respondents displayed a slight tendency to oppose control of lightning fires and a moderate tendency to oppose control of native insects and forest diseases. It is interesting to note that the ORRRC (1962) study found in general that less than one-half of their respondents favored control of forest insects by spraying.
>
> About nine out of 10 persons felt that sections of wilderness-type areas denuded by fire, insects, or disease, and subject to rapid erosion, should be protected as soon as possible by artificial restoration of an adequate cover of vegetation. However,

The heavily used Image Lake basin in the Glacier Peak Wilderness illustrates the problem of wilderness carrying capacity. The physical effects of overuse have required management measures, such as a special horse camp and a separate horse trail around the basin. Wilderness managers also wonder how many persons can be camped in such an area before the esthetic quality of the environment is so reduced that it ceases to be a wilderness experience. However, only three out of 10 wilderness users agreed that use of wilderness-type areas has to be restricted to limit numbers of people in a given area at a given time.

the more wildernist respondents were moderately inclined to oppose artificial revegetation of such denuded areas. The response to this statement resembles the ORRRC (1962) study finding that most users favored replanting trees in burned or barren areas.

Forty-five percent of the respondents approved and 40 percent disapproved of hunting in wilderness-type areas. Here, two successful hunters pack their kill from the Glacier Peak Wilderness.

Almost seven out of 10 persons disagreed that livestock grazing as a revenue-producing use should be encouraged in wilderness-type areas, since this will defray management costs. The more wildernist respondents, in particular, opposed such an idea.

About 45 percent of the persons felt that hunting should be forbidden in wilderness-type areas, but four out of 10 users disagreed. Strong wildernists showed a slight tendency to oppose hunting more than other users.

About 35 percent of the persons felt that even well-managed second-growth timber must always be assumed to have lower recreational value than a virgin forest, but almost one-half of the respondents disagreed. The more wildernist respondents showed a strong tendency to view second-growth forests as inferior, and visitors to the Glacier Peak Area were also more likely to feel this way.

In summary, **virtually all users endorsed the control of man-caused fires and exotic insects or disease, lightning-caused fires, and heavy infestations of native insects and forest diseases. But, the more wilderness-purist respondents, although above average in their degree of support for control of man-caused fires and exotic insects or disease, were less receptive to control of lightning-caused fires and native insects and diseases.**

Strange as it seems, the advisability of controlling all fires in wilderness is now being questioned by foresters, the ones, no doubt, responsible for selling total fire control to the public. The total exclusion of fire has led to large scale vegetation change in wilderness areas where fires occurred frequently before the white man's influence. Controlled burning, loose herding of wildfires, and even prescribed wildfire now find advocates when experienced wilderness managers gather. The problem of fire in wilderness will, no doubt, become a major issue in the management of such areas in the future.

Most users also felt that wilderness-type areas denuded by fire, insects, or disease

should be protected by artificial restoration of adequate vegetation, but the more wildernist respondents tended to oppose such a practice. About 35 percent of the respondents regarded second-growth timber as inferior to virgin forest in recreational value. Strong wildernists were especially likely to hold this view. But, about half of the respondents rejected the idea that second-growth timber must always be assumed inferior for recreation purposes.

About seven out of 10 persons opposed livestock grazing as a revenue-producing use, and this opposition was accentuated among the more wildernist users. Opinion was split regarding hunting, with 45 percent opposing such activity in wilderness-type areas, and 40 percent approving.

These findings clearly lend support to the contention of Dean Stephen H. Spurr (1966) that there is a difference between "ecological wilderness" and "sociological wilderness." For some people, even appreciable human interference with the natural ecological processes in an area does not remove the area from what they conceive to be "wilderness." But, according to our data, the socially acquired conception of wilderness that is held by the wilderness-purist comes closer to being equivalent to ecological wilderness than does the conception held by others. Even the purist, however, appears likely to tolerate or even desire some management of some ecological processes. Spurr expresses the notion that the aim of wilderness management techniques always should be to avoid the introduction of obvious man-created incongruities into the wilderness landscape. The biologically trained manager appears far more likely to detect such incongruities in the landscape than most wilderness users.[22] This perceptiveness should be used to guard against subtle man-created changes in the wilderness environment and to interpret natural changes as they occur.

Wilderness use is heaviest in some locations during the early high-country hunting season. (Washington State Department of Game photo.)

Most mountain goats in the Pacific Northwest are found in remote wilderness-type areas.

[22] *For further discussion of ecological aspects of wilderness management, see Stone (1965), Heinselman (1965), Lucas (1963b).*

Management Preferences Summarized

Responses to the 53 questionnaire statements concerning management policies for wilderness-type areas are too extensive to summarize here individually. Readers seeking an overview should refer to the summaries of the nine categories of statements in the preceding pages. At this point, we offer only a few general interpretations regarding variation in attitudes toward management policies by the different types of users and those persons who visited the different areas.

First of all, **those respondents who were more wilderness-purist in their orientation, as measured by the wildernism scores, often differed significantly in their management preferences from the preferences expressed by other respondents.** They frequently had the same opinions as other users but expressed them more intensely. In a number of cases, their preferences opposed the majority of other users. We suggest that the views of these purists represent the opinions of the group of people most perceptive of wilderness values. **To preserve wilderness of enduring character, opinions of wilderness-purists should be carefully weighed, even when they are in the minority.**

Second, **there was little variation in attitudes among visitors to the three different areas, despite alleged differences in the type of use each received.** This suggests some range of reliability and perhaps extends the validity of the data. It is particularly interesting that the respondents from the Eagle Cap Wilderness, presumed to be a horse-user area, did not differ in attitude, in most cases, from visitors to the other areas on statements relating to horse use or on other issues. Response from users of the Glacier Peak Wilderness, presumed to be a backpackers' area, and from persons sampled in the Three Sisters Area, reportedly a day-hiker area, were also similar. This suggests that characterizing an area on the basis of its perceived type of use should not be done without adequate data and is not as significant as many believe in its meaning to management. **This study indicates little support (in the form of systematic variations in user opinions) for different management policies for the three areas other than those necessary to adapt to obvious local conditions, such as terrain, access, weather, etc.**

Third, **many users expressed a preference for facilities and improvements** that are essentially prohibited under the terms of the Wilderness Act. The persons expressing such preferences were, in most cases, those users who were not as wilderness-purist as measured by their wildernism scores.

Summary

We undertook this study to find out what kinds of persons visit wilderness in the Northwest, what values and codes of behavior they associate with wilderness use, and how they feel about certain policies that might be used in the management of such areas. The study is based on the response of 1,350 persons to an eight-page questionnaire that was sent to a random sample of visitors recorded during 1965 in the Glacier Peak, Eagle Cap, and Three Sisters Wilderness Areas.

We found, as expected, that the wilderness users were highly educated. In fact, about one-third of them had postgraduate educations, and more than 60 percent of them came from less than the top 10 percent of the U. S. population in terms of educational attainment. Three out of four of the users were married, and all but 15 percent of these married respondents had children. About one-half of the wilderness use reported by the respondents took place in small family groups and much of the remainder with small clusters of friends, indicating that the wilderness experience is typically sought in the company of a few intimates.

The study indicated that our increasingly urban culture produces persons motivated to use wilderness; in fact, the more wilderness-purist users were most likely to have been raised in urban environments. The average respondent reported taking about six wilderness trips the previous year for approximately 2½ days each trip, accounting for an average of 14½ man-days of use. There was little dif-

This study and others indicate that recreationists tend to continue in the patterns learned in childhood. The families pictured here in the Three Sisters Wilderness will, no doubt, produce successive generations of wilderness users.

ference in these figures between users recorded in the three separate areas, indicating that wilderness visits in the Pacific Northwest are more frequent and of less duration than previously anticipated, particularly when compared with studies of wilderness use in the northern Rocky Mountains. Nearly 70 percent of the respondents reported taking their first wilderness trip before they were 15 years old. Almost half of the respondents indicated that three or more of their five closest friends also participated, at least occasionally, in wilderness-type recreation.

Membership was reported in 80 different groups identified by the respondents as "conservationist organizations," and 154 different groups identified as "outdoor clubs." Many groups were reported under both headings, but, amazingly, 218 different groups were mentioned. Approximately 30 percent of the wilderness users belonged to such groups, and they were more often urban residents, higher educated, and raised in urban areas than were most users. They made more and longer wilderness visits and had more close friends who were also wilderness users.

To differentiate between respondents who were wilderness-purist in their point of view and those who were less extreme in their wilderness values or even urban or convenience oriented in outlook, we designed an attitude scale in the questionnaire to measure these tendencies. The scale included a total of 60 items concerning features, activities, and benefits that might be associated with wilderness use. Wildernism (contraction of wilderness-purist) scores, based on the 30 most highly correlated items in the scale, were cal-

Wilderness trips can be taken "in style." Here, Trail Riders of the Wilderness enjoy their outfitter's cooking in the Glacier Peak Wilderness.

culated for each respondent. The more wilderness-purist respondents reacted differently to many of the suggested wilderness behavior norms and management policies. They opposed behavior and policies violating the complete naturalness of wilderness to a much greater degree than did most respondents. The more wildernist respondents also tended to be more highly educated, had more close friends who were wilderness users, and were more likely to belong to one or more conservationist organizations or outdoor clubs.

A factor analysis of the statements in the wildernism scale indicated seven clusters of statements about which most wilderness users felt the same. The factors which best differentiated the wilderness-purists from other users suggested, in general, a greater aversion to the artifacts and facilities of civilization and a greater devotion to satisfactions obtained from perceiving the undisturbed natural environment. Comparison of our findings with several other studies in widely different areas consistently revealed similar themes underlying wilderness use.

The total information on the characteristics of wilderness users suggests that wilderness values are the product of high sophistication, are typically developed early in life, and are spread largely through social processes like club membership and association with close friends. **To better understand the appeal of wilderness and the rapidly increasing use of these areas, resource managers must learn more about the social processes underlying such use and the values to which these persons are oriented.**

The questionnaire contained 22 suggested normative statements of informal rules and customs that might be observed when visiting wilderness-type areas. Factor analysis indicated five general groups of statements with consistent interrelated patterns of response. These groups of statements implied the presence of norms among wilderness users, suggesting: feelings of equality and a sense of responsibility for maintaining the propriety of each other's behavior; a rejection of behavior controls except where reasons were clearly understood; a rejection (particularly by wilderness-purists) of activities, behavior, and conveniences reminiscent of civilization; an informal code of conduct supporting maintenance of unpolluted campsites; endorsement of certain skills as appropriate to proper use of wilderness.

In general, we found very impressive norms of behavior among wilderness users. However, some of the behaviors sanctioned by wilderness users should be alarming to resource managers because they are inconsistent with sustaining the high quality of the resource. For example, many respondents felt that they should camp wherever they pleased and have the right to decide whether or not to shortcut trails. Almost four out of 10 persons saw nothing wrong with washing dishes, clothes, or themselves directly in streams or lakes, and 84 percent felt that noncombustible trash should be buried. Almost one-third of the respondents felt that making improvements in campsites by removing brush and limbs, putting nails in trees, and constructing simple box cupboards was appropriate, and half of the users felt cutting brush or limbs for beds, as well as wood for their campfires, was acceptable. Most wilderness managers have already had to cope with the effects of such practices. The rapid increase in wilderness use that is expected will undoubtedly bring larger numbers of visitors whose concepts of appropriate behavior deviate from what is consistent with preserving the resource. **Wilderness managers should immediately step up their attempts to educate such users and control their behavior.**

Fifty-three statements in the questionnaire called for reactions to suggested management practices, policies, and guidelines that might be implemented in wilderness-type areas. The statements refer to the following general areas of concern: (1) administration, (2) nature interpretation, (3) motorized equipment use, (4) helicopter use, (5) trails, (6) signing, (7) campsite facilities and improvements, (8) rationing and charging for use, and (9) restriction of resource management practices. In general, reactions to these statements indicated that users felt wilderness areas warranted management as distinct administrative units and that persons managing these areas should have special training for the task. They supported the concept of nature interpretation in wilderness with a small booklet that could be carried in the pack but not with signs. Not surprisingly, motorized trailbikes and powerboats were rejected by almost all users as being inconsistent with wilderness. The use of helicopters for many purposes was acceptable to a majority of wilderness visitors where such use was related to preservation of wilderness values, as in controlling fire, eliminating overuse of trails by large pack strings, and protecting wildlife. But, such a practice violated the ideals of wilderness-purists.

The respondents felt that trails should be developed and maintained appropriately with the amount of use received and should not be uniformly of high standard throughout wilderness-type areas. However, there was little support for low-standard trails or for surfacing of trails with sawdust or wood chips to keep the dust down. The implications under items concerning signs were for simple wood signs containing directions only, placed at trail junctions rather than concentrated at trailheads. The mixed preference for such facilities as tables, fireplaces, and toilets implied that they should be used only where necessary to protect the site and should be kept simple and rustic. There was little support for developments to implement horse use, such as corrals, drift fences, and hitching racks or posts. But such preferences might be related to a dislike by hikers for the presence of horses, and managers should be aware of the potential of such facilities for making the presence of horses less obtrusive and minimizing their esthetic and physical impact. Users were more likely to endorse three-sided shelters for hikers as being consistent with wilderness-type areas than locked patrol cabins for official use only. In all of the items concerning facilities and improvements, there was opposition from the more wilderness-purist users.

Most respondents did not seem to feel that human use or the use of pack animals needs to be restricted. More than four out of 10 persons favored a moderate charge for use, but strong wildernists opposed the idea. The general reluctance of users to support concepts of rationing and restricting use of wilderness warrants the concern of managers who will soon be forced to restrict use of some areas so as not to exceed physical and esthetic carrying capacities. Most respondents endorsed the control of man-caused fires, exotic insects or disease, lightning-caused fires, and heavy infestations of native insects and forest diseases. However, the more wildernist users were less receptive to control of these naturally occurring phenomena. Wilderness-purists also opposed artificial restoration of vegetation on denuded areas, whereas most respondents approved of such a practice. The opinion was split regarding hunting in wilderness areas, with 45 percent opposing and 40 percent approving of the activity.

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Appendix

This appendix contains data summarizing wilderness-user response to 22 questionnaire statements suggesting informal customs and rules that might be observed in wilderness-type areas and 53 statements suggesting wilderness management policies for such areas. Response is given in terms of the percent of respondents from each area and from all areas who agreed, were neutral, or disagreed with each statement.[23] In addition, the direction and degree to which response to each statement was associated (correlated) with the wildernism scores of the respondents are indicated in the right-hand margin. Following is an explanation of the process we used to categorize the relationship (correlation) between wildernism scores and response to other items as strong, moderate, or slight.

[23] *Statistical analyses were performed by use of all five categories of response requested in the questionnaire (SA, A, N, D, SD), although only the percentage of respondents agreeing, neutral, or disagreeing is given.*

Gamma Statistics--A Method of Relating Questionnaire Response to Wilderness-Purist Tendencies

The statistic we used to measure the association between wildernism scores and response to individual questionnaire statements is called gamma. It indicates the proportional reduction in error one could achieve in predicting rank order variation in response to the statements (strongly agree to strongly disagree) from knowledge of an individual's wildernism score over the errors one would make if such predictions were made at random (Costner 1965, Goodman and Kruskal 1954). Gamma varies from -1.0 to +1.0, the algebraic sign indicating the direction of association. For simplicity's sake, it might be compared to a squared correlation coefficient.

As previously noted, all of the respondents were wilderness users; thus, they all shared some measure of wilderness values and therefore scored relatively high in the wildernism attitude test. This led to a relatively concentrated grouping of wildernism scores near the upper end of the scale; i.e., very few respondents were urbanist (development oriented) in their attitudes. When we correlated these scores with response to the items concerning management and behavior preferences, the possibility of getting high gamma statistics (i.e., -.70 or +.70) was reduced, because there were few low wildernism scores to balance the analysis. The highest values of gamma that we discovered were, thus, around -.55 or +.55, which as we indicate, is due to the statistical structure of the data. However, for practical interpretation (in a relative sense), the statements receiving gamma values near the upper end of the distribution in this study can be considered as quite strongly associated with wilderness-purist concepts as expressed in the wildernism scores.

Table 10 gives the distribution of gamma statistics and the four categories of association (correlation) with wildernism scores – "strong," "moderate," "slight" and "negligible" – that we designated for different values of gamma. Table 10 is based on response to all statements from visitors to all three areas combined. The algebraic signs of gamma are not indicated in table 10 because the categories of association (strong, moderate, slight, or negligible) are based on the strength of association indicated by the value of the statistic, regardless of the direction.

Table 10. – Distribution of gamma statistics relating wildernism scores to 74 questionnaire statements for 1,348 respondents

Absolute value of gamma	Number of statements in a category	Percent of statements in a category	Designated (relative) degree of correlation with wildernism scores
.30+	20	27.0	Strong correlation with wildernism scores
.15-.29	21	28.4	Moderate correlation with wildernism scores
.06-.14	20	27.0	Slight correlation with wildernism scores
.00-.05	13	17.6	Negligible
	74	100.0	

Suggestions for Use of the Appendix Data

Wilderness managers and others may wish to use the actual response data for individual questionnaire statements to answer more specific questions concerning wilderness-user tastes, preferences, or values. For instance, in the course of selecting the kind of sign material or the kind of signs to be used in a wilderness-type area similar to the Glacier Peak Wilderness, an administrator might wish to review the preferences of wilderness visitors expressed in this study. We suggest that the following things be kept firmly in mind:

1. The three wilderness areas included in the study, Eagle Cap, Three Sisters, and Glacier Peak, are characterized as a horse-use area, a day-use area, and a backpackers' area, respectively. The study indicates little difference in user preferences from the three areas, but managers might wish to check for even minor differences in response of users from

the wilderness that best approximates the area they are interested in.

2. See if there is a clear preference indicated in the percentages given under agree, disagree, or neutral. (Even if there is a clear-cut preference, go on to the next step.)

3. Look under "correlation with wildernism scores" to see if response to the statement was correlated (strong, moderate, slight, or negligible) with respondents' wilderness-purist (wildernist) tendencies. This indicates whether the more strongly wilderness-purist respondents tended to agree or disagree, more than other respondents, with the statement as it was presented; i.e., a +strong under "correlation with wildernism scores" indicates that the more wildernist respondents consistently agreed with the statement as it is presented more than did other users. These purists are most perceptive of long-standing wilderness values. Their opinions should be carefully considered.

4. Recognize that the data represent the collective preferences of wilderness users, purist and otherwise, but that there are many other considerations, such as legal provisions of the Wilderness Act of 1964, the ecological capability of the resource, established policies, etc.

Statistical Summary of Response to Statements Concerning Rules and Customs of Wilderness Users

Following are 20 questionnaire statements suggesting informal customs and rules to be observed in wilderness-type areas, a summary of the response they received from visitors to the three areas, and the relative correlation of wildernism scores with response to the statements. In the main body of the report, these statements are grouped into categories based on the similarity of response to clusters of statements as identified by factor analysis. Here, the statements have been arbitrarily grouped into the following categories based on the issues with which they are concerned:

I. Statements Concerning Personal Freedom.—

1. One should camp wherever he pleases in the remote back country

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	64.1	7.9	28.0	G.25 + Moderate
Three Sisters users	55.2	8.8	36.0	G.13 + Slight
Glacier Peak users	55.9	6.4	37.7	G.13 + Slight
All users	57.8	7.7	34.5	G.15 + Moderate
				N=1326

2. Moderate improvement of a campsite is desirable (e.g., removing brush and limbs, putting nails in trees for utensils, simple box cupboards, etc.)

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	35.7	13.5	50.8	G-.39 - Strong
Three Sisters users	25.8	15.5	58.7	G-.21 - Moderate
Glacier Peak users	28.4	13.7	57.9	G-.33 - Strong
All users	29.2	14.3	56.5	G-.30 - Strong
				N=1329

3. In remote back country recreational areas, nobody had better try to tell me what I should or shouldn't do.^

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	5.6	12.3	82.1	G-.03 Negligible
Three Sisters users	3.2	10.4	86.4	G-.05 Negligible
Glacier Peak users	4.4	11.4	84.2	G .03 Negligible
All users	4.2	11.3	84.5	G-.02 Negligible
				N=1323

4. If a person sees a shorter route than the trailmakers used, he should have the right to decide whether to stay on the trail or not.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	34.8	15.2	50.0	G .08 + Slight
Three Sisters users	32.8	15.4	51.8	G .00 Negligible
Glacier Peak users	29.8	14.1	56.1	G-.06 - Slight
All users	32.2	14.9	52.9	G .00 Negligible
				N=1323

5. In the back country, a person should be free to cut brush or limbs for his bed, wood for his campfire.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	53.0	13.2	33.8	G .03 Negligible
Three Sisters users	50.3	14.5	35.2	G-.14 - Slight
Glacier Peak users	52.8	10.0	37.0	G-.15 - Moderate
All users	52.0	12.5	35.5	G-.10 - Slight
				N=1316

6. Every back country traveler (or party of travelers) should be required to obtain a fire permit from the administrative agency before entering an area.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	62.0	19.0	19.0	G .03 Negligible
Three Sisters users	64.6	17.1	18.3	G-.01 Negligible
Glacier Peak users	64.1	20.2	15.7	G .01 Negligible
All users	63.7	18.7	17.6	G .01 Negligible
				N=1329

7. In an emergency, the person or party in trouble has first claim on the time and energy of everyone near, even if some cherished plans have to be abandoned.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	93.8	3.5	2.7	G.28 + Moderate
Three Sisters users	93.0	3.8	3.2	G.19 + Moderate
Glacier Peak users	92.5	4.6	2.9	G.15 + Moderate
All users	93.0	4.0	3.0	G.20 + Moderate N=1324

II. Statements Concerning Camping Habits.—

1. One should not wash his dishes, his clothes, or himself directly in streams or lakes.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	60.6	11.7	27.7	G.00 Negligible
Three Sisters users	63.2	12.6	24.2	G.01 Negligible
Glacier Peak users	59.4	11.6	29.0	G.08 + Slight
All users	61.1	12.0	26.9	G.03 Negligible N=1326

2. All evidence of use of an area should be removed when leaving a campsite.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	91.1	3.5	5.2	G.12 + Slight
Three Sisters users	91.8	2.8	5.4	G.03 Negligible
Glacier Peak users	89.4	4.8	5.8	G.21 + Moderate
All users	90.8	3.7	5.6	G.12 + Slight N=1327

3. If a considerable quantity of wash water must be disposed of, a sump hole should be dug for it.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	79.0	11.4	9.6	G .06 + Slight
Three Sisters users	80.4	10.8	8.8	G-.08 - Slight
Glacier Peak users	75.4	12.4	12.2	G .03 Negligible
All users	78.3	11.5	10.2	G-.01 Negligible N=1326

4. Noncombustible trash (e.g., tin cans, aluminum foil, glass, unburned garbage) should be buried.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	87.1	.9	12.0	G .11 + Slight
Three Sisters users	80.6	2.2	17.2	G-.04 Negligible
Glacier Peak users	85.3	1.2	13.5	G.08 + Slight
All users	84.0	1.5	14.5	G. 04 Negligible
				N=1320

5. Trash left by previous back country users should be removed by other users if they can do so.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	93.3	2.9	3.8	G.40 + Strong
Three Sisters users	93.0	4.8	2.2	G.21 + Moderate
Glacier Peak users	95.7	2.3	2.0	G.24 + Moderate
All users	94.0	3.4	2.6	G.28 + Moderate
				N=1329

6. Campfires should be no larger than necessary.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	95.8	2.4	1.8	G.35 + Strong
Three Sisters users	96.4	2.6	1.0	G.14 + Slight
Glacier Peak users	94.8	2.5	2.7	G.32 + Strong
All users	95.6	2.5	1.9	G.26 + Moderate
				N=1324

III. Statements Concerning Expected Behavior in Wilderness.—

1. Camping isn't complete without an evening campfire.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	76.0	15.8	8.2	G-.08 - Slight
Three Sisters users	74.1	16.5	9.4	G-.16 - Moderate
Glacier Peak users	74.0	18.0	10.0	G-.11 - Slight
All users	73.8	16.9	9.3	G-.13 - Slight
				N=1326

2. The more luxuries a party can bring, the better the camping trip.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	3.7	8.5	87.8	G-.44 - Strong
Three Sisters users	2.2	10.7	87.1	G-.31 - Strong
Glacier Peak users	3.5	8.7	87.8	G-.33 - Strong
All users	3.1	9.4	87.5	G-.35 - Strong
				N=1330

3. Radios should not be brought into the back country.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	22.5	41.3	36.2	G.32 + Strong
Three Sisters users	36.0	32.3	31.7	G.39 + Strong
Glacier Peak users	31.6	35.8	32.6	G.43 + Strong
All users	30.9	35.9	33.2	G.38 + Strong
				N=1323

4. A road to a place takes most of the fun out of walking there even if the trail follows a different route.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	68.8	10.5	20.7	G.53 + Strong
Three Sisters users	70.0	15.1	14.9	G.54 + Strong
Glacier Peak users	75.5	11.6	12.9	G.59 + Strong
All users	71.7	12.7	15.6	G.56 + Strong
				N=1328

5. Barking dogs, car horns, and yelling people do not belong in remote back country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	91.2	5.0	3.8	G.54 + Strong
Three Sisters users	92.2	5.4	2.4	G.50 + Strong
Glacier Peak users	92.7	4.6	2.7	G.61 + Strong
All users	92.1	5.0	2.9	G.55 + Strong
				N=1326

6. In the back country, formality should be put aside; everyone should be equal there.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	78.8	16.2	5.0	G.15 + Moderate
Three Sisters users	81.7	13.3	5.0	G.09 + Slight
Glacier Peak users	81.7	11.6	6.7	G.15 + Moderate
All users	81.0	13.4	5.6	G.13 + Slight
				N=1313

7. If you see a person in a back-country recreational area doing something he shouldn't do, you should say something to him about it.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	78.6	16.4	5.0	G.31 + Strong
Three Sisters users	79.2	17.2	3.6	G.09 + Slight
Glacier Peak users	83.8	13.5	2.7	G.27 + Moderate
All users	80.6	15.7	3.7	G.22 + Moderate
				N=1322

8. Playing cards and reading books are not appropriate to back country, unless the weather is bad.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	14.5	31.6	53.9	G.06 + Slight
Three Sisters users	16.5	29.0	54.5	G.10 + Slight
Glacier Peak users	17.0	32.1	50.9	G.18 + Moderate
All users	16.1	30.8	53.1	G.12 + Slight
				N=1325

9. A good rule to follow in back-country recreation is to "take only pictures, leave only footprints."

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	79.9	10.9	9.2	G.24 + Moderate
Three Sisters users	87.4	8.2	4.4	G.24 + Moderate
Glacier Peak users	83.2	9.1	7.7	G.25 + Moderate
All users	84.0	9.2	6.8	G.25 + Moderate
				N=1323

Statistical Summary of Response to Questionnaire Statements Concerning Wilderness Management Policies

Following are the 52 statements concerning wilderness management policy that appeared in the questionnaire, a summary of the response they received from visitors to the three areas, and the relative correlation between wildernism scores and response to the statements. The statements are organized into the following categories, based on the issues with which they are concerned:

I. Statements concerning administration of wilderness-type areas.–

1. Administrators of back-country recreation areas should be specifically trained for this task, and the task should be recognized as different from administration of other types of wild lands.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	Percent			
Eagle Cap users	75.1	13.2	11.7	G.26 + Moderate
Three Sisters users	76.8	11.9	11.3	G.36 + Strong
Glacier Peak users	73.7	14.2	12.1	G.34 + Strong
All users	75.3	13.0	11.7	G.32 + Strong
				N=1319

2. Back-country recreational areas should be administered as units distinct from adjacent lands that may be devoted to harvesting timber and other resources.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	Percent			
Eagle Cap users	79.0	15.7	5.3	G.31 + Strong
Three Sisters users	76.2	19.4	4.4	G.24 + Moderate
Glacier Peak users	78.2	16.6	5.2	G.29 + Moderate
All users	77.7	17.4	4.9	G.27 + Moderate
				N=1321

3. It is not necessary to patrol remote back-country recreational areas regularly.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	Percent			
Eagle Cap users	22.0	13.8	64.2	G.13 + Slight
Three Sisters users	15.9	17.7	66.4	G.04 Negligible
Glacier Peak users	21.3	14.0	64.7	G.06 + Slight
All users	19.4	15.3	65.3	G.07 + Slight
				N=1324

4. All cleanup duties in remote back-country recreational areas should be handled by employed personnel on regular schedules.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	22.2	16.6	61.2	G-.22 - Moderate
Three Sisters users	21.9	18.3	59.8	G-.06 - Slight
Glacier Peak users	21.6	17.9	60.5	G-.15 - Moderate
All users	21.9	17.7	60.4	G-.13 - Slight
				N=1320

II. Statements concerning nature interpretation in wilderness-type areas.—

1. A small book, describing features observed along the trail and designed to be carried in the backpack, should be sold by the administrative agency to enhance the pleasure of a back-country trip.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	60.2	29.5	10.3	G-.24 - Moderate
Three Sisters users	63.8	28.4	7.8	G-.12 - Slight
Glacier Peak users	61.7	30.6	7.7	G-.08 - Slight
All users	62.1	29.5	8.4	G-.14 - Slight
				N=1323

2. Seasonal back-country rangers should be trained in public interpretation of the area's natural features, as well as in safety and trail techniques.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	79.4	15.9	4.7	G-.01 Negligible
Three Sisters users	79.9	15.9	4.2	G-.09 - Slight
Glacier Peak users	80.7	13.7	5.6	G .00 Negligible
All users	80.0	15.1	4.9	G-.03 Negligible
				N=1321

III. Statements concerning the use of motorized equipment in wilderness-type areas.—

1. Use of motorized trailbikes should be prohibited.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	83.2	7.1	9.7	G.45 + Strong
Three Sisters users	85.5	7.1	7.4	G.51 + Strong
Glacier Peak users	79.6	7.6	12.8	G.59 + Strong
All users	82.8	7.3	9.9	G.52 + Strong
				N=1327

2. If they can get them there, back-country recreationists should be permitted to use powerboats on back country waters.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	9.2	7.1	83.7	G-.63 - Strong
Three Sisters users	7.2	5.0	87.8	G-.56 - Strong
Glacier Peak users	8.9	11.6	79.5	G-.53 - Strong
All users	8.3	7.9	83.8	G-.55 - Strong
				N=1324

IV. Statements concerning the use of helicopters in wilderness-type areas.–

1. Use of helicopters is justified in remote back-country recreational areas for protection of the area (e.g., from fire).

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	96.7	1.5	1.8	G-.03 Negligible
Three Sisters users	96.6	1.6	1.8	G-.05 Negligible
Glacier Peak users	95.1	3.5	1.4	G-.05 Negligible
All users	96.0	2.3	1.7	G-.04 Negligible
				N=1328

2. Use of helicopters is justified in remote back-country recreational areas for protection of human life (e.g., rescues).

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	98.8	0.6	0.6	G.09 + Slight
Three Sisters users	98.4	0.8	0.8	G.04 Negligible
Glacier Peak users	98.6	1.4	0.0	G.03 Negligible
All users	98.6	1.0	0.4	G.06 + Slight
				N=1328

3. Use of helicopters is justified in remote back-country recreational areas for visits by prominent people.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	9.4	9.4	81.2	G-.34 - Strong
Three Sisters users	8.6	11.8	79.6	G-.29 - Moderate
Glacier Peak users	8.4	18.5	73.1	G-.42 - Strong
All users	8.8	13.7	77.5	G-.34 - Strong
				N=1326

4. Use of helicopters is justified in remote back-country recreational areas for routine administration and maintenance.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	62.3	9.8	27.9	G-.28 - Moderate
Three Sisters users	60.7	12.2	27.1	G-.31 - Strong
Glacier Peak users	61.6	13.2	25.2	G-.32 - Strong
All users	61.4	12.0	26.6	G-.30 - Strong
				N=1321

5. Use of helicopters is justified in remote back-country recreational areas for bringing material and equipment to construction sites which otherwise would require large strings of pack animals.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	66.8	12.8	20.4	G-.35 - Strong
Three Sisters users	66.3	13.7	20.0	G-.25 - Moderate
Glacier Peak users	66.6	16.0	17.4	G-.26 - Moderate
All users	66.5	14.3	19.2	G-.27 - Moderate
				N=1314

6. Use of helicopters is justified in remote back-country recreational areas for bringing patrolmen to and from the area.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	53.7	13.3	33.0	G-.36 - Strong
Three Sisters users	57.4	13.9	28.7	G-.30 - Strong
Glacier Peak users	56.7	16.8	26.5	G-.31 - Strong
All users	56.1	14.8	29.1	G-.31 - Strong
				N=1319

7. Use of helicopters is justified in remote back-country recreational areas for wildlife observation or control.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	75.1	9.1	15.8	G-.23 - Moderate
Three Sisters users	69.4	13.8	16.8	G-.30 - Strong
Glacier Peak users	73.0	11.5	15.5	G-.32 - Strong
All users	72.2	11.8	16.0	G-.28 - Moderate
				N=1327

V. Statements concerning trails in wilderness-type areas.–

1. Trails in remote back-country areas should be nonexistent, only blazed or marked routes.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	11.9	12.2	75.9	G .02 Negligible
Three Sisters users	13.5	13.9	72.6	G .08 + Slight
Glacier Peak users	11.2	13.3	75.5	G-.02 Negligible
All users	12.3	13.2	74.5	G .03 Negligible
				N=1314

2. Trails in remote back-country areas should be developed and maintained consistent with volume of use.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	85.6	7.6	6.8	G-.02 Negligible
Three Sisters users	86.8	8.2	5.0	G .02 Negligible
Glacier Peak users	87.3	7.4	5.3	G .09 + Slight
All users	86.6	7.8	5.6	G .04 Negligible
				N=1327

3. Trails in remote back-country areas should be of varied type and quality to different places, thus satisfying varied interests.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	78.0	14.4	7.6	G-.09 - Slight
Three Sisters users	74.8	19.0	6.2	G-.06 - Slight
Glacier Peak users	73.4	17.0	9.6	G-.05 Negligible
All users	75.2	17.1	7.7	G-.06 - Slight
				N=1322

4. Trails in remote back-country areas should be of high standard throughout the area.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	24.6	27.0	48.4	G-.33 - Strong
Three Sisters users	22.3	30.6	47.1	G-.25 - Moderate
Glacier Peak users	26.5	33.3	40.2	G-.21 - Moderate
All users	24.5	30.7	44.8	G-.25 - Moderate
				N=1320

5. Trails in remote back-country areas should be surfaced with sawdust or wood chips to keep dust down.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	---------------	-*Percent*-	---------------	
Eagle Cap users	4.1	18.4	77.5	G-.42 - Strong
Three Sisters users	3.0	16.4	80.6	G-.36 - Strong
Glacier Peak users	4.1	16.6	79.3	G-.42 - Strong
All users	3.7	17.0	79.3	G-.40 - Strong
				N=1324

VI. Statements concerning preferences for different kinds of signs in wilderness-type areas.–

A. Relating to sign construction materials

1. Signs in remote back-country areas should be of wood.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	---------------	-*Percent*-	---------------	
Eagle Cap users	81.6	13.9	4.5	G.19 + Moderate
Three Sisters users	74.9	19.3	5.8	G.05 Negligible
Glacier Peak users	78.4	13.5	8.1	G.01 Negligible
All users	77.9	15.8	6.3	G.07 + Slight
				N=1316

2. Signs in remote back-country areas should be of enameled metal.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	---------------	-*Percent*-	---------------	
Eagle Cap users	7.1	28.7	64.2	G-.20 - Moderate
Three Sisters users	7.5	34.6	57.9	G .00 Negligible
Glacier Peak users	9.7	31.9	58.4	G-.10 - Slight
All users	8.2	32.1	59.7	G-.08 - Slight
				N=1309

3. Signs in remote back-country areas should be of stamped aluminum or stainless steel.

	Agree	Neutral	Disagree	Correlation with wildernism score
	---------------	-*Percent*-	---------------	
Eagle Cap users	11.6	28.2	60.2	G-.17 - Moderate
Three Sisters users	18.1	33.8	48.1	G .07 + Slight
Glacier Peak users	16.9	31.3	51.8	G .13 + Slight
All users	16.0	31.5	52.5	G-.05 Negligible
				N=1313

B. **Relating to content of signs in wilderness-type areas**

1. Signs in remote back-country areas should be directional only, giving distances to key points.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	69.9	17.1	13.0	G.27 + Moderate
Three Sisters users	67.8	19.8	12.4	G.23 + Moderate
Glacier Peak users	70.2	17.7	12.1	G.24 + Moderate
All users	69.2	18.3	12.5	G.24 + Moderate
				N=1320

2. Signs in remote back-country areas should be descriptive, giving interpretation of features of the area.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	31.6	26.7	41.7	G-.47 - Strong
Three Sisters users	29.3	34.3	36.4	G-.36 - Strong
Glacier Peak users	26.4	34.3	39.3	G-.29 - Moderate
All users	28.9	32.3	38.8	G-.37 - Strong
				N=1321

C. **Relating to the complexity and design of signs**

1. Signs in remote back-country areas should be simple, one item per sign, several signs per post.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	46.8	29.4	23.8	G.18 + Moderate
Three Sisters users	35.9	35.9	28.2	G.06 + Slight
Glacier Peak users	41.6	31.8	26.6	G.01 Negligible
All users	40.8	32.7	26.5	G.07 + Slight
				N=1314

2. Signs in remote back-country areas should be simple, one item per sign, only one sign per post.

	Agree	Neutral	Disagree	Correlation with wildernism scores
	-Percent-			
Eagle Cap users	16.2	37.4	46.4	G-.21 - Moderate
Three Sisters users	18.8	43.2	38.0	G-.01 Negligible
Glacier Peak users	12.6	44.1	43.3	G-.09 - Slight
All users	15.9	42.1	42.0	G-.10 - Slight
				N=1298

3. Signs in remote back-country areas should be elaborate, each sign large enough to include several items.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	16.8	28.7	54.5	G-.33 - Strong
Three Sisters users	18.9	32.3	48.8	G-.24 - Moderate
Glacier Peak users	20.4	33.4	46.2	G-.07 - Slight
All users	18.9	31.8	49.3	G-.20 - Moderate
				N=1306

D. **Relating to the location of signs**

1. Signs in remote back-country areas should be placed at trail junctions only.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	54.0	23.6	22.4	G.18 + Moderate
Three Sisters users	48.4	25.9	25.7	G.13 + Moderate
Glacier Peak users	48.3	25.7	26.0	G.16 + Moderate
All users	49.8	25.2	25.0	G.14 + Moderate
				N=1319

