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Grading Options for Western Hemlock "Pulpwood" Logs From Southeastern Alaska

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Abstract

Properties and grade yield are estimated for structural lumber produced from No. 3, No. 4, and low-end No. 2 grade western hemlock logs of the type previously used primarily for the production of pulp chips. Estimates are given for production in the Structural Framing, Machine Stress Rating, and Laminating Stock grading systems. The information shows that significant amounts of higher grade structural lumber can be produced from these lower grade logs.

Keywords: western hemlock, grade yield, structural lumber, Alaska

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Research Highlights

In southeastern Alaska, large high-quality logs of western hemlock (*Tsuga heterophylla*) have traditionally been cut into export cants, and lower quality logs have generally been chipped for pulp. Although pulp chips are still being exported, the demise of local pulping facilities has greatly reduced markets for these lower quality logs. Product recovery studies conducted in the 1970s and 1980s did not focus on current grading systems for engineered wood products, such as wooden trusses, I-joists, and glued-laminated timbers. The objective of the study reported here was to estimate the grade yield of structural dimension lumber that can be obtained from lower quality western hemlock "pulpwood" logs.

A total of 409 logs were selected at random from inventory at a southeastern Alaska mill. The Puget Sound Log Scaling and Grading Bureau graded 89% of these logs as No. 3 or No. 4, 4% as No. 2, and 7% as "culls." The culls could not be processed in a commercial sawmill. Small-end diameter of the 32-ft- (9.8 m-) long logs ranged from 5 to 36 in. (130 to 910 mm); the small-end diameter of most of these logs was <12 in. (300 mm). The logs were sawn into nominal 2 by 4, 2 by 6, and 2 by 10 lumber[1] and visually graded as structural lumber by a Quality Supervisor of the Western Wood Products Association. All lumber graded as at least No. 3 Structural Framing in the rough, green condition (72% of total number of pieces of lumber produced) was dried, surfaced, and shipped to the Forest Products Laboratory in Madison, Wisconsin, for testing.

For dried and planed lumber, the results of this research indicate the following:

- As Structural Framing, No. 2 and better lumber is suited for framing and truss production and No. 3 for general construction. Approximately 50% of the dressed, dry lumber was graded as No. 2 and better, and 67% as No. 3 and better.
- As lumber for the production of glued-laminated structural timbers, about 28% of pieces qualified as L1, 17% as L2, and 17% as L3. For lamstock, the amount that qualifies as Dense is critical; 85% to 95% of the lumber qualified as Dense.
- Approximately 80% of machine-stress-rated (MSR) lumber is used in truss production and 20% for the production of wooden I-joists. Most trusses are made from 2 by 4 lumber. Two important grades for truss lumber are 1650f and 1800f. Approximately 33% of the 2 by 4 lumber could qualify as 1800f and 35% as 1650f. For 2 by 4 lumber of the highest grades, the yield of MSR lumber was often much higher than that of visually graded lumber with equivalent properties.

These results suggest the following conclusions:

- This research establishes that a significant amount of higher quality structural lumber can be produced from Alaskan hemlock logs that were once used primarily for the production of pulp chips.
- Most of this lumber would need to be kiln- or air-dried to be acceptable in the marketplace. This is especially true of MSR lumber and laminating stock. In this study, the yields of the higher grades of Structural Framing were improved by drying and surfacing.
- This study only considered yields from lower quality "pulpwood" logs. It is unlikely that a modern production-oriented mill would be established just to process such logs. A study is needed to evaluate yields from hemlock sawn from higher grade sawlogs.
- It is essential that markets be established for this lumber before production of a particular grade is considered.

The next steps for Alaskan mills interested in producing structural lumber are as follows:

1. Investigate potential markets and market requirements for specific types of lumber products.
2. Conduct a yield study at the mill for products of interest, using locally available logs.
3. Evaluate the economic feasibility of producing these specific lumber products.
4. Arrange certification by a grading agency certified by the American Lumber Standards Committee.

As is generally true with all the grading systems, markets are more easily found for higher grade lumber. The challenge is to find markets for the approximately 50% of the pieces that do not qualify as at least No. 2 Structural Framing and for the sawdust, bark, and slabs.

[1]Nominal 2- by 4-in. = standard 38- by 89-mm, 2- by 6-in. = 38- by 140-mm, and 2- by 10-in. = 38- by 235-mm. Lumber hereafter referred to as 2 by 4, 2 by 6, and 2 by 10.

Grading Options for Western Hemlock “Pulpwood” Logs From Southeastern Alaska

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Introduction

In southeastern Alaska, large high-quality logs of western hemlock (*Tsuga heterophylla*) have traditionally been cut into export cants and lower quality logs have generally been chipped for pulp. While pulp chips may still be exported, the demise of local pulping facilities has greatly reduced markets for these lower quality logs. Although product recovery studies were conducted on Alaskan hemlock in the 1970s and 1980s, these studies either focused on logs <14 in. (<360 mm) in diameter, did not relate lumber grade to log grade, or did not include structural grades and grading systems currently used for engineered products and structures. From the information available, it is not possible to obtain accurate estimates of utilization options for hemlock cut from the lower end of the log quality range. The objective of this study was to estimate the grade yield of structural dimension lumber that can be obtained from lower quality western hemlock logs of the type that have traditionally been pulped in southeastern Alaska. The study evaluated both visual and mechanical grades for a variety of lumber widths currently sold in domestic and Pacific Rim markets. It did not evaluate potential yield of structural lumber from the larger “sawlogs” that would be traditionally used for production of dimension lumber. Mills that are currently producing structural lumber have access to information on lumber recovery from sawlogs. Mills that are not currently producing structural products should conduct a recovery study on sawlogs.

Background

Forest Resources of Tongass National Forest

The Tongass National Forest covers an area of 16.9×10^6 acres (6.8×10^6 ha) in southeast Alaska. Of this, 2.4×10^6 acres (972×10^3 ha) have been tentatively judged suitable for timber production (Table 1) (USDA 1997). Because some of this area is being managed for other objectives, only approximately 576×10^3 acres (233×10^3 ha) are available for harvest (USDA 1999). About 61% of the timber volume on this land is hemlock, 28% Sitka spruce (*Picea sitchensis*), 6% yellow-cedar (*Chamaecyparis nootkatensis*), and 5% western redcedar (*Thuja plicata*). The small-end diameter of about 60% of the sawlogs is less than 29 in. (740 mm) and that of the remainder is larger than this dimension (Fig. 1). For spruce and hemlock, a significant proportion of these logs would grade as No. 2, No. 3, and Utility according to Forest Service “cruise” grades (Table 2).

Table 1—Distribution of land types on Tongass National Forest[a]

Land type	Area ($\times 10^3$ acres ($\times 10^3$ ha))
Nonforest	6,949 (2,812)
Forestland withdrawn	4,179 (1,691)
Nonproductive forests	2,400 (971)
Physically unsuited	524 (212)
Inadequate information	429 (174)
Tentatively suitable	2,400[b] (971)

[a]USDA 1997. Numbers reflect rounding.

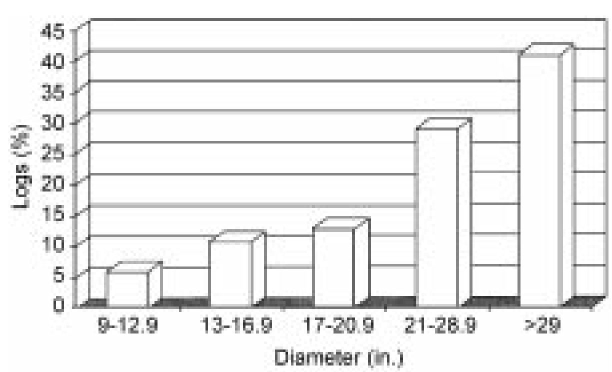

Figure 1—Size distribution of sawlogs on Tongass National Forest. 1 in. = 25.4 mm.