2. Signs in remote back-country areas should be grouped into a single directory of all routes emanating from one trailhead, with no further signs along the various trails.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	5.4	12.5	82.1	G-.02 Negligible
Three Sisters users	6.4	12.4	81.2	G .02 Negligible
Glacier Peak users	7.2	16.8	76.0	G-.01 Negligible
All users	6.5	14.0	79.5	G .00 Negligible
				N=1320

VII. Statements concerning facilities and site improvements in wilderness-type areas.—

A. **Relating to toilet facilities**

1. Outhouses are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	49.9	16.3	33.8	G-.46 - Strong
Three Sisters users	49.7	16.5	33.8	G-.31 - Strong
Glacier Peak users	51.5	17.3	31.2	G-.24 - Moderate
All users	50.5	16.7	32.8	G-.32 - Strong
				N=1316

2. No toilet facilities whatever are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	34.4	22.0	43.6	G.47 + Strong
Three Sisters users	32.4	22.9	44.7	G.30 + Strong
Glacier Peak users	30.4	23.8	45.8	G.24 + Moderate
All users	32.2	23.0	44.8	G.32 + Strong
				N=1305

3. Relating to tables and fireplaces

1. Tables constructed of logs or poles are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	38.9	19.5	41.6	G-.57 - Strong
Three Sisters users	39.5	22.9	37.6	G-.35 - Strong
Glacier Peak users	44.1	21.9	34.0	G-.41 - Strong
All users	41.0	21.7	37.3	G-.42 - Strong
				N=1311

2. Plank tables are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	23.1	21.5	55.4	G-.59 - Strong
Three Sisters users	22.2	24.4	53.4	G-.44 - Strong
Glacier Peak users	28.1	26.4	45.5	G-.48 - Strong
All users	24.5	24.4	51.1	G-.49 - Strong
				N=1308

3. Permanent (concrete) fireplaces are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	22.6	15.6	61.8	G-.61 - Strong
Three Sisters users	20.7	19.5	59.8	G-.39 - Strong
Glacier Peak users	25.9	17.3	56.8	G-.48 - Strong
All users	23.1	17.7	59.2	G-.47 - Strong
				N=1316

4. Movable rock fireplaces are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	40.6	23.5	35.8	G-.25 - Moderate
Three Sisters users	49.7	22.4	27.9	G-.11 - Slight
Glacier Peak users	52.4	22.5	25.1	G-.08 - Slight
All users	48.2	22.8	29.0	G-.13 - Slight
				N=1314

C. **Relating to developments implementing horse use**

1. Corrals for livestock are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	28.2	23.2	48.6	G-.31 - Strong
Three Sisters users	16.3	28.1	55.6	G-.14 - Slight
Glacier Peak users	25.6	25.4	49.0	G-.39 - Strong
All users	22.8	25.8	51.4	G-.27 - Moderate
				N=1313

2. Hitching racks or posts are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	30.8	25.8	43.4	G-.41 - Strong
Three Sisters users	21.7	23.5	44.8	G-.20 - Moderate
Glacier Peak users	33.2	27.7	39.1	G-.32 - Strong
All users	28.3	29.4	42.3	G-.29 - Moderate
				N=1309

3. Drift fences for control of livestock are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	35.5	23.5	41.0	G-.36 - Strong
Three Sisters users	29.0	28.3	42.7	G-.14 - Slight
Glacier Peak users	32.5	25.1	42.4	G-.34 - Strong
All users	32.0	25.9	42.1	G-.27 - Moderate
				N=1307

D. **Relating to constructed shelters**

1. Three-sided shelters for hikers are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	45.1	19.1	35.8	G-.41 - Strong
Three Sisters users	58.0	21.8	20.2	G-.12 - Slight
Glacier Peak users	63.0	16.1	20.9	G-.14 - Slight
All users	56.5	19.0	24.5	G-.19 - Moderate
				N=1323

2. Locked patrol cabins for official staff use only are consistent with proper use of remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	34.4	27.3	28.3	G-.24 - Moderate
Three Sisters users	36.3	33.4	30.3	G-.11 - Slight
Glacier Peak users	31.1	33.8	35.1	G-.22 - Moderate
All users	33.9	32.0	34.1	G-.18 - Moderate
				N=1313

VIII. Statements concerning rationing use or charging entrance fees in wilderness-type areas.—

1. Use of back country has to be restricted to limited numbers of people in a given area at a given time.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	28.5	23.5	48.0	G-.07 - Slight
Three Sisters users	33.7	23.9	42.4	G .12 + Slight
Glacier Peak users	24.7	21.8	53.5	G-.09 - Slight
All users	29.1	23.0	47.9	G-.02 Negligible
				N=1317

2. The use of pack animals should be prohibited in remote back-country recreational areas, since they do considerable damage to natural features.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	8.5	14.4	77.1	G-.01 Negligible
Three Sisters users	16.0	21.8	62.2	G .21 + Moderate
Glacier Peak users	17.4	17.8	64.8	G .21 + Moderate
All users	14.6	18.4	67.0	G .16 + Moderate
				N=1326

3. Costs of recreational back-country administration and maintenance should be defrayed by some form of moderate charge.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	44.2	23.2	32.6	G-.18 - Moderate
Three Sisters users	43.0	25.9	31.1	G-.10 - Slight
Glacier Peak users	37.6	26.4	36.0	G-.11 - Slight
All users	41.4	25.4	33.2	G-.13 - Slight
				N=1324

IX. Statements concerning restriction of resource management practices in wilderness-type areas.—

1. Man-caused fires in remote back-country recreational areas, and outbreaks of nonnative insects or diseases, should be extinguished as quickly as possible after they are detected.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	97.0	1.5	1.5	G.14 + Low
Three Sisters users	98.2	1.4	0.4	G.01 Negligible
Glacier Peak users	98.0	1.4	0.6	G.07 + Low
All users	97.9	1.4	0.7	G.06 + Low
				N=1330

2. Natural events in the normal history of a plant-and-animal community should not be artificially controlled in remote back-country areas; specifically, the following events should be allowed to run their course:

(a) Lightning-caused fires

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	2.7	3.2	94.1	G.06 + Low
Three Sisters users	3.0	1.8	95.2	G.14 + Low
Glacier Peak users	2.4	3.1	94.5	G.10 + Low
All users	2.7	2.6	94.7	G.10 + Low
				N=1328

(b) Heavy infestations of native insects

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	5.3	7.7	87.0	G.22 + Moderate
Three Sisters users	5.8	7.2	87.0	G.13 + Low
Glacier Peak users	6.8	5.7	87.5	G.13 + Low
All users	6.0	6.8	87.2	G.15 + Moderate
				N=1325

(c) Heavy infestations of forest diseases

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	5.1	4.7	90.2	G.23 + Moderate
Three Sisters users	3.4	5.2	91.4	G.15 + Moderate
Glacier Peak users	4.7	5.3	90.0	G.17 + Moderate
All users	4.3	5.1	90.6	G.18 + Moderate
				N=1326

3. Sections of remote back-country recreational areas, denuded by fire, insects, or disease, and subject to rapid erosion, should be protected as soon as possible by artificial restoration of an adequate cover of vegetation.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	91.2	4.1	4.7	G-.16 - Moderate
Three Sisters users	90.0	5.2	4.8	G-.12 - Low
Glacier Peak users	88.1	6.6	5.3	G-.15 - Moderate
All users	89.7	5.4	4.9	G-.16 - Moderate
				N=1326

4. Livestock grazing as a revenue-producing use should be encouraged in back-country areas principally devoted to recreation, since this will defray management costs.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	16.7	17.5	65.8	G-.31 - Strong
Three Sisters users	14.3	19.5	66.2	G-.29 - Moderate
Glacier Peak users	12.6	15.3	72.1	G-.36 - Strong
All users	14.3	17.5	68.2	G-.33 - Strong
				N=1322

5. Hunting should be forbidden in remote back-country recreational areas.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		-Percent-		
Eagle Cap users	36.9	12.0	51.1	G-.05 Negligible
Three Sisters users	43.6	17.2	39.2	G .12 + Slight
Glacier Peak users	39.7	15.0	45.3	G .09 + Slight
All users	44.6	15.0	40.4	G .06 + Slight
				N=1326

6. Even well-managed second-growth timber must always be assumed to have lower recreational value than a virgin forest.

	Agree	Neutral	Disagree	Correlation with wildernism scores
		Percent		
Eagle Cap users	35.0	15.3	49.7	G.31 + Strong
Three Sisters users	29.6	20.8	49.6	G.17 + Moderate
Glacier Peak users	40.0	15.5	44.5	G.40 + Strong
All users	34.8	17.4	47.8	G.30 + Strong
				N=1324

U.S.D.A. FOREST SERVICE RESEARCH PAPER PNW-62

SEASONAL HEIGHT GROWTH OF UPPER-SLOPE CONIFERS

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PACIFIC NORTHWEST FOREST & RANGE EXPERIMENT STATION

U.S. Department of Agriculture · Forest Service

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INTRODUCTION

There is little knowledge of seasonal distribution of height growth of some of the principal coniferous species of the middle to high elevations of the Cascade Range in the Pacific Northwest. This paper describes observations made during 1963 and 1964 on height growth of subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), noble fir (*A. procera* Rehd.), Pacific silver fir (*A. amabilis* (Dougl.) Forbes), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western white pine (*Pinus monticola* Dougl.), lodgepole pine (*P. contorta* Dougl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), mountain hemlock (*T. mertensiana* (Bong.) Carr.), and western redcedar (*Thuja plicata* Donn).

Measurements were made on saplings growing in association on two naturally stocked areas. All the above species were present on an old burn near Government Camp, Mount Hood National Forest. Only Pacific silver fir, Douglas-fir, noble fir, western hemlock, and western white pine saplings were present on the second study area--a clearcut (unit 9) within the Lava Lakes cutting block near the Santiam-Clear Lake Junction in the central Oregon Cascades. The two areas are similar in aspect (N-NE) and elevation (3,900 to 4,000 feet). The Government Camp area has poor-quality soil that developed on a mudflow approximately 1,700 years old. The Lava Lakes soil developed on several feet of volcanic ash that was deposited about 1,500 years ago. The forests at Lava Lakes are taller and more productive than at Government Camp. With the exception of Pacific silver fir, the saplings on each area were 10 to 15 years old and were post-logging regeneration. Pacific silver fir saplings were advanced regeneration that had survived logging and burning and many were 40 to 50 years old.

METHODS

The first 10 to 13 relatively isolated trees of each species, 5 to 6 feet in height, were selected for observations in each area. All selections were made as soon as snow conditions permitted access to the area in 1963. Selected trees were numbered by tags and the base of each year's terminal bud was marked with paint or with an insect pin to serve as a reference point for weekly elongation measurements. Dates of bud burst, cessation of height growth, and weekly height growth measurements in centimeters from the marked base to the tip of the elongating shoot were recorded for each tree.

At the end of each growing season, the average height growth of each species was plotted in centimeters and in percent of total by area and by date. Variations among species in (1) start of height growth (bud bursting), (2) average length of growing periods in days, (3) total amount of height growth, and (4) average time required to complete 50, 90, and 100 percent of growth were tested by analyses of variance. Differences among species were tested for significance by area and year. Western white pine saplings at Government Camp were heavily cankered by blister rust and were not used in the study.

RESULTS

Generally, the differences among the tree species at each area for the length of time to bud burst, completion of 50, 90, and 100 percent of total growth, length of growing season, and total amount of growth were significant at the 1-percent level (table 1).

The pines commenced height growth earlier and tended to have slightly longer growing seasons than any other species except western redcedar. The buds of the pines had already started to elongate by the time snow conditions permitted access to study areas during both growing seasons. Bud bursting did not occur on the other conifers until 3 to 4 weeks later. By that time, the pines had completed up to 30 percent of their seasonal height growth.

In 1964, height growth started 2 to 4 weeks later than in 1963 (table 1), due mainly to heavy snow accumulations and cool spring weather which retarded snow melting (U.S. Weather Bureau 1964,[1] pp. 62, 82, 102, 122). Height growth generally terminated later in 1964 than in 1963. The growing season generally was longer at Lava Lakes than at Government Camp.

At Government Camp, the 1964 growing season was shorter than the 1963 season for all species, although it was about the same both years for western hemlock and Douglas-fir. The true firs and mountain hemlock had a relatively short growing season, particularly in 1964. Western redcedar had the longest growing seasons of all for both years (fig. 1). Lodgepole pine, Douglas-fir, and western redcedar grew the most in height, whereas the true firs grew the least. Douglas-fir and western hemlock trees grew a little more in 1964 and 1963 despite the cooler spring and shorter growing season of 1964.

At Lava Lakes, the 1964 growing season was shorter than the 1963 season for all species except western hemlock. Western white pine, noble fir, and western hemlock had longer growing seasons than the other conifers and western hemlock was the last species to stop growing (fig. 2). Western white pine and noble fir grew the most in height during both seasons, whereas western hemlock grew the least during 1963 and Douglas-fir grew the least in 1964 (fig. 2). Western hemlock trees grew more in 1964 than in 1963. The true firs grew as well or better than their associates on the volcanic ash soil at Lava Lakes in contrast to their relative poor performances on the poor soil at Government Camp.

Evidently, conifers growing on the same area and, therefore, under apparently equivalent environmental conditions:

1. Begin height growth at different times,
2. Have seasonal height-growth periods of different lengths,
3. Seem to be affected differently by annual fluctuations of climate.

DISCUSSION

Results show definite individuality of bud bursting and seasonal height-growth patterns among the conifers studied. Total height growth and lengths of growing season of the species varied between years and places. That such differences are under partial genetic control has been well documented with

[1] Names and dates in parentheses refer to Literature Cited, p. 7.

Table 1.--*Results of analyses of variance tests on the average days from January 1 to bud burst, completion of 50, 90, and 100 percent of growth, length of growing season, and total amount of growth of upper-slope conifers at Lava Lakes and Government Camp in Oregon during 1963 and 1964*

Item	Location	Year	Tree species									Significance level[1]
			Pacific silver fir	Douglas-fir	Western hemlock	Western redcedar	Mountain hemlock	Subalpine fir	Noble fir	Lodgepole pine	Western white pine	
			Number of days									
From Jan. 1 to bud burst	Government Camp	1963	168	170	169	163	166	163	169	(2/)	(2/)	**
		1964	190	190	189	185	191	192	(3/)	--	--	NS
	Lava Lakes	1963	162	169	171	--	--	--	165	(2/)	(2/)	NS
		1964	186	191	180	--	--	--	184	--	--	**
From Jan. 1 to 50-percent completion of growth	Government Camp	1963	191	198	206	228	198	178	194	164	--	**
		1964	204	212	219	224	211	189	(3/)	187	--	**
	Lava Lakes	1963	189	195	205	--	--	--	201	--	168	**
		1964	204	204	216	--	--	--	208	--	188	**
From Jan. 1 to 90-percent completion of growth	Government Camp	1963	209	219	221	263	212	200	216	199	--	**
		1964	219	234	238	256	224	215	(3/)	211	--	**
	Lava Lakes	1963	210	216	224	--	--	--	220	--	206	**
		1964	218	223	236	--	--	--	227	--	209	**
From Jan. 1 to completion of growth	Government Camp	1963	222	234	234	283	229	216	231	233	--	**
		1964	229	250	251	273	232	223	(3/)	238	--	**
	Lava Lakes	1963	229	234	239	--	--	--	240	--	241	**
		1964	231	238	252	--	--	--	244	--	236	**
Length of growing season	Government Camp	1963	54	64	65	120	63	53	62	(2/)	(2/)	**
		1964	39	60	62	88	42	31	(3/)	--	--	**
	Lava Lakes	1963	67	65	68	--	--	--	74	(2/)	(2/)	*
		1964	45	51	71	--	--	--	59	--	--	**
			Centimeters									
Total amount of height growth	Government Camp	1963	11.5	27.5	17.1	23.9	17.5	13.0	17.7	33.5	--	**
		1964	9.1	31.6	17.9	18.5	16.2	9.2	(3/)	30.5	--	**
	Lava Lakes	1963	32.8	27.6	23.4	--	--	--	41.2	--	40.3	**
		1964	21.7	17.4	25.8	--	--	--	29.1	--	34.8	**

1/ NS = not significant; ** = significant at 1-percent level.

2/ Bud burst had already occurred on these species by the time the areas became accessible in the spring.

3/ The terminal buds formed in 1963 on the noble fir study trees at Government Camp were nipped by grouse.

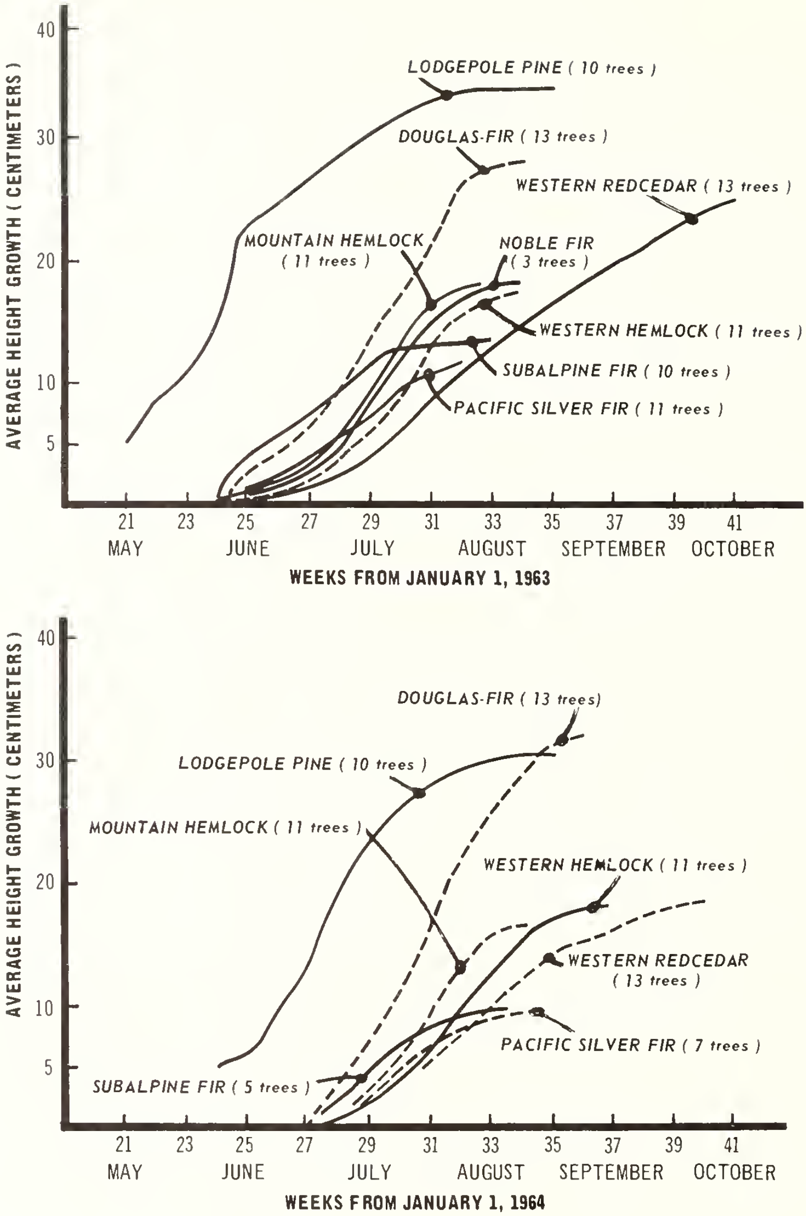
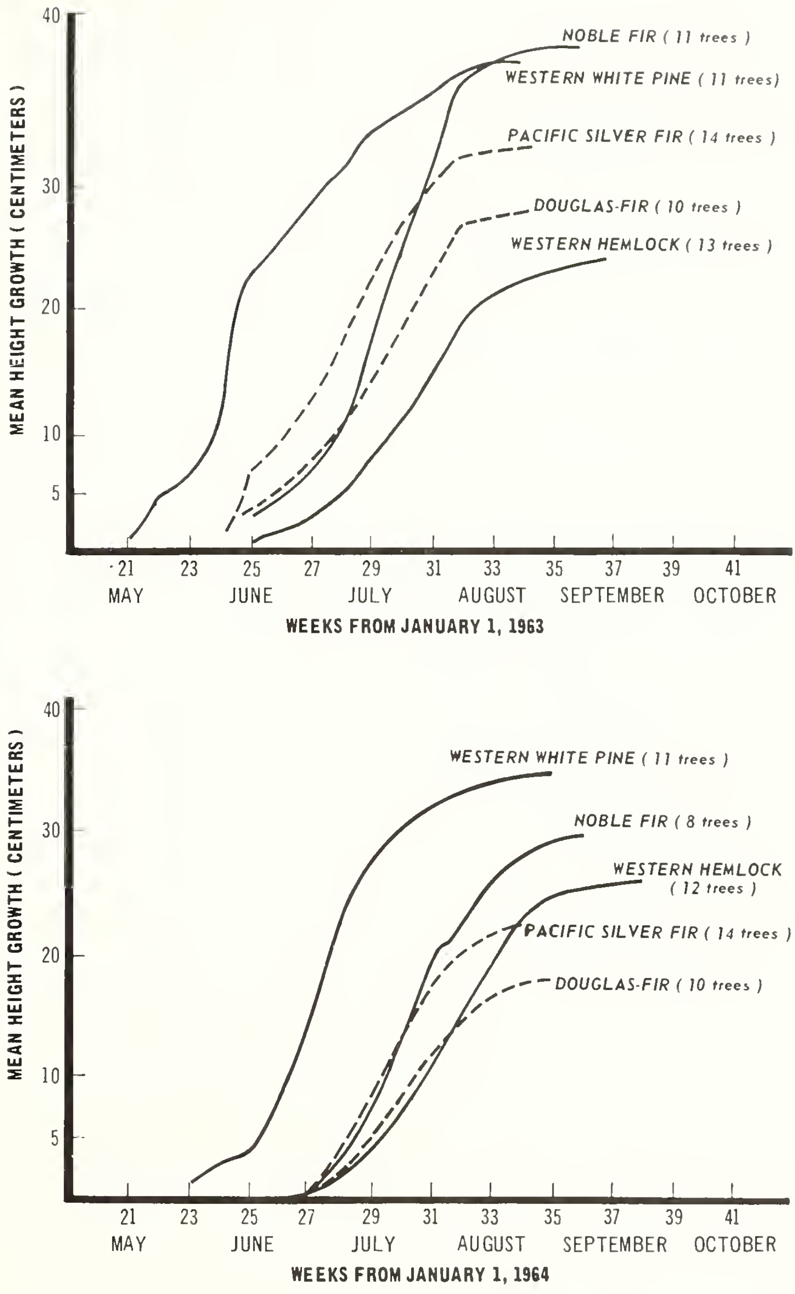


Figure 1.--Average cumulative height growth of coniferous tree species near Governm Camp, Oreg., in 1963 and 1964. Differences among species were significa at the 1-percent level.



gure 2.--Average cumulative height growth of five coniferous tree species at Lava Lakes, Oreg. Height growth among species was significantly different at the 1-percent level.

significant literature reviewed by Kozlowski (1964). The data reported here for Pacific silver fir, noble fir, and mountain hemlock apparently are the first available. For Douglas-fir, Irgens-Moller (1957) and Ching and Bever (1960) found important differences in time of bud break between seed sources. Silen (1962), working in a narrow environmental range, estimated the genetic component of the bud bursting trait among several Douglas-fir clones to be about 95 percent of the total variance. In general, seasonal distribution of leader growth of western hemlock, western redcedar, and Douglas-fir observed in this study followed the same pattern reported by Walters and Soos (1963) at lower elevations in British Columbia. Similar seasonal leader growth patterns for western hemlock have also been described by Godman (1953) and Gregory (1957) in Alaska and Buckland (1956) on Vancouver Island. The latter two studies also showed seasonal growth distribution for Douglas-fir which is similar to that reported here.

Some of the variation in bud bursting and shoot elongation between tree species is based on type of terminal bud. Species observed in this study, except western redcedar, had winter buds containing preformed shoots. Much of the potential of preformed shoots is formed during the year of bud formation. Such shoots begin elongation in the spring using carbohydrate reserves from the previous season, and internode elongation is often complete before the leaves are fully grown. Due to the dependence on carbohydrate reserves, shoot growth often shows closer correlation with weather of the year of bud formation rather than the year of shoot elongation (Kozlowski and Keller 1966). However, weather during the period of shoot elongation does influence the degree of realization of shoot growth potential. The effect of current weather on height (shoot) growth was well illustrated in the second year of this study.

The cool spring and shorter growing season of 1964 at both study areas affected the height growths of several species with preformed buds. On both areas, only western hemlock grew more in 1964 than in 1963. Its lengths of growing seasons were similar for both years. Douglas-fir trees grew more in height during the shorter 1964 season at Government Camp than they did in 1963. However, at Lava Lakes, their growing season and total height growth were less in 1964 than 1963. All other species with preformed shoots in their buds, particularly the true firs, grew less during the shorter 1964 season than they did during 1963. These observations suggest that at times length of current growing season is related to amount of height growth in some upper-slope species. The findings differ from those by Walters and Soos (1963) in their study of conifers growing at lower elevations in British Columbia. They reported no correlation between length of current growing season and quantity of leader growth.

Species having scale leaves like western redcedar do not form buds containing preformed shoots (Laubenfels 1953). They usually have long growing seasons and use considerable current photosynthate for shoot growth (Kozlowski and Keller 1966). Consequently, their height growth is usually well correlated with current weather. This study showed the height growth of western redcedar was related to current growing season as expected.

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INVESTIGATIONS OF

SHINGLE TOW PACKING MATERIAL FOR CONIFER SEEDLINGS

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PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
U.S.D.A. Forest Service Research Paper PNW-63
Portland, Oregon
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Cover Photo: Sprinklers installed over bales of stored shingle tow to supplement leaching from rainfall.

INTRODUCTION

Shingle tow, the stringy byproduct from the manufacture of western redcedar (*Thuja plicata* Donn) shingles, was first used about 1915 to keep tree seedling roots moist during shipment. In the decades since, shingle tow became the packing material most commonly used in Pacific Northwest forest nurseries. It has not been without critics, however.

Unexplained seedling mortality during the first season after outplanting has been frequent in the Pacific Northwest. While there are many possible causes for such mortality, shingle tow packed around seedling roots was one factor common to most planting failures. Though nurserymen could point to thousands of acres of successful plantation and feel secure in its use, the forester seeking a culprit for unexplained mortality often suspected shingle tow. Results of this investigation partially clarify the role of shingle tow as a packing material.

BACKGROUND

Only limited tests have been made on shingle tow's suitability as a packing material. In 1926, its moisture-holding capacity was determined to be adequate for shipping seedlings from Wind River Nursery to distant points in the Pacific Northwest.[1/] Mold-retarding properties, noted by Deffenbacher and Wright (1954), enhanced its popularity with nurserymen. Nonetheless, suspicions were raised by results of exploratory outplantings made in 1950 at the U.S. Forest Service's nursery at Bend, Oreg. Only 33 percent of ponderosa pines whose roots had been immersed for 3 hours in the leachate from a tank used to wet shingle tow survived the first growing season, compared to 90-percent survival for untreated seedlings. A slightly larger test was made to compare survival of ponderosa pine following packing of seedlings in shingle tow and sphagnum moss. Seedling survival following 2 weeks' storage favored shingle tow, but after 4 or 6 weeks' storage, survival of seedlings packed in

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[1/] Kummel, J. F. Use of shingle tow at Wind River Nursery. Unpublished report of April 30, 1926, on file at Pacific Northwest Forest & Range Exp. Sta., Portland, Oreg.

shingle tow was substantially less than for those packed in sphagnum moss. Unfortunately, the test was small and, in part of the test, survival of seedlings packed by both methods was low due to hot, dry field conditions during planting. 2/ During normal outside storage, shingle tow was leached by rainfall; following these planting trials, overhead sprinklers were installed (see cover photo). Leaching effectiveness was not explored, however, and unexplained planting failures continued.

Contentions that shingle tow could adversely affect seedlings gained support from investigations on decay resistance of western redcedar wood. At least two groups of fungicidal chemical compounds are found in the wood, the thujaplicins and water-soluble phenols (Rennerfelt 1948; Roff and Atkinson 1954). Thujaplicins are quite toxic; concentrations as low as 10 to 20 p.p.m. strongly inhibit spore germination and growth of fungi (Rennerfelt 1948; Rennerfelt and Nacht 1955). Explanations proposed for the physiological action of thujaplicins would lead one to predict toxicity to most organisms (Lyr 1961; Raa and Goksøyr 1965). While substantially less toxic to fungi than thujaplicins, water-soluble phenols occur in cedar heartwood at much greater concentrations. Thujaplicin and water-soluble phenol concentrations up to 12,000 and 233,000 p.p.m., respectively, on an ovendry basis have been found in western redcedar, but concentration varies widely between and within individual trees (Gardner and Barton 1958; MacLean and Gardner 1956a).

Exploratory experiments established that solutions leached from cedar containing thujaplicins or water-soluble phenols were damaging to Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings. Most 2-month-old seedlings died after their roots were immersed for 74 hours in 160-p.p.m. thujaplicin solution or in 1,000-p.p.m. water-soluble phenol solution. In another test, over 70 percent of dormant 2-year-old seedlings whose roots were immersed in a 65-p.p.m. solution of thujaplicins for 48 hours died in the following 60 days. Every seedling was affected to some degree (Krueger 1963). In light of the accumulated information, more intensive evaluation of shingle tow appeared needed.

EXPERIMENTAL

The possible relation between use of shingle tow and seedling mortality was studied by (1) further testing toxicity of extractives from shingle tow, (2) examining conditions causing seedling mortality, and (3) assessing certain nursery conditions influencing amount of toxic compounds available.

Investigation focused mainly on thujaplicins since water-soluble phenols

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2/ Tarrant, R. F., Isaac, L. A., and Mowat, E. L. Unpublished progress report on Deschutes 1950 test on ponderosa pine field planting. February 7, 1951. On file at Pacific Northwest Forest & Range Exp. Sta., Portland, Oreg.

appear to cause damage only at high concentrations and are largely uncharacterized for western redcedar. Analyses for thujaplicin were made by the method of MacLean and Gardner (1956b).

Toxicity of Extractives

Thujaplicin solutions used in seedling toxicity tests (Krueger 1963) were not pure but contained other extractives. Hence, two experiments were made using pure materials.

First, the effect of γ-thujaplicin[3/] on respiration of Douglas-fir roots was measured in a Warburg respirometer. Pieces 5 mm. long were cut from actively growing white root tips of seedlings 15 to 35 days old. Approximately equal numbers of pieces were placed in individual Warburg flasks, each containing 2 ml. of M/45 potassium citrate buffer at pH 5.0. Oxygen uptake was determined at 30° C. for four flasks of each concentration. After a 2-hour calibration period, 0.5 ml. of thujaplicin solution or water was tipped in, and measurements were continued for 6 more hours. Adjustments made for initial differences in flask volumes and initial respiration rates were less than 4 percent. Low concentrations of γ-thujaplicin depressed respiration of actively growing Douglas-fir roots (fig. 1). B-thujaplicin also lowered respiration.

Second, root systems of 10 actively growing 1-0 Douglas-fir seedlings were immersed in a 20 p.p.m. solution of pure B-thujaplicin or in distilled water for 96 hours. The seedlings were then replanted in vermiculite and grown in a growth chamber for 103 days under 20° C. day-10° C. night temperature and 16-hour day length. Twenty percent of the seedlings whose roots had been immersed in B-thujaplicin solution died; all controls lived. Three of the seedlings which survived the 20-p.p.m. concentration had shortened needles on new growth or browning at the base of needles.

In previous experiments with extractives, either the thujaplicin or phenol fraction was tested in solution. In combination, the two fractions can also kill, as shown when seedlings were placed with their roots in moist western redcedar sawdust for a week, then potted in vermiculite. All seven seedlings placed in unleached sawdust subsequently died, while all those placed in previously leached sawdust lived. Presumably, the harmful effect of thujaplicins and water-soluble phenols is additive; synergism is also possible.

[3/] The principal thujaplicin isomers in western redcedar are B- and γ-thujaplicin, 2-hydroxy-4-, and 5- isopropyl-2, 4, 6-cycloheptatriene-1-one, respectively. Samples were graciously furnished by J. A. F. Gardner, Canadian Department of Forestry, Vancouver, British Columbia, and by David Goheen, Crown Zellerbach Corp., Camas, Wash.

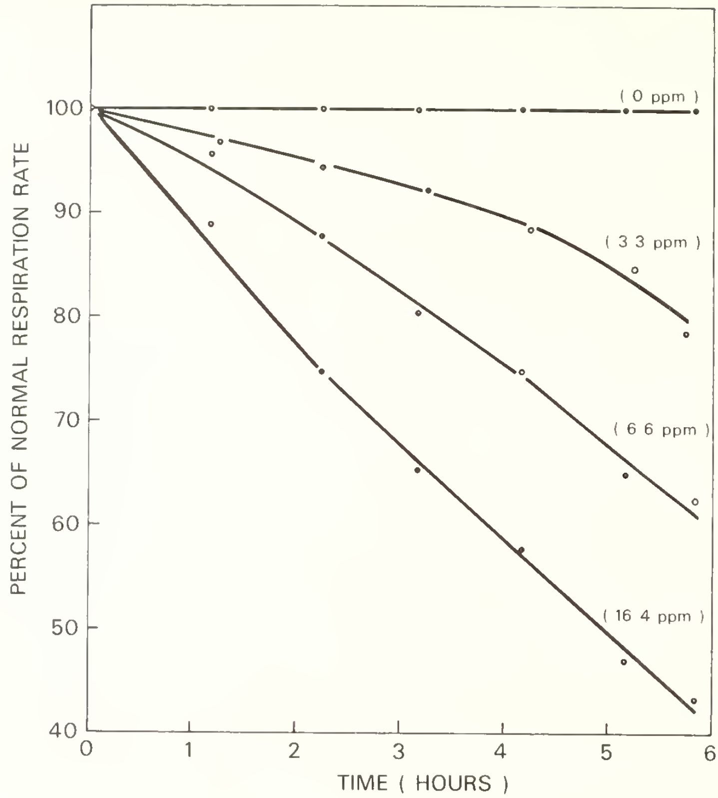

Figure 1.–Solutions of γ-thujaplicin depress respiration of Douglas-fir root tips in M/45 citrate buffer, pH 5.0 at 30° C.

Conditions Causing Seedling Mortality

Obviously, seedlings must take up toxic chemicals for mortality to occur. All tests described so far were under temperature and light conditions conducive to high transpiration and water uptake. Conditions for minimum uptake were simulated by placing 2-0 Douglas-fir seedlings in darkness at 8° C. (46° F.) with roots immersed in solutions of B-thujaplicin. Solutions ranged from 0 to 30 p. p. m. ; the 30-p. p. m. concentration contained about 1 mg. thujaplicin per seedling. After 72 hours, seedlings were removed from the test conditions, planted in vermiculite, and placed in the greenhouse. After 100 days, mortality was 0, 7, 13, and 0 percent for groups of 15 seedlings whose roots had been immersed in B-thujaplicin solutions of 0, 20, 25, and 30 p. p. m. , respectively. Under conditions where transpiration is low, little thujaplicin apparently enters the plants and hence few, if any, die. Water uptake and transpiration are not the only consideration, however--as shown by the following experiments.

If seedling mortality was directly related to quantity of thujaplicin taken up, better extrapolation between test results and field practice might be made. To test this relationship, 2-year-old seedlings weighing about 7.5 gm. fresh weight each were brought directly from the Wind River Nursery, their roots were carefully washed free of soil, and seedlings were then placed under conditions of 25° C. and 1,000 ft.-c. with roots immersed in 37-p.p.m. solutions (2.24 mg. per seedling) of mixed thujaplicins. Three replications of five seedlings each had roots immersed for 1, 3, 6, 24, or 48 hours. Roots were then removed from the solutions, drained, and seedlings were potted in sand. The remaining solutions were made to volume and analyzed for thujaplicins with uptake assumed to be the difference between starting and final concentrations.

Apparent uptake was extremely rapid as shown in figure 2. But only about 0.15 mg. difference resulted from 1- and 48-hour immersion, suggesting that most thujaplicin molecules were adsorbed on root surfaces rather than being absorbed into the plant. Mortality subsequent to immersion of seedling roots in thujaplicin solution averaged 20.1 percent greater than for seedlings whose roots were immersed in water for similar periods. Mortality was not closely correlated with either immersion time or apparent uptake. One feature of the preceding investigations thus assumed particular importance--roots of seedlings used had either been grown in sand from seed, been transplanted into sand, or tested bare rooted after washing. The effect of thujaplicins on seedlings with soil-covered roots had not been tested.

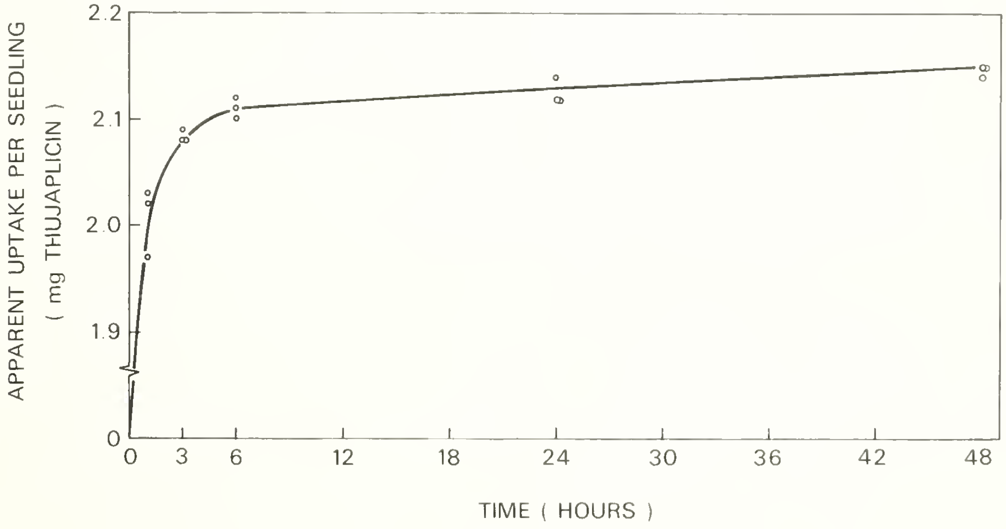

Figure 2.—Apparent uptake of thujaplicins by Douglas-fir seedlings.

Soil present on the roots might protect seedlings by adsorbing or reacting with thujaplicins present in solution. To test this possibility, a small sample of Wind River Nursery soil (Stabler shotty silt loam) was air-dried, sieved through a 60-mesh screen, and added in weighed amounts to 10 ml. aliquots of solution each containing 0.45 mg. B-thujaplicin. Solutions were stirred for 30 seconds, allowed to stand for 1 hour, then centrifuged and analyzed for the B-thujaplicin remaining in solution. About 100 mg. of this soil can almost remove 0.45 mg. B-thujaplicin from the solution (fig. 3). Thujaplicin adsorbed on the soil could not be re-extracted with ferric acetate, indicating that the forces involved are strong.

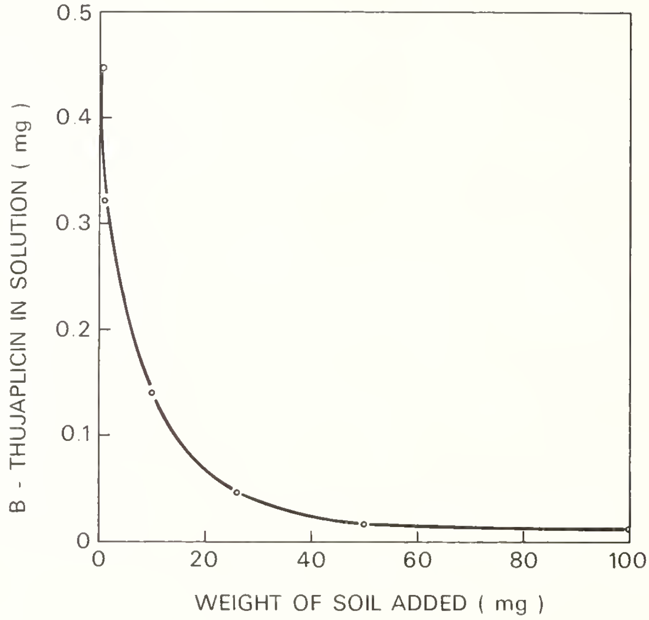

Figure 3.—Amount of B-thujoplicin remaining in solution after odding vorious omounts of nursery soil.

To test whether seedlings with unwashed roots would be protected by adhering soil, roots of dormant 2-0 seedlings from the Wind River Nursery were immersed from 6 to 96 hours in solutions containing 2.6 mg. of B-thujaplicin per seedling. All 180 seedlings tested, including controls, survived.

Thujaplicins Available from Shingle Tow Stored at Nurseries

Shingle tow from four different nurseries was analyzed for thujaplicin content; for seven samples it ranged from 0 to 120 p.p.m. All samples obtained from nurseries using supplemental sprinkling were low in thujaplicins, though the number of samples checked was too small to justify firm conclusions on its effectiveness.

Several factors, which are difficult to estimate in quantitative terms, regulate the amount of thujaplicins actually available for uptake by a seedling. Quantity of thujaplicins reaching solution may be only part of the total content present in shingle tow, since water used in packing and planting seedlings is cold, which reduces its extractive ability (fig. 4). The amount of water in shingle tow may vary, and the amount subsequently added varies even more

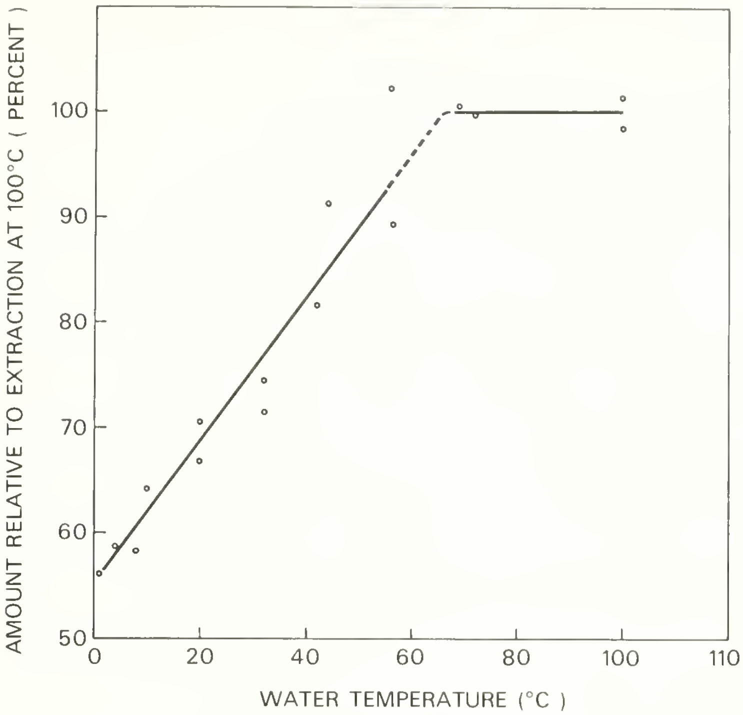

Figure 4.–Thujaplicins extracted from western redcedar sawdust with water of various temperatures. (Initial concentration– 0.55 mg. per g. cedar.)

widely depending on field conditions and the judgment of people in charge.

Nurserymen estimate that 100 bales of shingle tow will pack 1 million trees of the size used in these tests. At 25 bales per ton, a thujaplicin content of 120 p.p.m., and 50 percent extraction, an average of 0.2 mg. thujaplicins per seedling might be available for uptake. The actual amount available to an individual seedling could be much higher or lower if the starting concentration were different or if moisture distribution were uneven in the packed bundle.

DISCUSSION

Shingle tow is a potentially toxic agent--chemicals naturally present in cedar wood may kill or injure nursery seedlings. However, even when substantial amounts of toxic compounds remain in inadequately leached shingle tow, conditions favoring low uptake of these compounds or their adsorption by soil could protect seedlings packed within the tow. Field performance trials would reveal shingle tow's total effect on seedling survival and growth, but such trials are prohibitively complex. For example, the numerous variables involved include: size, condition, and moisture content of seedlings; enviromental conditions affecting moisture loss and subsequent solute uptake by seedlings; concentration of toxic compounds in the tow; amount and temperature of water added to the tow during packing and later during seedling shipping and planting; amount of packing material used per seedling; and type and amount of soil remaining on seedling roots, which would vary by nursery and even by weather conditions prevailing during lifting. As in all field tests, weather conditions during and following planting could either totally obscure or strongly influence the magnitude of any differences in seedling survival caused by shingle tow.

Seedling mortality percentages experienced in growth chamber or greenhouse tests may have little direct relation to survival in the field where conditions are more severe. They merely foretell probabilities for field mortality. The influence of lower, but not directly fatal, concentrations of thujaplicins on seedling vigor and subsequent field survival might be seen only under stress conditions such as drought. Shortened needles and shoots observed on seedlings in some experiments make one wonder if shingle tow is a contributor to so-called "transplant shock" or "planting check."

The protection provided by soil particles is uncertain. Seedlings grown in sand, as in the first tests, may receive little or no protection from solutions of thujaplicins. Two-percent cedar sawdust of unknown content in sandy loam soil affected growth of peas (Allison, DeMar, and Smith 1963). Flowers have sometimes been killed after being mulched with fresh cedar sawdust. Soils vary widely in adsorption of organic pesticides, and thus modify their toxicity (Bailey and White 1964). Different nursery soils might also modify the toxic effect of thujaplicins in varying degree. A protective root coating provided by soil might often be incomplete since physical damage occurring to roots during lifting and root tips growing actively on Douglas-fir during the lifting season could provide sites for thujaplicin uptake.

Has shingle tow caused large-scale seedling mortality in the past? It appears unlikely, judging from thujaplicin concentrations found in shingle tow at nurseries and assuming reasonable care was taken in handling shingle tow and planting stock. An adverse effect on growth and occasional small losses of seedlings seem more likely, with larger losses being the exception. Considering the particular combination of circumstances required to produce mortality, it is easy to understand continuance of the long-standing argument between nurserymen and foresters on the merits of shingle tow.

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COMPETITION FOR FEDERAL TIMBER IN THE PACIFIC NORTHWEST – an analysis of Forest Service and Bureau of Land Management timber sales

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Competition for Federal Timber in the Pacific Northwest —

An Analysis of Forest Service and Bureau of Land Management Timber Sales

by

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1968

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
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U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE

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INTRODUCTION

Objectives

The primary purpose of this paper is to identify differences in competitive behavior in the market for National Forest and Bureau of Land Management timber and to explain the influence of a specified set of market characteristics on these differences. Economic theory would lead one to expect that the degree of competition for timber will vary positively with the number of competitors, inversely with barriers to entry, and that large firms will achieve a significant degree of market power in the timber market.

Examination of sale data will indicate the degree of competition for Federal timber in the Douglas-fir (west side) and pine (east side) regions of the Pacific Northwest. Attention will be focused on a dichotomy between competitive and noncompetitive sales based on the premium paid on these two classes of timber sales.

An analysis of the extent of competition by small geographical areas (working circles on National Forests and master units on Bureau of Land Management lands) will be made to identify any geographical differentials in the degree of competition. Individual timber sales made by the two agencies will also be examined to determine factors which affect competition. Multiple regression analysis will be used in an attempt to determine the mathematical relationship between the degree of competition for timber as the dependent variable and the following independent variables: (1) number of bidders, (2) road construction cost, (3) sale size, (4) time, (5) bidder group (large or small firm), (6) appraised price of timber, (7) the price index for lumber, (8) sale type (whether oral auction or sealed bid), and (9) housing starts.

Finally, the objectives of the timber sales programs of the two agencies will be reexamined in view of the findings, and recommendations will be given.

Scope of the Analysis

Analysis is limited to the Pacific Northwest (Oregon and Washington); more precisely, to Region 6 of the National Forest System and to Bureau of Land Management lands in the State of Oregon. Within the Pacific Northwest, the west side and the east side will be treated separately. The west side is defined as the 19 counties of western Oregon and the 19 counties of western Washington lying west of the summit of the Cascade Range. The east side is the eastern portion, approximately two-thirds by geographical area, of each of the two States, but not including the Colville and Kaniksu National Forests in northeast Washington, which are part of Region 1. The Bureau of Land Management analysis will include only the State of Oregon.

Complete data on National Forest timber sales are available beginning with 1959, and Bureau of Land Management timber sale data are available over a longer period beginning with 1951. The hurricane that struck the Pacific Northwest on Columbus Day 1962 led to some changes in the 1963 timber sales patterns and may have disrupted the basic economic relationships that we wish to identify. Our analysis, therefore, ends with 1962 data.

Method of Analysis

The study is based on the record of timber sales as published.[1] [2] All timber sales have been punched on cards and processed through computers in order to allow a number of different

[1] U. S. Forest Service, Region 6. National Forest advertised timber sales. (Quarterly.) Portland, Oreg.

[2] Bureau of Land Management, U. S. Department of the Interior. Results of timber sales. (Quarterly.) Portland, Oreg.

classifications, tabulations, and analyses. Study of the published record was supplemented by about 140 informal discussions with persons directly involved in the process of bidding for Federal timber. About three-fourths of the interviews were with buyers of Federal timber, principally on the west side. The remaining one-fourth were with timber sale administrators.

With sales recorded on IBM cards, they may be classified in several ways. Classified by geographical area (by working circle for Forest Service sales and by master unit for Bureau of Land Management sales), sale characteristics may be identified by sale groupings somewhat more homogeneous than can be expected on a subregion basis. Further, the tools of stepwise multiple regression may be employed to identify the variables (sale characteristics) which are important in explaining competitive differences among the several geographical areas. The analysis can also be extended to an examination of individual sales. Again by means of stepwise multiple regression, the relationship between a number of independent variables and an index of the intensity of competition may be estimated.

Definition of Terms

In this study, the bid-appraisal ratio, in conjunction with the number of bidders per sale, will be used to establish the competitiveness of timber sales. These two measures are used in combination to establish three classes of competition for oral-auction sales, two noncompetitive and one competitive. The bid-appraisal ratio and classes of competition are defined below.

Bid-Appraisal Ratio

This is the ratio of the weighted average bid price for the timber in a given sale to the weighted average appraised price for the same timber. Since timber may not legally be sold for less than the appraised price, the minimum ratio is 1.00. The bid-appraisal ratio is used in this study as a measure of competition. The appraised and/or bid price per unit of volume in dollars cannot be used because these differ from sale to sale due to timber quality, accessibility, road construction cost which the bidder must bear, distance to market, and other factors not related to competition. The ratio between the appraised and bid price is comparable between sales since appraisal methods are uniform for each agency within a subregion and the appraised price varies only because of the above-mentioned factors. Having defined the bid-appraisal ratio, we will now define the three classes of sale competition.

Noncompetitive Sales

ONE-BIDDER SALES.—The selling procedure adopted by the two agencies for oral-auction sales requires that any person intending to bid for a given timber sale first become qualified as a bidder. The requirement of qualification for Forest Service sales is that a sealed bid be submitted in advance of the sale at not less than the appraised price[3] of the timber. For Bureau of Land Management sales, persons intending to bid orally must submit a bid deposit of 10 percent of the appraised price at the time of the sale. Since a qualifying bid cannot be submitted after the sale commences, those who fail to submit this bid are excluded from the oral auction. In most instances, qualifying bids for Forest Service sales are submitted at the appraised price for each species of timber. Where only one bidder submits a qualifying bid (and where such bidder is otherwise legally qualified), the offering is awarded to the one bidder at his bid price, normally the appraised price. In the case of Bureau of Land Management sales, the bid deposit does not obligate the bidder to take the sale. In this report, number of bidders for Bureau of Land Management sales refers to number of firms qualified to bid on a sale whether or not they made oral bids at the time the timber was sold.

TOKEN-BID SALES.—This second class of noncompetitive sale is defined as a sale having two or more bidders qualified to make oral bids, but where evidence of serious bidding is lacking. Serious bidding is defined as a ratio of bid price to appraised price equal to or greater than 1.01.

[3] Appraised price is defined by the Forest Service as synonymous with "market value" and "fair market value" as follows: " . . . the price acceptable to a willing buyer and seller, both with knowledge of the relevant facts and not under pressure or compulsion to deal. This price is sometimes called 'fair market value.'" Further, " . . . National Forest timber may be sold at not less than the appraised value." Determination of the appraised value is based on the residual value theory, that " . . . timber is worth the selling value of the products manufactured from it, minus cost of production and margin for profit and risk to the purchaser." (Forest Service Manual, 2423.12 and 2423.22.)

Where two or more bidders are qualified by identical bid prices (equal to appraised price), the tie bids must be broken by oral-auction bidding. If the qualified bidders, for a variety of possible reasons, do not wish to compete against each other by successive oral-auction bidding, the tie is frequently resolved by one such qualified bidder casting a minimum bid (normally 5 cents) above appraised price on the species of minimum quantity.[4] Other qualified bidders often remain silent, and in due time the sale is awarded to the high bidder on the basis of a token bid above appraised price. Token bids are seldom found on Bureau of Land Management sales. Since each qualifying BLM bid is made orally and posted at sale time, a prospective bidder knows which other firms are interested enough in the sale to qualify and can decide at that time whether he wants to compete with them for the sale. In contrast, Forest Service procedures require that sealed qualifying bids be submitted. Therefore, the qualifying bids must be submitted without knowing the identity of other bidders. The token-bid sale by its nature suggests a degree of understanding among bidders. In the absence of significant competitive bidding, notwithstanding the presence of two or more qualified bidders, the token-bid sales are here classified among the noncompetitive sales.

Competitive Sales

The competitive sales are defined as all sales other than the two noncompetitive classes listed above. This class would, therefore, consist of sales having two or more bidders who engage in serious bidding, wherein evidence of serious bidding is found in a bid-appraisal ratio equal to or greater than 1.01.

[4] A given timber sale normally will consist of several different species. Each species may have a different value — the appraised value per thousand board feet. Bidding is by species. Thus, if Douglas-fir is appraised at $12 per thousand board feet, a 5-cent increase would take the form of a $12.05 bid on the Douglas-fir, leaving the bid price unchanged on other species. Since the total bid value of timber for any one sale is calculated by multiplying the bid price by the volume by species and summing, total value can be minimized on the token-bid sales by casting the token bid on the species having the least volume.

Special Circumstances of the Shelton Working Circle

The National Forest timber sales data, analyzed throughout this study, exclude sales in the Shelton Working Circle of the Olympic National Forest which were made exclusively to the Simpson Timber Co. During the period covered by this analysis, National Forest timber in the Shelton Working Circle was combined with timber under the private ownership of the Simpson Timber Co. and dedicated to restricted use under a cooperative sustained-yield agreement. Under the terms of the agreement, the Forest Service is obligated to sell National Forest timber within the sustained-yield unit to Simpson Timber Co. at appraised prices. Standard and current appraisal procedures are used in establishing the appraised price. Bidding by firms other than Simpson Timber Co. is precluded. The agreement has been in effect since January 1, 1947. During the 4-year period under study, the Simpson Co. acquired 189,260,000 board feet of timber by oral auction at appraised price in the Shelton Working Circle.[5]

[5] For an analysis and appraisal of the performance record under the Shelton cooperative agreement, see: Mason, David T., and Henze, Karl D. The Shelton sustained yield unit. J. Forest. 57: 163-168. 1959.

CHARACTERISTICS OF ORAL-AUCTION SALES

Having before us the definitions of noncompetitive sales, consisting of one-bidder sales, and two-or-more-bidder sales, where there is no significant bidding, and competitive sales, we may now proceed with an analysis of the bidding record. Basic information is supplied in tables 1 and 2 for both the west side and east side of the Pacific Northwest.

Number of Competitive and Noncompetitive Sales

West Side

FOREST SERVICE SALES.—For the west side, excluding the Shelton Working Circle, the 4-year Forest Service sale analysis covers 2,340 oral-auction sales. Of this total, 17.6 percent were noncompetitive by reason of only one bidder. In addition, 14.5 percent were in the noncompetitive token-bidding group. In total, 32.1 percent or about one out of three oral-auction sales fell within the noncompetitive classification. The remaining 1,588 sales, two-thirds of the total, were classified as competitive and had a ratio of bid price to appraised value equal to or greater than 1.01.

Because average sale size differed widely among the three competitive classifications, the percent of volume competitive and noncompetitive differed somewhat from the percent of number of sales measure. Table 1 shows that only 10.3 percent of the volume was transacted as one-bidder sales. However, 17.0 percent of the volume was sold under token-bidding conditions, somewhat more than by the percent of sales measure. In total, 27.3 percent of volume was sold without meaningful competition. Correspondingly, 72.7 percent of all volume sold was classified as competitive.

Table 1.—Characteristics of competitive and noncompetitive Forest Service oral-auction timber sales, 1959-62

Region and kind of sale	Number of sales	Percent of total sales	Total sale volume	Percent of total sale volume	Average bid-appraisal ratio	Average number of bidders per sale	Average volume per sale	Percent of each class of sales requiring road construction	Average road construction cost for sales requiring road construction
			M bd. ft.				M. bd. ft.		Dollars
West side:[1]									
Noncompetitive:									
One-bidder	412	17.6	1,171,956	10.3	1.00	1.00	2,852	59.9	41,077
Token-bid	340	14.5	1,936,586	17.0	1.00	3.06	5,746	75.4	69,545
Total noncompetitive	752	32.1	3,108,542	27.3	1.00	--	--	--	--
Competitive	1,588	67.9	8,273,407	72.7	1.63	5.28	5,206	71.8	59,941
Total sales, west side	2,340	100.0	11,381,949	100.0	1.46	4.20	4,872	70.2	58,625
East side:									
Noncompetitive:									
One-bidder	223	37.5	1,316,880	34.9	1.00	1.00	5,932	76.7	45,146
Token-bid	117	19.7	1,182,294	31.3	1.00	2.46	9,832	89.7	71,965
Total noncompetitive	340	57.2	2,499,174	66.2	1.00	--	--	--	--
Competitive	255	42.8	1,276,410	33.8	1.60	3.56	5,017	80.0	30,447
Total sales, east side	595	100.0	3,775,584	100.0	1.20	2.39	6,307	80.7	44,766

[1] Sales to Simpson Timber Co. in the Shelton Working Circle of the Olympic National Forest are excluded from the west-side data. These sales are covered by a cooperative sustained-yield agreement and are transacted at appraised price.

Table 2.—Characteristics of competitive and noncompetitive Bureau of Land Management oral-auction timber sales, 1951-62 [1]

Region and kind of sale	Number of sales	Percent of total sales	Total sale volume	Percent of total sale volume	Average bid-appraisal ratio	Average number of bidders per sale	Average volume per sale
			M bd. ft.				M bd. ft.
West side:							
Noncompetitive:							
One-bidder	899	29.9	2,271,307	29.9	1.00	1.00	2,526
Token-bid	16	0.5	37,951	0.5	1.00	1.88	2,372
Total noncompetitive	915	30.4	2,309,258	30.4	1.00	1.02	2,524
Competitive	2,095	69.6	5,296,073	69.6	1.47	2.95	2,528
Total sales, west side	3,010	100.0	7,605,331	100.0	1.33	2.36	2,527
East side:							
Noncompetitive:							
One-bidder	91	61.1	99,636	58.8	1.00	1.00	1,095
Token-bid	2	1.3	2,122	1.3	1.00	2.00	1,061
Total noncompetitive	93	62.4	101,758	60.1	1.00	1.02	1,094
Competitive	56	37.6	67,692	39.9	1.37	2.50	1,209
Total sales, east side	149	100.0	169,450	100.0	1.16	1.58	1,137

[1] Data not available for percent of, and average road construction cost for, sales requiring road construction.

BUREAU OF LAND MANAGEMENT SALES.—The Bureau of Land Management analysis for the west side includes 3,010 sales made over the 12-year, 1951-62, period (table 2). Of these, 915 or 30.4 percent were noncompetitive, 29.9 percent in the one-bidder group and 0.5 percent in the token-bid group. Sales classed as competitive numbered 2,095 and made up 69.6 percent of the total.

Average sale size did not differ greatly among the three competitive classifications. The percent of total volume sold under each of the competitive conditions was identical to the percent of sales measure.

The larger percentage of one-bidder sales and very few token-bid sales would be expected since Bureau of Land Management sale procedures do not require qualifying sealed bids as do Forest Service sales. The overall noncompetitive-competitive breakdown was about the same on both ownerships, with about two-thirds of all sales sold competitively and one-third sold at approximately the appraised value.

East Side

FOREST SERVICE SALES.—Only 595 Forest Service sales were made on the east side during the 1959-62 period — one-fourth as many as on the west side — but a larger proportion of these sales was in the noncompetitive group. The one-bidder sales on the east side accounted for 37.5 percent of all sales and the token-bid sales, an additional 19.7 percent. In total, 57.2 percent of all sales were noncompetitive. Only 42.8 percent, or 255 sales, were sold competitively in the region.

The volume proportions show 34.9 percent of the total east-side volume in the one-bidder group. This proportion was about 3 1/2 times the percentage found for the west side. The token bid sales accounted for 31.3 percent of total volume sold on the east side and the proportion was nearly twice that of the west side. Total noncompetitive volume on the east side represented nearly two-thirds of all volume sold, 66.2 percent, well over twice the proportion of noncompetitive sale volume found on the west side. Only 33.8 percent of the volume was sold competitively.

BUREAU OF LAND MANAGEMENT SALES.—Very few east-side sales were made by the Bureau of Land Management; the 1951-62 total was only 149. As was the case with Forest Service sales in the two regions, a much larger proportion of Bureau of Land Management east-side sales were noncompetitive. One-bidder sales made up 61.1 percent of the total number of sales and token-bid sales, 1.3 percent. Fifty-six competitive sales were made, accounting for 37.6 percent of the total number.

The volume sold under the various competitive conditions on the east side followed the pattern found on the west side; that is, the proportion of total volume and the proportion of total sales in each of the competitive classifications were about the same.

Bid-Appraisal Ratios

West Side

FOREST SERVICE SALES.—Although bidding at oral auction during the periods examined produced a 46-percent premium over appraised value for Forest Service sales, a sharp distinction existed between the competitive and noncompetitive components of all oral-auction sales. For the volume sold under noncompetitive conditions, there was, by definition, no premium over appraised price. The average ratio of bid price to appraised value was 1.00.

In sharp contrast, the 72.7 percent of all Forest Service volume sold under competitive conditions carried an average premium of 63 percent over appraised price.[6]

BUREAU OF LAND MANAGEMENT SALES.—Bidding on Bureau of Land Management oral-auction sales over the 1951-62 period resulted in an average premium over appraised price of 33 percent. When only the 69.6 percent of the total BLM sales volume sold competitively was considered — noncompetitive sales had a bid-appraisal ratio of 1.00 — the bid premium amounted to 47 percent, somewhat lower than that found for Forest Service sales but well above the appraised level.[7]

Figures 1 and 2 show bid-appraisal ratios for west-side Forest Service and Bureau of Land Management sales from 1951-66. The year-to-year movements in the bid-appraisal ratio indicate a cyclical type of behavior which closely follows cycles in residential construction.[8]

East Side

FOREST SERVICE SALES.—The difference between premium prices paid for competitive and noncompetitive sales was also found on the east side. Competitive Forest Service sales carried a 60-percent average premium over appraised price, only slightly less than the west-side experience. However, the high premium for competitive sales applied to only 33.8 percent of the east-side volume compared with 72.7 percent for the west side.[9]

BUREAU OF LAND MANAGEMENT SALES.—The Bureau of Land Management east-side competitive premium was 37 percent. As was the case when Forest Service sales in the two regions were compared, this premium applied to a much smaller proportion of the total volume sold, 39.9 percent, as compared with 69.6 percent on the west side.[10]

Average Number of Bidders

There is no readily available measure of the number of active and potential competitors for Federal timber in a given geographical area. We may, however, use the recorded data on number of qualified bidders (see pages 4 and 5) per sale as an indicator of the number of active bidders.

[6] A separate analysis of the 1964-66 sales record shows that the average premium paid in competitive sale has increased sharply to 100 percent over the appraised price.

[7] In the 1964-66 period, this premium increased to 75 percent.

[8] For an elaboration of the relationship between residential construction and cyclical behavior in the lumber industry, see: Mead, Walter J. Character of residential construction and its impact on lumber production and prices. West. Econ. Ass. Proc. 1961: 32-39.

[9] In the 1964-66 period, the premium bid over the appraised price increased slightly to 63 percent.

[10] In the 1964-66 record, the premium declined to 19 percent. The reader is reminded that the volumes involved in BLM east-side sales were relatively small.

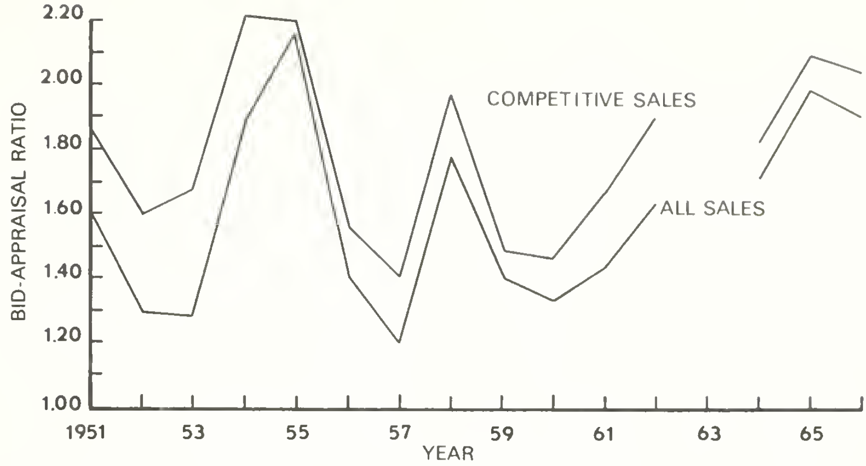

Figure 1.—Bid-appraisal ratio for oral-auction timber sales and for competitive sales only, Forest Service west-side sales, 1951-66.

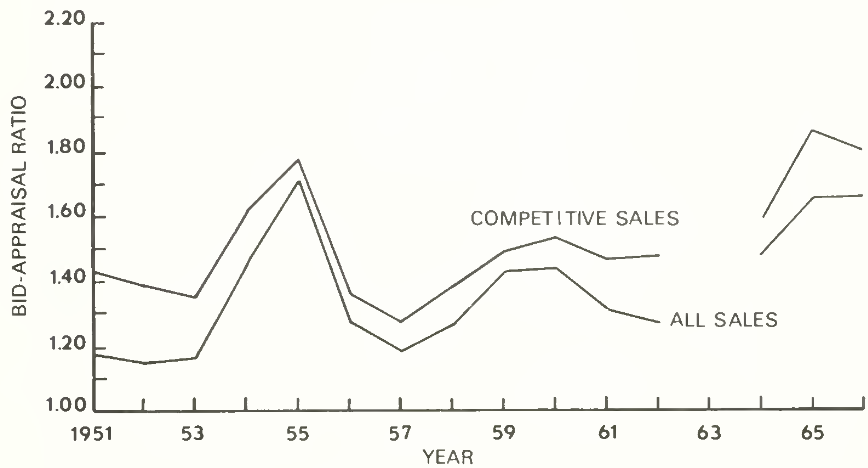

Figure 2.—Bid-appraisal ratio for oral-auction timber sales and for competitive sales only, Bureau of Land Management west-side sales, 1951-66.

Presumably, the areas having many active and potential bidders will also show a relatively large number of qualified bidders. Conversely, in areas where bidders are few, the number of bidders becoming qualified to bid on individual sales will be small. A smaller number of qualified bidders per sale would be expected on Bureau of Land Management sales since it is not necessary to qualify for these sales prior to the actual time of sale.

West Side

FOREST SERVICE SALES.—The average number of qualified bidders per sale on the west side differed among the two sales classes which have more than one bidder. Forest Service sales in the noncompetitive group — token-bid sales — had an average number of bidders per sale of 3.06. In contrast, the competitive sales had an average of 5.28 bidders.

BUREAU OF LAND MANAGEMENT SALES.—Bureau of Land Management sales averaged fewer bidders than did those made by the Forest Service but had the same relationship between classes of sales. Sales in the token-bid class averaged 1.88 bidders per sale, and competitive sales had an average of 2.95 bidders per sale.

East Side

FOREST SERVICE SALES.—On the east side, where a higher proportion of noncompetitive sales was found, there was evidence of fewer competitors. Forest Service token-bid sales averaged 2.46 bidders per sale, and competitive sales averaged 3.56 bidders. Both sales classes had a lesser number of competitors than was found on the west side.

BUREAU OF LAND MANAGEMENT SALES.—Only two Bureau of Land Management sales were purchased with token bids on the east side; two firms qualified to bid on each of these sales. Competitive sales averaged 2.50 bidders, again indicating less competition than was found on the west side.

There appears to be a positive relationship between the two sale characteristics we have just discussed: bid-appraisal ratio and average number of bidders (figs. 3 and 4). All noncompetitive single-bidder and token-bid sales are included in the 1.00 bid-appraisal class. For both ownerships and for both the west and east side, there is an increasing trend in the number of qualified bidders for competitive sales associated with larger bid-appraisal ratios.

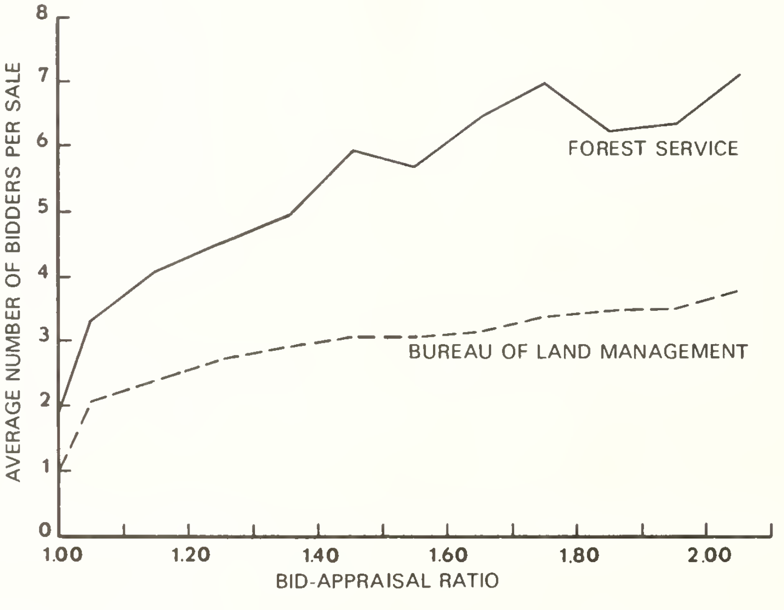

Figure 3.—Average number of bidders per sale by bid-appraisal ratio classes, Forest Service 1959-62) and Bureau of Land Management (1951-62) oral-auction sales only, west side (see tables 17, p. 48, and 27, p. 57).

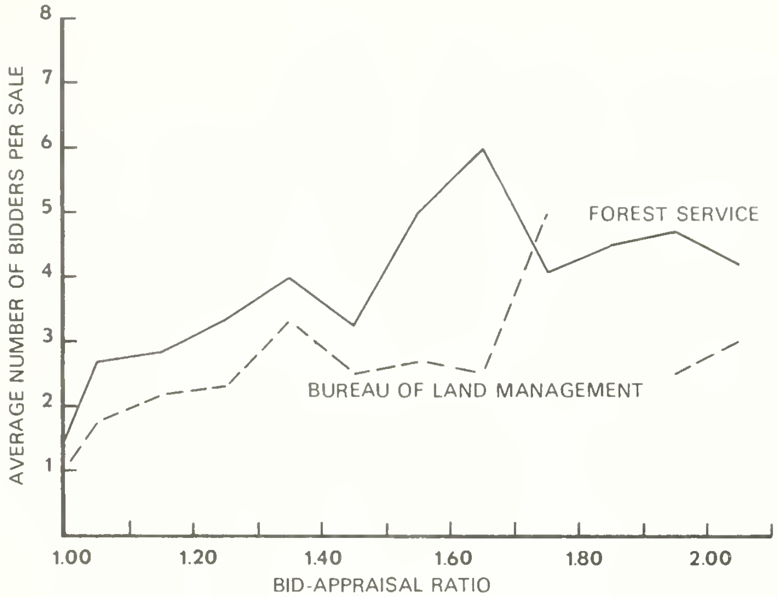

Figure 4.—Average number of bidders per sale by bid-appraisal ratio classes, Forest Service (1959-62) and Bureau of Land Management (1951-62) oral-auction sales only, east side (see tables 18, p. 48, and 28, p. 58).

Sale Size and Road Construction Cost

West Side

FOREST SERVICE SALES.—One-bidder Forest Service sales were smaller on the average than the other two groupings. Mean volume per sale for the one-bidder group amounted to 2,852,000 board feet, compared with 5,746,000 board feet for the token-bid group and 5,206,000 board feet for all competitive sales. Differences also existed in the percent of sales requiring road construction and the average road construction cost for those sales requiring construction. Only 59.9 percent of the one-bidder sales required road construction compared to 75.4 percent for the token-bid group, and 71.8 percent for the competitive sales. Sales characterized by token bidding had a high average volume per sale, a high proportion of such sales required road construction, and the average road construction cost per sale was highest of the three sales classes. On the other hand, the one-bidder class had the lowest volume per sale, the least proportion of sales requiring road construction, and the lowest average road construction cost when road construction was required.

There appears to be a positive relation between the average bid-appraisal ratio and volume size classes (fig. 5). The lowest premiums shown are for the smallest size class, sales of less than 1 million board feet. The average premium increases steadily to a relatively large class, 10 to 14.9 million board feet, and then declines for sales of 15 million board feet and larger.

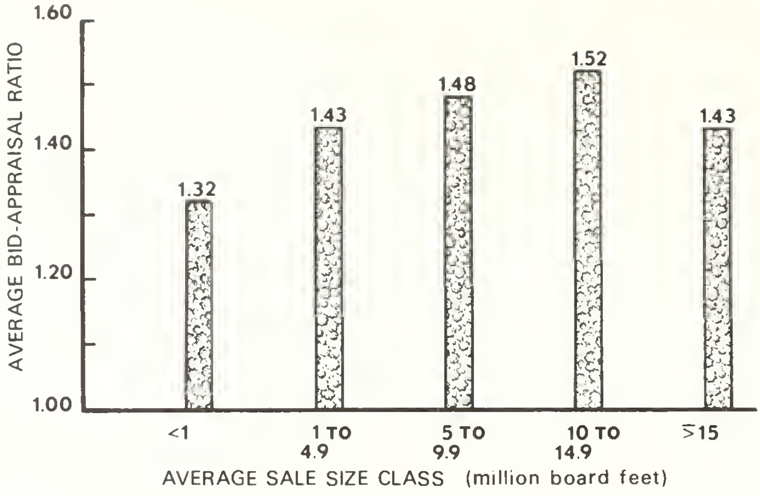

Figure 5.—Average bid-appraisal ratio by sale size classes for all Forest Service oral-auction timber sales, west side, 1959-62.

BUREAU OF LAND MANAGEMENT SALES.—Bureau of Land Management sales on the west side did not show the same relation between sale size and competitive class as Forest Service sales. One-bidder sales and competitive sales had practically the same average sale volume; and token-bid sales, which accounted for only 0.5 percent of the total, had only a slightly lower average volume. (Road construction cost information was unavailable for Bureau of Land Management sales.)

The relation between sale size and the bid-appraisal ratio also differs from Forest Service sales (fig. 6). For west-side Bureau of Land Management sales the relationship is negative with the higher premium found in the smallest sale size class and the lowest premium found for sales of over 15 million board feet. Most BLM sales fall into the first three size classes; the ratio shows only a slight decline for these sales.

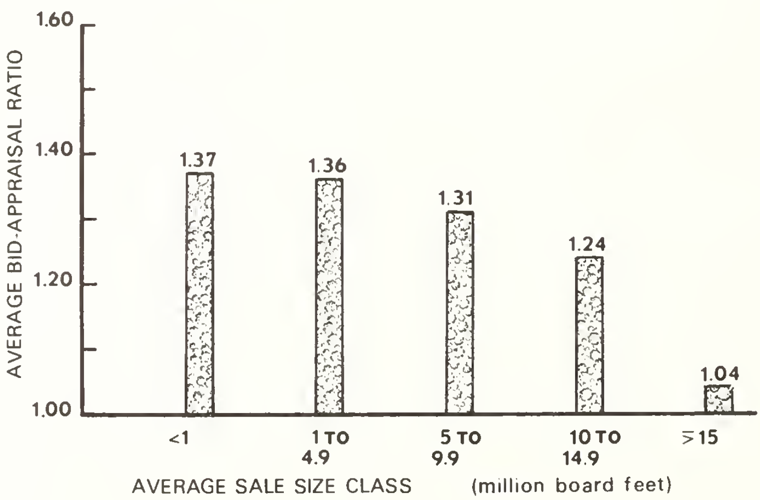

Figure 6.—Average bid-appraisal ratio by sale size classes for all Bureau of Land Management oral-auction timber sales, west side, 1951-62.

East Side

FOREST SERVICE SALES.—East-side Forest Service sales also showed average volume differences by competitive class, but the pattern was not the same as that found on the west side. The smallest sale size for the east side was found in the competitive group rather than in the one-bidder noncompetitive class. The one-bidder sales averaged 5,932,000 board feet, approximately twice the average size of the west-side one-bidder sales. The east-side token-bid sales were also relatively large at 9,832,000 board feet. But competitive sales on the east side averaged 5,017,000 board feet per sale, slightly smaller than their counterparts on the west side. The percent of sales requiring road construction on the east side was slightly higher than for comparable groups on the west side. Like west-side sales, a higher proportion of the token-bid sales required road construction.