Table 2—Distribution of log grades for suitable timberland on Tongass National Forest[a]

Log grade	Distribution (% total)	
	Western hemlock	Spruce
Peeler, select, No. 1	7.0	4.9
No. 2	26.6	16.3
No. 3	18.2	6.1
Utility	17.2	3.7

[a]Walk 1997.

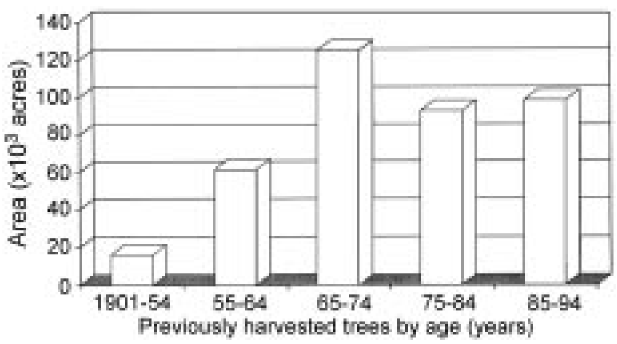

Figure 2—Age distribution of young-growth trees on Tongass National Forest. 1 acre = 0.405 hectare.

However, about 35% of the hemlock is graded as No. 3 and Utility. These lower quality hemlock logs have traditionally been pulped. With the closing of the last pulp mill in Alaska in March 1997, these lower quality hemlock logs represent the greatest opportunity to improved utilization.

Because of an expected harvesting rotation of about 80 years, a significant amount of the younger growth (stands cut since 1954) will not be available for 30 to 40 years (Fig. 2). However, this second-growth timber will have different species, size, and volume attributes than does the old-growth timber that is currently being harvested.

Structural Grading Systems

Several structural grading systems are used commercially for nominal 2-in.- (standard 38-mm-) thick dimension lumber (Forest Products Laboratory 1999).[2] Three visual grading systems and one mechanical grading system will be discussed here. In all three systems, western hemlock, including hemlock cut in Alaska, is sold in a marketing group called Hem–Fir. The Hem–Fir grouping includes western hemlock, California red fir, grand fir, noble fir, Pacific silver fir, and white fir. Of these, western hemlock and Pacific silver fir grow in southeastern Alaska (Viereck and Little 1972). These grading systems gain their legal authority through a system of model building codes and voluntary product standards used throughout Alaska, Hawaii, and the continental United States. This system is discussed for the full range of building products in Green and Hernandez (1998) and summarized for solid-sawn lumber in Appendix A.

Visual grading, the oldest stress-grading method, is based on visual assessment of growth characteristics and defects. The Light Framing visual grading system is used primarily in the western United States for lumber of nominal 2- to 4-in. (standard 38- to 89-mm) thickness and 2- to 4-in. (38- to 89-mm) width. The Structural Framing visual grading system is used throughout the United States for the higher grades of 2 by 4 lumber and for wider width lumber. The grade names used by these two systems are as follows:

Light Framing	Structural Framing[a]
Construction	Select Structural
Standard	No. 1
Utility	No. 2
Stud	No. 3

[a]Defined here as both Structural Light Framing and Structural Joist and Plank grades.

These grading systems have evolved over time. Prior to 1968 nominal 6-in. (standard 140-mm) and wider lumber produced in the western United States was assigned to Construction, Standard, and Utility grades. After 1970, the current system of restricting these grades to lumber nominal ≤4 in. (standard ≤89 mm) in width was adopted throughout the West. As will be described, the older yield studies on structural lumber from western species reported results for only Select Structural, Construction, Standard, and Utility grades, regardless of lumber width. Increasingly, however, Structural Framing lumber is being used in engineered structures such as wood trusses.

The concept of “strength ratio” may be used to gain some appreciation of the differences between Light Framing and Structural Framing grades. A strength ratio is the theoretical ratio of the strength of a piece of lumber containing defects (such as a knot) to that of the same piece of lumber if no defects were present. Table 3 shows the minimum bending strength ratio associated with each grade in both systems. By current grade rules, the minimum strength ratio of Standard grade in the Light Framing system is less than that of No. 3 in the Structural Framing system. Thus, older studies that report yields only as “Standard and better” provide little information about yields of the Structural Framing grades.

[2]Nominal 2- by 4-in. = standard 38- by 89-mm, 2- by 6-in. = 38- by 140-mm, and 2- by 10-in. = 38- by 235-mm. Lumber hereafter referred to as 2 by 4, 2 by 6, and 2 by 10.

Table 3—Assumed minimum bending strength ratios for visually graded structural lumber

	Strength ratio	
Lumber grade	Structural Light Framing	Light Framing
Select Structural	0.65	—
No. 1	0.55	—
No. 2	0.45	—
Construction	—	0.34
No. 3 and STUD	0.26	—
Standard	—	0.19
Utility	—	0.09

Table 4—Visual quality levels for MSR lumber from western species

Visual quality level	Edge knot displacement (% cross section)	F_b
1	1/6	≥2100
2	1/4	1500–2050
3	1/3	950–1450
4	1/2	0–900

Mechanically graded lumber offers the engineer a greater degree of consistency and reliability in structural properties than does visually graded lumber. Mechanically graded lumber also offers unique combinations of mechanical properties not available through visual grading that may enable the engineer to make more efficient use of the available forest resource—especially a lower coefficient of variation (COV) on modulus of elasticity (MOE) (Winistorfer and Theilen 1997). The system for machine-stress-rated (MSR) lumber uses both visual assessment of defects and nondestructive determination of flexural MOE to sort lumber into grades (Galligan and McDonald 2000, Brown and others 1997). Grade names for MSR lumber are a combination of the allowable bending stress (F_b) and the average allowable MOE (E) assigned to the grade. For example, a grade "name" of 1450f–1.3E is a grade assigned an allowable bending stress of 1,450 lb/in^2 and MOE of 1.3×10^6 lb/in^2. Most MSR lumber is used in the production of metal-plate wood trusses, with perhaps 20% used in the production of wood I-joists. The MSR grade assignment for western species is a combination of visual limitations and specifications on MOE. In assigning grade, the importance of knots, holes, and distorted grain on the edge of the piece is stressed. The percentage of the net cross section of the member that these edge characteristics may occupy limits F_b assignment, as shown in Table 4. There are also restrictions on general slope of grain and other characteristics.

A special set of visual grades is also available for lumber of western species to be used in glued-laminated timbers

Table 5—Distribution of log grades for western hemlock[a]

	Distribution (% total)	
Log grade	Mill length	Wood length
Peeler	0.2	0.4
No. 1	4.3	4.4
No. 2	45.0	33.2
No. 3	42.9	56.0
Cull	7.6	5.9

[a]Woodfin and Snellgrove 1976.

Table 6—Lumber grade yield from mill-length logs[a]

	Yield (%) from various grades			
Lumber grade	Peeler	No. 1	No. 2	No. 3
C & Btr Select[b]	45.8	39.2	15.0	1.1
Select Structural	4.1	5.1	10.8	9.1
Construction	20.6	17.1	25.4	29.8
Standard	16.1	15.5	22.1	28.6
Utility	8.5	16.1	20.5	24.7
Economy	4.5	7.0	6.1	6.6

[a]Woodfin and Snellgrove 1976.
[b]Common & better Select.