The relation between sale size and the bid-appraisal ratio for east-side Forest Service sales is similar to that found for west-side BLM sales (fig. 7). The premium increases from the smallest sale size to the second class, but declines throughout the next three classes.

BUREAU OF LAND MANAGEMENT SALES.—Bureau of Land Management average sale volumes showed a competitive class pattern similar to that found on the west side; however, sale volumes were smaller. Again, the few token-bid sales had a slightly smaller average volume than the one-bidder and competitive sales, and the latter two classes had about the same average size.

No sales were made in the two largest sale size classes and only one sale was made in the 5- to 9.9-million-board-foot class. The two smaller size classes had relatively low premiums (fig. 8).

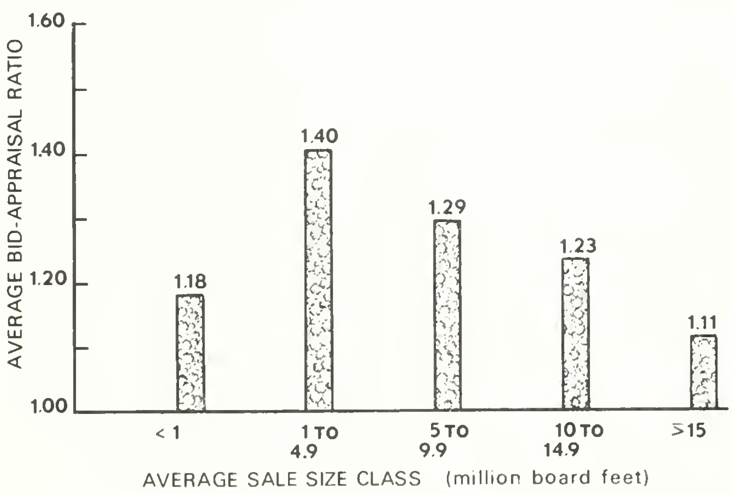

Figure 7.—Average bid-appraisal ratio by sale size classes for all Forest Service oral-auction timber sales, east side, 1959-62.

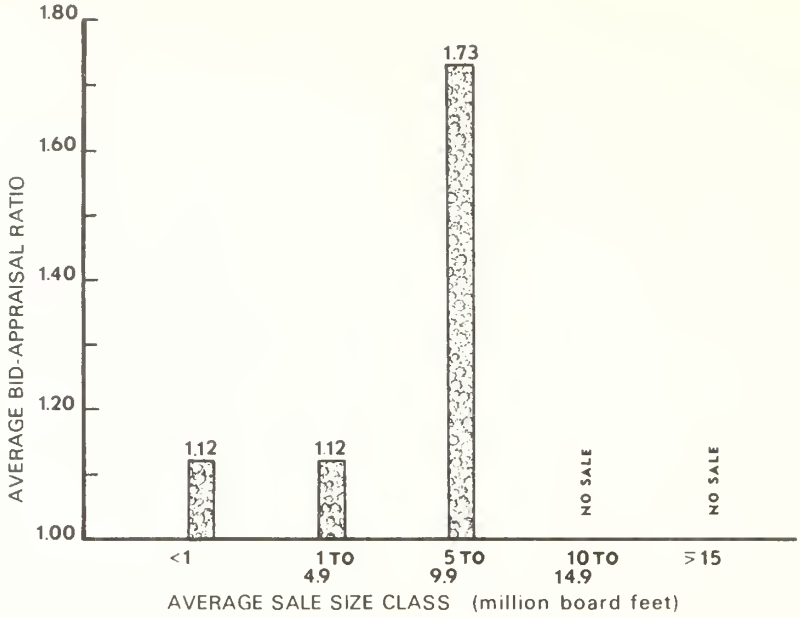

Figure 8.—Average bid-appraisal ratio by sale size classes for all Bureau of Land Management oral-auction timber sales, east side, 1951-62.

Size of Buyer

West Side

FOREST SERVICE SALES.—In the 4-year period being analyzed, the large firms on the west side purchased 22.6 percent of all timber volume sold by the Forest Service.[11] The remaining 77.4 percent was sold to all other buyers (small firms). The large firms obtained 11.6 percent of their volume in one-bidder sales, while small firms obtained 9.9 percent of their volume under similar conditions (table 3). Further, the large firms purchased 22.2 percent of their volume in the token-bid class. In contrast small firms purchased only 15.5 percent of their volume in this noncompetitive class where bidding is at a minimum. The balance of timber purchased by both groups fell in the competitive class where large firms obtained 66.2 percent or about two-thirds of their volume and small firms obtained 74.6 percent or approximately three-fourths of their volume.

The small firms, in addition to purchasing a large share of their timber under competitive conditions, paid a significantly higher premium over appraised price for such competitive sales. The small firms paid a premium of 68 percent over appraised value for timber purchased under competitive conditions. In contrast, the premium paid by large firms was only 43 percent, and this applied to a smaller share of their total volume purchased.

Since all sales classified as noncompetitive were transacted without significant premium over appraised value, the premium for all purchases, competitive plus noncompetitive, is substantially lower than the premium for competitive sales alone.

[11] Large firms consist of the 20 largest lumber producers, the 20 largest plywood producers, and the eight largest timberland owners. (Purchases by Simpson Timber Co., in the Shelton Working Circle under a cooperative sustained yield agreement, were not included in this study.) A list of large west-side firms is given on page 63.

Table 3.—Characteristics of Forest Service oral-auction timber sales to large firms[1] compared with small firms,[2] west side, 1959-62

Kind of sale and firm size	Volume	Percent of total volume	Average bid-appraisal ratio (weighted)	Average number of bidders per sale	Average volume per sale	Percent of sales requiring road construction	Average road construction cost for sales requiring road construction
	M bd. ft.				M bd. ft.		Dollars
Noncompetitive:							
One-bidder:							
Large firms	298,499	11.6	1.00	1.00	4,502	68.7	69,263
Small firms	873,457	9.9	1.00	1.00	2,531	58.1	34,594
Token-bid:							
Large firms	570,463	22.2	1.00	2.91	8,022	88.6	87,294
Small firms	1,366,123	15.5	1.00	3.10	5,160	72.1	63,931
Competitive:							
Large firms	1,699,750	66.2	1.43	4.80	7,454	84.2	76,011
Small firms	6,573,657	74.6	1.68	5.36	4,841	69.7	56,785
Total sales:							
Large firms	2,568,712	100.0	1.28	3.72	7,014	82.2	77,330
Small firms	8,813,237	100.0	1.51	4.29	4,483	68.0	54,531

Source: Developed from quarterly reports of U.S.D.A. Forest Service, Region 6, National Forest advertised timber sales, Portland, Oregon.
[1] The 20 largest lumber producers, the 20 largest plywood producers, and the eight largest timberland owners. (Purchases by Simpson Timber Co., in the Shelton Working Circle under a cooperative sustained yield agreement, were not included in this study.)
[2] All buyers other than the large firms as defined above.

The overall premium reflects not only the important difference in proportions between competitive and noncompetitive sales but the differing premiums on the competitive portion as well. As a result, the large firms acquired their National Forest timber for an average premium of 28 percent over appraised value, whereas small firms paid a 51-percent premium over appraised price.

The foregoing is an examination of the difference in premium over appraised price where the entire west side is the unit. It may be of interest to compare premiums within those working circles where both large and small firms buy timber. Among the 43 west-side working circles, there were 36 in which both groups were successful bidders. In only seven of these 36 working circles did we find the large firms paying a higher premium than their smaller competitors for the timber purchased. In contrast, the small operators paid the higher premium in 28 working circles. In one working circle, the premiums were identical between the two groups. A listing of the working circles involved and the recorded bid-appraisal ratios is provided in table 4.

Table 4.—Bid-appraisal ratios for large firms and all others in Forest Service working circles where both buyer groups purchased timber, west side, 1959-62

Working circle	Bid-appraisal ratio by buyer groups: Large firms	All others	Working circle	Bid-appraisal ratio by buyer groups: Large firms	All others
Soleduck	1.21	1.28	Mapleton	1.19	1.15
Quilcene	1.25	1.39	North Santiam	1.51	1.27
Quinault	1.00	1.13	South Santiam	1.10	1.33
Skagit	1.64	2.55	McKenzie	1.24	1.48
Suiattle	1.33	1.74	Lowell	1.38	1.54
Darrington	1.18	2.18	Oakridge	1.27	1.31
Skykomish	1.06	1.35	North Umpqua	1.17	1.26
Snoqualmie	1.72	1.64	South Umpqua	1.21	1.38
Green River	1.00	1.19	Coquille	1.20	1.18
Mineral	1.00	1.10	Rogue River (Siskiyou)	1.17	1.52
Packwood	1.16	1.33			
Randle	1.21	1.82	Chetco	1.00	1.24
Spirit Lake	1.03	1.86	Josephine	1.15	1.51
Lewis River	1.60	1.56	Applegate	1.16	1.64
Mt. Adams	1.41	1.22	Ashland	1.22	1.32
Wind River	1.48	1.73	Butte Falls	1.14	1.52
Hood River	1.25	1.33	Rogue River	1.23	1.41
Clackamas-Sandy	1.80	1.80	Weighted average[1]	1.29	1.51
Hebo	1.29	1.44			
Waldport	1.53	1.32			

NOTE: Of these working circles, the largest premiums were paid by:

Large firms	7
Small firms	28
Same	1
Total	36

[1] Weighted average of all working circles, whether listed or not.

The data shown above on the premiums paid by economic size class were based upon *prices bid* for National Forest timber. For two reasons, the prices *actually paid* for such timber may not correspond precisely with the *bid prices*. First, the final buying price was subject to a price escalator provision whereby stumpage rates are adjusted up or down by 50 percent of the difference between the base period price index and a current price index for stumpage. Thus, if the stumpage price index should increase by $2 per thousand from the base period, determined as of the date of the sale, the actual price paid would be increased by $1 per thousand above the bid price. Similar adjustments are made if the stumpage price index should decline. The escalator provision has applied to west-side timber since the spring of 1961; for east-side timber, the escalator provision has applied throughout the period under study. Adjustments that are made in the stumpage price as a result of changes in the stumpage price index presumably are randomly distributed between large and small firms. Thus, we have no reason to suspect that changes made in the premium over appraised price would significantly affect the premium differentials by economic size class shown above.

Second, the procedure called rate redetermination is required on large timber sales, which tended to reduce the effective price for those sales where bidding had significantly exceeded the appraised price during the period of this study. The Forest Service Manual[12] states that "Rate redetermination will be required in contracts for all sales where the operation, including development, requires more than four full operating seasons." Thus, for large sales, competitive bidding determines the price of the minimum volume which must be removed prior to the point of rate redetermination. The minimum volume appears to vary between 40 and 60 percent of the total volume for large sales and averages 50 percent of the total volume. Competitive bidding does not affect the price of timber remaining in the sale after rate redetermination in large sales when bidding has significantly exceeded the appraised price. Rather, reappraisal is based on the same procedures used to establish the original appraised price. We may illustrate the effect of rate redetermination by a hypothetical example. Let us consider a sale having the following conditions: (1) total volume estimated and actually produced, 20 million feet; (2) a bid price exceeding appraised price by 100 percent; (3) rate redetermination taking place when 50 percent of the total production has been removed; and finally, (4) no basic changes occurring in the underlying economic data affecting stumpage value during the previous life of the contract. Under these circumstances, rate redetermination would normally restore the original appraised price for the second half of total log production. Thus, 10 million feet would be sold at a 100-percent premium over appraised price as given by the bid price, and the remaining 10 million feet would be sold at the redetermined rate which, in this example, would equal the appraised price. The final cost of the timber would involve not a 100-percent premium over appraised price but an average 50-percent premium. Since the period over which sales were examined here, the Forest Service rate redetermination procedure has been changed so that the bid premium is also applied to the redetermined appraisal.

Table 3 shows that the average size of sales purchased by large firms was substantially greater than sales purchased by smaller firms. Since large sales are more likely to involve rate redetermination, and large sales tend to be concentrated among large firms, then downward adjustments due to rate redetermination would reduce the premiums paid by large firms more than they would reduce the premiums paid by smaller firms. Thus, whereas the escalator factor appears to have had no significant effect on the differential premiums by economic size class, the rate redetermination factor would have had differential effects with the result that the premium advantage enjoyed by large firms was even greater than the very significant differentials shown in table 3. The analysis contained in the report is based entirely on the published bid prices and not upon the actual prices, which differ due to operation of the escalator provision and the rate redetermination process. The reader, however, is asked to keep in mind these two qualifications.

[12] U. S. D. A. Forest Service. Forest Service Manual, 2423.8, R-6 Supplement No. 101.

Other sale characteristics representing differences by size of buyer are also shown in table 3. In all three competitive categories, the average volume per sale in sales purchased by large firms was significantly larger than that of small firms.

For uncontested sales, the average sale size of large firm purchases exceeded the small firm purchases by 78 percent. For the token-bid sales, the differential was 55 percent. And for competitive sales, the average sale size purchased by large firms exceeded that of their smaller competitors by 54 percent. Overall, the differential was 56 percent.

Similarly, differences existed in the average number of bidders per sale between sales acquired by large firms compared to small firms on the west side. By definition there is only one bidder in the uncontested sale. For the token-bid sale, the number of firms qualified to bid at sales where a large firm was the successful bidder averaged 2.91 bidders per sale. Where a small firm was the successful bidder in a token-bid sale, the average number of bidders per sale amounted to 3.10. Among the competitive sales, there was an average of 4.80 bidders per sale qualified to bid where a large firm was the successful bidder. Where a small firm was the successful bidder, there were 5.36 qualified bidders on the average.

The average road construction cost, the percent of sales requiring construction, and the average sale size are all substantially greater for large firms for each of the three sale classes shown in table 3. These factors would appear to be related to degree of competition for Federal timber and therefore to the premium paid over appraised price. A large sale requires a greater degree of financing than a small sale. Financial competence must be established by a successful bidder. An accompanying large road construction cost requirement further increases the financial obligation. The greater the financial requirements on account of sale size and road construction cost, the fewer will be the number of small firm bidders able to compete for a given sale.

On the other hand, larger firms with greater financial resources have more interest in larger sales and hence may become qualified bidders for large sales, whereas they are less interested and may not qualify to bid on small sales. Thus, even though sale size is a barrier to entry for small operators, it may not reduce the number of bidders. Instead, it changes the composition of bidders from small operators to a higher proportion of large firms.[13] But among larger firms that may have a longer term operating horizon and more permanent associations in their communities, there appears to be a tendency to avoid competition with other qualified bidders. This is particularly true on the west side where the record shows that the big firms obtained a significantly larger share of single-bid and token-bid sales than did the smaller firms. Thus, there is a logical relationship between degree of competition, on one hand, and barriers to entry in the form of sale size and road construction cost, on the other.

BUREAU OF LAND MANAGEMENT SALES.—Large firms purchased 22.8 percent of the Bureau of Land Management timber sold on the west side during the period 1951-62 (table 5). Both size classes of firms purchased about seven-tenths of their total volume competitively; large firms acquired 70.5 percent of their total volume through competitive sales and small firms purchased 69.4 percent. The balance, 29.5 percent for large firms and 30.6 percent for small firms, was obtained in noncompetitive sales. This percentage distribution in sale type differs from Forest Service sales where smaller firms obtained a larger proportion of their sales competitively than did large firms.

Bureau of Land Management sales also differed from Forest Service sales when premiums paid by large as compared with small firms were examined. In the Forest Service sales, the premium paid by small firms was substantially higher. For Bureau of Land Management sales there was little difference in the premium over appraised price as related to firm size. The small firms paid a premium of 47 percent of appraised value for sales purchased competitively, and large firms paid a 46-percent premium. For all sales, including those purchased noncompetitively, small firms paid a premium of 34 percent and large firms paid 33 percent.

[13] It would be difficult to formally quantify and demonstrate this point. An examination of the names of qualified bidders in a large number of individual sales produces a clear pattern. The qualified bidders for large sales are generally well-known and well-established firms, whereas small-sale bidders consist of a few established firms plus other operators whose firm names are not well known in the industry The picture is often confused by private arrangements whereby a logger will be bidding on behalf of, and financed by, another firm.

Table 5.—Characteristics of Bureau of Land Management oral-auction timber sales to large firms[1] compared with small firms,[2] west side, 1951-62[3]

Kind of sale and firm size	Volume	Percent of total volume	Average bid-appraisal ratio (weighted)	Average number of bidders per sale	Average volume per sale
	M bd. ft.				M bd. ft.
Noncompetitive:					
One-bidder:					
Large firms	488,585	28.2	1.00	1.00	3,257
Small firms	1,782,722	30.3	1.00	1.00	2,380
Token-bid:					
Large firms	22,915	1.3	1.00	1.80	4,583
Small firms	15,036	.3	1.00	1.91	1,367
Competitive:					
Large firms	1,219,542	70.5	1.46	2.66	3,608
Small firms	4,076,531	69.4	1.47	3.01	2,320
Total sales:					
Large firms	1,731,042	100.0	1.33	2.14	3,511
Small firms	5,874,289	100.0	1.34	2.41	2,334

Source: Developed from quarterly reports of Bureau of Land Management, "Results of Timber Sales," Portland, Oregon.

[1] The 20 largest lumber producers, the 20 largest plywood producers, and the eight largest timberland owners. (Purchases by Simpson Timber Co., in the Shelton Working Circle under a cooperative sustained-yield agreement, were not included in this study.)

[2] All buyers other than the large firms as defined above.

[3] Data not available for percent of, and average road construction cost for, sales requiring road construction.

Further information on bid premiums as related to firm size can be obtained by comparing the results in the 12 west-side master units. In contrast with the results of our Forest Service working circle examination, we find that large firms paid a higher premium in eight of the 12 master units, and smaller firms paid a higher premium in only four master units (table 6).

Table 6.—Bid-appraisal ratios for large firms and all others in Bureau of Land Management master units where both buyer groups purchased timber, west side, 1951-62

Master unit	Large firms	All others
Alsea-Rickreall	1.43	1.45
Clackamas-Molalla	1.64	1.55
Columbia	1.42	1.35
Douglas	1.34	1.23
Jackson	1.25	1.32
Josephine	1.50	1.22
Klamath	1.68	1.29
Santiam	1.23	1.34
Siuslaw	1.40	1.52
South coast	1.27	1.26
South Umpqua	1.31	1.20
Upper Willamette	1.46	1.43
Weighted average	1.33	1.34

NOTE: Master units in which largest premiums were paid by:
Large firms 8
Small firms 4
Total 12

Unlike Forest Service sales, where provisions for price escalation and rate redetermination exist, the prices bid for Bureau of Land Management timber are the prices that apply over the duration of the sale. For this reason, no advantage accrues to a firm that is able to purchase a large sale, and the examination of prices paid for BLM timber is not subject to price adjustment qualifications.

In relating sale size to size of buyer, we find results similar to those for Forest Service sales; in all cases, the average sale size for large firm purchases exceeded that for sales purchased by small firms. For single-bidder sales, the average sale size for purchases by large firms was 37 percent larger; for token-bid sales, large firm purchases were more than three times the size of small firm volume; and for competitive sales, the average large firm sale volume was 56 percent greater than small firm volume. For all sales combined, the difference was 50 percent.

Sales purchased by large firms also averaged fewer bidders per sale. For token-bid sales, this difference was not great; large firm purchases averaged 1.80 bidders whereas purchases by small firms averaged 1.91. This would be expected since the uncertainty underlying Forest Service token-bid sales is eliminated in the Bureau of Land Management sale procedure. Competitive sales acquired by large firms averaged 2.66 bidders per sale. In contrast, when a competitive sale was purchased by a small firm, an average of 3.01 bidders qualified to bid.

Sale size may be a financial barrier to entry here just as it may be for Forest Service sales. However, unlike the evidence shown in our examination of Forest Service sales, competition between large firms appears to be just as intense as between small firms for BLM sales.

East Side

FOREST SERVICE SALES.—The large firms on the east side, though fewer in number, occupied a more important position as buyers of National Forest timber than the large firms of the west side.[14] The Big Eight of the east side purchased 37.1 percent of all National Forest timber sold by oral auction, leaving 62.5 percent for all other purchases. The large firms obtained 45.1 percent of their purchased volume under one-bidder conditions, whereas small firms obtained only 28.8 percent of their volume as one-bidder buyers (table 7). The token-bid sales showed the opposite relationship; namely, the small firms purchased a larger share, 33.1 percent of their volume with token bids compared with 28.3 percent by large firms. However, the large firms were able to purchase in total substantially more of their timber under noncompetitive conditions relative to the small firms. Only 26.6 percent of the large firm purchases were under competitive conditions, whereas 38.1 percent of the small purchases were competitive.

The average premiums paid by the two purchaser groups for their competitive sales were almost identical. The difference in premiums paid between the two groups originates rather with the percent acquired under noncompetitive conditions. Thus, the overall cost of National Forest timber to the large firms involved a 16-percent premium, whereas the smaller firms paid a 23-percent premium.

If we examine the premiums paid by each of the two groups for timber purchased in those working circles in which both groups were successful buyers, we find the same premium pattern emerging. Table 8 shows 15 east-side working circles in which both firm-size groups purchased timber. In only four did the large firms pay a premium in excess of that paid by small firms. In contrast, in 10 working circles the smaller firms paid the larger premium. In one working circle, the premiums were identical.

[14] The list of large firms on the east side is given on page 63.

Table 7.—Characteristics of Forest Service oral-auction timber sales to large firms[1] compared with small firms,[2] east side, 1959-62

Kind of sale and firm size	Volume	Percent of total volume purchased by group	Average bid-appraisal ratio (weighted)	Average number of bidders per sale	Average volume per sale	Percent of sales requiring road construction	Average road construction cost for sales requiring road construction
	M bd. ft.				M bd. ft.		Dollars
Noncompetitive:							
One-bidder:							
Large firms	634,381	45.1	1.00	1.00	9,959	81.3	70,937
Small firms	682,499	28.8	1.00	1.00	4,311	74.8	33,876
Token-bid:							
Large firms	398,226	28.3	1.00	2.52	15,809	96.0	108,824
Small firms	784,068	33.1	1.00	2.45	8,207	88.0	61,043
Competitive:							
Large firms	374,270	26.6	1.59	3.15	9,357	90.0	58,624
Small firms	902,140	38.1	1.60	3.64	4,210	78.1	24,410
Total sales:							
Large firms	1,406,877	100.0	1.16	1.96	10,906	86.8	75,098
Small firms	2,368,707	100.0	1.23	2.50	5,034	79.0	35,534

[1] The eight largest lumber-producing firms on the east side.
[2] All buyers other than the eight firms above.

Table 8.—Bid-appraisal ratios for large firms and all others in Forest Service working circles where both buyer groups purchased timber, east side, 1959-62

Working circle	Large firms	All other
Okanogan	1.23	1.32
Ellensburg	1.35	1.59
Naches Tieton	1.34	1.08
West Klamath	1.05	1.60
East Klamath	1.22	1.28
Deschutes Plateau	1.23	1.15
Crooked River	1.05	1.07
Burns	1.00	1.01
John Day	1.00	1.07
Burnt River	1.00	1.40
Elkhorn	1.00	1.04
Pendleton-Pilot Rock	1.29	1.36
Grande Ronde (Wallowa-Whitman)	1.37	1.01
Union	1.00	1.00
Wallowa	1.08	1.01
Weighted average[1]	1.16	1.23

NOTE: Of these working circles, the largest premiums were paid by:

Large firms	4
Small firms	10
Same	1
Total	15

[1] Weighted by volume for all working circles whether listed or not.

The differences noted for the west side in average volume per sale are found emphasized for east-side Forest Service sales. Again, for all three competitive categories of sales, the average sale size purchased by large firms was substantially larger than for the small firms. Overall, the average volume per sale purchased by the large firms exceeded that of the small firms by more than twofold.

The average number of bidders per sale on the east side differed substantially between sales purchased by large firms relative to those purchased by small firms. Overall, there was an average of 2.5 bidders qualified to bid for those sales purchased by small firms. In contrast, the sales acquired by large firms registered only 1.96 average bidders per sale. Unlike the west side, this relationship was not consistent. The token sales on the east side averaged slightly more bidders per sale competing for the timber purchased by large firms relative to the small firm sales.

The road construction factors identified for Forest Service sales on the west side were found in nearly identical form on the east side. The single difference in the buyer-size relationship was one of magnitude and reflected differences in sale size. The average road construction cost for sales to large firms was more than double the average cost for road construction for sales to small firms.

BUREAU OF LAND MANAGEMENT SALES.—Few comparisons can be made between large and small firm purchases of BLM timber on the east side. Only two of 149 sales were purchased by large firms, both in the single-bidder class (table 9).

Table 9.—Characteristics of Bureau of Land Management oral-auction timber sales to large firms[1] compared with small firms,[2] east side, 1951-62[3]

Kind of sale and size of firm	Volume	Percent of total volume	Average bid-appraisal ratio (weighted)	Average number of bidders per sale	Average volume per sale
	M bd. ft.				M bd. ft.
Noncompetitive:					
One-bidder:					
Large firms	3,332	100.0	1.00	1.00	1,666
Small firms	96,304	58.0	1.00	1.00	1,082
Token-bid:					
Large firms	--	--	--	--	--
Small firms	2,122	1.3	1.00	2.00	1,061
Competitive:					
Large firms	--	--	--	--	--
Small firms	67,692	40.7	1.37	2.50	1,209
Total sales:					
Large firms	3,332	100.0	1.00	1.00	1,666
Small firms	166,118	100.0	1.16	1.59	1,130

Source: Developed from quarterly reports of Bureau of Land Management, "Results of Timber Sales," Portland, Oregon.
[1] The eight largest lumber-producing firms on the east side.
[2] All buyers other than the eight firms above.
[3] Data not available for percent of, and average road construction cost for, sales requiring road construction.

DIFFERENCES IN COMPETITION AMONG NATIONAL FOREST WORKING CIRCLES AND BUREAU OF LAND MANAGEMENT MASTER UNITS

The differences observed among Federal timber sales in the preceding section are primarily attributable to differing competitive conditions in the areas where the sales are made and to the different bidder qualification procedures followed by the two agencies. To examine the effect of competition, a suitable means of measuring differences in competition must be found.

Measures for Identifying the Strength of Competition by Forest Service Working Circle or Bureau of Land Management Master Unit

There are several possible measures of competitive performance by working circles or master units. Three will be considered here:

1. *The weighted average bid-appraisal ratio* might be used to measure the extent of competition in these areas. Thus, a high ratio would be taken as an indicator of intense competition, and a low ratio or 1.00 would indicate minimal or no competition. However, this measure is not without its faults. It may be particularly weak when averaged because it obscures competitiveness on individual sales. Further, if bidders tend to offer nearly constant dollar premiums over appraised prices, then a given dollar premium bid will produce a high bid-appraisal ratio where the appraised price is low and the opposite where the appraised price is high. Although the bid-appraisal ratio as a measure of extent of competition may have its shortcomings, if used with caution and an appreciation for other differences among the several working circles and master units, it is still a useful indicator of competition.

2. *The average number of bidders per sale* may also be used as an indicator of the strength of competition. If there are many sales having only one qualified bidder, competition may be considered minimal. Yet, as illustrated in the case of token-bid sales, the presence of several qualified bidders may not necessarily indicate effective competition. The record contains many illustrations of several bidders qualifying themselves to bid for a given sale, but failing to cast an oral-auction bid. This measure also has the weakness of all averages — it obscures variation of individual sales. Further, as Weintraub[15] points out, "through appraisal technique alone the number of bidders will be reduced and the situation may end up with only a single bidder present." Thus, by a sufficiently high appraisal, all bidders except the

[15] Weintraub, Sidney. An examination of some economic aspects of Forest Service stumpage prices and appraisal policies. 201 pp., illus 1958. (Unpublished report prepared for Forest Service, U. S. Dep. Agr. On file at Pacific Northwest Forest & Range Exp. Sta., Portland, Oregon.)

single most efficient firm, or the firm most desperately in need of timber, may be eliminated from bidding. Although this situation is conceivable, it hardly seems likely, since appraisals are made to the "average efficiency" firm and in view of the large number of competitive sales taking place at substantial premiums over appraised price (on the west side, 63 percent of Forest Service sales and 70 percent of Bureau of Land Management sales). There is sufficient supervision of appraisal technique to provide uniformity among working circles and master units and between sales. As in the instance of the bid-appraisal ratio, the average number of bidders is not without its faults as an indicator of the extent of competition, but is a useful measure if used cautiously.

3. *The percent of total volume sold which is purchased under competitive conditions*, as here defined, is another measure that has considerable merit as an indicator of competitive pressure in working circles and master units. As competition is here defined, a competitive sale must have two or more bidders who make serious oral-auction bids above the appraised price. A serious bid in turn is defined as a bid at least one-half of 1 percent in excess of appraised price. The competitive sale therefore excludes both the one-bidder sale and the token-bid sale. Percent of volume sold competitively, or percent competitive, is therefore defined as the ratio of competitive sales to total sales where competitive sales are identified as those sales having a bid-appraisal ratio equal to or greater than 1.01. A fault of the percent competitive measure in identifying competitive and noncompetitive areas is that it says nothing about the degree of competition for the sales volume classified as competitive. In other words, a competitive sale may be one in which two bidders have raised the price 1 percent above the appraised price, or a dozen bidders may have doubled the appraised price.

It is judged that percent competitive is the most sensitive and least faulty for use in measuring competition. Therefore, in judging the extent of competition by working circles and master units, the percent competitive will be used as the primary measure, with secondary attention given to the bid-appraisal ratios and the average number of bidders. This measure will be used as the dependent variable in the multiple regression analysis where we will attempt to "explain" the observed differences in degree of competition among the working circles and among the master units.

Timber Sale Characteristics on Forest Service Working Circles and Bureau of Land Management Master Units

To identify the characteristics of the working circles and master units, a classification system based on percent competitive has been established. This classification system is not independent of the working circles and master units to be classified. The record shown in tables 10 and 11 was examined for natural breaks in the data and judgments were made about the extent of competition in individual areas, based on discussions with buyers in many areas. The areas were classified as "highly competitive" if they had a weighted average percent of volume sold under competitive conditions between 85 and 100 percent. At the other extreme, areas having less than 60 percent of volume sold competitively were classified as areas of minimal competition. Areas having between 60 and 85 percent of volume sold under competitive conditions were classified as "intermediate" in degree of competition.

Table 10.—Degree of competition by Forest Service working circle, arrayed according to percent of volume competitive, west side, 1959-62[1]

Working circle	Number of sales	Total volume sold by oral auction	Percent of volume competitive	Bid-appraisal ratio, all sales	Average number of bidders, all sales	Average volume per sale
		M bd. ft.				M bd. ft.
Highly competitive:						
Cedar River	2	7,360	100 0	1.32	3.00	3,680
Hood River	29	143,495	99.9	1.32	3.17	4,948
Lewis River	31	406,945	99.8	1.57	5.03	13,127
Suiattle	21	75,055	98.9	1.65	10.95	3,574
Green River	4	27,080	96.0	1.18	2.50	6,770
Baker River	24	130,672	95.3	3.16	6.92	5,445
Clackamas-Sandy	182	1,017,830	93.1	1.80	5.47	5,592
Wind River	46	235,535	93.1	1.71	3.11	5,120
White River	30	115,855	92.7	1.40	4 43	3,862
McKenzie	140	496,652	91.0	1.47	3.99	3,548
Lowell	79	388,285	87.6	1.50	5.46	4,915
Canyon Creek	27	118,550	86.1	1.76	4.26	4,391
Glacier	28	106,392	85.9	2.99	3.89	3,800
Intermediately competitive:						
Quilcene	32	216,450	82.6	1.33	3.94	6,764
Soleduck	32	221,575	82.3	1.28	4.19	6,924
Waldport	87	434,864	81.8	1.41	4.49	4,998
Rogue River (RR)	70	268,710	81.6	1.35	5.54	3,839
South Umpqua	99	399,230	80.8	1.32	4 77	4,033
Snoqualmie	7	46,458	78 7	1 69	3.57	6,637
Randle	67	375,870	76.1	1.73	6.31	5,610
Skagit	15	98,830	74.1	2.53	7.53	6,589
Darrington	50	240,178	73.2	2.14	11.22	4,804
S. Fork Stillaguamish	25	138,550	72.2	1.42	4.40	5,542
North Santiam	67	303,080	70.8	1.34	3.73	4,524
Hebo	66	263,650	69.9	1.36	3.79	3,995
Josephine	87	227,622	68.5	1.50	3 37	2,616
Oakridge	162	824,161	67.1	1.28	3.29	5,087
Rogue River (Siskiyou)	47	286,947	63 3	1.42	3.57	6,105
North Umpqua	153	802,771	62.8	1.24	4.56	5,247
Ashland	25	80,345	62.4	1.23	3.00	3,214
Minimally competitive:						
Packwood	62	268,440	59.9	1.30	4.05	4,330
Cottage Grove	58	205,550	58.3	1.32	2.83	3,544
Spirit Lake	15	123,615	57.9	1.62	2.93	8,241
Butte Falls	30	112,605	57.5	1.17	4.90	3,754
South Santiam	100	366,489	56.6	1.20	2.53	3,665
Chetco	27	130,745	54.8	1.24	2.22	4,842
Applegate	19	84,875	51.0	1.50	2.84	4,467
Coquille	29	107,550	49.3	1.18	2.21	3,709
Mt. Adams	72	388,385	48.3	1.23	2.47	5,394
Mapleton	113	502,631	47.4	1.17	2.42	4,448
Quinault	46	325,142	44.9	1.13	2.30	7,068
Skykomish	20	130,665	42.4	1.14	3.10	6,533
Mineral	15	136,260	28.4	1.17	3 00	9,084
Shelton	8	189,260	0.0	1.00	1.13	23,685

[1] See table 13, page 43.

Table 11.—Degree of competition by Bureau of Land Management master unit, arrayed according to percent of volume competitive, west side, 1951-62

Master unit	Total volume sold by oral auction	Percent of volume competitive	Bid-appraisal ratio, all sales	Average number of bidders, all sales	Number of sales	Average volume per sale
	M bd. ft.					M bd. ft.
Highly competitive:						
Clackamas-Molalla	209,986	88.6	1.57	2.50	88	2,386
Intermediately competitive:						
Siuslaw	867,553	83.47	1.51	2.79	468	1,854
Klamath	146,068	82.32	1.30	2.75	57	2,563
Upper Willamette	614,161	81.49	1.43	2.60	303	2,027
Jackson	522,372	77.64	1.30	2.49	194	2,693
Alsea-Rickreall	636,568	72.10	1.44	2.18	258	2,467
Santiam	581,072	71.77	1.31	2.40	192	3,026
Columbia	414,908	71.48	1.37	2.47	189	2,195
South Coast	1,452,602	67.91	1.26	2.15	389	3,734
Minimally competitive:						
Douglas	1,143,224	56.23	1.26	2.07	483	2,367
South Umpqua	257,872	55.15	1.22	1.97	105	2,456
Josephine	758,945	54 75	1.22	2.18	284	2,672

West-Side Working Circles

Table 10 shows that the 13 working circles classified as highly competitive on the basis of percent competitive averaged three or more bidders per sale with one exception, and, with the same one exception, had a weighted average bid-appraisal ratio equal to or larger than 1.32. The 14 working circles classified as having only minimal competition with three exceptions averaged three bidders per sale or less and, with three exceptions, had a weighted average bid-appraisal ratio of 1.30 or less.

The spread between most competitive and least competitive working circles runs the entire range of possibilities, from 100 percent competitive in the Cedar River Working Circle to legally precluded competition in the Shelton Working Circle. Neither working circle at the two extremes was representative, however. There were only two sales on the Cedar River Working Circle in the 4-year period under study; and, as pointed out earlier, the Shelton Working Circle was covered by a cooperative sustained yield agreement. On the Hood River Working Circle of the Mount Hood National Forest, all sales except one involved serious challenge. The one exception was a small (100,000 board feet) single-bidder sale. The largest volume working circle on the west side was the Clackamas-Sandy Working Circle, also the the Mount Hood National Forest. This was one of the most intensely competitive areas in the entire region. Competitive sales accounted for 93.1 percent of all volume sold. Further, there was an 80-percent premium over appraised price paid for timber purchased within this working circle. The high premium, moreover, cannot be accounted for by a low appraised price, since the average appraised price for the working circle was $15.01 per thousand board feet for all oral-auction timber. This compares with $16.75 average appraised price for all oral-auction sales on the west side. Finally, the average number of bidders qualified to bid on oral-auction sales within the Clackamas-Sandy Working Circle was 5.47, compared with 4.20 for the west side (excluding the Shelton Working Circle).

West-Side Master Units

There are 12 Bureau of Land Management master units on the west side. Under the same classification system, eight master units were classed as having intermediate competition, three had minimal competition, and only one, the Clackamas-Molalla Master Unit, was classed as highly competitive (table 11).

There was some decline in the weighted average bid-appraisal ratios and in average number of bidders per sale as the percent competitive by master unit declined. The Clackamas-Molalla Master Unit was characterized by a lower total sale volume and a smaller number of sales than the average for all master units. On the other hand, the two largest volume master units — South Coast and Douglas — were ranked near the bottom in terms of percent competitive.

The range in percent competitive was much narrower for master units as compared with working circles. We would expect this difference since master units generally cover much larger areas and would therefore be less likely to show competitive extremes found in the more confined working circles.

East-Side Working Circles

On the east side, the spread between the most competitive and the least competitive working circles shown in table 12 was nearly as extreme as that found on the west side. Five small working circles had no competitive sales during the 4-year period. The Burns, Wenatchee, and Lakeview Working Circles were all subject to competition and yet less than 6 percent of the total volume sold was transacted under competitive conditions. At the other end of the competitive spectrum, the Grande Ronde Working Circle of the Umatilla National Forest recorded 90.4 percent of all volume sold as competitive.

By applying the same classification system established for the west side to the east side, we found that only two of the 26 east-side working circles fell within the highly competitive classification, only three were in the intermediate classification, and the remaining 21 were classified as minimally competitive.

The difference in east-side and west-side competitiveness can be explained by comparison of some of their physical relationships. The spatial relationship between timber supply and milling facilities is quite different in the two subregions. On the east side, the timber is more scattered relative to the west side. National Forest timber sales on

Table 12.—Degree of competition by Forest Service working circle, arrayed according to percent of volume competitive, east side, 1959-62

Working circle	Total volume of all oral-auction sales	Percent of volume competitive	Bid-appraisal ratio for all sales	Average number of bidders, all sales
	M bd. ft.			
Highly competitive:				
Grande Ronde (Umatilla)	58,576	90.4	1.71	3.38
Ellensburg (Cle Elum)	161,620	88.6	1.44	4.48
Intermediately competitive:				
West Klamath	197,025	83.1	1.60	3.82
East Klamath	274,940	81.3	1.25	2.55
Winema	50,525	61.2	1.10	2.16
Minimally competitive:				
N. Fork (Pendleton-Pilot Rock)	179,229	57.8	1.33	2.90
Clearwater	29,700	57.6	1.15	2.33
Grande Ronde (Wallowa-Whitman)	73,041	51.1	1.36	2.43
East Side	145,990	49.7	1.73	3.38
Deschutes Plateau	510,376	36.1	1.19	2.38
Morrow (Heppner)	54,239	32.6	1.20	2.00
Okanogan (Chelan)	216,569	28.0	1.26	1.73
Elkhorn	136,294	22.4	1.04	1.95
John Day	195,835	17.5	1.05	2.03
Burnt River	66,278	12.3	1.10	1.44
Wallowa	91,980	11.6	1.06	1.94
Crooked River	261,695	11.5	1.07	1.94
Naches Tietan	189,040	11.2	1.24	1.68
Burns	336,164	5.9	1.00	1.32
Wenatchee	138,670	5.1	1.05	2.05
Lakeview	164,632	4.2	1.01	1.28
Union	73,330	0.0	1.00	2.60
Pine	24,300	0.0	1.00	2.50
Entiat	55,610	0.0	1.00	1.14
Middle Fork	54,826	0.0	1.00	1.00
Chelan	35,100	0.0	1.00	1.00

the east side averaged only 2.8 thousand board feet per acre, whereas west-side timber sales averaged 30.7 thousand board feet per acre. At the same time, on the west side in 1961, there were 532 active sawmills and 124 active veneer and plywood plants. In contrast, on the east side there were very few veneer and plywood plants in operation and only 196 sawmills. With timber more widely scattered and fewer processors interested in buying timber, we should expect that in any given location there would be fewer potential bidders for Federal timber on the east side than would be expected on the west side. In fact, the number of bidders per sale averaged 2.39 on the east side and 4.19 on the west side. For this reason, east-side sales would be more frequently uncontested sales with timber more often being sold at the appraised price.

East-side Bureau of Land Management lands are not divided into master units. Because of this and because few sales are made on the east side, we will confine our BLM master unit analysis to the west side.

Nature of the Competitive Circumstance

For both regions, the working circles and master units may be classified as having minimal competition for several reasons. First, the situation in which the total annual log supply in a given area is approximately equal to or greater than the normal milling capacity of the region would presumably result in a high proportion of the timber sales being transacted at approximately the appraised price. One would expect to find some timber being sold at appraised price under one-bidder conditions. Where two or more bidders qualify to bid on a given sale, one would expect to find bidding limited to a few percentage points above appraised price. Second, minimal degrees of competition might also prevail in an area characterized by regular increases in timber offered for sale within the area, paired with a milling capacity situation lagging in its growth somewhat behind log supplies.

There is a third general situation which might lead to evidence of minimal competition. In this situation, there are relatively few buyers with normal milling capacity in excess of the total log supply available within the area. Unrestrained competition would normally lead to relatively high premiums over appraised price. The function of competition in a situation of this kind would be to ration the relatively scarce timber by means of the price system with the result that timber is allocated to the highest bidders who presumably are also the most efficient operators. By this process, the least efficient producers would be unable to obtain timber — or do so at prices which would not allow profitable operations — and eventually would be forced to withdraw from the market. In a situation in which there are few rather than many potential bidders for timber, it can be easier for the few to allocate the scarce raw material among themselves. A possible result is that bidding becomes restrained, that buyers "take turns" as successful bidders, that several or all producers within the area receive less timber than they would like to have, and finally, that some inefficient producers may be able to maintain operations.[16]

Relationship Between Observed Competition and Quantifiable Variables

The following analysis attempts to define the relationship between the degree of observed competition among working circles and among master units and other measurable variables which may offer an explanation of the varying degrees of observed competition. Our measure of the degree of observed competition will be the percent competitive. This measure is defined as the ratio of competitive sales to total sales where competitive sales are identified as those sales having a bid-appraisal ratio equal to or greater than 1.01.

[16] This sort of restrained competition might result in token-bid sales. For a further discussion of token-bid sales see pp. 155-157 in: Mead, Walter J. Competition and oligopsony in the Douglas-fir lumber industry. 276 pp. Berkeley: Univ. Calif. Press. 1966.

We start with the question: Why are certain working circles and master units observed to be highly competitive (to have relatively many sales where serious bidding is evident in a bid-appraisal ratio equal to or greater than 1.01), whereas others are found to be almost totally lacking in evidence of competition? Economic theory suggests several relationships which may explain the observed differences among these areas in percent competitive. We will use stepwise multiple regression analysis to test for these relationships in Forest Service and Bureau of Land Management timber sale areas.

Variables To Be Tested

The following variables will be used in an attempt to explain the observed differences in percent competitive among the specified areas.

1. The percent competitive should be a positive function of the number of bidders present in a given working circle or master unit. As an index of the number of bidders active in a given area, we may use the average number of bidders per sale. For the west side, the average number of bidders per working circle, excluding the Shelton Working Circle, varies from a low of 2.21 on the Coquille Working Circle (Siskiyou National Forest) to a high of 11.22 on the Darrington Working Circle (Mount Baker National Forest) (table 13). For the east side, the average number of bidders per sale varies from a low of 1.00 bidder per sale in the Middle Fork Working Circle (Malheur National Forest) and the Chelan Working Circle (Wenatchee National Forest) to a high of 4.48 bidders per sale on the Ellensburg Working Circle (Wenatchee National Forest) (table 14). The average number of bidders varies from a low of 1.97 bidders per sale on the South Umpqua Master Unit to a high of 2.79 bidders per sale on the Siuslaw Master Unit (table 23).

A linear relationship between number of bidders and percent competitive should not be expected. Sales having only one bidder are noncompetitive by definition. In working circles and master units where there are many one-bidder sales, the average percent competitive will be correspondingly low. A sharp increase in percent competitive will be registered as two-bidder sales are encountered, but no sharp increase should be expected for percent competitive as the average number of bidders increases beyond two bidders per sale. The logic of this situation suggests a curvilinear relationship. Accordingly, the arithmetic mean number of bidders will be transformed into a logarithmic value to be inserted into the linear multiple regression equation.

2. The percent competitive by working circles and master units should be a negative linear function of the proportion of timber purchased by large firms relative to small firms. The logic supporting this statement is that large firms are generally well-established firms within a given area and, in addition, are normally well financed relative to their smaller competitors. Well-established firms are there because they have survived the rigors of competition. The bidding situation within such an area would be relatively stable. Smaller firms are less likely to initiate a challenge of established firms' positions.

3. The percent competitive by working circles and master units should be a negative linear function of average sale volume. The logic of such a relationship is that small buyers are unable to finance large sales; hence, the number of small firms in competition for Federal timber declines as sale size increases. Stated in another way, large sales, by virtue of heavier capital requirements, represent a barrier to entry and therefore restrict bidder competition. Although the share purchased by big firms may adequately embrace the logical support offered here, we will include the possibility of a relationship between sale size and percent competitive beyond what may previously be accounted for by the second variable.

4. The percent competitive by working circles should be a negative linear function of the average road construction cost per sale. A high degree of interrelationship is to be expected between average volume per sale and average road construction cost. This high interrelationship (multicollinearity) results naturally from the fact that large sales may be made to facilitate road construction. We have no basis for hypothesizing about the dominant relationship between these alternative independent variables. They are offered as alternative hypotheses indicating thot either may prove to be significant. But it is highly unlikely that both will enter the equation.

Due to the lack of road construction data for Bureau of Land Management sales, this hypothesis will be tested only for Forest Service sales. Since o high degree of multicollinearity is expected between this variable and sole size, we should not lose a great deal in our explanation of percent competitive on Bureau of Land Management master units.

Additional variables can also be suggested where no practicol means of testing are availoble. For exomple, one might hypothesize that highly competitive working circles or master units occur where established firms are challenged by "outsiders" attempting to establish a buyers' position in a given area, thot percent competitive is positively correlated with the presence of feuding within given areas, or that changes in the level of allowable cut and changes in appraisal procedures have influenced competitiveness. Although these factors may assist in explaining the differing degrees of competition observed, there is no readily available means of testing their importance.

A word of caution is necessary at this point concerning the interpretation of multiple regression findings. Statistical analysis alone is not intended to establish the existence of causality or causal direction between several variables but, rather, it can only suggest relationships between variables. If causality is to be inferred, it must come as a result of deductive analysis as well as quantitative observations.

West-Side Working Circles

The four variables outlined above will be used as possible explanatory variables in a stepwise multiple regression analysis of the competitive differences between the 43 west-side working circles. Average values for each working circle represent sales toking place over the 4 years beginning with January 1959 and ending with December 1962. In all, 2,340 oral-auction west-side timber sales are represented, excluding those sales within the Shelton Working Circle.

In our stepwise regression analysis, we have regressed percent competitive (Y) on the logarithmic value of the average number of bidders (X_1) size of buyer (X_2), average sole size (X_3), and average road construction cost (X_4). X_3 and X_4 failed to enter the regression equation.[17] Our

[17] The finol regression equotion is:

$$Y = 47.65 + \underset{(14.12)}{52.26X_1} - \underset{(0.11)}{0.28X_2}$$

The volues shown in porentheses ore the standard errors of estimote for the regression coefficients.

regression equation has a coefficient of multiple regression $R = 0.59$, and a coefficient of determination $R_2 = 0.35$. Thus, by taking into consideration the logarithm of the average number of bidders and a measure of the importance of large firms in the west-side working circles, we are able to account for 35 percent of the total variation in the percent competitive among the working circles.

It has been the function of the stepwise multiple regression analysis to examine a complex competitive situation collectively. By this process we have found that the differences in competitive conditions among the working circles are in part a positive function of number of bidders and a negative function of the share of timber purchased by large firms relative to small firms. Average volume per sale and the average road construction cost are not important in explaining the variation in competitive conditions among working circles.

There is further evidence indicating a relationship between the importance of large firms in a geographical market and percent competitive. In interviews of persons involved in buying Federal timber, most small operators revealed a high degree of respect for the economic power of their large competitors and a feeling of futility concerning competition with large firms for timber sales. This "bidder futility" is based on four factors: (1) superior location of well-established large firms; (2) large firm ownership of private logging roads enabling "off highway" log transportation; (3) superior economic power of large firms because of private timber holdings, better financial position, and greater diversification resulting in more stable income; and (4) capital gains treatment of timber income.[18]

In addition, nothing has been said in the foregoing discussion about the possibility that large firms are more efficient than small firms. Mead[19] examined this possibility and concluded that medium and medium-large firms appeared to be the most efficient. The complexities in lumber manufacturing, however, make conclusive evidence on this subject difficult to obtain.

Size alone may not provide for more efficient operations. Through integrated operations including plywood processing and marketing, as well as pulp and paper production and marketing, the large firm may achieve real economies and thereby become more efficient. Pulp and paper, in particular, is an industry probably subject to impressive economies of scale. If so, then integrated operations may well make a significant contribution to large-firm efficiency. Our conclusion concerning the issue of efficiency is therefore mixed and preliminary. Additional study is needed to resolve this issue.

West-Side Master Units

Only the hypotheses concerned with number of bidders, size of successful bidder, and volume per sale are tested for sales made on Bureau of Land Management master units; data on cost of road construction are not available.

The analysis of percent competitive by master units is weakened because there are only 12 observations corresponding to the 12 west-side master units. However, the analysis covers the period beginning with January 1951 and ending with December 1962, and the volume sold exceeds 200 million board feet in all but one of the master units. In total, the analysis includes 3,010 oral-auction sales.

Employing the stepwise regression technique used in the working circle analysis, except for the elimination of average road construction cost as an independent variable, we find that only the log of the number of bidders enters the regression equation.[20]

The regression equation has a coefficient of multiple regression, $R = 0.87$, and a coefficient of determination, $R^2 = 0.75$. Therefore, we can explain 75 percent of the total variation in percent competitive among the master units by taking into account the average number of bidders per sale.

[18] For a further discussion of "bidder futility" see pp. 220-228 in: Mead, Walter J. Competition and oligopsony in the Douglas-fir lumber industry. 276 pp. Berkeley: Univ. Calif. Press. 1966.

[19] Pp. 11-31 in Mead (1966); see footnote 18.

[20] The regression equation is:

$$Y = -4.78 + \underset{(37.31)}{205.11} X_1$$

The size of buyer variable, which entered our equation on west-side working circles, did not prove important here. The geographic characteristics of master units as compared with working circles may partially explain the lack of firm size importance. There were only 12 master units covering the entire western Oregon area. Because of their large size they encompassed much more diversified areas of economic conditions than did the smaller working circles. This greater diversification is also demonstrated by the range in percent competitive between the two area classifications. For master units, percent competitive ranged from 88.6 to 54.8. The west-side working circle range was much wider, from 100 percent competitive down to 28.4 percent (excluding the Shelton Working Circle).

East-Side Working Circles

When applying the same techniques of regression analysis to explain competitive differences among east-side working circles, we are confronted with data limitations. First, the east-side working circles were highly variable in percent competitive.[21] Second, for the east side our number of observations was relatively low. There are only 26 working circles, 12 of which are very small. Only 14 working circles had 4-year total sales in excess of 100 million feet. In contrast, there were 43 west-side working circles and 37 of them had total sales in excess of 100 million feet. With so few reliable observations available on a working circle basis for the east side, our analysis is correspondingly weaker.

However, with these reservations in mind, we may proceed with the analysis, using the same four variables as on the west side. Again, the dependent variable is percent competitive and the four independents are the logarithmic value of the average number of bidders (X_1), percent purchased by large firms (X_2), average volume per sale (X_3), and average road construction cost per sale (X_4). In our stepwise regression analysis, two variables, X_1 and X_4, enter the regression equation.[22]

Our regression equation has a coefficient of multiple regression, $R = 0.81$, and a coefficient of multiple determination, $R^2 = 0.66$. Thus, by taking into consideration the logarithm of the average number of bidders and average road construction cost per sale in the east-side working circles, we are able to account for 66 percent of the total variation in the percent competitive.

Summary

The reader should bear in mind that the objective of regression analysis at this point has been to identify the factors which may "explain" the observed differences in degrees of competition among the west-side and east-side working circles and the west-side master units. At a later point, we will examine individual sales with a similar objective in mind — that of explaining observed differences in degrees of competition by sale. We have established that the dominant variable which accounts for differences in percent competitive among the working circles and master units is the differing degree of bidder activity in each area, where bidder activity is identified by the average number of bidders qualified to bid on the timber sales. The relationship is positive, indicating that, where bidders are many, we may confidently expect a relatively high percent of total sales to be sold under competitive conditions.

For the west-side working circles, we have established that firm size in working circles is also important in explaining the degree of observed competition. We found that the greater the share of total volume acquired by large firms in given working circles, the lesser will be the percent sold competitively and the greater will be the percent sold noncompetitively.

For east-side working circles, we have found that, in addition to bidder numbers, the average cost of road construction is useful in explaining the degree of competition for timber sales. We found that, as road construction costs increase, the percent of total sale volume sold competitively decreases.

[21] The standard deviation of percent competitive among east-side working circles is 30.85 percentage points. This may be compared with 18.40 percentage points for west-side working circles and 11.60 percentage points for west-side master units.

[22] The regression equation is:

$$Y = 15.26 + \underset{(25.29)}{114.52X_1} - \underset{(0.00017)}{0.00035X_4}$$

DIFFERENCES IN COMPETITION BETWEEN INDIVIDUAL SALES

In the preceding section where analysis was based upon working circle and master unit data, aggregate variables were used in the form of percent competitive for sales and percent purchased by large firms. When the analysis is based upon individual sale data, obviously these aggregate variables are no longer available. A given sale is either single-bidder, token-bid, or competitive, and it is either purchased by a large firm or a firm not classified among the large operators. The dependent variable for our analysis based upon individual sale data will be the bid-appraisal ratio rather than the percent competitive. The appraised price is the base to this ratio. We have assumed that appraisal procedures are uniform for each agency within a region and that there was no major error in appraisal. Thus, the appraised price represents a common standard of value for stumpage. The ratio of bid price to appraised price thereby becomes a measure of the degree of competition for a given timber sale as well as a measure of the percent premium paid.

Our attempt to account mathematically for the observed variability in bid-appraisal ratios is limited by the variables that can be quantified from the historical record. We have selected the following nine factors that may be treated as independent variables and occupy a hypothetical relationship to the dependent variable, the bid-appraisal ratio:

1. Number of bidders that qualify to bid on any given timber sale.
2. Size class — large or small — of the successful bidder on each timber sale, where large firms are defined as the 20 largest lumber producers, the 20 largest plywood producers, and the eight largest timberland owners for west-side sales, and the eight largest lumber producers for east-side sales, as of the year 1960.
3. Road construction cost for each sale.
4. Total volume per sale.
5. Weighted average appraised price per thousand board feet.
6. Housing starts on a monthly, seasonally adjusted basis.
7. Douglas-fir lumber price index for west-side sales and ponderosa pine lumber price index for east-side sales.
8. Sale type — oral auction or sealed bid.
9. Time, identified by the month and year in which the sale was made.

In the following section the hypothetical relation of these variables to the bid-appraisal ratio will be explained.

Variables To Be Tested

1. There should be a positive relationship between the bid-appraisal ratio and the number of qualified bidders per sale. We know that, where only one bidder is qualified on a given sale, the bid-appraisal ratio will usually be 1.00. The occasional premium bid reflects a mistake in judgement by a single qualified bidder. In a Forest Service (but not Bureau of Land Management) oral-auction sale, a sealed bid must be submitted as part of the process of becoming a qualified bidder. Occasionally, a potential bidder will submit a qualified bid significantly in excess of the appraised price to demonstrate his determination to acquire the sale. If no other bidders become qualified, the sale is consummated at the sealed-bid price. When the number of qualified bidders are few but more than one, bid-appraisal ratio tends to increase sharply and, when bidders are many, the ratio continues to increase but at a decreasing rate. Thus, a logarithmic function will be used to represent the relationship between number of bidders and bid-appraisal ratio.

2. We would expect a negative relationship between the percent premium paid for Federal timber and the economic size class of the buyer. In the analysis based upon west-side working circle data, we found that, where large firms occupied an important position as timber buyers, the percent of total volume sold competitively tended to be low, This expected relationship is based upon the proposition that large firms possess relatively great market power, and that all other firms in their bidding practices show respect for the market power of larger firms. We will now examine the relationship between the premium on individual timber sales and the size class of the buyer.

3. A heavy road construction requirement would lead to fewer bidders in that the capital requirement and the risk attached to road construction would serve as barriers to entry. The greater the road construction requirement, the greater will be the financial burden on a bidder and the greater will be the risk arising out of an unknown error in the road construction appraisal. Small firms are not able to assume either burden, and hence one would expect fewer small-firm bidders on sales with high road construction requirements. If fewer bidders are qualified for high-cost sales, then we would find evidence of multicollinearity between road cost and number of bidders.

4. The bid-appraisal ratio should be negatively correlated with the size of a sale. Since the supporting argument is identical to that for the third variable, the fourth variable will be considered alternative to the third; i.e., if either the third or fourth variable is acceptable in either region, then the other variable is automatically rejected by the regression program. We expect to find a high degree of multicollinearity between road cost and average sale size.

5. The bid-appraisal ratio should be negatively associated with the weighted average appraised price per thousand board feet by sale. This variable is based upon the mathematical character of the bid-appraisal ratio itself. Since our dependent variable is a ratio, a constant absolute premium over appraised price will produce a relatively high ratio any time the denominator (appraised price) is relatively low. Where timber is of low value, due to a high road construction requirement or an unusually long log haul, or is underappraised and therefore has a relatively low denominator in the ratio, very high bid-appraisal ratios may result. A bid-appraisal ratio of 3.00 or greater is relatively common for timber appraised at between $2 and $5 per thousand board feet. This result seldom occurs for timber appraised in excess of $20 per thousand board feet. Because the appraised price offers an absolute floor for the bid value, we would expect the bid-appraisal ratio to decline rather sharply for initial increases in appraised price and to decline at a lower rate as higher appraised values are approached. Therefore, a curvilinear relationship should be expected. As in the instance of the number of bidders, we will again use a logarithmic transformation of the appraised price per thousand board feet.

6. The bid-appraisal ratio should be positively correlated with the level of housing starts. This relationship depends upon cyclical behavior. Unlike number of bidders, economic size class, road construction requirement, and sale size, housing starts are not likely to be affected by local Federal timber sale policy. If the variable enters the regression equation, it will simply contribute to the total explanation of observed differences in bid-appraisal ratio among individual timber sales.

7. The bid-appraisal ratio on individual sales should be positively correlated with variations in lumber prices. The relationship is similar to that advanced for housing starts. It rests on cyclical behavior. Multicollinearity would appear to be present between housing starts and lumber prices; hence, if one variable enters the equation, the other most likely will not. However, lumber prices may have an important degree of relationship independent of housing starts. The timing of lumber price variation is correlated with housing starts but is not identical to housing starts' behavior.

8. We would expect higher bid-appraisal ratios with sealed-bid sales and lower bid-appraisal ratios with oral-auction sales. The logical basis for this relationship is that sealed-bid sales inject a note of uncertainty into the bidding process. When a sealed bid is made, a bidder does not know who his competitors are, if any, and does not know how high a bid is necessary to obtain the sale. In contrast, many oral-auction sales are transacted at appraised price because the successful bidder knows he is the only bidder. In other oral-auction cases where two or more bidders are qualified and identified, only token bidding may take place. If all other sale characteristics are

constant, we would therefore expect that the uncertainty implicit in sealed-bid sales would result in higher premiums over appraised prices. However, we know that other factors are not constant. For example, sealed-bid sales tend to be substantially smaller than oral-auction sales. Also, small firms tend to buy a higher percent of sealed-bid sales than do the large firms. For purposes of this analysis, however, we will ignore these complications. In the hypotheses test concerned with sale type, oral-auction sales will be assigned the number 1; and sealed-bid sales, the number 2.

9. Finally, the bid-appraisal ratio may be correlated with the passage of time. If there is a persistent linear trend in bid-appraisal ratio, it will be identified by this variable.

We will now examine the effect of these variables on the bid-appraisal ratio, using the information we have developed for individual Forest Service and Bureau of Land Management timber sales.

West Side

FOREST SERVICE SALES.—Complete data for testing all nine hypotheses on Forest Service sales are available for the period 1959-62. Data on number of bidders per sale, road construction cost per sale, and sale type were not available before 1959.

Using stepwise multiple regression analysis on the relation between west-side bid-appraisal ratios and the nine independent variables, we find that the log of the number of bidders (X_1), size of purchaser (X_2), sale size (X_4), and the log of the appraised price per thousand board feet (X_5), enter the regression equation as explanatory variables.[23]

The coefficient of multiple correlation for our resulting equation is $R = 0.60$. The coefficient of determination is $R^2 = 0.36$. Thus, 36 percent of the total variation in bid-appraisal ratios is accounted for by the four variables.

Even with the four variables included in our multiple regression equation, we find that the coefficient of determination is relatively low. This means that there were causal factors at work on the bid-appraisal ratio other than those which have been quantified and included in the equation. Several important nonquantifiable variables can be suggested; for example, one important determinant in the vigor of bidding in a given sale is the personality of each individual bidder and the human relationships existing between bidders. Thus, with an equal desire for given timber, a single bidder may bid vigorously on a given sale when opposed by A, who is regarded as an "outsider," but refrain from bidding entirely when opposed by B, who may be a neighbor and friend. Further, the degree of need for logs at a given point in time is also a determinant of the vigor of bidding. Perhaps the psychological attitude at the moment occasionally influences premium bidding over appraised price. One's personal assessment of future events, such as, for example, the probability of getting a future timber sale, may influence bidding at any given sale. Finally, the existence of "deals" among bidders will influence the vigor of bidding. Thus, we have not and cannot include all of the variables that determine the bidding outcome of a given sale. Our primary concern is not with fully accounting for all variability; rather, we are concerned with determining whether or not certain variables are related to the observed variation in bid-appraisal ratios. In particular, because this is a study of competition for Federal timber, we are vitally interested in the relationship of economic size of the successful bidder, X_2, the importance of the number of qualified bidders, X_1, and the importance of potential barriers to entry, such as the sale size, X_4, and the road construction costs, X_3.

Summarizing the foregoing analysis, we found that four variables are accepted for our explanation of competitive variability: the logarithm of the number of bidders, size class of buyer, sale size, and the logarithm of the appraised price per thousand board feet. The remaining five variables involving road construction cost, monthly housing starts, a lumber price index, sale type, and a time trend did not enter the equation.

[23] The regression equation is:

$$Y = 2.19 + \underset{(0.0306)}{0.8881X_1} - \underset{(0.028)}{0.083X_2} - \underset{(0.000002)}{0.00001X_4} - \underset{(0.0402)}{0.9569X_5}$$

BUREAU OF LAND MANAGEMENT SALES.—Data are available for testing eight of the nine hypotheses for Bureau of Land Management sales over the entire 1951-62 timespan. Road construction cost information is not available. Since BLM sales are made in the same areas as Forest Service sales and are bid on and purchased by the same buyers, they should provide additional information on which to base conclusions.

The independent variables tested here are number of bidders expressed in logarithmic form (X_1), size class of successful bidder (X_2), sale size (X_3), appraised price per thousand board feet expressed in logarithmic form (X_4), housing starts (X_5), the price index of Douglas-fir lumber (X_6), sale type (X_7), and time (X_8).

Again using stepwise regression techniques on the relation between bid-appraisal ratios and the eight independent variables, we find that number of bidders (X_1), appraised price per thousand board feet (X_4), housing starts (X_5), the price index of Douglas-fir lumber (X_6), and sale type (X_7), enter the equation.[24]

The coefficient of multiple correlation is $R = 0.67$, and the coefficient of determination, $R^2 = 0.45$. This means that we can account for 45 percent of the variation in the bid-appraisal ratio between sales with the five independent variables shown in the equation.

Two variables that entered the equation in the west-side Forest Service analysis but did not enter here are sale size and size class of successful bidder. We would expect sale size to be less important here since Bureau of Land Management sales were uniformly small relative to the large spread in Forest Service sale size.

The failure of firm size to enter the Bureau of Land Management regression equation may be due to the definition of the "big firm" category. This definition is based on 1959 production data for lumber and plywood firms and 1959 timber ownership. The Bureau of Land Management analysis extended back to 1951. About half of the 20 big lumber firms operating in the early 1950's had disappeared due to merger or closing by 1959 and therefore were not included in our definition of "big firms."[25] Conversely, about half of the firms in our definition were not large or were not in the timber market in the early 1950's.

East Side

As we shift to the pine region to continue the analysis, it should be made clear that the east side is economically different from the west side. Although the east side involves a considerably larger geographical area, the annual volume of National Forest timber sold is only about one-third that of the west side and the annual volume of Bureau of Land Management sales is less than 5 percent of the west-side volume. Bidder activity on the east side is much less intense. The average number of bidders for Forest Service sales during the 1959-62 period was 2.38 bidders per sale on the east side compared with 4.19 on the the west side. Bureau of Land Management sales averaged 1.63 bidders on the east side and 2.43 on the west side during the 1951-62 period. Other evidence also indicates a lower degree of competition on the east side. The average premium over appraised price for all Forest Service east-side sales was only 26 percent compared with 40 percent on the west side. Bid prices for Bureau of Land Management sales averaged 16 percent more than appraisals on the east side and 33 percent more for west-side sales. Finally, east-side timber was of lower value. The average appraised price of all National Forest timber sold over the period studied was $12.25 per thousand board feet on the east side, compared with $20.11 on the west side. Bureau of Land Management east-side timber had an average appraised price of $17.15 per thousand board feet, whereas west-side timber averaged $21.41 per thousand board feet.

FOREST SERVICE SALES.—The logical relationships among the quantifiable variables are the same as previously stated for the west side. Therefore, the same nine hypotheses outlined for west-side Forest Service sales will be tested for east-side sales. Information in exactly the same form concerning the nine independent variables is available

[24] The regression equation is:

$$Y = 1.174 + \underset{(0.024)}{1.071X_1} - \underset{(0.039)}{0.852X_4} + \underset{(0.00004)}{0.00017X_5} + \underset{(0.0009)}{0.0069X_6} - \underset{(0.0195)}{0.0895X_7}$$

[25] See p. 50 in: Mead, Walter J. Mergers and economic concentration in the Douglas-fir lumber industry. U. S. D. A. Forest Serv. Res. Pap. PNW-9, 81 pp., illus. 1964.

for the east side. The lumber price index will be based on No. 3 ponderosa pine boards rather than Douglas-fir. Four variables entered the multiple regression equation: the log of the number of bidders (X_1), road cost (X_3), the log of the appraised price per thousand board feet (X_5), and the wholesale lumber price index (X_7).[26]

The coefficient of multiple correlation for the above equation is $R = 0.50$; the coefficient of multiple determination, $R^2 = 0.25$. Thus, only 25 percent of the total variability in the dependent variable is accounted for by the four independent variables.

The fact that a lumber price index entered the equation here but not on west-side Forest Service sales may be due to the greater homogeneity of buyers on the east side and their more direct contact with the lumber market. East-side bidders were, almost exclusively, lumber mill operators. In contrast, west-side buyers were a more heterogeneous group consisting of lumber mill operators, veneer mill operators, veneer-plywood operators, log exporters, loggers, and even a few pulpmill operators. For this group, lumber price would not always be the most relevant market indicator.

The most significant omission is economic size of the successful bidder. The rejection of this variable may be a result of a significant degree of multicollinearity between number of bidders, average road cost, and the economic size of the successful bidder. As a result, some of the relationship between economic size class of bidder and bid-appraisal ratio is accounted for by other variables that are present in the regression equation.

BUREAU OF LAND MANAGEMENT SALES.—The same eight hypotheses tested for Bureau of Land Management west-side sales will be examined here; data on road construction costs are not available. Sufficient information is available to examine all eight hypotheses over the entire 1951-62 period. The multiple regression equation for these sales includes the log of the number of bidders (X_1), size class of successful bidder (X_2), and the log of the appraised price (X_4).[27]

The coefficient of multiple correlation is $R = 0.72$, and the coefficient of determination, $R^2 = 0.52$, which means 52 percent of the total variability in the bid-appraisal ratio is accounted for by the three independent variables.

Two of these variables also entered the east-side Forest Service analysis. The most notable variable which did not appear in the equation is the lumber price index. We had expected this variable to be even more important on the east side than on the west side, since east-side buyers make up a more homogeneous group, characterized by lumber production.

Summary

It is important to distinguish between the present section, where we are concerned with the <u>individual sale</u> data, and the preceding section based upon <u>working circle</u> and <u>master unit</u> data. In the section where the analysis was based upon working circle and master unit data, we were testing hypotheses concerned with differences in the degree of competition between the working circles and master units. Our measure of degree of competition was the percent of total volume sold competitively.

In the present section, we are no longer analyzing data on an area basis but rather have based the analysis upon individual sales. For Forest Service sales on the west side, rather than operating with 43 working circles, we based the analysis upon the record of 2,588 individual timber sales. And for the east side, rather than working with 26 working circles, we based the analysis upon 1,275 individual sales. For Bureau of Land Management sales on the west side, the analysis has been based on 3,372 individual sales rather than 12 master units. In addition, we have

[26] The regression equation is:

$$Y = 0.88 + \underset{(0.6706)}{1.0159X_1} - \underset{(0.0000002)}{0.0000007X_3} - \underset{(0.066)}{0.574X_5} + \underset{(0.0025)}{0.0059X_7}$$

[27] The regression equation is:

$$Y = 1.33 + \underset{(0.083)}{1.012X_1} - \underset{(0.042)}{0.089X_3} - \underset{(0.063)}{0.267X_4}$$

examined 162 individual sales on the east side where no analysis of master units could be made. On an individual sale basis, we have examined nine variables — eight for Bureau of Land Management sales — to explain the high variability in bid-appraisal ratio among the many individual sales, and we found important relationships for each region.

For both agencies, Forest Service and Bureau of Land Management, and for both the west side and the east side, we have established clear relationships between the logarithmic value of the number of bidders and the logarithmic value of the weighted average appraised price per thousand board feet and the dependent variable, the bid-appraisal ratio.

The other variables representing the market's structure — size class of successful bidder, sale size, and road construction cost — were not as uniformly important. Buyer size class was useful in explaining the bid-appraisal ratio for both west- and east-side Forest Service sales, but was important in explaining bid-appraisal ratio variability only for east-side Bureau of Land Management sales.

Sale size entered the regression equation for west-side Forest Service sales, whereas the relation between road construction cost and the bid-appraisal ratio proved important for Forest Service sales on the east side. It was of little importance which of these two variables entered the equation, since their logical relationship to the bid-appraisal ratio was the same and the two independent variables were closely related.

We also found some relationships between the bid-appraisal ratio and variables not associated with the market's structure. The Douglas-fir price index and the level of housing starts were important in explaining variations in the bid-appraisal ratio on the west-side Bureau of Land Management sales. On the east side, the price index of ponderosa pine No. 3 boards was an important variable when Forest Service sales were examined, but was not for Bureau of Land Management sales.

Of the remaining two independent variables tested, sale type and a time trend, only sale type appeared and then only once during the entire analysis. We had hypothesized that sealed-bid sales, which inject an additional degree of uncertainty into a sale, would command a higher premium over the appraised price. However, in the one analysis where sale type entered the equation (west-side Bureau of Land Management sales), the opposite result was found; sales sold under sealed bids brought a smaller percent premium over the appraisal.

Our analysis here contained two possible shortcomings. First, we examined all sales without regard to whether they were made in areas of strong competition or in areas where competition was weak. In areas where competition is strong, we should not expect to find a difference in bid-appraisal ratios as they relate to sale type. In fact, oral-auction sales may well have a higher ratio since sealed bids do not contain the emotional aspect of oral auctions. Where competition is weak, the uncertainty injected by sealed bidding should result in higher premiums over appraised prices than would be expected with oral-auction sales.

Second, the effect of sale type is highly related to the number of bidders. All oral-auction sales with only one bidder would be expected to sell at the appraised price. When sealed bids are used, a potential buyer does not know who his competitors are, and his bid should reflect this uncertainty. The number-of-bidders variable should, therefore, account for some of the variation resulting from sale type.

By taking account of these factors in an analysis of selected Forest Service working circles, Mead found a significantly higher ratio of bid price to appraised price for sealed-bid sales.[28]

[28] Mead, Walter J. National resource disposal policy — oral auction versus sealed bids. Natur. Resources J. 7(2): 194-224, illus. 1967.

CONCLUSIONS AND RECOMMENDATIONS

We have found that, where there is competition for Federal timber, bid prices rise substantially above appraised prices. About 70 percent of the volume sold by the Forest Service in the Douglas-fir subregion was classed as competitive and the bid price on these sales exceeded the appraised price by 63 percent. Competitive sales made by the Bureau of Land Management on the west side also accounted for about 70 percent of the total volume; the bid price on these sales exceeded appraisals by 47 percent. On the east side, competitive sales made up 34 percent of total volume and competitive prices exceeded appraised price by 60 percent for Forest Service sales. Bureau of Land Management east-side competitive sales accounted for 40 percent of total sale volume and had bid prices that exceeded appraisals by 37 percent.

In specified areas where Federal timber sales are made — 43 west-side working circles, 26 east-side working circles, and 12 west-side master units — we found that the percent of total sale volume sold under competitive conditions varied directly with the average number of bidders per sale. In addition, in one analysis (west-side working circles), the size class of the successful bidder was found to be important in explaining the degree of sale competitiveness, and in another (east-side working circles), road construction costs proved to be important as a barrier to competitive bidding.

When examining individual sales, we found that certain specified structural variables were important in determining the extent to which bid prices exceeded appraisals. In every case, the number of bidders qualified to bid on each sale proved to be the most important variable in explaining the ratio between bid and appraised prices. The size class of the successful bidder was also important in explaining bid-appraisal ratios. We concluded that large firms are generally able to obtain Federal timber at a smaller premium over appraised price than that paid by small firms.

Two potential barriers to entry were examined for their effect on bid prices: Sale size, and the amount of road construction required on a given sale. Sale size and road construction requirements — whichever appeared in the Forest Service sale analysis — had a negative effect on the bid-appraisal ratio; as sale size became larger and as road costs became higher, we could expect the ratio to decline.

The type of sale — sealed-bid or oral-auction — was important in explaining the size of the bid-appraisal ratio in only one of the analyses, west-side Bureau of Land Management sales. However, the appearance of this variable did not lend support to our hypothesis. The analysis showed that we could expect a lower premium over appraised price when sealed-bid rather than oral-auction sales are made, just the reverse of what we had hypothesized.

Two variables not related to the competitive structure of the Federal timber market were also examined, lumber price indexes and current level of housing starts. Lumber prices appeared more frequently than did housing starts in the final equations, but both variables showed some positive influence on the bid-appraisal ratio.

We can conclude from this study that important differences occur in the degree of competition (measured by bid price premium over the appraised price) between individual Federal timber sales and between specified areas where Federal timber sales are made. Part of these price differences can be explained by the structure of the timber-buying industry and the characteristics of the sales. The differences raise questions as to what constitutes a "reasonable price" for Federal timber buyers and for the public as owners of Federal timber resources.

There has been a long and continuing debate and disagreement concerning the question of a reasonable price for Federal timber. A discussion of a reasonable price must begin by clarifying the fact that there are several economic interests involved in this issue, each holding different concepts of a reasonable price. Five separately identifiable economic groups may be listed:

1. Timber buyers and manufacturers of wood products. The lumber mill or veneer mill operator is interested in the lowest possible price for the Federal timber which he buys. His economic incentive is profit. The prices of his final products are determined in competitive markets over which he has no control. Variables over which he has some control include product mix and the costs of logging and manufacturing. His principal raw material cost is stumpage or log cost. It follows that the lower the cost of log input, the greater will be his profit or the lesser will be his loss. Those operators who are in highly competitive areas would be delighted to obtain Federal timber at the present appraised prices. At the other end of the competitive spectrum, those who obtain their timber with minimal or no competition write extensive reports addressed to the Federal agencies setting forth their case for lower appraised values. In either case, the timber buyer-processor has a strong economic interest arising out of the profit motive to lower the cost of public timber, and those who expect to obtain some of their timber at appraised price generally argue that present appraisals are too high.