(glulam). Grade names for this system are L1, L2, and L3. Lumber meeting the visual requirements of L1 and L2 grades and having a specific gravity of 0.39 or higher at 12% moisture content may also qualify as "dense" (AITC 1993). The laminating grades of L1, L2, and L3 also limit the percentage of the cross section that a knot can occupy to the same visual quality levels as MSR. Laminating grades that combine visual characteristics with assessment of MOE are also produced. These "*E*-rated" grades would be required for higher strength glulam beams produced in the United States.

Grade Yield Studies of Alaskan Hemlock

Three previous Forest Service studies focused on grade yield of western hemlock logs from Alaska. Woodfin and Snellgrove (1976) sampled 30 logs at each of 12 locations in southeastern Alaska. At each location, the logs were chosen to represent the size and quality of timber available to any sawmill in that region, rather than the normal log mix at that mill. The logs were scaled according to rules of the Puget Sound Log Scaling and Grading Bureau. As might be expected, the majority of these logs were graded as No. 2 or No. 3 (Table 5). At the mill, the logs were cut into 10- to 28-ft (3.0- to 8.5-m) lengths and sawn primarily for the production of nominal 4- by 4- in. (standard 89- by 89-mm) "babysquares." From non-cull logs, recovery of green lumber was 48% of gross log volume. In contrast, recovery from cull logs was only 26%. Of the 335,400 board feet of lumber recovered, about 88% was nominal 4-in.- (standard 89-mm-) thick material. This lumber was graded according to rules of the West Coast Lumber Inspection Bureau (WCLIB 1956). The yield of sawn lumber by lumber and log grade is given in Table 6. The No. 2 and No. 3 logs yielded similar percentages of Construction, Standard, and Utility grades of lumber. Although this study provided good estimates of total product recovery from logs of all quality levels, it is not possible to estimate the yield of lumber in the Structural Framing, MSR, or glulam grading systems from these data.

Fahey (1983) evaluated product recovery from 365 lower quality "pulpwood" logs processed through either a stud or dimension mill. The diameter of all the logs was ≤14 in. (≤356 mm). Because of the small diameter of the logs, no information was taken on log grade. Based on surface characteristics, Fahey (1983) stated that most logs would have met requirements for the No. 2 grade. The logs were sawn primarily for production of nominal 2-in.- (standard 38-mm-) thick dimension lumber. For lumber sawn at a dimension mill, 53% of the log volume was recovered as dimension lumber.

Product	Log volume (%)
Chips	40.6
Sawdust	6.2
Rough green lumber	53.2
Dressed dry lumber	41.5
Shavings and shrinkage	11.7

At the dimension mill, about 68% of the lumber produced was 2 by 4 and 26%, 2 by 6 (Table 7). The grade name 1650f also appears in the results and seems unusual for visually graded lumber by current definitions. This is the allowable bending strength that was assigned to Select Structural Hem–Fir in the early 1980s. At that time, western hemlock had an allowable strength of 1,800 lb/in^2. We are not sure why Fahey (1983) decided to call this lumber 1650f rather than Select Structural.

A third study was conducted on the suitability of Sitka spruce and western hemlock logs recovered from beaches in southeastern Alaska for the production of lumber, pulp, and energy generation (Ernst and others 1986). Three classes of logs were evaluated: logs from live trees (control), from trees that had recently died ("recently dead"), and from trees that had been dead for a longer time ("older dead"). No information was presented on the grade of the logs. Logs were sawn at a dimension mill and a cant mill. No significant difference in percent yield (cubic recovery) was found between live and recently dead trees. For these classes, the recovery at the

Table 7—Recovery of nominal 2-in.- (standard 38-mm-) thick lumber from small-diameter hemlock logs[a]

	Recovery of mill dimension lumber (% log volume)	
Lumber grade	2 by 4	2 by 6
Select Structural	1.3	0.3
1650f	4.2	1.4
Construction or No.1	12.9	4.4
Standard or No. 2	23.1	11.4
Utility or No. 3	20.3	6.7
Economy	5.7	1.9

[a]Fahey 1983. Note: 2.3% logs were sawn as nominal 1- by 4-in. (standard 19- by 89-mm) lumber, 2.2% as 1- by 6-in. (19- by 140-mm) lumber, and 1.9% as 2- by 3-in. (38- by 62-mm) lumber.

Table 8—Grade yield for lumber cut from beached logs[a]

	Yield (% log volume)		
		Western hemlock	
Lumber grade	Sitka spruce	Live and recently dead	Older dead
Clear	3.3	7.6	3.8
Standard and better	65.0	60.5	53.3
Utility	19.4	20.9	25.8
Economy	12.3	11.0	17.1

[a]Ernst and others 1986.

dimension mill averaged 62% and for the older dead trees, 53%. For Sitka spruce, recovery averaged 61% for the live and recently dead trees. Insufficient logs were obtained for reliable estimates for older dead spruce. Standard and better lumber grade recovery averaged 65% for Sitka spruce (Table 8). For western hemlock, the recovery of Standard and better lumber averaged 60.5% for live and recently dead trees and 53.3% for older dead trees.

Summary

The information presented in this section indicates that the forest resource on the Tongass could sustain a supply of logs with diameters ≥29 in. (≥737 mm) for the next several decades. However, many of these logs are of lower grade and do not necessarily have an established market. It is also apparent that historical studies are of limited use in estimating the yield of structural grades of dimension lumber presently used for engineered wood products and structures. To help foster improved utilization of the forest resource in southeast Alaska, it is important to make estimates of grade yield for western hemlock logs from the lower end of the log quality range that formerly were pulped for chip production.

Materials and Methods

Sampling

A common practice in southeast Alaska is to "woods sort" logs into sawlogs (high grade, larger logs) and pulpwood logs (lower grade, generally smaller logs). These tree-length logs are then inventoried separately at the sawmill. At a mill on Prince of Wales Island in southeastern Alaska, 409 western hemlock pulpwood logs were selected at random from inventory. The logs were of random length in the range of 14 to 48 ft (4.3 to 14.6 m), with an average length of 32 ft (9.8 m). Small-end log diameter ranged from 5 to 36 in. (127 to 914 mm); for most logs, small-end diameter was ≤12 in. (≤305 mm) (Fig. 3). The logs were graded and scaled using the Scribner scale by a representative of the Puget Sound Log Scaling and Grading Bureau (Gray's Harbor 1982). The net log volume was 20,920 board feet. The logs were graded as follows: low end of No. 2 grade, 3.7% (15 logs); No. 3, 38.9% (159 logs); No. 4, 49.9% (204 logs); and cull, 7.5% (31 logs). The cull logs were too decayed and deformed to process.

Grading and Processing

The woods-length logs were cut into 14-ft (4.3-m) lengths prior to sawing and physically sorted by log grade. This length was chosen for handling and shipping convenience. The approximately 400 mill-length logs were painted on the ends; different colors of paint were used for each log grade. The logs were then processed through the mill, one log grade at a time. Based on recommendation of trends for domestic and Japanese markets, the logs were sawn to maximize production of 2 by 4, 2 by 6, and 2 by 10 lumber. The rough, green lumber was graded as Structural Framing by a Quality Supervisor of the Western Wood Products Association (WWPA 1998). All lumber with a rough green grade of No. 3 or better was shipped to Seattle, Washington, and dried by a conventional schedule in a commercial dry kiln. The Economy grade lumber was left in Alaska to minimize shipping charges. The dry lumber was then shipped to the Forest Products Laboratory (FPL) in Madison, Wisconsin, where it was re-graded by the same WWPA Quality Supervisor who had graded the rough green lumber. Each piece of lumber was graded as Structural Framing, as Lamstock, or by the visual requirements of MSR. The lumber was then placed in a conditioning chamber to equilibrate to approximately 15% moisture content.