2. Taxpayers and citizens who indirectly own the Federal timber. The taxpayer has not voiced his position to the same degree that the timber buyer has. Income from the sale of Federal timber is income in lieu of taxes. The greater the Federal revenue from the sales of timber, the lesser the need for taxes; and the lesser the revenue from timber sales, the greater the need for taxes. Taxpayer interest is broader than a Federal Government interest. County governments in which Federal timber is located receive a portion of the proceeds from timber sales. On these sales, after certain expenses, counties receive 25 percent of the sale proceeds from Forest Service sales and 50 percent from Bureau of Land Management sales.[29]

3. Local business and labor interests. Within individual communities, local businessmen and labor have an interest in maintaining local industry. Sales and profits for local businessmen and jobs for labor are involved. A firm that is unable to compete profitably in the resource input and product output markets frequently takes its case to local business and labor organizations with the argument that lower appraised prices on Federal timber are needed to save jobs and markets. Within the last decade, a large number of old sawmills have been closed, sometimes bringing community hardships as a result. The argument can, therefore, be illustrated with a multitude of cases, and we frequently find community interests lined up with buyer interests in favor of lower appraised prices. The point should be made clear that lower appraised prices would benefit only those operators who obtain a significant volume of timber at appraised price. It would be of no benefit to producers in highly competitive areas who are currently paying premiums over the appraisal and in fact may place them at a further competitive disadvantage relative to producers in noncompetitive areas.

4. The General Accounting Office and the Bureau of the Budget of the Federal Government. The responsibility of these agencies is to insure that "fair value" is received in exchange for assets sold from public ownership. In practice, their emphasis has been to question whether a sufficiently high price has been received for public timber. As representatives of the broad rather than regional or community interest, they are lined up with the taxpayer interest on behalf of higher appraised values.

5. Agencies in charge of timber sales. These agencies are under legal obligation to appraise timber at its "fair market value," which is synonymous with the "market value" realized under competitive conditions. The agencies have been petitioned and questioned by both sides. The result has been the development of an extremely elaborate system of appraisal. The system starts with competitive markets in final products and subtracts all costs of processing where costs are estimated in detailed studies to arrive at an estimate of stumpage value with an allowance for processor profit.

[29] Counties are legally entitled to receive 75 percent of sale proceeds from Bureau of Land Management O&C sales, but they voluntarily contribute one-third (25 percent of the total) for development of O&C lands. Receipts from Bureau of Land Management sales on the public domain are split between the Bureau of Reclamation, which receives 95 percent, and the State where the timber is located, which receives the remaining 5 percent.

Economists have a view of what constitutes a "reasonable" price for timber resources or any other economic goods. The reasonable price is that price which is determined by buyers and sellers operating in competitive markets. The principal requirement for a competitive market is that there be a sufficient number of buyers and sellers in the market so that no single economic unit exerts a perceptible influence on the prices of the things it buys and sells. Two further conditions are that there are no monopolistic or institutional restraints and that all participants in the market are well informed.[30] To the extent that collusive agreements or monopolistic behavior on the part of buyers and sellers interferes with the market process, market prices will depart from competitive prices.

The results of this analysis suggest certain areas where modification of existing procedures may reduce stumpage price differences that arise because of differences in sale or market characteristics:

1. It may be possible to reduce an observed barrier to entry into the market for Federal timber by constructing all main-line logging roads into each given sale area prior to its sale. This would require that the timber-selling agencies contract to have roads constructed instead of requiring that the successful bidder construct specified roads. If the main-line logging roads were constructed prior to sale, the capital requirements would be lower, and additional firms would become eligible bidders. As a further benefit, eliminating the road construction requirement as a condition of sale would reduce an element of uncertainty associated with purchasing Federal timber. At present, the required road system is specified in the sale contract, and the construction cost is estimated but is not guaranteed. Bureau of Land Management sales require construction of the roads. Forest Service sales do not require the operator to build the roads, but it is generally necessary for removal of the timber. In both cases, all roads that are built must meet the specifications set down by the selling agency. Occasionally, the actual construction cost differs widely from the estimated cost. This factor increases uncertainty and acts as a further barrier to entry for small firms.

[30] For a more thorough discussion of the nature of competition, see pp. 87-89 in: Stigler, George J. The theory of price. Ed. 3, 335 pp., illus. New York: The MacMillan Co. 1966.

2. It may also be possible to reduce barriers to entry by avoiding the current practice of offering some very large sales. For Forest Service sales in the 1959-62 period, 31 percent of all volume sold on the west side and 53 percent of all east-side volume were transacted in sales of 15 million feet or larger. Our analysis showed some evidence that large Forest Service sales tended to be the least competitive.

Sale size was not significant in explaining variations in the bid-appraisal ratio for Bureau of Land Management sales. From 1951-62, only four west-side sales had volumes exceeding 15 million board feet and no east-side sales exceeded this volume.

Two justifications for large sales have commonly been offered. First, large sales have often been necessary to amortize heavy road construction costs. If the roads were constructed prior to a given sale, this justification for large sales would no longer hold. Second, large sales have been requested by the industry to assure a continued log supply which,in turn, would allow heavy capital investments for plant expansion and modernization. Specifically what is desired are long-term sales to permit the accumulation of a large reserve of timber under contract. Present sales policy allows firms to build some reserves of timber under contract. As of January 1, 1967, timber under contract from previous sales totaled slightly less than twice the allowable cut for Region 6. Smaller sales would generally mean shorter term sales and thus any benefits of long-term sales in the form of improved efficiency and better raw material utilization would be lost. Yet it appears that smaller sales during the period we have examined would have increased competition.

3. The sale type variable might receive further examination. Sale type — sealed bid or oral auction — did not prove significant in helping explain variations in the bid-appraisal ratio with the exception of the west-side BLM analysis. We had reasoned that the uncertainty associated with sealed bids should result in a higher ratio of bid price to appraised price; in the BLM analysis we obtained the opposite result.

As indicated earlier, when the analysis is limited to areas where competition is weak, and when the effect of number of bidders is eliminated, additional analysis of sale type has shown that sealed bidding produces a significantly higher premium over the appraised price.

4. In view of the large differences observed between competitive and noncompetitive sales throughout Washington and Oregon, the appraisal policy should be reexamined in light of its objective of approximating a "fair market value." We have seen that, for Forest Service sales where competition determined the price, the weighted average high bid exceeded the appraised value by 63 percent on the west side and 60 percent on the east side. Also, an analysis of the 1964-66 record shows that these discrepancies between bid and appraised prices have increased to 100 percent and 63 percent, respectively. For Bureau of Land Management sales the weighted average high bid exceeded the appraisal on competitive sales by 47 percent on the west side and 37 percent on the east side. In the 1964-66 period the difference increased to 75 percent on the west side and declined to 19 percent on the east side where only a small number of sales are made. It appears from this evidence that appraisals may be falling short of the fair market value goal. Where competition is weak and timber is consequently sold at the appraised price, the public owners may not be receiving a fair market value for timber. A reexamination of the appraisal methods and procedures may be necessary to narrow the discrepancy between the selling agency valuation and the market valuation of publicly owned timber.

APPENDIX A

Tables

of

National Forest Sales Data

Table 13.—Sale data by Forest Service working circle, total west side, 1959-62

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
One-bidder sales:									
Soleduck	3	1.00	540	0.2	180	33.69	1.00	33.3	200
Quilcene	6	1.00	11,730	5.4	1,955	12.31	1.00	83.3	27,667
Quinault	17	1.00	89,459	27.5	5,262	6.25	1.00	64.7	75,407
Shelton	7	1.00	173,260	91.5	24,751	19.91	1.00	100.0	237,942
Glacier	4	1.00	14,340	13.5	3,585	15.14	1.00	75.0	39,413
Skagit	3	1.00	24,040	24.3	8,013	2 53	1.00	--	--
Baker River	1	1.00	92	0.1	92	34.83	1.00	--	--
South Fork Stillaguamish	2	1.00	11,750	8.5	5,875	3.81	1.00	100.0	77,698
Skykomish	3	1.00	21,750	16.6	7,250	5.93	1.00	33.3	337,760
Snoqualmie	1	1.00	9,900	21.3	9,900	17.48	1.00	100.0	77,180
Green River	1	1.00	1,080	4.0	1,080	15 30	1.00	100.0	4,420
White River	2	1.00	3,755	3.2	1,878	6.69	1.00	50.0	12,035
Mineral	8	1.00	90,600	66.5	11,325	14.43	1.00	100.0	84,212
Packwood	13	1.00	54,925	20.5	4,225	15.08	1.00	84.6	49,722
Randle	4	1.00	1,670	0.4	418	16.07	1.00	50.0	100
Spirit Lake	5	1.00	41,625	33.7	8,325	12.44	1.00	60.0	169,647
Lewis River	1	1.00	900	0.2	900	23.84	1.00	--	--
Mt. Adams	23	1.00	153,840	39.6	6,689	13.27	1.00	87.0	54,788
Wind River	11	1.00	4,385	1 9	399	24.62	1.00	45.5	1,855
Canyon Creek	4	1.00	5,500	4.6	1,375	15.77	1.00	50.0	21,306
Hood River	1	1.00	100	0.1	100	21.26	1.00	--	--
Clackamas-Sandy	11	1.00	17,110	1.7	1,555	8.65	1.00	45.5	13,845
Hebo	10	1.00	19,569	7.4	1,957	13.80	1.00	70.0	10,260
Waldport	14	1.00	18,435	4.3	1,317	19.23	1.00	57.1	12,984
Mapleton	42	1.00	83,362	16.6	1,985	24.56	1.00	45.2	37,941
North Santiam	9	1.00	15,040	5.0	1,671	18.98	1.00	77.8	12,328
South Santiam	38	1.00	75,999	20.7	2,000	20.40	1.00	52.6	23,402
McKenzie	27	1.00	18,910	3.8	700	24.62	1.00	48.1	8,028
Lowell	10	1.00	18,670	4.8	1,867	19.07	1.00	60.0	27,130
Oakridge	36	1.00	111,896	13.6	3,108	14.43	1.00	66.7	52,372
Cottage Grove	11	1.00	64,600	31.4	5,873	25.63	1.00	90.9	40,535
North Umpqua	20	1.00	29,336	3.6	1,467	25.82	1.00	55.0	12,985
South Umpqua	18	1.00	10,694	2.7	594	19.74	1.00	35 3	11,989
Coquille	13	1.00	38,220	35.5	2,940	20.95	1.00	61.5	66,994
Rogue River (Siskiyou NF)	9	1.00	20,097	7.0	2,233	13.87	1.00	55.6	53,130
Chetco	9	1.00	26,940	20.6	2,993	18.25	1.00	100.0	50,542
Josephine	11	1.00	14,617	6.4	1,329	12.52	1.00	45.5	37,846
Applegate	2	1.00	10,980	12.9	5,490	6.39	1.00	100.0	62,698
Ashland	6	1.00	13,010	16.2	2,168	15.24	1.00	33.3	72,364
Rogue River (Rogue River NF)	3	1.00	22,490	8.4	7,497	14.21	1.00	66.7	87,166
All working circles — west side	419	1.00	1,345,216	11.6	3,219	16.24	1.00	60.5	46,524
All working circles except Shelton	412	1.00	1,171,956	10.3	2,852	15.69	1.00	59.9	41,077

Table 13.—Sale data by Forest Service working circle, total west side, 1959-62 (Continued)

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
Token-bid sales:									
Soleduck	4	2.25	38,600	17.5	9,650	18.95	1.00	100.0	93,460
Quilcene	4	3.25	26,050	12.0	6,513	12.91	1.00	100.0	66,247
Quinault	9	2.56	89,728	27.6	9,970	6.75	1.00	88.9	114,003
Shelton	1	2.00	16,000	8.5	16,000	20.43	1.00	100.0	122,560
Glacier	2	2.00	615	0.6	308	22.55	1.00	100.0	3,477
Skagit	2	2.00	1,600	1.6	800	8.45	1.00	100.0	7,018
Baker River	3	5.33	6,020	4.6	2,007	5.88	1.00	100.0	18,574
Suiattle	2	4.00	850	1.1	425	13.09	1.00	50.0	5,610
Darrington	9	7.44	64,438	26.8	7,160	6.49	1.00	88.9	74,452
South Fork Stillaguamish	5	4.80	26,700	19.3	5,340	5.67	1.00	100.0	60,355
Skykomish	7	3.14	53,630	41.0	7,661	14.28	1.00	42.9	93,150
White River	4	2.75	4,755	4.1	1,189	11.09	1.00	75.0	10,219
Mineral	1	2.00	7,000	5.1	7,000	14.53	1.00	100.0	9,700
Packwood	8	2.50	52,600	19.6	6,575	11.87	1.00	87.5	60,431
Randle	7	3.86	88,300	23.5	12,614	8.31	1.00	100.0	126,333
Spirit Lake	2	2.50	10,440	8.4	5,220	12.66	1.00	100.0	28,690
Mt. Adams	7	2.29	47,150	12.1	6,736	8.40	1.00	85.7	66,271
Wind River	2	2.50	11,750	5.0	5,875	14.56	1.00	50.0	70,424
Canyon Creek	2	2.50	11,000	9.3	5,500	17.43	1.00	100.0	55,042
Clackamas-Sandy	11	2.73	52,572	5.2	4,779	11.92	1.00	63.6	54,665
Heba	17	2.94	59,880	22.7	3,522	16.29	1.00	88.2	23,857
Waldport	10	2.90	60,265	13.9	6,026	23.81	1.00	100.0	42,450
Mapleton	34	2.59	180,968	36.0	5,279	24.56	1.00	79.4	61,864
North Santiam	19	3.11	73,310	24.2	3,858	13.08	1.00	73.7	38,739
South Santiam	17	2.82	83,190	22.7	4,894	20.93	1.00	70.6	48,540
McKenzie	8	3.25	26,065	5.2	3,258	29.21	1.00	25.0	20,429
Lowell	6	4.14	29,660	7.6	5,123	31.09	1.00	57.1	39,271
Oakridge	23	2.46	158,915	19.3	6,896	17.78	1.00	66.7	127,584
Cottage Grove	11	2.18	21,250	10.3	1,932	27.55	1.00	27.3	23,646
North Umpqua	26	3.54	270,015	33.6	10,801	14.56	1.00	80.8	118,144
South Umpqua	16	3.62	65,850	16.5	4,390	14.84	1.00	68.8	45,536
Coquille	4	2.50	16,345	15.2	4,086	30.39	1.00	50.0	78,881
Rogue River (Siskiyou NF)	10	2.70	85,120	29.7	8,512	13.01	1.00	100.0	130,626
Chetco	6	2.00	32,205	24.6	5,368	20.13	1.00	83.3	95,055
Josephine	16	2.63	57,155	25.1	3,572	14.96	1.00	62.5	60,242
Applegate	7	2.43	30,675	36.1	4,382	8.30	1.00	85.7	60,311
Ashland	6	2.50	17,190	21.4	2,865	18.78	1.00	50.0	130,654
Butte Falls	7	3.71	47,890	42.5	6,841	15.18	1.00	100.0	55,865
Rogue River (Rogue River NF)	6	3.50	26,840	10.0	4,473	14.23	1.00	66.7	33,499
All working circles — west side	341	3.06	1,952,586	17.1	5,776	15.69	1.00	75.5	69,750
All working circles except Shelton	340	3.06	1,936,586	17.2	5,746	15.65	1.00	75.4	69,545

Table 13.—Sale data by Forest Service working circle, total west side, 1959-62 (Continued)

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
Competitive sales:									
Soleduck	25	4.88	182,435	82.3	7,297	13.15	1.34	92.0	68,019
Quilcene	22	4.86	178,670	82.6	8,121	14.87	1.40	100.0	90,002
Quinault	20	3.30	145,955	44.9	7,298	8.73	1.29	80.0	70,729
Glacier	22	4.59	91,437	85.9	4,156	6.34	3.31	90.9	49,831
Skagit	10	10.60	73,190	74.1	7,319	4.07	3.07	90.0	91,186
Baker River	20	7.45	124,560	95.3	6,228	6.14	3.27	95.0	61,054
Suiattle	19	11.68	74,205	98.9	3,906	11.67	1.66	73.7	47,844
Darrington	41	12.05	175,740	73.2	4,286	10.33	2.56	82.9	45,807
South Fork Stillaguamish	18	4.67	100,100	72.2	5,561	6.43	1.59	100.0	57,382
Skykomish	10	3.64	55,285	42.4	5,528	10.88	1.35	80.0	43,367
Snoqualmie	6	4.00	36,558	78.7	6,093	17.70	1.87	83.3	66,779
Cedar River	2	3.00	7,360	100.0	3,680	15.08	1.32	100.0	14,960
Green River	3	3.00	26,000	96.0	8,667	10.74	1.19	33.3	99,090
White River	24	4.17	107,345	92.7	4,473	15.44	1.43	66.7	43,226
Mineral	6	5.83	38,660	28.4	6,443	20.69	1.61	50.0	21,482
Packwood	41	5.32	160,915	59.9	3,925	13.79	1.50	73.2	41,190
Randle	56	7.00	285,900	76.1	5,105	16.34	1.95	67.9	57,232
Spirit Lake	8	4.25	71,550	57.9	8,944	14.76	2.07	62.5	85,047
Lewis River	30	5.17	406,045	99.8	13,535	15.34	1.57	93.3	104,856
Mt. Adams	42	3.31	187,395	48.3	4,462	16.41	1.48	64.3	56,464
Wind River	33	3.85	219,400	93.1	6,648	16.72	1.76	72.7	64,325
Canyon Creek	21	5.05	102,050	86.1	4,860	13.24	1.89	66.7	84,723
Hood River	28	3.25	143,395	99.9	5,121	25.26	1.32	78.6	35,330
Clackamas-Sandy	160	5.97	948,148	93.1	5,926	15.30	1.86	71.3	70,611
Hebo	39	4.87	184,201	69.9	4,723	16.73	1.52	74.4	51,467
Waldport	63	5.48	356,164	81.8	5,653	24.55	1.51	87.3	42,609
Mapleton	37	3.89	238,301	47.4	6,441	23.61	1.35	78.4	75,110
North Santiam	39	4.67	214,730	70.8	5,506	18.11	1.49	69.2	74,725
South Santiam	45	3.71	207,300	56.6	4,607	21.34	1.35	77.8	38,299
McKenzie	105	4.82	451,677	91.0	4,302	20.22	1.52	54.3	65,847
Lowell	62	6.32	339,955	87.6	5,383	23.73	1.57	75.8	59,869
Oakridge	102	4.29	553,350	67.1	5,360	21.13	1.43	63.7	77,978
Cottage Grove	36	3.58	119,700	58.3	3,325	16.88	1.54	72.2	41,796
North Umpqua	108	5.32	503,420	62.8	4,661	18.17	1.39	58.9	62,775
South Umpqua	66	6.02	322,686	80.8	4,904	18.26	1.40	77.3	57,162
Coquille	12	3.42	52,985	49.3	4,415	18.63	1.36	75.0	58,999
Rogue River (Siskiyou NF)	28	4.71	181,730	63.3	6,490	18.57	1.67	78.6	81,319
Chetco	12	3.25	71,600	54.8	5,967	18.17	1.44	100.0	55,035
Josephine	60	4.00	155,850	68.5	2,598	19.25	1.73	55.0	49,627
Applegate	10	3.50	43,220	51.0	4,322	12.65	1.98	100.0	32,158
Ashland	13	4.15	50,145	62.4	3,857	10.94	1.44	69.2	49,797
Butte Falls	23	5.26	64,715	57.5	2,814	17.70	1.30	73.9	19,195
Rogue River (Rogue River NF)	61	5.97	219,380	81.6	3,596	16.65	1.42	50.8	40,344
All working circles — west side	1,588	5.28	8,273,407	71.3	5,206	17.16	1.63	71.8	59,941
All working circles except Shelton	1,588	5.28	8,273,407	72.5	5,206	17.16	1.63	71.8	59,941

Table 13.—Sale data by Forest Service working circle, total west side, 1959-62 (Continued)

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
All sales:									
Saleduck	32	4.19	221,575		6,924	14 21	1 28	87.5	69,232
Quilcene	32	3.94	216,450		6,764	14.49	1 33	96.9	76,883
Quinault	46	2.30	325,142		7,068	7.50	1.13	76.1	82,090
Shelton	8	1.13	189,260		23,685	19.96	1.00	100.0	223,519
Glacier	28	3.89	106,392		3,800	7.62	2.99	89.3	44,873
Skagit	15	7.53	98,830		6,589	3.77	2.53	73.3	75,882
Baker River	24	6.92	130,672		5,445	6.15	3.16	91.7	55,262
Suiattle	21	10.95	75,055		3,574	11.69	1.65	71.4	45,029
Darrington	50	11.22	240,178		4,804	9.30	2.14	84.0	51,263
South Fork Stillaguomish	25	4.40	138,550		5,542	6.06	1.42	100.0	59,602
Skykamish	20	3.10	130,665		6,533	11 44	1.14	60.0	80,346
Snaqualmie	7	3.57	46,458		6,637	17.66	1.69	85.7	68,512
Cedar River	2	3.00	7,360		3,680	15.08	1.32	100.0	14,960
Green River	4	2.50	27,080		6,770	10.92	1.18	50.0	51,755
White River	30	4.43	115,855		3,862	14.98	1.40	66.7	36,715
Mineral	15	3.00	136,260		9,084	16.21	1.17	80.0	62,318
Packwood	62	4 05	268,440		4,330	13.68	1.30	77.4	45,951
Randle	67	6.31	375,870		5,610	14.45	1.73	70.1	65,092
Spirit Lake	15	2.93	123,615		8,241	13.80	1.62	66.7	99,156
Lewis River	31	5.03	406,945		13,127	15.36	1.57	90.3	104,856
Mt. Adams	72	2.47	388,385		5,394	14.20	1.23	73.6	56,942
Wind River	46	3.11	235,535		5,120	16.76	1.71	65.2	54,116
Canyon Creek	27	4.26	118,550		4,391	13.74	1.76	66.7	74,379
Hood River	29	3 17	143,495		4,948	25.26	1.32	75.9	35,330
Clackamas-Sandy	182	5.47	1,017,830		5,592	15.01	1.80	69.2	67,472
Hebo	66	3.79	263,650		3,995	16.41	1 36	77.3	37,690
Waldport	87	4.49	434,864		4,998	24.22	1 41	83.9	39,340
Mapleton	113	2.42	502,631		4,448	24.11	1.17	66.4	60,925
North Santiam	67	3.73	303,080		4,524	16.94	1.34	71.6	55,130
South Santiam	100	2.53	366,489		3,665	21.05	1.20	67.0	35,686
McKenzie	140	3.99	496,652		3,548	20.86	1.47	51.4	54,146
Lowell	79	5.46	388,285		4,915	24.18	1.50	72.2	54,977
Ookridge	162	3.29	824,161		5,087	19.55	1.28	64.8	79,684
Cottage Grove	58	2.83	205,550		3,544	20.73	1.32	67.2	40,076
North Umpqua	153	4.56	802,771		5,247	17.25	1.24	62.1	69,249
South Umpqua	99	4.77	399,230		4,033	17.73	1.32	68.7	51,290
Coquille	29	2 21	107,550		3,709	21.24	1.18	65.5	64,458
Rogue River (Siskiyou NF)	47	3.57	286,947		6,105	16.59	1.42	78.7	90,836
Chetco	27	2.22	130,745		4,842	18.67	1.24	96.3	61,176
Josephine	87	3.37	227,622		2,616	17.74	1.50	55.2	50,611
Applegate	19	2.84	84,875		4,467	10.26	1.50	94.7	44,936
Ashland	25	3.00	80,345		3,214	13.31	1.28	56.0	70,347
Butte Falls	30	4.90	112,605		3,754	16.63	1.17	80.0	29,891
Rogue River (Rogue River NF)	70	5 54	268,710		3,839	16.20	1.35	52.9	42,135
All working circles — west side	2,348	4.19	11,571,209		4,936	16.80	1.45	70.3	59,424
All working circles except Shelton	2,340	4.20	11,381,949		4,872	16.75	1.46	70.2	58,625

Table 14.—Sale data by Forest Service working circle, total east side, 1959-62

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
One-bidder sales:									
Okanogan	26	1.00	153,362	70.8	5,899	6.94	1.00	84.6	50,646
Entiat	6	1.00	46,710	84.0	7,785	7.82	1.00	100.0	65,198
Wenatchee	2	1.00	12,370	8.9	6,123	8.04	1.00	100.0	37,202
Ellensburg	1	1.00	5,000	3.1	5,000	7.56	1.00	100.0	17,991
Naches Tieton	9	1.00	65,210	34.5	7,246	10.43	1.00	77.8	75,015
East Side	8	1.00	35,760	24.5	4,470	8.61	1.00	87.5	28,306
West Klamath	6	1.00	21,400	10.9	3,567	11.97	1.00	66.7	26,446
Lakeview	26	1.00	155,789	94.6	5,992	16.72	1.00	73.1	33,993
East Klamath	12	1.00	26,806	9.7	2,234	22.66	1.00	66.7	11,316
Deschutes Plateau	20	1.00	184,081	36.1	9,204	18.45	1.00	65.0	62,311
Crooked River	22	1.00	40,005	15.3	1,818	13.92	1.00	50.0	13,556
Burns	29	1.00	255,903	76.1	8,824	12.95	1.00	75.9	68,914
John Day	12	1.00	43,710	22.3	3,643	9.46	1.00	91.7	39,538
Middle Fork	3	1.00	54,826	100.0	18,275	15.21	1.00	100.0	110,985
Burnt River	7	1.00	50,838	76.7	7,263	9.70	1.00	100.0	52,033
Elkhorn	9	1.00	61,941	45.5	6,882	9.60	1.00	88.9	45,810
Heppner	1	1.00	4,000	7.4	4,000	10.84	1.00	--	--
Pendleton Pilot Rock	7	1.00	26,734	14.9	3,819	6.67	1.00	57.1	9,055
Grande Ronde (Wallowa-Whitman)	1	1.00	1,240	1.7	1,240	4.27	1.00	100.0	2,852
Union	1	1.00	6,400	8.7	6,400	6.08	1.00	100.0	41,682
Pine	1	1.00	1,300	5.3	1,300	9.97	1.00	100.0	702
Wallowa	5	1.00	18,475	20.1	3,695	8.92	1.00	80.0	24,881
Winema	4	1.00	9,920	19.6	2,480	10.69	1.00	100.0	6,434
Chelan	4	1.00	35.100	100.0	8,775	10.02	1.00	100.0	84,758
All working circles — East side	223	1.00	1,316,880	35.25	5,932	12.53	1.00	76.7	45,146
Token-bid sales									
Okanogan	2	3.00	2,527	1.2	1,264	4.87	1.00	100.0	2,396
Entiat	1	2.00	8,900	16.0	8,900	6.45	1.00	100.0	24,188
Wenatchee	15	2.00	119,300	86.0	8,093	13.26	1.00	100.0	77,717
Ellensburg	7	3.43	13,400	8.3	1,914	12.02	1.00	100.0	11,980
Naches Tieton	7	2.17	102,650	54.3	14,664	7.94	1.00	100.0	115,740
East Side	9	2.89	37,730	25.8	4,192	8.65	1.00	100.0	22,273
West Klamath	2	2.50	11,800	6.0	5,900	17.67	1.00	100.0	23,624
Lakeview	1	2.00	1,950	1.2	1,950	28.85	1.00	100.0	3,510
East Klamath	3	2.33	24,764	9.0	8,255	21.13	1.00	100.0	47,994
Deschutes Plateau	12	2.25	141,765	27.8	11,814	18.48	1.00	83.3	58,759
Crooked River	13	2.38	191,445	73.2	14,727	14.94	1.00	61.5	185,652
Burns	5	2.20	60,441	18.0	12,088	9.71	1.00	100.0	109,940
John Day	11	2.36	117,970	60.2	10,725	9.04	1.00	90.9	82,885
Burnt River	1	3.00	7,300	11.0	7,300	12.59	1.00	100.0	57,664
Elkhorn	7	2.71	43,783	32.1	6,255	10.01	1.00	85.7	33,581
Heppner	3	2.33	32,539	60.0	10,846	10.60	1.00	66.7	96,564
Pendleton Pilot Rock	5	2.80	48,860	27.3	9,772	13.49	1.00	60.0	81,424
Grande Ronde (Wallowa-Whitman)	2	2.00	34,470	47.2	17,235	2.77	1.00	100.0	83,882
Union	4	3.00	66,930	91.3	16,733	8.59	1.00	100.0	83,360
Pine	1	4.00	23,000	94.7	23,000	7.70	1.00	100.0	187,260
Wallowa	5	2.20	62,870	68.3	12,574	11.00	1.00	100.0	71,766
Grande Ronde (Umatilla)	1	2.00	5,600	9.6	5,600	10.73	1.00	100.0	11,322
Clearwater	1	2.00	12,600	42.4	12,600	7.57	1.00	100.0	95,140
Winema	1	2.00	9,700	19.2	9,700	9.05	1.00	100.0	74,906
All working circles — east side	117	2.46	1,150,294	30.7	9,832	12.19	1.00	89.7	71,965

Table 14.—Sale data by Forest Service working circle, total east side, 1959-62 (Continued)

Kind of sale and working circle	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio	Percent of sales requiring road construction	Average road construction cost for sales requiring construction
			M bd. ft.		M bd. ft.	Dollars			Dollars
Competitive sales									
Okanogan	13	3.00	60,680	28.0	4,668	5.31	1.94	100.0	19,654
Wenatchee	3	3.33	7,000	5.1	2,333	7.11	2.00	100.0	13,323
Ellensburg	34	4.79	143,220	88.6	4,212	10.14	1.49	97.1	29,832
Naches Tieton	5	2.40	21,180	11.2	4,236	4.77	3.13	100.0	48,404
East Side	15	4.93	72,500	49.7	4,833	9.44	2.47	93.3	26,362
West Klamath	30	4.47	163,825	83.1	5,461	16.24	1.72	66.7	42,965
Lakeview	5	2.60	6,893	4.2	1,379	15.84	1.26	80.0	3,390
East Klamath	29	3.21	223,370	81.3	7,702	17.47	1.30	82.8	38,694
Deschutes Plateau	36	3.19	184,530	36.1	5,126	13.54	1.53	61.1	31,251
Crooked River	16	2.88	30,245	11.5	1,890	6.77	1.57	43.8	7,108
Burns	3	3.00	19,820	5.9	6,607	15.71	1.03	100.0	56,250
John Day	9	3.00	34,155	17.5	3,795	13.42	1.28	100.0	28,508
Burnt River	1	3.00	8,140	12.3	8,140	8.78	1.78	100.0	72,393
Elkhorn	4	2.75	30,570	22.4	7,643	1.53	1.16	100.0	31,117
Heppner	1	2.00	17,700	32.6	17,700	9.77	1.60	100.0	73,445
Pendleton Pilot Rock	17	3.71	103,635	57.8	6,096	7.41	1.58	82.4	29,644
Grande Ronde (Wallowa-Whitman)	4	3.00	37,331	51.1	9,333	5.29	1.70	75.0	70,913
Wallowa	6	2.50	10,635	11.6	1,773	6.66	1.50	83.3	11,724
Grande Ronde (Umatilla)	7	3.57	52,976	90.4	7,568	12.20	1.78	71.4	47,834
Clearwater	2	2.50	17,100	57.6	8,550	8.98	1.25	100.0	34,872
Winema	14	2.50	30,905	61.2	2,208	10.93	1.16	78.6	4,098
All working circles — east side	255	3.56	1,276,410	34.1	5,017	11.92	1.60	80.0	30,447
All sales:									
Okanogan	41	1.73	216,569		5,282	6.46	1.26	90.2	37,149
Entiat	7	1.14	55,610		7,944	7.60	1.00	100.0	59,340
Wenatchee	20	2.05	138,670		6,934	12.26	1.05	100.0	61,980
Ellensburg	42	4.48	161,620		3,848	10.21	1.44	97.6	26,495
Naches Tieton	21	1.68	189,040		9,949	7.74	1.24	90.5	84,139
East Side	32	3.38	145,990		4,562	9.03	1.73	93.8	25,589
West Klamath	38	3.82	197,025		5,185	15.86	1.60	68.4	38,936
Lakeview	32	1.28	164,632		5,145	16.83	1.01	75.0	27,622
East Klamath	44	2.55	274,940		6,249	18.31	1.25	79.5	33,233
Deschutes Plateau	68	2.38	510,376		7,506	16.69	1.19	66.2	46,337
Crooked River	51	1.94	261,695		5,131	13.84	1.07	51.0	64,772
Burns	37	1.32	336,164		9,086	12.53	1.00	81.1	74,485
John Day	32	2.03	195,835		6,120	9.90	1.05	93.8	50,678
Middle Fork	3	1.00	54,826		18,275	15.21	1.00	100.0	110,985
Burnt River	9	1.44	66,278		7,364	9.91	1.10	100.0	54,921
Elkhorn	20	1.95	136,294		6,815	7.92	1.04	90.0	38,468
Heppner	5	2.00	54,239		10,848	10.35	1.20	60.0	88,857
Pendleton Pilot Rock	29	2.90	179,229		6,180	8.96	1.33	72.4	33,119
Grande Ronde (Wallowa-Whitman)	7	2.43	73,041		10,434	4.08	1.36	85.7	63,892
Union	5	2.60	73,330		14,666	8.37	1.00	100.0	75,024
Pine	2	2.50	24,300		12,150	7.82	1.00	100.0	93,981
Wallowa	16	1.94	91,980		5,749	10.08	1.06	87.5	36,927
Grande Ronde (Umatilla)	8	3.38	58,576		7,322	12.06	1.71	75.0	41,749
Clearwater	3	2.33	29,700		9,900	8.38	1.15	100.0	54,961
Winema	19	2.16	50,525		2,659	10.52	1.10	84.2	9,107
Chelan	4	1.00	35,100		8,775	10.02	1.00	100.0	84,758
All working circles — east side	595	2.39	3,775,584		6,307	12.22	1.20	80.7	44,766

Table 15.—Sale characteristics by volume size classes for all oral-auction National Forest timber sales, west side (excepting Shelton Working Circle), 1959-62

Volume size class	Competitive closs[1]	Number of sales	Percent of sales in competitive closs	Totol number of bidders	Average number of bidders	Total volume sold	Percent size class	Weighted averoge bid-appraisal rotio av.=WBR/vol.
						M bd. ft.		
Less than 1 million feet	1	251	29.6	251	1.00	85,951	25.4	1.00
	2	95	11.3	247	2.57	36,541	10.8	1.00
	3	502	59.1	2,251	4.48	215,668	63.8	1.50
Totals, or average by closs		849	100.0	2,749	3.24	338,160	100.0	1.32
Percent of all sales by closs		36.3	--	--	--	3.0	--	--
1-4.9 million feet	1	85	12.9	85	1.00	205,030	12.6	1.00
	2	95	14.4	293	3.08	236,475	14.5	1.00
	3	478	72.7	2,693	5.63	1,187,756	72.9	1.59
Totols, or overage by closs		658	100.0	3,071	4.67	1,629,261	100.0	1.43
Percent of oll soles by class		28.1	--	--	--	14.3	--	--
5-9.9 million feet	1	47	9.6	47	1.00	339,000	9.4	1.00
	2	83	17.0	276	3.33	633,170	17.5	1.00
	3	359	73.4	2,003	5.58	2,646,080	73.1	1.66
Totols, or averoge by class		489	100.0	2,326	4.76	3,618,250	100.0	1.48
Percent of all soles by closs		20.9	--	--	--	31.8	--	--
10-14.9 million feet	1	13	7.1	13	1.00	164,000	7.4	1.00
	2	36	19.8	115	3.19	419,000	18.8	1.00
	3	133	73.1	753	5.66	1,639,270	73.8	1.71
Totals, or overage by class		182	100.0	881	4.84	2,222,270	100.0	1.52
Percent of oll sales by closs		7.8	--	--	--	19.5	--	--
15 million feet or more	1	17	10.5	17	1.00	378,900	10.6	1.00
	2	30	18.5	107	3.57	624,200	17.5	1.00
	3	115	71.0	682	5.93	2,570,908	71.9	1.60
Totols, or average by closs		162	100.0	806	4.98	3,574,008	100.0	1.43
Percent of all soles by closs		6.9	--	--	--	31.4	--	--
Totol or average, oll soles		2,340		9,833	4.20	11,381,949		1.46

[1] The three competitive classes are defined as follows:
1. One bidder, bid-appraisal ratio = 1.00
2. Token bid (two or more bidders, bid-oppraisal ratio = 1.00)
3. Two or more bidders, bid-approisol rotio greater than 1.00 rounded to nearest 0.01.

Table 16.—Sale characteristics by volume size classes for all oral-auction National Forest timber sales, east side, 1959-62

Volume size class	Competitive class[1]	Number of sales	Percent of sales in competitive class	Total number of bidders	Average number of bidders	Total volume sold	Percent size class	Weighted average bid-appraisal ratio av. = WBR/vol.
						M bd. ft.		
Less than 1 million feet	1	91	50.3	91	1.00	38,705	49.2	1.00
	2	19	10.5	47	2.47	8,206	10.4	1.00
	3	71	39.2	240	3.38	31,761	40.4	1.44
Totals, or average by class		181	100.0	378	2.09	78,672	100.0	1.18
Percent of all sales by class		30.4	--	--	--	2.1	--	--
1-4.9 million feet	1	66	33.5	66	1.00	146,612	31.5	1.00
	2	36	18.3	83	2.30	92,526	19.7	1.00
	3	95	48.2	342	3.60	228,964	48.8	1.81
Totals, or average by class		197	100.0	491	2.49	469,102	100.0	1.40
Percent of all sales by class		33.1	--	--	--	12.4	--	--
5-9.9 million feet	1	27	25.0	27	1.00	212,063	25.7	1.00
	2	27	25.0	70	2.59	215,590	26.1	1.00
	3	54	50.0	200	3.70	397,115	48.2	1.60
Totals, or average by class		108	100.0	297	2.75	824,768	100.0	1.29
Percent of all sales by class		18.2	--	--	--	21.8	--	--
10-14.9 million feet	1	12	36.4	12	1.00	150,600	36.1	1.00
	2	7	21.2	18	2.57	86,550	20.7	1.00
	3	14	42.4	53	3.78	180,440	43.2	1.52
Totals, or average by class		33	100.0	83	2.52	417,590	100.0	1.23
Percent of all sales by class		5.5	--	--	--	11.1	--	--
15 million feet or more	1	27	35.5	27	1.00	773,900	39.0	1.00
	2	29	38.2	72	2.48	773,422	38.9	1.00
	3	20	26.3	71	3.55	438,130	22.1	1.52
Totals, or average by class		76	100.0	170	2.24	1,985,452	100.0	1.11
Percent of all sales by class		12.8	--	--	--	52.6	--	--
Total or average, all sales		595		1,419	2.38	3,775,584		1.20

[1] The three competitive classes are defined as follows:
1. One bidder, bid-appraisal ratio = 1.00
2. Token bid (two or more bidders, bid-appraisal ratio = 1.00)
3. Two or more bidders, bid-appraisal ratio greater than 1.00 rounded to nearest 0.01.