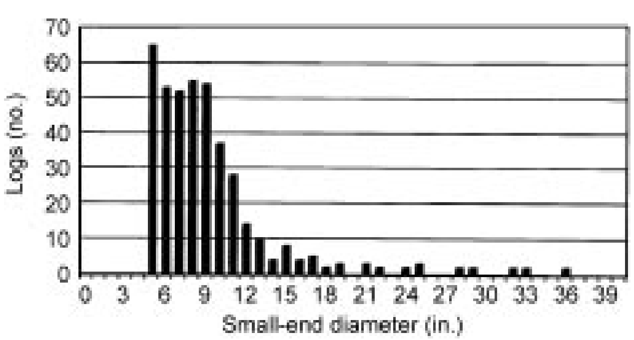

Figure 3—Size distribution of hemlock pulpwood logs from Alaska.

Testing

The primary objective of testing the lumber was to provide data with which to simulate MSR grades, not to assess the strength of lumber produced in any of the visual grading systems. To reduce the amount of testing, only those pieces with potential to qualify for an MSR grade were tested; that is, lumber with a visual quality level (VQL) of 4 or higher (Table 4). Potential effects of this type of sorting will be discussed in appropriate sections of the results. A flatwise dynamic MOE was determined for each piece selected for testing using transverse vibration procedures, MOE_{tv} (Ross and others 1991). The pieces were then tested in edgewise bending using third-point loading and a span-to-depth ratio of 21:1 (ASTM D4761, ASTM 1996), with the apparent worst defect as close to the middle of the test span as possible but randomly located with respect to the edge to be stressed in tension. After testing, a cross section was cut from near the point of failure for determining oven-dry moisture content and specific gravity (ASTM D4442, D2395–Method A).

MSR Simulation

Simulations were conducted on selected MSR grades from 1450f–1.3E to 2400f–2.0E. The same grades were simulated for both 2 by 4 and 2 by 6 lumber to help potential producers in assessing the resource quality with respect to MSR production. This does not imply that each of these grades is commonly produced in each of these widths, nor that it is undesirable to produce other grades. There was insufficient 2 by 10 lumber to conduct a meaningful computer simulation.

With MSR lumber, the grade yield for any one grade is affected by how many grades are being produced at the same time. Normally, at least two grades are produced at once. Producing more than three grades simultaneously is not common. To help judge the potential of the resource for the production of MSR lumber, we first simulated what the yield would be if only one MSR grade were produced at a time. This helped us to ascertain the highest grade useful to produce. One rule of thumb suggests that the yield of the highest grade should be at least 10% of the pieces graded. Following the initial simulations, additional simulations were done to illustrate the effect on yield of producing two grades simultaneously.

Table 9—Grade yield of Structural Framing from rough, green lumber[a]

Lumber grade	Number of pieces			Percentage of pieces				Percentage of volume			
	2 by 4	2 by 6	2 by 10	2 by 4	2 by 6	2 by 10	All	2 by 4	2 by 6	2 by 10	All
SS	43	106	19	3.7	8.4	10.8	6.5	1.2	4.6	1.4	7.2
No. 1	134	243	26	11.6	19.3	14.8	15.6	3.8	10.5	1.9	16.2
No. 2	310	344	61	26.8	27.3	34.7	27.6	8.8	14.9	4.4	28.1
No. 3	281	277	18	24.3	22.0	10.2	22.2	8.0	12.0	1.3	21.3
Economy	388	289	52	33.6	23.0	29.5	28.1	11.1	12.5	3.7	27.2
All	1,156	1,259	176	100	100	100	100	32.9	54.4	12.7	100

[a]SS denotes Select Structural.

Table 10—Grade yield of Structural Framing from dressed, dry lumber

Lumber grade	Number of pieces			Percentage of pieces				Percentage of volume			
	2 by 4	2 by 6	2 by 10	2 by 4	2 by 6	2 by 10	All	2 by 4	2 by 6	2 by 10	All
SS	114	203	26	10.1	16.3	15.0	13.4	3.3	8.9	1.9	14.1
No. 1	202	153	15	17.9	12.2	8.7	14.5	5.8	6.7	1.1	13.6
No. 2	218	298	50	19.3	23.9	28.9	22.2	6.3	13.1	3.6	23.0
No. 3	146	247	31	12.9	19.8	17.9	16.6	4.2	10.8	2.3	17.3
Economy	451	348	51	39.8	27.8	29.5	33.3	13.1	15.2	3.7	32.0
All	1,131	1,249	173	100	100	100	100	32.7	54.7	12.6	100

Results and Discussion

Structural Framing

The grade yield for the rough, green lumber graded in Alaska is given in Table 9. Note that because all pieces were 14 ft (4.3 m) long, grade yield by piece and by lumber volume would be equal for a given lumber width. Overall, 52% of the lumber was graded as No. 2 or better and 73% as No. 3 or better relative to the total board foot volume of the lumber. Although no directly comparable values are available, these yields would appear to be good for structural lumber from such low quality logs. From the perspective of a mill, 27% of the lumber did not make No. 3 grade. Generally, a mill producing Structural Framing makes its profits on the amount of No. 3 and better lumber (Standard and better for 2 by 4's), so finding a market for the lower 28% represents a real challenge.

The yields of dressed, dry lumber are given in Table 10. Like the yield for Structural Framing lumber, the grade yield of No. 2 and better lumber was about 50%. The yield of No. 3 and better was about 67%. It is generally noted that the number of pieces of lumber is higher in the upper grades for surfaced lumber compared to those for rough lumber. Because the same person graded all the lumber, this difference is believed to be primarily the result of the difficulty of seeing defects in rough lumber. As discussed previously, the pieces that graded lower than No. 3 based on rough, green dimensions were not taken to FPL for testing. The pieces that remained in Alaska, plus those pieces that were graded as Economy after arrival at FPL, are combined into the Economy grade in Table 10. Thus, we assumed that Economy pieces left in Alaska would not be given a higher grade after drying and surfacing. Although this assumption is not always correct, it should be conservative (that is, give a slightly lower yield in grades No. 3 or higher for dry lumber). Slight differences in the total number of pieces for a given size were the result of counting errors while at the mill and the loss of a few pieces in drying or shipping. The yield by log grade is shown in Table 11. Because of the limited number of pieces, a breakdown by log grade for 2 by 10's would not be meaningful.

For dressed, dry lumber, the yield of Construction grade 2 by 4's was 35 %. Because only those pieces that could make No. 3 grade were shipped to FPL, the yield of Standard grade 2 by 4's may not be meaningful (Table 3). This is because the No. 3 grade restricts knots on the edge of the wide face to a maximum of 1.75 in. (44.4 mm) whereas Standard allows a knot of up to 2 in. (51 mm) anywhere on the wide face.

Table 11—Grade yield of Structural Framing by log grade for dry Alaskan hemlock

	Number of pieces of dry lumber from individual log grades[a]					
	2 by 4			2 by 6		
Lumber grade	No. 2	No. 3	No. 4	No. 2	No. 3	No. 4
SS	12	52	50	32	129	42
No. 1	15	97	90	7	96	50
No. 2	25	116	77	28	173	96
No. 3	23	71	52	27	150	69
Economy	20	284	147	28	245	75

[a]Insufficient volume of 2 by 10's by log grade to make valid comparisons.

Table 12—Flexural properties of hemlock Structural Framing lumber[a]

Lumber grade	Pieces (no.)	MC (%)	SG (OD/OD)	MOE[b] ($\times10^6$ lb/in^2 (GPa))		MOR ($\times10^3$ lb/in^2 (MPa))		
				Mean	SD	Mean	SD	5th percentile
2 by 4								
SS	110	14.1	0.477	1.756 (12.108)	0.330 (2.275)	7.827 (53.967)	1.913 (13.190)	4.796 (33.068)
No. 1	197	13.9	0.467	1.649 (11.370)	0.390 (2.689)	6.836 (47.134)	2.473 (17.051)	3.184 (21.954)
No. 2	202	13.7	0.468	1.508 (10.398)	0.428 (2.951)	6.156 (42.446)	2.447 (16.872)	2.358 (16.258)
2 by 6								
SS	203	13.5	0.476	1.998 (13.776)	0.354 (2.441)	7.216 (49.754)	2.113 (14.569)	3.759 (25.918)
No. 1	152	13.3	0.462	1.841 (12.694)	0.356 (2.455)	5.272 (36.345)	1.926 (13.280)	2.316 (15.969)
No. 2	291	13.1	0.460	1.819 (12.542)	0.419 (2.889)	5.127 (35.351)	2.051 (14.142)	2.174 (14.990)

[a]MC is moisture content, OD ovendry, SG specific gravity, and SD standard deviation.
[b]MOE for edgewise orientation by static test.

Likewise, the yield of Utility grade would be biased because the maximum size of a wide face knot is 2.5 in. (64 mm). Thus, some pieces that remained in Alaska might have made Standard or Utility grade.

The properties of No. 2 and higher grades are summarized in Table 12. This information is provided to help the producer understand the quality of the resource. Because the normal range of log quality was not tested, the lumber properties are not directly comparable to data obtained in the U.S. in-grade testing program (Evans and Green 1987). For 2 by 4 and 2 by 6 lumber, only those pieces were tested that had a sufficiently high visual quality level (VQL 4 or better) to potentially qualify for MSR grades. This had little effect on the number of samples for a given grade except for No. 3. About half the No. 3 lumber would not qualify for MSR. For this reason, results for the No. 3 grade are not included in Table 12. The 2 by 10 lumber was not tested because there was not enough lumber to compare properties.

Laminating Stock

Another traditional use of hemlock is for the production of glulam beams. Table 13 shows the yield of the laminated grades obtained by visual grading (lam-grades) based on dressed, dry lumber. About 28% of all pieces was graded as L1, approximately 17% as L2, and 17% as L3. Again, this would appear to be a good yield of high quality lumber from logs that would have previously been used only for pulp production. The properties of this lumber are summarized in Table 14. Only those pieces that were tested for MOR, MOE by transverse vibration (MOE_{tv}), and specific gravity were included in this table. Thus, the sample sizes are somewhat lower than those shown in Table 10. Of the 2 by 4 lumber, 90% of L1 pieces and 84% of L2 pieces had a specific gravity of 0.39 or higher and would qualify as Dense. For 2 by 6 lumber, 94% of L1 pieces and 90% of the L2 pieces would qualify as Dense.

As mentioned previously, higher strength glulam beam must be produced using *E*-rated laminations. Table 15 provides

Table 13—Grade yield of Lamstock from dressed, dry lumber

Grade	Number of pieces			Percentage of pieces				Percentage of lumber volume			
	2 by 4	2 by 6	2 by 10	2 by 4	2 by 6	2 by 10	All	2 by 4	2 by 6	2 by 10	All
L1	300	347	64	26.5	27.8	37.0	27.8	8.7	15.1	4.7	28.5
L2	169	225	28	15.0	18.0	16.2	16.6	4.9	9.9	2.0	16.8
L3	161	239	21	14.2	19.1	12.1	16.5	4.6	10.5	1.5	16.6
Economy	501	438	60	44.3	35.1	34.7	39.1	14.5	19.2	4.4	38.1
All	1,131	1,249	173	100	100	100	100	32.7	54.7	12.6	100

Table 14—Properties of Alaskan western hemlock by Lamstock grade[a]

Size	Grade[b]	Pieces (no.)	MC (%)	SG (OD/test)	MOE_{tv} ($\times 10^6$ lb/in^2 (GPa)) Mean	MOE_{tv} SD	MOR ($\times 10^3$ lb/in^2 (MPa)) Mean	MOR SD	MOR 5^{th} percentile
2 by 4	L1	272	13.9	0.443	1.681 (11.590)	0.303 (2.089)	7.580 (52.264)	2.294 (15.817)	3.371 (28.243)
	L1 Dense	245	13.9	0.451	1.712 (11.804)	0.292 (2.013)	7.769 (53.567)	2.240 (15.445)	3.548 (24.463)
	L2	155	13.8	0.436	1.584 (10.922)	0.289 (1.993)	6.163 (42.494)	2.382 (16.424)	2.870 (19.789)
	L2 Dense	131	13.5	0.447	1.610 (11.101)	0.287 (1.979)	6.382 (44.004)	2.409 (16.610)	2.913 (20.085)
	L3	121	13.8	0.432	1.583 (10.915)	0.319 (2.200)	5.193 (35.806)	2.271 (15.659)	2.032 (14.011)
2 by 6	L1	323	13.5	0.445	1.782 (12.287)	0.287 (1.979)	6.760 (46.610)	2.222 (15.321)	3.217 (22.181)
	L1 Dense	303	13.5	0.450	1.800 (12.411)	0.282 (1.944)	6.878 (47.424)	2.197 (15.148)	3.423 (23.602)
	L2	203	13.3	0.434	1.658 (11.432)	0.249 (1.717)	4.936 (34.034)	1.767 (12.183)	2.295 (15.824)
	L2 Dense	182	13.1	0.442	1.686 11.625)	0.239 (1.648)	5.098 (35.151)	1.687 (11.632)	2.667 (18.389)
	L3	214	13.0	0.428	1.577 (10.873)	0.259 (1.786)	4.234 (29.193)	1.861 (12.832)	1.706 (11.763)

[a]MOE_{tv} denotes MOE by flatwise transverse vibration.
[b]Note that the Dense pieces are a subset of the L grades.

Table 15—Distribution of flatwise MOE values by transverse vibration for dressed, dry Alaskan hemlock by visual quality level

MOE_{tv} group ($\times 10^6$ lb/in^2 (GPa))	Distribution of MOE by visual quality level							
	2 by 4				2 by 6			
	1/6	1/4	1/3	1/2	1/6	1/4	1/3	1/2
	Pieces (no.)							
0.7 (4.8)	0	1	0	0	0	0	0	0
0.8 (5.5)	2	0	2	0	0	1	1	0
0.9 (6.2)	3	2	1	2	1	0	0	0
1.0 (6.9)	7	7	1	2	2	2	3	1
1.1 (7.6)	6	6	7	8	9	3	2	5
1.2 (8.3)	15	16	6	6	11	8	7	7
1.3 (9.0)	15	12	3	6	16	16	4	11
1.4 (9.7)	27	19	6	6	30	13	16	10
1.5 (10.3)	36	15	8	7	45	19	11	11
1.6 (11.0)	41	19	6	7	59	22	12	6
1.7 (11.7)	35	23	2	3	69	21	8	12
1.8 (12.4)	30	19	4	1	53	17	10	2
1.9 (13.1)	25	7	4	4	59	9	5	2
2.0 (13.8)	28	8	1	1	31	9	0	3
2.1 (14.5)	11	3	1	0	17	6	1	1
2.2 (15.2)	4	2	0	0	11	1	1	1
2.3 (15.9)	4	0	0	0	6	1	0	0
2.4 (16.5)	1	0	0	0	2	0	1	0
2.5 (17.2)	0	0	0	0	1	0	0	0
2.6 (17.9)	0	0	0	0	2	0	0	0
Mean MOE_{tv} ($\times 10^6$ lb/in^2 (GPa))	1.68 (11.59)	1.58 (10.89)	1.48 (10.20)	1.44 (9.93)	1.75 (12.07)	1.65 (11.38)	1.57 (10.83)	1.54 (10.62)
COV (%)	18.2	19.0	20.5	19.0	15.5	16.6	17.3	17.0