Table 17.—Sale characteristics by bid-appraisal ratio class for all oral-auction National Forest timber sales, west side (excepting Shelton Working Circle), 1959-62

Bid-appraisal ratio class[1]	Number of sales	Percent of total sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Average volume per sale	Percent of total volume
					M bd. ft.	M bd. ft.	
1.00	751	32.1	1,437	1.91	3,109,467	4,140	27.3
1.01-1.10	247	10.6	823	3.33	1,198,356	4,852	10.5
1.11-1.20	173	7.4	700	4.05	829,595	4,795	7.3
1.21-1.30	193	8.3	858	4.45	885,565	4,588	7.8
1.31-1.40	162	6.9	787	4.86	773,869	4,777	6.8
1.41-1.50	162	6.9	966	5.96	1,003,050	6,192	8.8
1.51-1.60	126	5.4	715	5.67	594,398	4,717	5.2
1.61-1.70	118	5.0	758	6.42	643,355	5,452	5.7
1.71-1.80	84	3.6	583	6.94	400,677	4,770	3.5
1.81-1.90	68	2.9	422	6.21	373,804	5,497	3.3
1.91-2.00	43	1.8	273	6.35	182,360	4,241	1.6
Greater than 2.00	213	9.1	1,511	7.09	1,387,453	6,514	12.2
Total or average values	2,340	100.0	9,833	4.20	11,381,949	4,864	100.0

[1] Rounded to nearest 0.01.

Table 18.—Sale characteristics by bid-appraisal ratio classes for all oral-auction National Forest timber sales, east side, 1959-62

Bid-appraisal ratio class[1]	Number of sales	Percent of total sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Average volume per sale	Percent of total volume
					M bd. ft.	M bd. ft.	
1.00	341	57.3	513	1.50	2,499,174	7,329	66.2
1.01-1.10	71	11.9	191	2.69	355,832	5,012	9.4
1.11-1.20	35	5.9	99	2.83	149,259	4,265	4.0
1.21-1.30	26	4.4	87	3.35	99,207	3,816	2.6
1.31-1.40	22	3.7	88	4.00	117,733	5,352	3.1
1.41-1.50	9	1.5	29	3.22	34,745	3,861	.9
1.51-1.60	14	2.4	70	5.00	65,208	4,658	1.7
1.61-1.70	9	1.5	54	6.00	31,640	3,516	.8
1.71-1.80	12	2.0	49	4.08	65,976	5,498	1.8
1.81-1.90	4	.7	18	4.50	75,250	18,812	2.0
1.91-2.00	6	1.0	28	4.67	72,000	12,000	1.9
Greater than 2.00	46	7.7	193	4.20	209,560	4,556	5.6
Total or average values	595	100.0	1,419	2.38	3,775,584	6,346	100.0

[1] Rounded to nearest 0.01.

Table 19.—Sale characteristics by year and quarter for all National Forest timber sales, 1951-58, and for oral-auction sales only, 1959-62, west side (excepting Shelton Working Circle)

Year and quarter	Number of sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Weighted average bid-appraisal ratio
				M bd. ft.	
1951					
1st quarter	8			12,266	2.62
2nd quarter	83			508,265	1.64
3rd quarter	62			307,692	1.39
4th quarter	49			210,874	1.78
Total or average	202			1,039,097	1.61
1952					
1st quarter	50			388,870	1.08
2nd quarter	84			403,956	1.43
3rd quarter	158			569,428	1.13
4th quarter	65			273,877	1.76
Total or average	357			1,636,131	1.30
1953					
1st quarter	32			61,821	1.40
2nd quarter	126			362,423	1.29
3rd quarter	92			382,860	1.17
4th quarter	71			299,655	1.42
Total or average	321			1,106,759	1.29
1954					
1st quarter	39			108,146	1.44
2nd quarter	140			724,092	1.81
3rd quarter	107			410,128	2.01
4th quarter	58			202,449	2.21
Total or average	344			1,444,815	1.89
1955					
1st quarter	65			152,136	2.38
2nd quarter	135			656,123	2.14
3rd quarter	122			625,333	2.48
4th quarter	105			384,879	1.63
Total or average	427			1,818,471	2.17
1956					
1st quarter	43			104,199	1.93
2nd quarter	109			430,098	1.36
3rd quarter	173			977,470	1.45
4th quarter	98			440,200	1.30
Total or average	423			1,951,967	1.42
1957					
1st quarter	45			153,089	1.28
2nd quarter	123			561,951	1.16
3rd quarter	137			657,004	1.15
4th quarter	97			457,117	1.33
Total or average	402			1,829,161	1.21
1958					
1st quarter	101			397,491	1.29
2nd quarter	254			1,269,699	1.85
3rd quarter	168			1,027,384	2.02
4th quarter	90			517,115	1.52
Total or average	613			3,211,689	1.78
1959					
1st quarter	78	557	7.14	397,250	1.36
2nd quarter	227	1,226	5.40	1,285,819	1.48
3rd quarter	110	472	4.29	635,087	1.40
4th quarter	91	355	3.90	467,415	1.27
Total or average	506	2,610	5.16	2,785,571	1.41
1960					
1st quarter	77	378	4.91	299,106	1.32
2nd quarter	287	1,146	3.99	1,272,773	1.33
3rd quarter	108	302	2.80	681,454	1.47
4th quarter	124	438	3.53	555,010	1.20
Total or average	596	2,264	3.80	2,808,343	1.34
1961					
1st quarter	72	242	3.36	298,176	1.25
2nd quarter	278	1,051	3.78	1,249,359	1.53
3rd quarter	110	388	3.53	612,150	1.46
4th quarter	132	500	3.79	691,620	1.35
Total or average	592	2,181	3.68	2,851,305	1.44
1962					
1st quarter	72	299	4.15	235,074	1.33
2nd quarter	291	1,230	4.23	1,652,334	1.82
3rd quarter	91	310	3.41	304,544	1.34
4th quarter	192	939	4.89	744,778	1.47
Total or average	646	2,778	4.30	2,936,730	1.64

Table 20.—Sale characteristics by year and quarter for all National Forest timber sales, 1951-58, and oral-auction sales only, 1959-62, east side

Year and quarter	Number af sales	Tatal number af bidders	Average number af bidders per sale	Total valume sold	Weighted average bid-appraisal ratia
				M bd. ft.	
1951					
1st quarter	2			6,320	1.45
2nd quarter	31			299,173	1.23
3rd quarter	14			103,544	4.20
4th quarter	12			19,871	1.32
Total ar average	59			428,908	1.95
1952					
1st quarter	1			2,900	1.00
2nd quarter	16			99,548	1.10
3rd quarter	32			232,068	1.11
4th quarter	19			81,771	1.20
Tatal ar average	68			416,287	1.13
1953					
1st quarter	3			1,495	1.00
2nd quarter	29			221,340	1.04
3rd quarter	17			90,647	1.03
4th quarter	11			138,491	1.02
Total ar average	60			451,973	1.03
1954					
1st quarter	7			6,670	1.08
2nd quarter	32			276,708	1.27
3rd quarter	29			174,603	1.29
4th quarter	19			168,227	1.04
Tatal ar average	87			626,208	1.21
1955					
1st quarter	4			151,388	1.40
2nd quarter	31			258,732	1.34
3rd quarter	27			126,456	1.94
4th quarter	32			182,454	1.12
Tatal ar average	94			719,030	1.40
1956					
1st quarter	7			26,503	1.09
2nd quarter	18			112,509	1.13
3rd quarter	26			301,217	1.09
4th quarter	18			90,202	1.01
Tatal ar average	69			530,431	1.08

Year and quarter	Number af sales	Tatal number af bidders	Average number af bidders per sale	Tatal volume sold	Weighted average bid-appraisal ratia
				M bd. ft.	
1957					
1st quarter	4			56,450	1.01
2nd quarter	23			260,087	1.18
3rd quarter	27			261,402	1.58
4th quarter	18			77,679	1.03
Tatal ar average	72			655,618	1.30
1958					
1st quarter	8			66,133	1.33
2nd quarter	32			262,526	1.36
3rd quarter	38			398,685	1.43
4th quarter	34			176,888	1.52
Tatal ar average	112			904,232	1.42
1959					
1st quarter	18	50	2.78	182,000	1.06
2nd quarter	32	133	4.16	232,751	1.43
3rd quarter	30	64	2.13	154,013	1.18
4th quarter	32	68	2.12	251,785	1.16
Tatal ar average	112	315	2.81	820,549	1.22
1960					
1st quarter	15	43	2.87	70,077	1.08
2nd quarter	51	136	2.67	306,598	1.05
3rd quarter	38	64	1.68	336,758	1.10
4th quarter	46	95	2.06	200,187	1.28
Tatal ar average	150	338	2.25	913,620	1.12
1961					
1st quarter	18	38	2.11	112,139	1.59
2nd quarter	57	151	2.65	252,363	1.18
3rd quarter	34	80	2.35	178,057	1.43
4th quarter	34	72	2.12	307,244	1.16
Tatal ar average	143	34.1	2.38	849,803	1.28
1962					
1st quarter	17	35	2.06	115,367	1.23
2nd quarter	68	171	2.51	662,465	1.21
3rd quarter	30	67	2.23	122,280	1.15
4th quarter	75	152	2.03	291,500	1.17
Tatal ar average	190	425	2.24	1,191,612	1.20

Table 21.—Competitive characteristics by year for all National Forest timber sales, 1951-58, and oral-auction sales only, 1959-62, west side (excepting Shelton Working Circle)

Year	Competitive class	Number of sales	Percent of year sales	Total number of bidders	Average number of bidders	Total volume sold	Average volume per sale	Percent of year volume	Weighted average bid-appraisal ratio
						M bd. ft.	M bd. ft.		
1951	Noncompetitive sales	74	36.6	--	--	303,465	4,101	29.2	1.00
	Competitive sales	128	63.4	--	--	735,632	5,747	70.8	1.86
	Total	202	100.0	--	--	1,039,097	5,144	100.0	1.61
1952	Noncompetitive sales	147	41.2	--	--	840,790	5,720	51.4	1.00
	Competitive sales	210	58.8	--	--	795,341	3,787	48.6	1.61
	Total	357	100.0	--	--	1,636,131	4,583	100.0	1.30
1953	Noncompetitive sales	129	40.2	--	--	632,820	4,906	57.2	1.00
	Competitive sales	192	59.8	--	--	473,939	2,468	42.8	1.68
	Total	321	100.0	--	--	1,106,759	3,448	100.0	1.29
1954	Noncompetitive sales	65	18.9	--	--	387,408	5,960	26.8	1.00
	Competitive sales	279	81.1	--	--	1,057,407	3,790	73.2	2.22
	Total	344	100.0	--	--	1,444,815	4,200	100.0	1.89
1955	Noncompetitive sales	49	11.5	--	--	46,536	950	2.6	1.00
	Competitive sales	378	88.5	--	--	1,771,935	4,688	97.4	2.20
	Total	427	100.0	--	--	1,818,471	4,259	100.0	2.16
1956	Noncompetitive sales	131	31.0	--	--	494,851	3,777	25.4	1.00
	Competitive sales	292	69.0	--	--	1,457,116	4,990	74.6	1.57
	Total	423	100.0	--	--	1,951,967	4,614	100.0	1.42
1957	Noncompetitive sales	153	38.1	--	--	885,692	5,789	48.4	1.00
	Competitive sales	249	61.9	--	--	943,469	3,789	51.6	1.41
	Total	402	100.0	--	--	1,829,161	4,550	100.0	1.21
1958	Noncompetitive sales	115	18.8	--	--	667,142	5,801	20.8	1.00
	Competitive sales	498	81.2	--	--	2,544,547	5,110	79.2	1.98
	Total	613	100.0	--	--	3,211,689	5,239	100.0	1.78
1959	Noncompetitive sales	117	23.1	220	1.88	496,167	4,241	17.8	1.00
	Competitive sales	389	76.9	2,390	6.14	2,289,404	5,885	82.2	1.50
	Total	506	100.0	2,610	5.16	2,785,571	5,505	100.0	1.41
1960	Noncompetitive sales	217	36.4	390	1.80	810,092	3,733	28.8	1.00
	Competitive sales	379	63.6	1,874	4.94	1,998,251	5,272	71.2	1.47
	Total	596	100.0	2,264	3.80	2,808,343	4,712	100.0	1.34
1961	Noncompetitive sales	222	37.5	398	1.79	958,732	4,319	33.6	1.00
	Competitive sales	370	62.5	1,783	4.82	1,892,573	5,115	66.4	1.67
	Total	592	100.0	2,181	3.68	2,851,305	4,816	100.0	1.44
1962	Noncompetitive sales	197	30.5	443	2.25	857,276	4,352	29.2	1.00
	Competitive sales	449	69.5	2,335	5.20	2,079,454	4,631	70.8	1.91
	Total	646	100.0	2,778	4.30	2,936,730	4,546	100.0	1.64

Table 22.—Competitive characteristics by year for all National Forest timber sales, 1951-58, and oral-auction sales only, 1959-62, east side

Year	Competitive class	Number of sales	Percent of year sales	Total number of bidders	Average number of bidders	Total volume sold	Average volume per sale	Percent of year volume	Weighted average bid-appraisal ratio
						M bd. ft.	M bd. ft.		
1951	Noncompetitive sales	34	57.6	--	--	150,862	4,437	35.2	1.00
	Competitive sales	25	42 4	--	--	278,046	11,122	64.8	2.47
	Total	59	100.0	--	--	428,908	7,270	100.0	1.95
1952	Noncompetitive sales	39	57.4	--	--	266,967	6,845	64.1	1.00
	Competitive sales	29	42.6	--	--	149,320	5,149	35.9	1.35
	Total	68	100.0	--	--	416,287	6,122	100.0	1.13
1953	Noncompetitive sales	43	71.7	--	--	404,666	9,411	89.5	1.00
	Competitive sales	17	28.3	--	--	47,307	2,783	10.5	1.28
	Total	60	100.0	--	--	451,973	7,533	100.0	1.03
1954	Noncompetitive sales	40	46.0	--	--	434,654	10,866	69.4	1.00
	Competitive sales	47	54.0	--	--	191,554	4,076	30.6	1.69
	Total	87	100.0	--	--	626,208	7,198	100.0	1.21
1955	Noncompetitive sales	39	41.5	--	--	363,227	9,314	50.0	1.00
	Competitive sales	55	58.5	--	--	355,803	6,469	49.5	1.82
	Total	94	100.0	--	--	719,030	7,649	100.0	1.40
1956	Noncompetitive sales	45	65.2	--	--	395,812	8,796	74.6	1.00
	Competitive sales	24	34.8	--	--	134,619	5,609	25.4	1.33
	Total	69	100.0	--	--	530,431	7,687	100.0	1.08
1957	Noncompetitive sales	42	58.3	--	--	351,962	8,380	53.7	1.00
	Competitive sales	30	41.7	--	--	303,656	10,122	46.3	1.66
	Total	72	100.0	--	--	655,618	9,106	100.0	1.31
1958	Noncompetitive sales	60	53.6	--	--	504,871	8,414	55.8	1.00
	Competitive sales	52	46.4	--	--	399,361	7,680	44.2	1.95
	Total	112	100.0	--	--	904,232	8,074	100.0	1.42
1959	Noncompetitive sales	63	56.2	113	1.79	562,519	8,929	68.6	1.00
	Competitive sales	49	43.8	202	4.12	258,030	5,266	31.4	1.70
	Total	112	100.0	315	2.81	820,549	7,326	100.0	1.22
1960	Noncompetitive sales	96	64.0	142	1.48	666,671	6,944	73.0	1.00
	Competitive sales	54	36.0	196	3.63	246,949	4,573	27.0	1.44
	Total	150	100.0	338	2.25	913,620	6,091	100.0	1.12
1961	Noncompetitive sales	84	58.7	117	1.39	524,799	6,248	61.8	1.00
	Competitive sales	59	41.3	224	3.80	325,004	5,509	38.2	1.74
	Total	143	100.0	341	2.38	849,803	5,943	100.0	1.28
1962	Noncompetitive sales	98	51.6	141	1.44	745,185	7,604	62.5	1.00
	Competitive sales	92	48.4	284	3.09	446,427	4,852	37.5	1.52
	Total	190	100.0	425	2.24	1,191,612	6,272	100.0	1.20

APPENDIX B

Tables

of

Bureau of Land Management Sales Data

Table 23.—Sale data by Bureau of Land Management master unit, total west side, 1951-62

Kind of sale and master unit	Number of sales	Average number of bidders per sale	Volume	Percent of total volume sold	Average sale size	Weighted average appraised price	Weighted average bid-appraisal ratio
			M bd. ft.		M bd. ft.	Dollars	
One-bidder sales:							
Alsea-Rickreall	80	1.00	175,888	27.6	2,199	19 72	1.00
Clackamas-Molalla	21	1.00	23,966	11.4	1,141	17.01	1.00
Columbia	50	1.00	102,818	24.8	2,056	20 03	1.00
Douglas	179	1.00	497,129	43.5	2,777	21.07	1.00
Jackson	56	1.00	112,869	21.6	2,016	20.15	1.01
Josephine	121	1.00	342,471	45.1	2,830	21.18	1.00
Klamath	13	1.00	23,691	16.2	1,822	21.20	1.00
Santiam	46	1.00	164,032	28.2	3,566	19.70	1.00
Siuslaw	84	1.00	141,108	16.3	1,680	21.71	1.00
South Coast	133	1.00	458,143	31.5	3,445	20.10	1.01
South Umpqua	52	1.00	115,644	44.8	2,224	19 32	1.00
Upper Willamette	64	1.00	113,548	18.5	1,774	23.90	1.00
All master units — west side	899	1.00	2,271,307	29.9	2,526	20.64	1.00
Token bid sales:							
Alsea-Rickreall	1	1.00	1,726	0.3	1,726	18.91	1.00
Clackamas-Molalla	0	0	0	0	0	0	0
Columbia	3	1.67	15,505	3.7	5,168	19.34	1.00
Douglas	1	2.00	3,230	0.3	3,230	18.46	1.00
Jackson	2	2.00	3,945	0.8	1,972	22.44	1.00
Josephine	3	2.00	977	0.1	326	21.39	1.00
Klamath	1	2.00	2,134	1.5	2,134	28.00	1.00
Santiam	0	0	0	0	0	0	0
Siuslaw	1	2.00	2,289	0.2	2,289	30.63	1.00
South Coast	2	2.00	7,985	0.6	3,992	24.42	1.00
South Umpqua	0	0	0	0	0	0	0
Upper Willamette	2	2.00	160	0.0	80	15.44	1.00
All master units — west side	16	1.88	37,951	0.5	2,372	21.84	1.00
Competitive sales:							
Alsea-Rickreall	177	2.72	458,954	72.1	2,593	22.27	1.59
Clackamas-Molalla	67	2.97	186,020	88.6	2,776	17.47	1.64
Columbia	136	3.03	296,585	71.5	2,181	20.15	1.52
Douglas	303	2.71	642,865	56.2	2,122	21.46	1.45
Jackson	136	3.12	405,558	77.6	2,982	21.38	1.38
Josephine	160	3.07	415,497	54.8	2,597	23.24	1.39
Klamath	43	3.30	120,243	82.3	2,796	20.92	1.36
Santiam	146	2.84	417,040	71.8	2,856	21.62	1.41
Siuslaw	383	3.19	724,156	83.5	1,891	23.15	1.60
South Coast	254	2.76	986,474	67.9	3,884	21.96	1.37
South Umpqua	53	2.92	142,228	55.2	2,684	20.36	1.39
Upper Willamette	237	3.04	500,453	81.5	2,112	24.10	1.52
All master units — west side	2,095	2.95	5,296,073	69.6	2,528	21.99	1.47
All sales:							
Alsea-Rickreall	258	2.18	636,568	100.0	2,467	21.56	1.44
Clackamas-Molalla	88	2.50	209,986	100.0	2,386	17.41	1.57
Columbia	189	2.47	414,908	100.0	2,195	20.09	1.37
Douglas	483	2.07	1,143,224	100.0	2,367	21.28	1.26
Jackson	194	2.49	522,372	100.0	2,693	21.12	1.30
Josephine	284	2.18	758,945	100.0	2,672	22.31	1.22
Klamath	57	2.75	146,068	100.0	2,563	21.07	1.30
Santiam	192	2.40	581,072	100.0	3,026	21.08	1.31
Siuslaw	468	2.79	867,553	100.0	1,854	22.94	1.51
South Coast	389	2.15	1,452,602	100.0	3,734	21.38	1.26
South Umpqua	105	1.97	257,872	100.0	2,456	19.90	1.22
Upper Willamette	303	2.60	614,161	100.0	2,027	24.06	1.43
All master units — west side	3,010	2.36	7,605,331	100.0	2,527	21.59	1.33

Table 24.—Sale characteristics by volume size classes for all oral-auction Bureau of Land Management timber sales, west side, 1951-62

Volume size class	Competitive class[1]	Number of sales	Percent of sales in competitive class	Total number of bidders	Average number of bidders	Total volume sold	Percent size class	Weighted average bid-appraisal ratio av.=WBR/vol.
						M bd. ft.		
Less than 1 million feet	1	363	34.4	363	1.00	117,321	27.8	1.01
	2	7	0.7	14	2.00	1,933	0 5	1.00
	3	684	64.9	2,027	2.96	302,711	71.7	1.50
Totals or average by class		1,054	100.0	2,404	2.28	421,965	100 0	1.37
Percent of all sales by class		35.0	--	--	--	5.6	--	--
1-4.9 million feet	1	387	25.5	387	1.00	1,028,629	26.2	1.00
	2	7	0.5	12	1.71	18,774	0.5	1.00
	3	1,122	74.0	3,354	2.99	2,879,023	73.3	1.48
Totals or average by class		1,516	100.0	3,753	2.48	3,926,426	100.0	1.36
Percent of all sales by class		50.4	--	--	--	51.6	--	--
5-9.9 million feet	1	133	33.4	133	1.00	912,678	33.4	1.00
	2	1	0.3	2	2.00	5,315	0.2	1.00
	3	264	66.3	736	2.79	1,815,378	66.4	1.47
Totals or average by class		398	100.0	871	2.19	2,733,371	100.0	1.31
Percent of all sales by class		13.2	--	--	--	35.9	--	--
10-14.9 million feet	1	13	34.2	13	1.00	156,173	34 7	1.02
	2	1	2.6	2	2 00	11,929	2.7	1.00
	3	24	63.2	60	2.50	281,591	62.6	1.38
Totals or average by class		38	100.0	75	1.97	449,693	100.0	1.24
Percent of all sales by class		1.3	--	--	--	5.9	--	--
15 million feet or more	1	3	75.0	3	1.00	56,506	76.5	1.00
	2	0	0	0	0	0	0	0
	3	1	25.0	5	5.00	17,370	23.5	1.13
Totals or average by class		4	100.0	8	2.00	73,876	100.0	1.04
Percent of all sales by class		0.1	--	--	--	1.0	--	--
Total or average, all sales		3,010	100.0	7,111	2.36	7,605,331	100 0	1.33

[1] The three competitive classes are defined as follows:
1. One bidder, bid-appraisal ratio = 1.00
2. Taken bid (two or more bidders, bid-appraisal ratio = 1.00)
3. Two or more bidders, bid-appraisal ratio greater than 1.00 rounded to nearest 0.01.

Table 25.—Sale characteristics by volume size classes for all oral-auction Bureau of Land Management timber sales, east side, 1951-62

Volume size class	Competitive class[1]	Number of sales	Percent of sales in competitive class	Total number of bidders	Average number of bidders	Total volume sold	Percent size class	Weighted average bid-appraisal ratio av.=WBR/vol.
						M bd. ft.		
Less than 1 million feet	1	53	61.6	53	1.00	23,150	62.19	1.00
	2	1	1.2	2	2.00	475	1.28	1.00
	3	32	37.2	76	2.38	13,600	36.53	1.29
Totals or average by class		86	100.0	131	1.52	37,225	100.00	1.12
Percent of all sales by class		57 7	--	--	--	22.0	--	--
1-4.9 million feet	1	38	61.3	38	1.00	76,486	60.93	1.00
	2	1	1.6	2	2 00	1,647	1.31	1.00
	3	23	37.1	59	2.57	47,397	37.76	1.32
Totals or average by class		62	100.0	99	1.60	125,530	100.00	1.12
Percent of all sales by class		41.6	--	--	--	74.1	--	--
5-9.9 million feet	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	1	100.0	5	5.00	6,695	100.00	1.73
Totals or average by class		1	100.0	5	5.00	6,695	100.00	1.73
Percent of all sales by class		0.7	--	--	--	3.9	--	--
10-14.9 million feet	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
Totals or average by class		0	0	0	0	0	0	0
Percent of all sales by class								
15 million feet or more	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
Totals or average by class		0	0	0	0	0	0	0
Percent of all sales by class								
Total or average, all sales		149	100.0	235	1.58	169,450	100.00	1.16

[1] The three competitive classes are defined as follows:
1. One bidder, bid-appraisal ratio = 1.00
2. Token bid (two or more bidders, bid-appraisal ratio = 1.00)
3. Two or more bidders, bid-appraisal ratio greater than 1.00 rounded to nearest 0.01.

Table 26.—Sale characteristics by bid-appraisal ratio classes for all oral-auction Bureau of Land Management timber sales, west side, 1951-62

Bid-appraisal ratio class[1]	Number of sales	Percent of total sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Average volume per sale	Percent of total volume
					M bd. ft.	M bd. ft.	
1.00	913	30.3	950	1.04	2,327,759	2,550	30.6
1.01-1.10	258	8.6	539	2.09	715,845	2,775	9.4
1.11-1.20	239	7.9	574	2.40	615,683	2,576	8.1
1.21-1.30	254	8.4	696	2.74	700,563	2,758	9.2
1.31-1.40	241	8.0	692	2.87	559,500	2,322	7.4
1.41-1.50	217	7.2	657	3.03	545,913	2,516	7.2
1.51-1.60	213	7.1	650	3.05	533,344	2,504	7.0
1.61-1.70	161	5.3	511	3.17	370,383	2,301	4.9
1.71-1.80	127	4.2	431	3.39	299,987	2,362	3.9
1.81-1.90	92	3.1	318	3.46	251,580	2,735	3.3
1.91-2.00	69	2.3	240	3.48	180,956	2,623	2.4
Greater than 2.00	226	7.5	853	3.77	503,818	2,229	6.6
Total or average values	3,010	100.0	7,111	2.36	7,605,331	2,527	100 0

[1] Rounded to nearest 0.01.

Table 27.—Sale characteristics by bid-appraisal ratio classes for all oral-auction Bureau of Land Management timber sales, east side, 1951-62

Bid-appraisal radio class[1]	Number of sales	Percent of total sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Average volume per sale	Percent of total volume
					M bd. ft.	M bd. ft.	
1.00	94	63.2	101	1.07	102,346	1,089	60.4
1.01-1.10	15	10.1	26	1.73	13,793	920	8.2
1.11-1.20	6	4.0	13	2.17	5,253	876	3.1
1.21-1.30	10	6.7	23	2.30	16,145	1,614	9.5
1.31-1.40	6	4 0	20	3.33	4,586	764	2.7
1.41-1.50	2	1.3	5	2.50	3,377	1,688	2.0
1.51-1.60	3	2.0	8	2.67	2,258	753	1.3
1.61-1.70	2	1.3	5	2.50	393	196	0.2
1.71-1.80	1	0.7	5	5.00	6,695	6,695	4.0
1.81-1.90	0	0	0	0	0	0	0
1.91-2.00	2	1.3	5	2.50	2,922	1,461	1.7
Greater than 2.00	8	5.4	24	3 00	11,682	1,460	6.9
Total or average values	149	100.0	235	1.58	169,450	1,137	100.0

[1] Rounded to nearest 0.01.

Table 28.—Sale characteristics by year and quarter, for all oral-auction Bureau of Land Management timber sales, west side, 1951-62

Year and quarter	Number of sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Weighted average bid-appraisal ratio
				M bd. ft.	
1951					
1st quarter	18	30	1.67	39,611	1.15
2nd quarter	46	85	1.85	142,375	1.08
3rd quarter	19	29	1.53	59,474	1.40
4th quarter	24	47	1.96	82,530	1.20
Total or average	107	191	1.79	323,990	1.18
1952					
1st quarter	22	31	1.41	32,789	1.04
2nd quarter	37	54	1.46	104,866	1.16
3rd quarter	37	63	1.70	125,054	1.14
4th quarter	18	45	2.50	61,750	1.24
Total or average	114	193	1.69	324,459	1.15
1953					
1st quarter	22	48	2.18	54,140	1.11
2nd quarter	40	80	2.00	109,625	1.22
3rd quarter	47	67	1.43	61,335	1.14
4th quarter	48	114	2.38	118,047	1.14
Total or average	157	309	1.97	343,147	1.17
1954					
1st quarter	53	159	3.00	96,062	1.35
2nd quarter	81	183	2.26	192,121	1.33
3rd quarter	58	166	2.86	94,064	1.64
4th quarter	62	192	3.10	150,923	1.58
Total or average	254	700	2.76	533,170	1.46
1955					
1st quarter	45	159	3.53	72,844	1.69
2nd quarter	62	202	3.26	111,616	2.03
3rd quarter	38	113	2.97	91,170	1.86
4th quarter	51	157	3.08	174,240	1.54
Total or average	196	631	3.22	449,870	1.72
1956					
1st quarter	47	152	3.23	94,128	1.51
2nd quarter	112	263	2.35	246,743	1.27
3rd quarter	53	116	2.19	105,779	1.18
4th quarter	31	67	2.16	72,098	1.11
Total or average	243	598	2.46	518,748	1.27
1957					
1st quarter	43	93	2.16	77,079	1.26
2nd quarter	99	197	1.99	318,944	1.16
3rd quarter	54	124	2.30	78,766	1.19
4th quarter	49	102	2.08	155,535	1.18
Total or average	245	516	2.11	630,324	1.18
1958					
1st quarter	60	149	2.48	147,992	1.17
2nd quarter	100	229	2.29	309,370	1.20
3rd quarter	67	171	2.55	160,325	1.37
4th quarter	62	161	2.60	200,896	1.39
Total or average	289	710	2.46	818,583	1.27
1959					
1st quarter	55	174	3.16	134,389	1.60
2nd quarter	131	381	2.91	365,169	1.56
3rd quarter	71	188	2.65	210,991	1.31
4th quarter	66	177	2.68	174,951	1.24
Total or average	323	920	2.85	885,500	1.43
1960					
1st quarter	61	160	2.62	152,791	1.49
2nd quarter	160	396	2.47	467,531	1.49
3rd quarter	87	214	2.46	166,933	1.46
4th quarter	59	132	2.24	218,195	1.28
Total or average	367	902	2.46	1,005,450	1.44
1961					
1st quarter	42	114	2.71	105,742	1.37
2nd quarter	150	305	2.03	390,667	1.33
3rd quarter	97	180	1.86	180,676	1.27
4th quarter	70	130	1.86	204,666	1.26
Total or average	359	729	2.03	881,751	1.31
1962					
1st quarter	65	145	2.23	179,308	1.37
2nd quarter	131	249	1.90	335,252	1.25
3rd quarter	101	195	1.93	212,740	1.29
4th quarter	59	123	2.08	163,039	1.16
Total or average	356	712	2.00	890,339	1.27

Table 29.—Sale characteristics by year and quarter for all oral-auction Bureau of Land Management timber sales, east side, 1951-62

Year and quarter	Number of sales	Total number of bidders	Average number of bidders per sale	Total volume sold	Weighted average bid-appraisal ratio
				M bd. ft.	
1951					
1st quarter	0	0	0	0	0
2nd quarter	1	5	5.00	6,695	1.73
3rd quarter	1	1	1.00	2,060	1.00
4th quarter	0	0	0	0	0
Total or average	2	6	3.00	8,755	1.48
1952					
1st quarter	1	1	1.00	3,217	1.30
2nd quarter	0	0	0	0	0
3rd quarter	0	0	0	0	0
4th quarter	0	0	0	0	0
Total or average	1	1	1.00	3,217	1.30
1953					
1st quarter	4	4	1.00	2,686	1.01
2nd quarter	0	0	0	0	0
3rd quarter	2	3	1.50	2,238	1.08
4th quarter	3	3	1.00	4,003	1.00
Total or average	9	10	1.11	8,927	1.01
1954					
1st quarter	0	0	0	0	0
2nd quarter	1	1	1.00	460	1.00
3rd quarter	3	5	1.67	1,945	1.48
4th quarter	2	2	1.00	2,100	1.00
Total or average	6	8	1.33	4,505	1.29
1955					
1st quarter	3	3	1.00	3,717	1.00
2nd quarter	7	12	1.71	10,570	1.28
3rd quarter	2	4	2.00	551	1.20
4th quarter	4	11	2.75	1,814	1.10
Total or average	16	30	1.88	16,652	1.21
1956					
1st quarter	4	5	1.25	3,919	1.04
2nd quarter	8	16	2.00	9,567	1.14
3rd quarter	3	9	3.00	3,473	1.24
4th quarter	1	1	1.00	2,729	1.00
Total or average	16	31	1.94	19,688	1.13
1957					
1st quarter	0	0	0	0	0
2nd quarter	13	17	1.31	15,620	1.03
3rd quarter	1	1	1.00	321	1.00
4th quarter	2	2	1.00	818	1.00
Total or average	16	20	1.25	16,759	1.03
1958					
1st quarter	6	8	1.33	8,944	1.01
2nd quarter	11	19	1.73	13,631	1.32
3rd quarter	0	0	0	0	0
4th quarter	0	0	0	0	0
Total or average	17	27	1.59	22,575	1.18
1959					
1st quarter	0	0	0	0	0
2nd quarter	23	40	1.74	26,832	1.17
3rd quarter	1	1	1.00	1,065	1.00
4th quarter	0	0	0	0	0
Total or average	24	41	1.71	27,897	1.16
1960					
1st quarter	1	3	3.00	2,561	2.03
2nd quarter	11	17	1.55	18,917	1.02
3rd quarter	1	1	1.00	83	1.00
4th quarter	1	2	2.00	223	1.13
Total or average	14	23	1.64	21,784	1.07
1961					
1st quarter	0	0	0	0	0
2nd quarter	16	20	1.25	11,288	1.05
3rd quarter	1	2	2.00	544	1.23
4th quarter	2	3	1.50	565	1.01
Total or average	19	25	1.32	12,397	1.06
1962					
1st quarter	1	1	1.00	401	1.00
2nd quarter	5	7	1.40	4,949	1.12
3rd quarter	1	3	3.00	510	1.56
4th quarter	2	2	1.00	434	1.01
Total or average	9	13	1.44	6,294	1.15

Table 30.—Competitive characteristics by year for all oral-auction Bureau of Land Management timber sales, west side, 1951-62

Year	Competitive class	Number of sales	Percent of year sales	Total number of bidders	Average number of bidders	Total volume sold	Average volume per sale	Percent of year volume	Weighted average bid-appraisal ratio
						M bd. ft.	M bd. ft.		
1951	Noncompetitive sales	57	53.3	57	1.00	191,279	3,355.77	59.0	1.00
	Competitive sales	50	46.7	134	2.68	132,711	2,654.22	41.0	1.43
	Total	107	100.0	191	1.79	323,990	3,027.94	100.0	1.18
1952	Noncompetitive sales	67	58.8	69	1.03	205,638	3,069.22	63.4	1.00
	Competitive sales	47	41.2	124	2.64	118,821	2,528.11	36.6	1.39
	Total	114	100.0	193	1.69	324,459	2,846.13	100.0	1.15
1953	Noncompetitive sales	74	47.1	74	1.00	192,139	2,596.47	56.0	1.00
	Competitive sales	83	52.9	235	2.83	151,008	1,819.37	44.0	1.35
	Total	157	100.0	309	1.97	343,147	2,185.65	100.0	1.17
1954	Noncompetitive sales	58	22.8	59	1.02	138,572	2,389.17	26.0	1.00
	Competitive sales	196	77.2	641	3.27	394,598	2,013.26	74.0	1.62
	Total	254	100.0	700	2.76	533,170	2,099.09	100.0	1.46
1955	Noncompetitive sales	24	12.2	24	1.00	34,667	1,444.46	7.7	1.01
	Competitive sales	172	87.8	607	3.53	415,203	2,413.97	92.3	1.78
	Total	196	100.0	631	3.22	449,870	2,295.26	100.0	1.72
1956	Noncompetitive sales	60	24.7	61	1.02	121,347	2,022.45	23.4	1.00
	Competitive sales	183	75.3	537	2.93	397,401	2,171.59	76.6	1.36
	Total	243	100.0	598	2.46	518,748	2,134.77	100.0	1.27
1957	Noncompetitive sales	91	37.1	92	1.01	209,120	2,298.02	33.2	1.00
	Competitive sales	154	62.9	424	2.75	421,204	2,735.09	66.8	1.27
	Total	245	100.0	516	2.11	630,324	2,572.75	100.0	1.18
1958	Noncompetitive sales	78	27.0	80	1.03	227,371	2,915.01	27.8	1.00
	Competitive sales	211	73.0	630	2.99	591,212	2,801.95	72.2	1.38
	Total	289	100.0	710	2.46	818,583	2,832.47	100.0	1.27
1959	Noncompetitive sales	48	14.9	49	1.02	116,141	2,419.60	13.1	1.03
	Competitive sales	275	85.1	871	3.17	769,359	2,797.67	86.9	1.49
	Total	323	100.0	920	2.85	885,500	2,741.49	100.0	1.43
1960	Noncompetitive sales	81	22.1	81	1.00	187,340	2,312.84	18.6	1.00
	Competitive sales	286	77.9	821	2.87	818,110	2,860.52	81.4	1.53
	Total	367	100.0	902	2.46	1,005,450	2,739.65	100.0	1.44
1961	Noncompetitive sales	133	37.0	138	1.04	303,263	2,280.17	34.4	1.00
	Competitive sales	226	63.0	591	2.62	578,488	2,559.68	65.6	1.46
	Total	359	100.0	729	2.03	881,751	2,456.13	100.0	1.31
1962	Noncompetitive sales	144	40.4	145	1.01	382,381	2,655.42	43.0	1.00
	Competitive sales	212	59.6	567	2.67	507,958	2,396.03	57.0	1.47
	Total	356	100.0	712	2.00	890,339	2,500.95	100.0	1.27

Table 31.—Competitive characteristics by year for all oral-auction Bureau of Land Management timber sales, east side, 1951-62

Year	Competitive class	Number of sales	Percent of year sales	Total number of bidders	Average number of bidders	Total volume sold	Average volume per sale	Percent of year volume	Weighted average bid-appraisal ratio
						M bd. ft.	M bd. ft.		
1951	Noncompetitive sales	1	50.0	1	1.00	2,060	2,060.00	23.5	1.00
	Competitive sales	1	50.0	5	5.00	6,695	6,695.00	76.5	1.73
	Total	2	100.0	6	3.00	8,755	4,377.50	100.0	1.48
1952	Noncompetitive sales	1	100.0	1	1.00	3,217	3,217.00	100.0	1.30
	Competitive sales	0	0	0	0	0	0	0	0
	Total	1	100.0	1	1.00	3,217	3,217.00	100.0	1.30
1953	Noncompetitive sales	8	88.9	8	1.00	7,047	880.88	78.9	1.00
	Competitive sales	1	11.1	2	2.00	1,880	1,880.00	21.1	1.16
	Total	9	100.0	10	1.11	8,927	991.89	100.0	1.01
1954	Noncompetitive sales	4	66.7	4	1.00	2,964	741.00	65.8	1.00
	Competitive sales	2	33.3	4	2.00	1,541	770.50	34.2	1.71
	Total	6	100.0	8	1.33	4,505	750.83	100.0	1.29
1955	Noncompetitive sales	8	50.0	8	1.00	6,202	775.25	37.2	1.00
	Competitive sales	8	50.0	22	2.75	10,450	1,306.25	62.8	1.31
	Total	16	100.0	30	1.88	16,652	1,040.75	100.0	1.21
1956	Noncompetitive sales	8	50.0	8	1.00	12,126	1,515.75	61.6	1.00
	Competitive sales	8	50.0	23	2.88	7,562	945.25	38.4	1.34
	Total	16	100.0	31	1.94	19,688	1,230.50	100.0	1.13
1957	Noncompetitive sales	12	75.0	12	1.00	10,265	855.42	61.2	1.00
	Competitive sales	4	25.0	8	2.00	6,494	1,623.50	38.8	1.06
	Total	16	100.0	20	1.25	16,759	1,047.44	100.0	1.03
1958	Noncompetitive sales	10	58.8	10	1.00	17,088	1,708.80	75.7	1.00
	Competitive sales	7	41.2	17	2.43	5,487	783.86	24.3	1.61
	Total	16	100.0	27	1.59	22,575	1,327.94	100.0	1.18
1959	Noncompetitive sales	15	62.5	16	1.07	14,628	975.20	52.4	1.00
	Competitive sales	9	37.5	25	2.78	13,269	1,474.33	47.6	1.39
	Total	24	100.0	41	1.71	27,897	1,162.38	100.0	1.16
1960	Noncompetitive sales	8	57.1	9	1.13	12,357	1,544.63	56.7	1.00
	Competitive sales	6	42.9	14	2.33	9,427	1,571.17	43.3	1.20
	Total	14	100.0	23	1.64	21,784	1,556.00	100.0	1.07
1961	Noncompetitive sales	12	63.2	12	1.00	9,023	751.92	72.8	1.00
	Competitive sales	7	36.8	13	1.86	3,374	482.00	27.2	1.21
	Total	19	100.0	25	1.32	12,397	652.47	100.0	1.06
1962	Noncompetitive sales	6	66.7	6	1.00	4,781	796.83	76.0	1.00
	Competitive sales	3	33.3	7	2.33	1,513	504.33	24.0	1.47
	Total	9	100.0	13	1.44	6,294	699.33	100.0	1.15

APPENDIX C

Firms Classed as Large on the West Side

1. U. S. Plywood Corporation
2. Clemens Forest Products, Inc.
3. Cascades Plywood Corporation
4. Willamette Valley Lumber Co.
5. Diamond Lumber Company
6. Weyerhaeuser Company
7. Edward Hines Lumber Co.
8. Simpson Timber Co.
9. Rayonier Incorporated
10. Stomar Lumber Co.
11. Roseburg Lumber Co.
12. Pope and Talbot, Inc.
13. Medford Corporation
14. Timber Products Company
15. Scott Paper Company
16. Everett Plywood & Door Corporation
17. Mountain Fir Lumber Co.
18. Coquille Valley Lumber Co.
19. West Coast Plywood Co.
20. Santiam Lumber Company
21. Georgia-Pacific Corp.
22. Coos Head Timber Company
23. Steve Wilson Co.
24. Evans Products Company
25. St. Regis Paper Co.
26. International Paper Company
27. Crown Zellerbach Corp.
28. Olson Lawyer Lumber, Inc.
29. Rainier Manufacturing Co.
30. Puget Sound Plywood, Inc.
31. Eugene Plywood Co.
32. Fort Vancouver Plywood Co.
33. Hub City Plywood Corp.
34. Jones Veneer & Plywood Company
35. Longview Fibre Company
36. Plywood Products Corp.
37. Lane Plywood, Inc.