Table 16—Simulated grade yields of MSR lumber from Alaskan hemlock pulpwood logs based on pieces graded as No. 3 and better[a]

Size	MSR grade	Pieces of MSR	Pieces from visual falldowns from MSR					Total number of pieces
			SS	No. 1	No. 2	No. 3	VQL 5	
Sorting one MSR grade at once								
2 by 4	2400f-2.0E	104	74	151	180	46	548	1,103
	2100f-1.8E	207	40	120	143	45	548	1,103
	1800f-1.6E	368	0	59	90	38	548	1,103
	1650f-1.5E	388	0	47	84	36	548	1,103
	1450f-1.3E	461	0	0	66	28	548	1,103
2 by 6	2400f-2.0E	105	144	142	253	93	502	1,239
	2100f-1.8E	146	124	132	242	93	502	1,239
	1800f-1.6E	240	0	197	213	87	502	1,239
	1650f-1.5E	297	0	161	194	85	502	1,239
	1450f-1.3E	461	0	82	117	77	502	1,239
Sorting two MSR grades at once								
2 by 4 and	2100f-1.8E	207	0	0	0	0	0	—[b]
	1650f-1.5E	169	0	52	88	39	548	1,103
2 by 6 and	2100f-1.8E	146	0	0	0	0	0	—[b]
	1450f-1.3E	309	0	87	118	77	502	1,239

[a]Note that when grades are sorted one at a time, the number of pieces in lower MSR grades includes the pieces from a higher grade.
[b]Falldowns.

Table 17—Estimated percentage grade yields of Alaskan hemlock sorted as MSR lumber, from Table 16[a]

Size	MSR grade	MSR yield (%)	Yield from visual falldowns of MSR (%)					
			SS	No. 1	No. 2	No. 3	VQL 5	All
Sorting one MSR grade at once								
2 by 4	2400f-2.0E	9.4	6.7	13.7	16.3	4.2	49.7	100
	2100f-1.8E	18.8	0	14.5	13.0	4.0	49.7	100
	1800f-1.6E	33.4	0	5.3	8.2	3.4	49.7	100
	1650f-1.5E	35.2	0	4.3	7.6	3.2	49.7	100
	1450f-1.3E	41.8	0	0	6.0	2.5	49.7	100
2 by 6	2400f-2.0E	8.5	11.6	11.5	20.4	7.4	40.6	100
	2100f-1.8E	11.8	10.0	10.6	19.6	7.4	40.6	100
	1800f-1.6E	19.4	0	15.9	17.2	6.9	40.6	100
	1650f-1.5E	24.0	0	13.0	15.7	6.7	40.6	100
	1450f-1.3E	37.2	0	6.6	9.4	6.2	40.6	100
Sorting two MSR grades at once								
2 by 4 and	2100f-1.8E	18.8	0	0	0	0	0	—
	1650f-1.5E	15.3	0	4.7	8.0	3.5	49.7	100
2 by 6 and	2100f-1.8E	11.8	0	0	0	0	0	—
	1450f-1.3E	24.9	0	7.0	9.5	6.2	40.6	100

[a]Note that when grades are sorted one at a time, the number of pieces in lower MSR grades includes the pieces in a higher grade.

the distribution of MOE_{tv} values within a given edge knot class and the average MOE_{tv} for each class. This information could be used to make initial estimates of the yield of *E*-rated Hem–Fir for various glulam layups (AITC 1993).

Machine-Stress-Rated Lumber

Table 16 shows the number of pieces for selected MSR grades from the computer simulation. The percentage grade yield is shown in Table 17. According to current American Lumber Standards Committee guidelines, any lumber that fails to make an MSR grade (called falldowns) may be sold as visually graded lumber provided that the assigned allowable bending strength F_b for the visual grade is less than that of the MSR grade for which the lumber failed to qualify. For each MSR grade, or grade combination, Tables 16 and 17 also give the yield of falldowns by visual grade. The top section of each table shows simulated yields if only one MSR grade is produced at a time. For 2 by 4 lumber, approximately 19% of the lumber qualified as 2100f–1.8E MSR (Table 17). For 2 by 6 lumber, the grade must be dropped to 1800f to obtain about the same yield. The observation that yield of a given grade will drop with increasing lumber width will generally be true for MSR lumber and is a reflection of the effect of size on lumber strength. With visually graded lumber, allowable properties are adjusted to lower values as width increases (ASTM D1990, ASTM 1996). To simplify specification of MSR lumber, allowable properties for MSR grades traditionally have not been adjusted for width.

As already mentioned, producing two MSR grades simultaneously would affect the yield of the lower grade. For example, producing 2100f–1.8E 2 by 4 lumber in combination with 1650f–1.5E would not affect the yield of 2100f, but it would reduce the yield of 1650f from 35.2% to 15.4% (bottom section of Table 17). In addition, it would also affect the amount of falldowns available for sale as visually graded lumber.

However, the two grading systems cannot be easily compared on the basis of assigned properties. Table 18 shows the allowable properties for visually graded Hem–Fir lumber and the MSR grades simulated in this report. The grades for MSR lumber are determined by market demand, and they do not necessarily match those of visually graded lumber. For some customers (or some uses), lumber strength F_b may be the primary property of interest; for others, MOE. The last two columns of Table 18 "match" the MSR grades used in this report to the properties of the visual grades by F_b and then by E.

Suppose that a mill was approached by a customer who wanted primarily 2 by 4 lumber with a bending strength F_b of 2100f. For visually graded lumber, this would require Select Structural grade. From Table 10, we would estimate the yield at 10.1% for visually graded lumber. For MSR 2 by 4 lumber, the top grade could be set at 2100f–1.8E, with an estimated yield of 18.8%% (Table 17). However, if the customer were using No. 1 and better (No. 1 & Btr) as the top grade, an MSR grade of 1650f–1.5E would give an estimated yield of 35.2%, compared to a yield of 28.0% for visually graded No. 1 & Btr (add yields of No. 1 and Select Structural in Table 10).

If an MOE value of 1.8E were specified by the customer, this high a value cannot be achieved with traditional visually graded lumber (Table 18). If an MOE of 1.6×10^6 lb/in^2 were the primary selection criterion, then the estimated yield of 1800f–1.6E MSR would be 33.4% as compared to 10.1%

Table 18—Comparison of visual and selected MSR grades of Hem–Fir by bending strength (F_b) or MOE

	Visually graded		MSR matched[a]	
Size	Grade	Properties	by F_b	by E
2 by 4				
				2400f-2.0E
			2400f-2.0E	2100f-1.8E
	SS	2100f-1.6E	2100f-1.8E	1800f-1.6E
			1800f-1.6E	
	No. 1&Btr	1650f-1.5E	1650f-1.5E	1650f-1.5E
	No. 1	1460f-1.5E	1450f-1.3E	1650f-1.5E
	No. 2	1275f-1.3E		1450f-1.3E
	No. 3	750f-1.2E		
2 by 6				
			2400f-2.0E	
			2100f-1.8E	
	SS	1820f-1.6E	1800f-1.6E	1800f-1.6E
			1650f-1.5E	
	No. 1&Btr	1430f-1.5E	1450f-1.3E	1650f-1.5E
	No. 1	1260f-1.5E		1650f-1.5E
	No. 2	1100f-1.3E		1450f-1.3E
	No. 3	650f-1.2E		

[a]MSR grades other than those used in this report are available from WWPA (1998).

for visually graded Select Structural lumber. Additional comparisons could be made for other grades of 2 by 4's and 2 by 6's by using Tables 10, 17, and 18. For a discussion of the technical advantages of MSR lumber, see Winistorfer and Theilen (1997).

Implications

This study presents information on the anticipated yields of structurally graded lumber for western hemlock produced from Alaskan pulpwood logs. It is not likely that a commercial mill could profitably process only this type of log; however, this material could supplement lumber cut from higher quality sawlogs. Production of the lumber is of no use unless markets can be found and the lumber can be produced at a profit. Mills interested in producing a particular lumber product should first establish potential markets for their material. Then, they should conduct a yield study at their mill using available timber resources and the grades of lumber that are in demand. Only then will the mills have adequate information on which to make marketing decisions. As with all grading systems, it is generally easier to find markets for higher grade lumber. The challenge is to find markets for the approximately 50% of the pieces that did not make at least No. 2 grade, plus the sawdust, bark, and sawdust.

Conducting a market analysis using yield data such as given in this report is a tricky business, best left to companies or mills that intend to market the product. For example, this study presents information about grade yield for a wide range of grades and sizes. However, an individual mill must focus on those grades and sizes for which they can find customers. Deciding to produce lumber using two grading systems, a common situation, is further complicated because the grades produced in one system affect the yield of grades produced in the other system. Also, general trends in pricing for a product may not reflect what a particular mill can get for its product. A small mill can sometimes find a niche market that supports an activity that would not be profitable for a big mill. To aid mills in conducting their own market analysis, Appendix B outlines some considerations needed to extend the results presented in this report, or similar reports, to an analysis of market potential.

Conclusions

- This research establishes that a significant amount of higher quality structural lumber can be produced from Alaskan hemlock logs that were once used primarily for the production of pulp chips.
- Most of this lumber would need to be kiln- or air-dried to be acceptable in the marketplace. This is especially true of MSR lumber and laminating stock. In this study, the yields of the higher grades of Structural Framing were improved by drying and surfacing.
- This study only considered yields from lower quality "pulpwood" logs. It is unlikely that a modern production-oriented mill would be established just to process such logs. A study is needed to evaluate yields from hemlock sawn from higher grade sawlogs.
- It is essential that markets be established for this lumber before production of a particular grade is considered.

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Appendix A—Building Codes and Voluntary Products Standard PS–20

The system of model building codes and voluntary product standards for lumber in use throughout the United States ensures that the quality of these products is well established and reliable. However, this system can appear complicated and confusing to those new to the system. This appendix will briefly summarize the system as applied to structural lumber. A more detailed discussion, including the full range of structural wood products, may be found in Green and Hernandez (1998).

Building Codes and Product Standards

The regulation of building construction in the United States is accomplished through a document called a building code. A building code is a collection of laws, regulations, ordinances, or other statutory requirements adopted under the legislative authority of State or local governments. The code specifies the minimum acceptable construction requirements to protect public health and safety. Because of the complexity of issues faced by State and local governments in writing building codes, so called “model” building codes began to be developed early in the 20th century. These codes are intended to be the foundation upon which a legislative body can create its own regulations.

Currently, the three organizations in the United States that write model building codes are the

- International Conference of Building Officials (ICBO),
- Building Officials & Code Administrators International, Inc. (BOCA), and
- Southern Building Code Congress International (SBCCI).

Each is a non-profit organization owned and operated by voting members composed of representatives of city, county, and State governments who have adopted that organization’s model code, plus representatives from the Federal government. The Uniform Building Code of ICBO has been adopted by most States west of the Mississippi River, including Alaska (Fig. 4). In establishing comprehensive regulations for all types of building construction, model building codes excerpt or directly reference numerous standards promulgated by a variety of nationally recognized technical and trade organizations. The text of the building code describes how each referenced standard is to be used for regulation purposes. Organizations producing voluntary consensus standards for wood-based materials referenced by model building codes include the

- American Forest and Paper Association,
- American Society of Civil Engineers,
- American Society for Testing and Materials, and
- Department of Commerce.

Voluntary Product Standard PS–20

Standard PS–20 establishes nationally recognized requirements for the grading of lumber. This standard was developed by the American Lumber Standards Committee (ALSC) in accordance with procedures of the U.S. Department of Commerce and is administered by the National

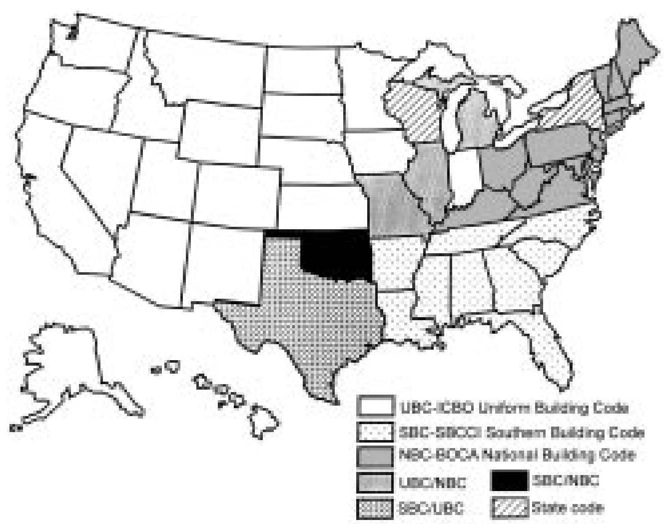

Figure 4—Current areas of model building code use in United States.

Institute of Standards and Technology (NIST). Members of ALSC are appointed by the Secretary of Commerce to constitute an independent consensus body. The ALSC consists of representatives from

- each agency that participates in the program and publishes and maintains grading rules and inspection facilities covering various species (rules-writing agencies),
- each lumber inspection agency participating in the program that does not publish grading rules (non-rules-writing agencies), and
- the construction community, including architects, engineers, general contractors, home builders, wood-using industries, millwork manufacturers, lumber wholesalers and retailers, and consumers.

The ALSC operates as an independent body with defined functions with regard to maintaining, implementing, and enforcing PS–20. The ALSC established the National Grading Rules Committee (NGRC) as an autonomous body charged with establishing and maintaining nomenclature and descriptions of lumber grades (Fig. 5). The NGRC is composed of members of rules-writing and non-rules-writing grading agencies, BOCA, ICBO, SBCCI, the American Society of Civil Engineers, the American Institute of Architects, consumer and distributor organizations, the Federal Highway Administration, the Defense Logistics Agency, NIST, and the Forest Products Laboratory.

The ALSC also established a Board of Review as an independent body composed of three elected members (Fig. 5b). The function of the Board is certification and accreditation of grade rules and allowable properties established by the NGRC and of agencies that wish to grade lumber under PS–20 provisions. PS–20 states that design values contained in grading rules shall be developed in accordance with appropriate standards of the American Society of Testing and Materials and other technically sound criteria. NIST, with the advice and council of the Forest Products Laboratory, is the final authority in regard to the appropriateness of such standards and criteria. Once grade marks are approved, Board-approved quality inspectors conduct periodic inspections to verify that grading agencies are following ALSC-approved procedures. Model building code for solid-sawn structural lumber is generally approved through recognition of the American Forest and Paper Association (AF&PA) National Design Specifications for Wood Construction.