Firms Classed as Large on the East Side

1. Biles Coleman Lumber Co.
2. Weyerhaeuser Company
3. Edward Hines Lumber Co.
4. Boise Cascade Corporation
5. Brooks-Scanlon, Inc.
6. Kinzua Corporation
7. Ellingson Lumber Co.
8. J. Herbert Bate Co.

HE HEMLOCK SAWFLY
N SOUTHEAST ALASKA

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1968
FOREST SERVICE RESEARCH PAPER PNW-65

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D.C. SCHMIEGE

CONTENTS

INTRODUCTION

The hemlock sawfly, *Neodiprion tsugae* Midd., is a primary defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg., in southeast Alaska. Sawfly outbreaks have occurred with black-headed budworm, *Acleris variana* (Fern.), outbreaks resulting in defoliation of large acreages of western hemlock. A general collapse of black-headed budworm populations in 1965 throughout southeast Alaska left almost pure sawfly populations available for study. Since then, the sawfly has defoliated many acres of western hemlock, and heavily defoliated areas show some evidence of top-kill.

TAXONOMY

The hemlock sawfly was described by Middleton in 1933.[1/] Although it has been confused with closely related sawflies in some portions of its range, no related species are known to occur in Alaska in appreciable numbers. Sawfly larval and pupal collections sent to taxonomists have all been identified as *Neodiprion tsugae*.

STUDY AREAS

Sawfly populations were studied in tidewater western hemlock-Sitka spruce stands at Limestone Inlet and Taku Harbor on the mainland, and on Chichagof Island at Todd (fig. 1). Populations at Sitkoh, Trap, Crab, and Freshwater Bays on Chichagof Island were also sampled to determine the species and relative importance of sawfly parasites.

DISTRIBUTION AND HOSTS

The sawfly occurs throughout the range of its host, western hemlock, in southeast Alaska. Other species which may be defoliated are mountain hemlock, *Tsuga mertensiana* (Bong.) Carr.; Pacific silver fir, *Abies amabilis* (Dougl.) Forbes; and Sitka spruce, *Picea sitchensis* (Bong.) Carr. Whether sawfly females will oviposit on the latter three species is unknown.

LIFE HISTORY

Hemlock sawflies overwinter in the egg stage (fig. 2A). Eggs hatch in early June, and the larvae feed gregariously on old foliage (fig. 2B). As larvae mature, they disperse and feed singly. New foliage is fed on in the absence of old foliage. Larvae complete development in late July and spin cocoons (fig. 2C) on the foliage and in the litter beneath host trees. Cocoons spun on the host foliage are found most frequently in the lower tree crowns. Adult sawflies (fig. 2D) emerge from August through October, with males normally emerging earlier than females. The earliest record of cocoons in the field was July 12. Adults were observed in the field as late as October 15.

1/ Middleton, William. Five new sawflies of the genus Neodiprion Rohwer. Can. Entomol. 65(4): 77-79. 1933.

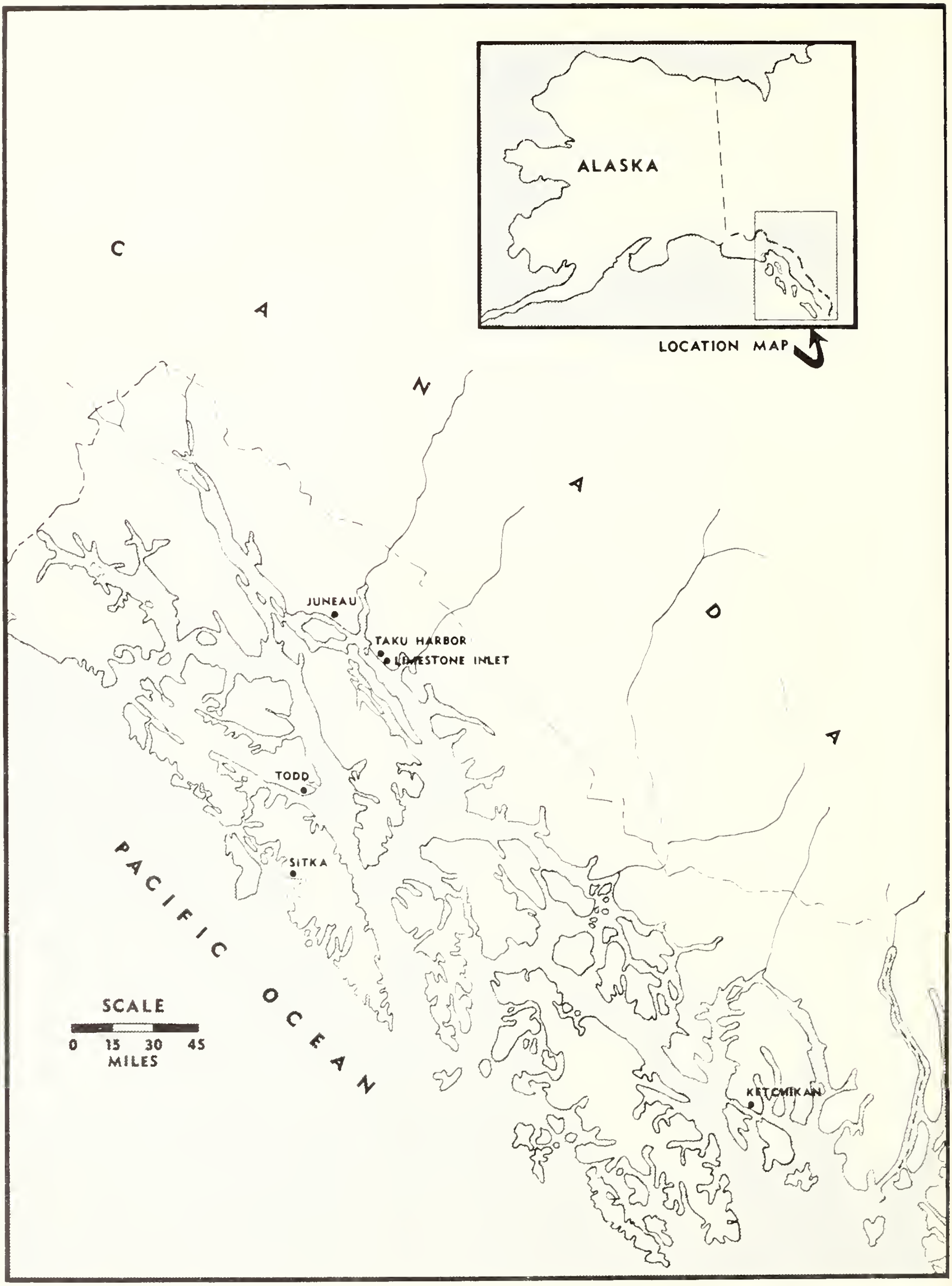

Figure 1.—Southeast Alaska.

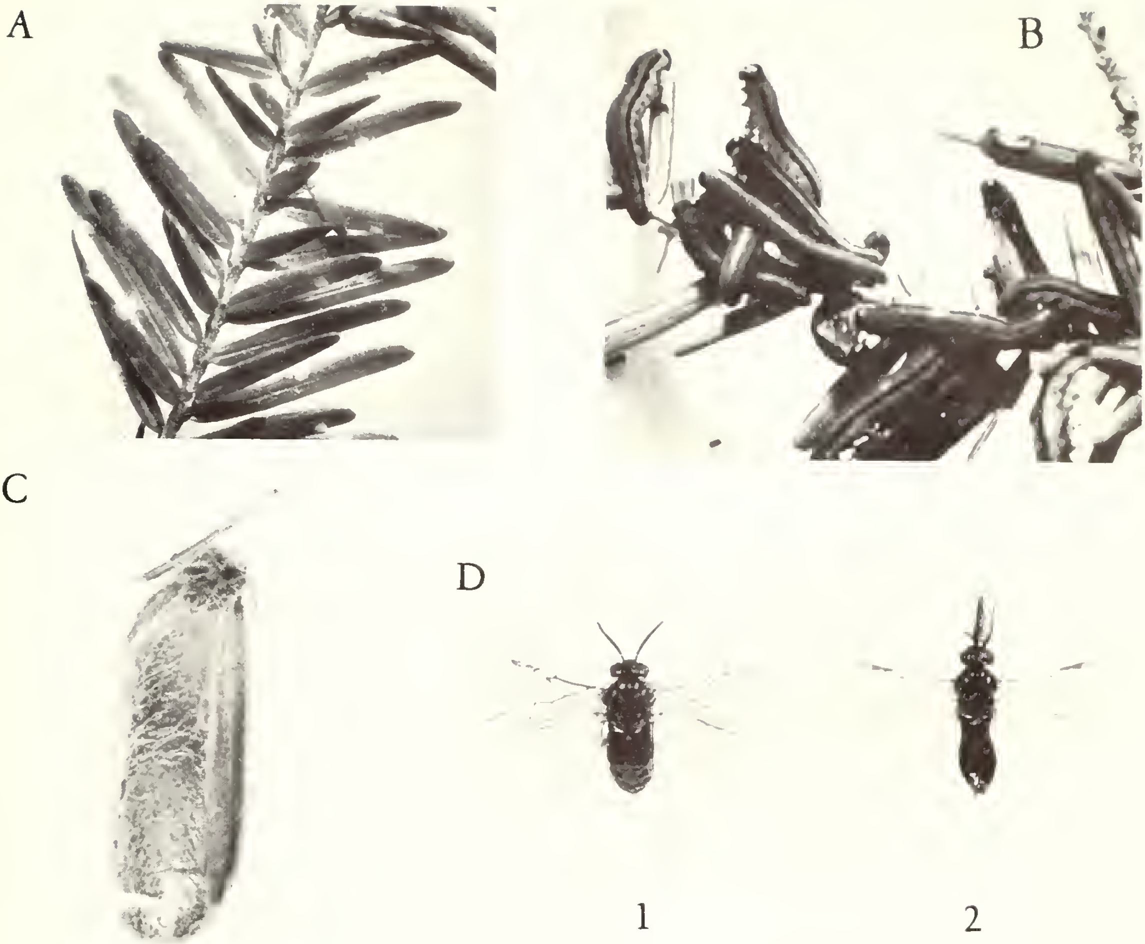

Figure 2.—Hemlock sawfly: A, Eggs on foliage; B, feeding larvae; C, cocoon; D, adults—(1) female and (2) male.

Although only one generation occurs annually, larvae of various sizes can be found from late June through August.

When adult females emerge, most of their eggs are mature, and mating occurs immediately. Of 81 captive females, some began ovipositing on the day of emergence, but others did not deposit eggs for several days. A mean of 3.4 days occurred from emergence to oviposition with a maximum of 12 days. Females deposit eggs singly in slits cut in the edge of needles, usually one egg per needle.

Hopping and Leech[2/] and Furniss and Dowden[3/] state that both sexes of larvae have five feeding instars. Our studies indicate that males have four

[2/] Hopping, G. R., and Leech, H. B. Sawfly biologies I. *Neodiprion tsugae* Middleton. Can. Entomol. 68(4): 71-79. 1936.

[3/] Furniss, R. L., and Dowden, P. B. Western hemlock sawfly, *Neodiprion tsugae* Middleton, and its parasites in Oregon. J. Econ. Entomol. 34(1): 46-52. 1941.

feeding instars and females five. A graph of frequency of larval head capsule sizes (fig. 3) shows five distinct peaks. When these five peaks were plotted over date of occurrence, however, the fourth and fifth peaks occurred simultaneously (fig. 4). This indicates four feeding instars for each sex, the fourth peak representing fourth-instar males and the fifth peak indicating fourth-instar females. Two additional late larval collections were made, and head capsule size frequencies plotted by sex (fig. 5, A and B). The male peaks, which include a few prepupal larvae, coincide in size range with the fourth peak of figure 3. The female peaks overlap the fourth

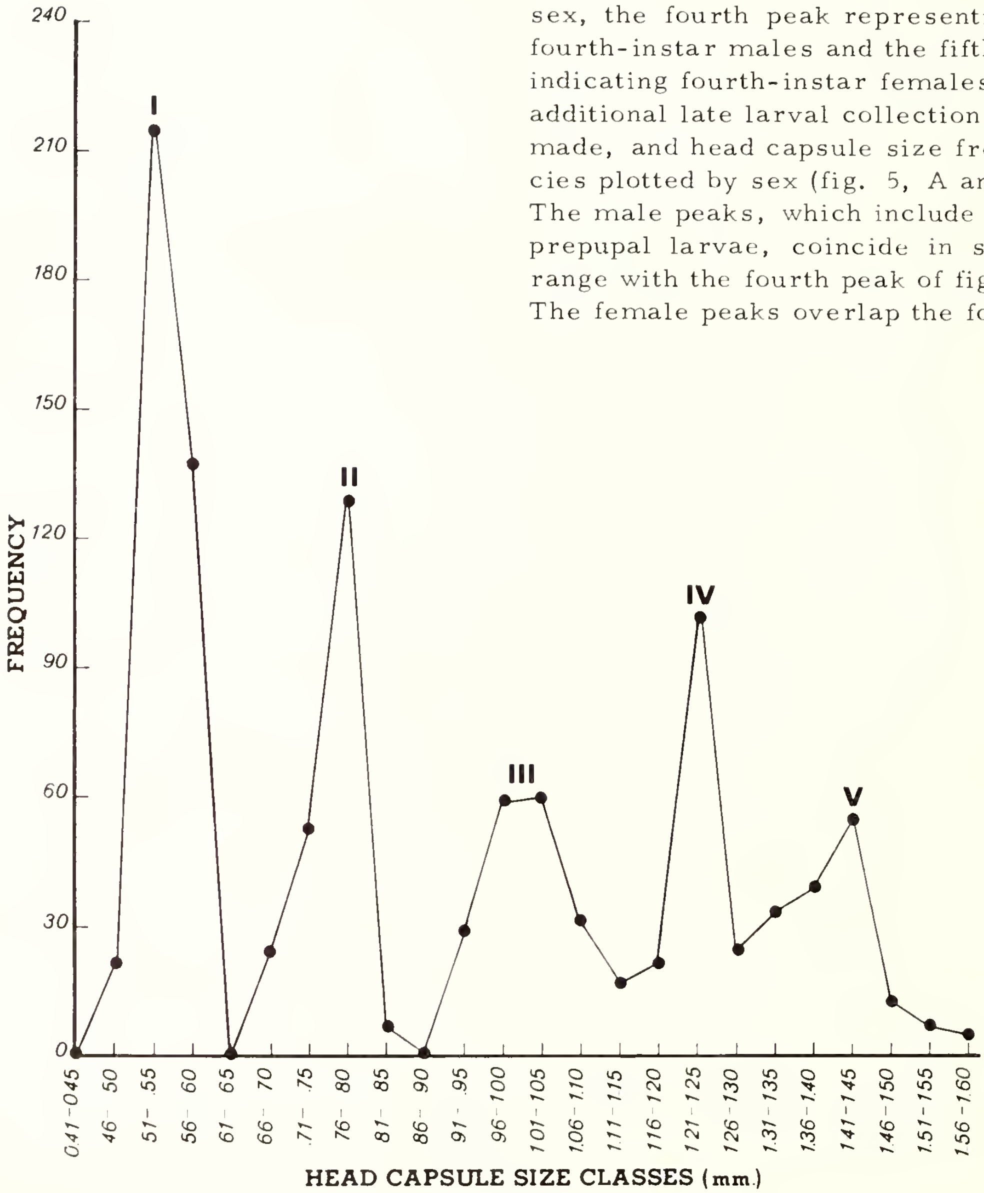

Figure 3.—Hemlock sawfly larval head capsule sizes (1,083 larvae), Limestone Inlet, 1961.

peak of figure 3, but the greatest frequency of females falls within the fifth peak of figure 3. This suggests that there are only four male sawfly feeding instars and five female feeding instars. The fourth peak of figure 3 is apparently composed of both sexes, and the fifth peak only females.

LARVAL SEXING

Larvae were sexed by slitting the integument of the fifth abdominal segment laterally and exposing one of the gonads (fig. 6). Female gonads were almost invariably smaller than male gonads.

LARVAL FEEDING

To determine needle consumption per larva and to compare survival of solitary versus group-reared larvae, we reared sawfly larvae on hemlock foliage in a field laboratory approximating field temperature and humidities.[4/] Forty-one larvae reared singly consumed an average of 79.98 SE± 44.70 needles per larva and 414 larvae group-reared in 42

[4/] Werner, R. A. Feeding and oviposition behavior of the hemlock sawfly. Unpublished progress report, Northern Forest Exp. Sta., Juneau, Alaska. 1964.

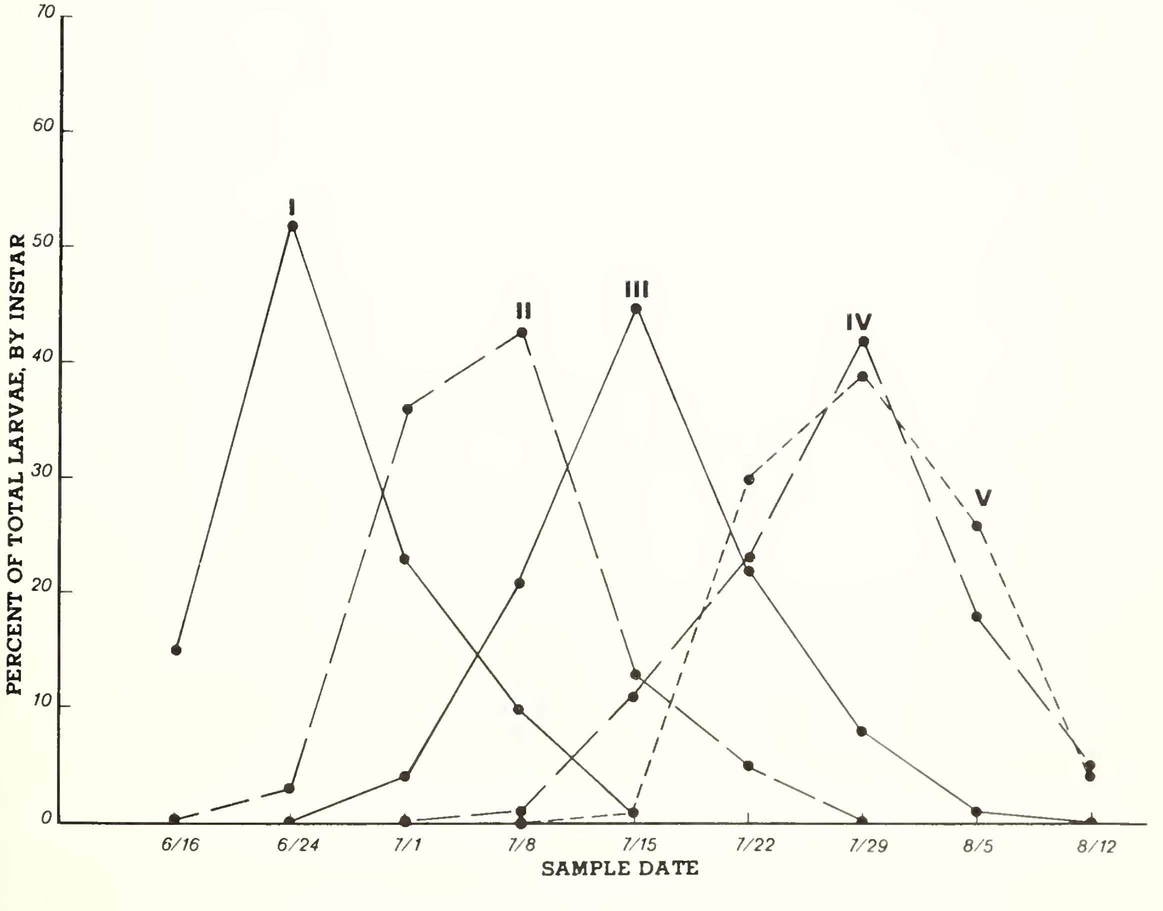

Figure 4.—Hemlock sawfly larval instar composition, Limestone Inlet, 1964.

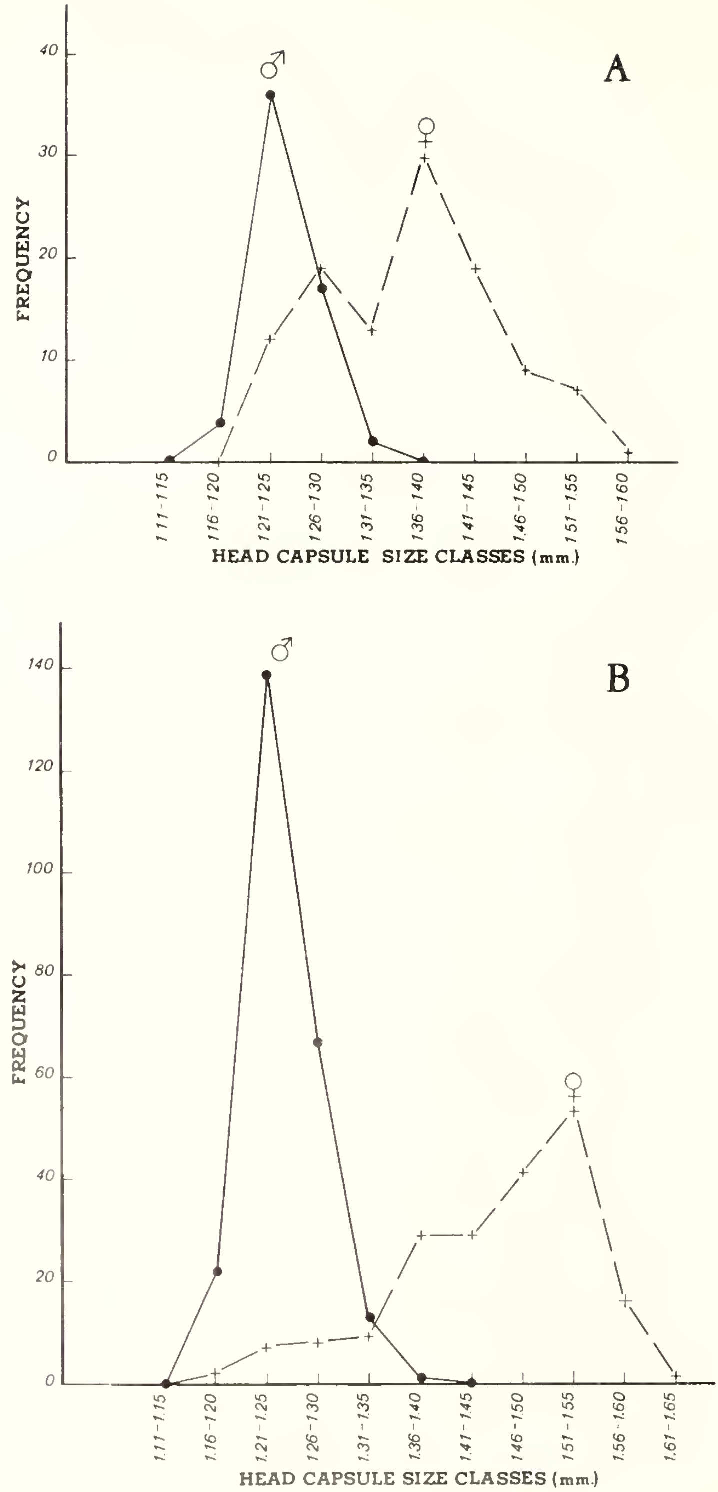

Figure 5.—A, Hemlock sawfly larval head capsule sizes by sex (169 larvae), Trap Bay, July 25, 1966; B, hemlock sawfly larval head capsule sizes by sex (439 larvae), Crab Bay, July 25, 1966.

Figure 6.—Hemlock sawfly mature larval gonads: *A*, male; *B*, female.

cages consumed an average of 82.38 SE ± 13.74 needles per larva. An F test showed no significant difference at the 5-percent level between single and group-reared larvae in needle consumption per individual. In addition, a chi-square test indicated no significant difference in percent survival between single and group-reared larvae. Therefore, group feeding has no apparent survival value over solitary feeding. Incidence of parasitization or predation of sawfly larvae could vary under the two types of feeding conditions, however.

COCOON SIZE RELATED TO SEX

Cocoon measurements indicate that size is a fairly reliable means of sexing sawflies within the cocoons. One hundred and fifty male cocoons had a mean length of 7.01 SD ± 0.29 mm. and a mean width of 2.65 SD ± 0.16 mm. (fig. 7, A and B). There was no overlap of male and female cocoon lengths within a range of two standard deviations. Therefore, more than 95 percent of the cocoon population could be sexed by measuring the length. This technique provides a useful tool for determining sex ratio of a field population prior to adult emergence. Comparing sex ratios of cocoons and emerging adults could reveal differential mortality of the sexes while in the cocoons.

FECUNDITY

In order to determine the reproductive potential of the sawfly, we allowed 81 females collected in the field as cocoons to oviposit. We then dissected them to determine the number of remaining mature eggs. The mean number of laid and unlaid eggs

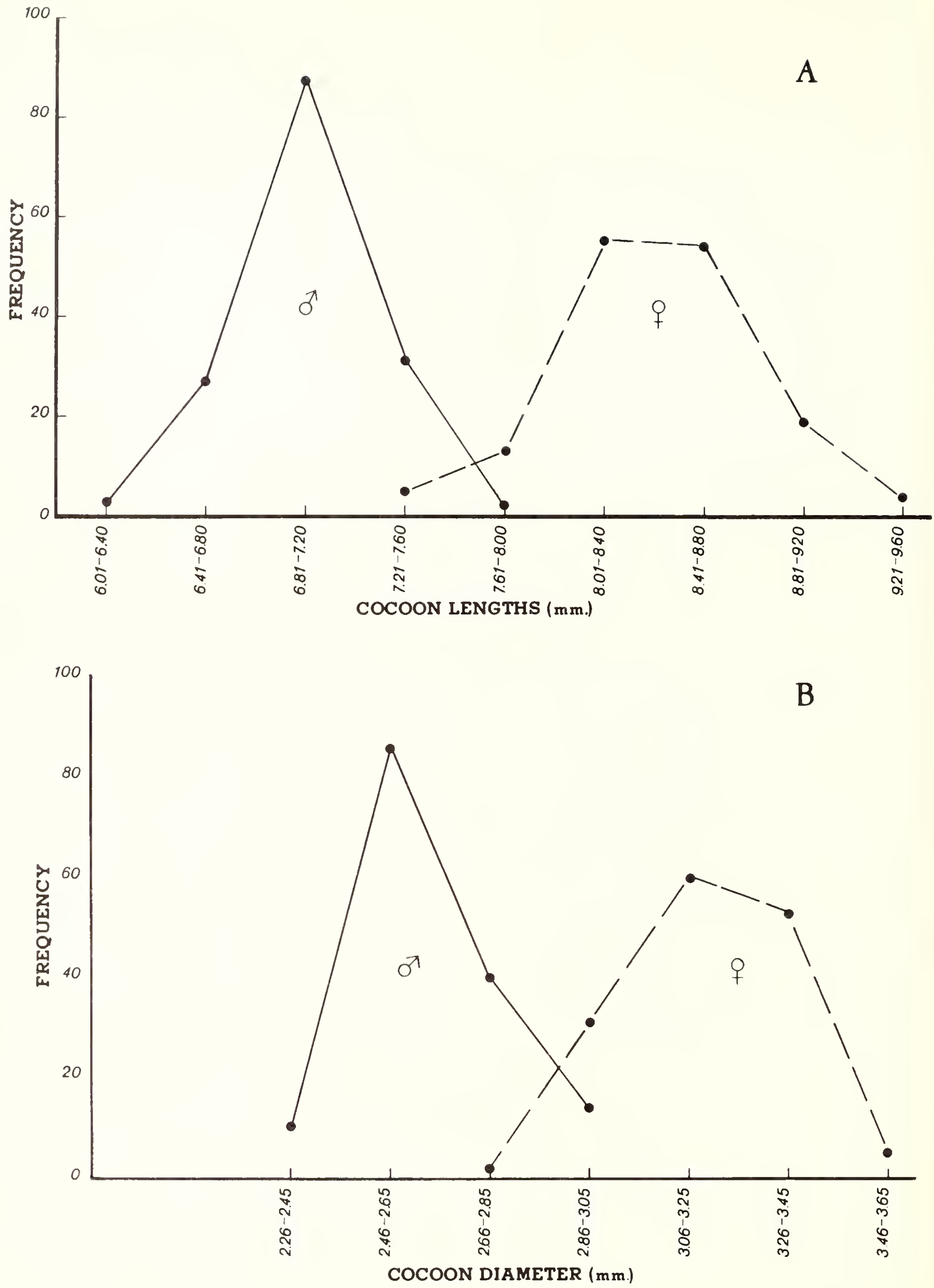

Figure 7.—A, Hemlock sawfly cocoon lengths by sex, Taku Harbor, 1963; *B,* hemlock sawfly cocoon diameters by sex, Taku Harbor, 1963.

for each female was 72.3 SE $\pm$ 1.9. Maximum range was 20 to 112. Hopping and Leech[5] dissected 10 females and determined a mean of 72.5 developed eggs. Range was from 61 to 103 eggs. Although fecundity varies with general health of individuals, it appears that approximately 72 eggs is close to the mean for a healthy hemlock sawfly population.

OVIPOSITION HABITS AND EGG DISTRIBUTION

Downing[6] and Furniss and Dowden[7] state that sawflies oviposit only on the current year's needles. We have observed eggs on both current and older foliage in the field, but oviposition predominated on the new foliage. A laboratory test of 24 ovipositing females showed no significant difference in egg deposition on current versus older foliage. A total of 117 eggs was laid on 176.6 linear inches of current year's foliage, and 121 eggs were laid on 173.3 linear inches of older foliage. The test was conducted in complete darkness to eliminate phototropic responses by the sawflies, and foliage was oriented horizontally to eliminate effects of geotropism. This test indicates that either phototropic or geotropic responses, or both, are responsible for heavier egg deposition on current foliage in the field.

In heavy sawfly infestations, two or more eggs may be deposited in a single needle. A chi-square test of 246 egg-bearing needles was made to determine whether a significant difference in oviposition occurred on distal versus proximal edges of needles (distal edges are the needle edges facing the shoot tip; proximal edges face the base of the shoot). Significantly more eggs (140) occurred on the proximal edges.

An additional chi-square test was made of 272 egg-bearing needles to determine whether a significant difference in oviposition occurred on apical versus basal halves of needles. Most eggs (234) occurred on the apical halves.

Upper and lower crowns of 126 hemlock trees in seven stands were sampled to determine sawfly egg distribution. Analysis of variance showed that there were no significant differences in egg deposition (1) between intermediate and dominant or codominant trees; (2) among fringe trees on the beach, trees inside the fringe, and trees up the slope to 500 feet; or (3) among 10-inch, 18-inch, and 36-inch branch-tip samples. There were significant differences in oviposition between upper and lower crowns in moderate to high egg-population levels, however. Almost twice as many eggs were laid on upper crown samples as on lower crown samples. This was not true at low population levels.

Laboratory tests of over 100 females were made at 59° F., 75-percent relative humidity, and in complete darkness or at 90 foot-candles light intensity to determine factors

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[5] See footnote 2.

[6] Downing, George L. Hemlock sawfly. U.S. Dep. Agr. Forest Pest Leafl. 31. February 1959.

[7] See footnote 3.

affecting oviposition. Egg counts showed that the ovipositing females were positively phototropic and negatively geotropic. This accounts, in part, for heavier egg deposition in upper tree crowns in the field. However, additional tests showed that females preferred to lay eggs on lower crown foliage as compared to upper crown foliage from the same trees. This preference overpowered phototropic and geotropic effects in the laboratory. Different environmental conditions such as greater light intensities that occur in the field could alter this preference. Whether the foliage preference is determined chemically or physically is unknown.

NATURAL CONTROL

Parasites.--Sawfly cocoons collected from foliage and litter in southeast Alaska yielded the following primary Ichneumonid parasites: *Opidnus tsugae tsugae* (Cushman), *Delomerista japonica diprionis* Cushman, *Itoplectis quadricingulatus* (Provancher), *Lamachus* spp., *Mastrus* spp., *Scambus (Scambus) nucum* (Ratzeburg), *Diadegma* sp., and *Rhorus* sp. *O. tsugae tsugae* accounted for more than half of the parasitized cocoons.[8] Total parasitism varied from 3 to 40 percent. No parasites have been collected from sawfly larvae or eggs.

Diseases.--Fungus diseases caused almost complete larval sawfly mortality at Limestone Inlet in 1964 and at Todd in 1967. The insects collected at Todd in 1967 were filled with resting spores of an entomophthorales fungus. Cool, moist conditions in southeast Alaska are favorable for fungi. No bacterial or virus diseases have been found in Alaska sawfly populations.

Other.--During the period of study, weather and predators did not cause noticeable sawfly mortality. However, mechanical injury and resultant drying of egg-bearing hemlock needles caused up to 34-percent overwintering sawfly egg mortality.[9]

SUMMARY

1. There is one generation of the hemlock sawfly each year, and the winter is spent as eggs.

2. There is some evidence showing that males undergo four feeding instars and females five.

3. Although young larvae are normally gregarious, some are solitary, and laboratory studies showed that single larvae survived as well as those reared in colonies.

4. Most pupae can be sexed based on cocoon size since there was no overlap of male and female cocoon lengths within a range of two standard deviations.

5. Females produced an average of 72 eggs.

6. Field collections of eggs showed that nearly twice as many eggs were laid per square foot on upper

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8/ Torgerson, Torolf R. Parasites of the hemlock sawfly, *Neodiprion tsugae* (Hymenoptera: Diprionidae), in coastal Alaska. (Ann. Entomol. Soc. Amer., in press.)

9/ Schmiege, D. C. Mortality of overwintering eggs of the black-headed budworm and hemlock sawfly in southeast Alaska. U.S. Forest Serv. Res. Note NOR-15. 1966.

tree crown samples as on lower crown samples at moderate to high egg-population levels.

7. Laboratory studies indicated that ovipositing females are positively phototropic and negatively geotropic. Despite this, and contrary to egg distribution in the field, foliage from lower crown areas was preferred over that of upper crowns.

8. Eight primary parasites have been collected from this sawfly. Fungus diseases may be responsible for sharp population declines, but adverse weather and predation have not been important control factors.

DATE DUE

SEP 30 1992	
Rec'd SEP 28 1992	