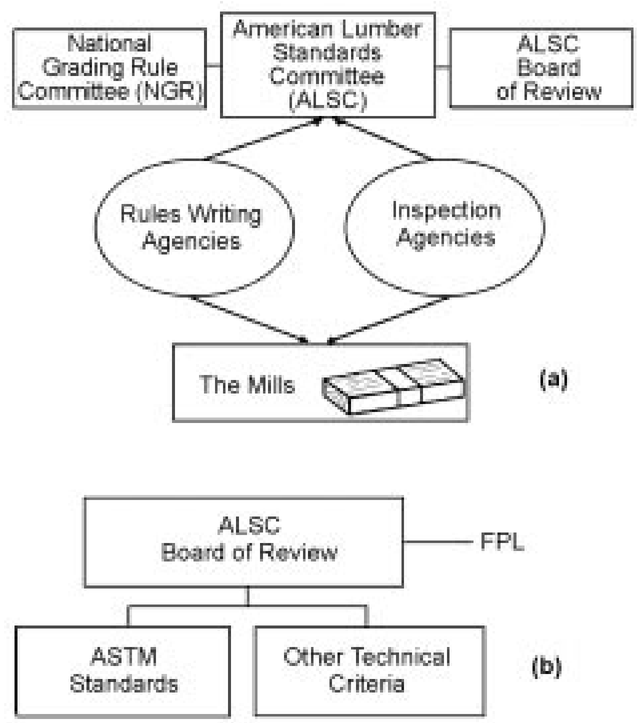

Figure 5—Relationship of American Lumber Standards Committee to other entities: (a) process for writing and implementing standards, (b) Board of Review. FPL is Forest Products Laboratory.

Selected Contacts

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Appendix B—Marketing Considerations

This appendix provides basic data from which a marketing analysis can proceed.[3] It does not provide an analysis as such because many variables that are essential to such an analysis must be addressed by individual companies or, in some cases, by individual production facilities. In addition, there are technical characteristics in any "case-study" type of analysis that must be recognized and interpreted by the end user as part of the market analysis. This appendix briefly outlines, in a general way, some considerations needed to extend the results presented in a yield study, such as this one, to an analysis of market potential.

Technical Characteristics of a Case Study

Sampling

Yield studies are necessarily based on samples of a larger population about which inferences are to be made. The limitations of sampling should be considered. All samples are estimates; however, if the size of the original sample was quite small or limited in any way as a result of practical limitations, the yield values obtained from the study may need to be adjusted by judgment prior to setting market targets.

Grades

The grades used in the yield study were selected to represent the range of quality expected in the sample. This allowed inferences about the effect of the grading system variables on grade yield. The selection was not intended to represent the actual grade mix that might ultimately be chosen for the market. Consequently, the results of the yield sample must be further adjusted to meet current or anticipated market needs. Here are some examples.

"**And better" grades—**One example of an "and better" (&Btr) grade is 2 by 4 No. 1&Btr under the American Lumber Standard system of stress grades for Structural Light Framing. This is a grade that includes both No. 1 and Select Structural grades, but the lumber may be grade stamped No. 1&Btr with no distinction between the constituent grades. In a yield study, both No. 1 and Select Structural may be identified to illustrate the amount of "and better" in the sample, but the yields will likely be merged by marketing personnel to
forecast sales yields.

[3] Source of information: William L. Galligan, Consultant, 5223 Verda Lane, NE, Salem, OR 53705–2398.

Another example is the Light Framing grade of 2 by 4 Standard and Better (Std&Btr). If a mill chooses not to grade Construction grade lumber separately, the mill is permitted to include this grade in the mix and stamp all pieces in the category as Std&Btr. Clearly, it is important that the study identify the amount of Construction-grade lumber; however, for sales purposes, Construction lumber may be grouped with Standard lumber and not separately identified.

"And better" market mixes—For lumber in the wider widths, sales are commonly based on grouping No. 1 and No. 2 lumber as No. 2&btr. As opposed to the No. 1&Btr grade that can be stamped on a combination of two grades (as previously discussed), both No. 1 and No. 2 lumber must be individually grade stamped even if commonly placed together in a bundle for sales. This is a case where sample yields of both No. 1 and No. 2 lumber are essential in a grade yield study so that the marketing expectations for the percentage of "No. 1" in the sales mix (called No. 2&btr) can be estimated. This market expectation can have significant price sensitivity.

Grading categories—In dimension lumber, the categories Light Framing and Structural Light Framing overlap in the characteristics permitted. In the West, Light Framing is commonly used for 2 by 4 and Structural Light Framing lumber for the higher grades of 2 by 4's. Structural Light Framing is used for all grades of wider width. To simplify a yield study, the grade analysis may be limited to the Structural Light Framing grades, or some grades of each category may be left out of the grade yield study. For example, the lower grade of Structural Light Framing (No. 3) is seldom sold in western species. As a result, the market analysis based on a yield sample that included No. 3 must convert the amount of No. 3 to Utility and Standard—perhaps in a side study, if the amount of No. 3 is significant. Clearly, the need for this type of refinement depends on the overall market potential of the study and the percentages of the grades in the study. Another example is measuring the amount of Select Structural lumber even if the mill has no intent of marketing that grade.

Mill Optimization

No sooner does a yield study arrive on the mill manager's desk than the mill begins to explore ways to further extend the "good news" and minimize the "bad news." If the study suggests promising results and the sample is judged by the mill to be adequate and representative, the "half life" of the results as accurate predictions can be very short; the insights of the study often immediately influence changes in mill practice even if the study recommendations are not followed.

Log Bucking and Breakdown

If the study suggests grade yields that can be improved by an adjustment in log bucking or breakdown, these adjustments will be addressed by the mill. In addition, the price of the end product is likely to be a function of length, which will be addressed in log breakdown and subsequent trimming. This will include market insights not included in the basic study, which is usually based on a limited number of lumber lengths. These insights include the inelasticity of the market for some lengths and the premiums for others.

Edging—Grades are often sensitive to width; that is, the yield may vary between widths because of the quality of the wood included in the piece—where it comes from in the log, the mill edging practice, and, consequently, the amount and quality of material incorporated in the piece. Mill studies on the effect of changing the edger settings for grade are not usually considered in initial yield studies. Furthermore, so-called "optimizing" edgers optimize primarily on volume, not grade, except as influenced by some grade characteristics such as wane.

Trimming—Grade can usually be significantly affected by trimming "for grade" in the mill. The mill will employ a "trim list" with price-related rules on the amount to trim a piece based on the potential up-grade (+) and loss of trim (–). This may be an automated operation. Yield studies can incorporate this information but seldom do because of the complication in data collection and analysis.

Grading—As carefully as a grading system is analyzed in a typical yield study, further scrutiny of the grading system will often generate more information needed for market analysis. This is because the grading system (or systems, because many mills are actually using more than one system simultaneously) is a family of grades—change one grade or introduce a new one and the grade yield of the adjacent grades shifts. It is even more significant when two of the grading systems employed are machine grading and visual grading because there are specifications on the grades permitted in simultaneous operation of the two systems. Market analysis should consider the entire spectrum of grades the mill can produce and should include mill insights on yield interactions that are anticipated because of mill experience.

Market Pricing

Any feasibility study is contingent upon the values assigned to the manufacturing costs and the market pricing. These are subject to both short- and long-term variation. A mill must make the assumptions most relevant to the operation and conduct sensitivity analysis on the results to include the effects of variability and uncertainty.

Availability of Pricing Data

Often no data are publicly available on grades such as those developed in machine grading or that are included within the "and better" market combinations. This makes it difficult to conduct a study of the impact of adding manufacturing efficiency to generate more product if the mill has no market experience in that product area. In some product areas, such as laminating lumber, grades are almost always sold in combinations, with re-grading taking place at secondary manufacture sites. In this instance, no prices are publicly reported; therefore, pricing of component grades requires networking with other companies or experience in the industry.

Relevance of Public Price Data

A word of caution is always needed in the use of published price data obtained from surveys. Commonly, this reflects some aspect of an average or consensus. These data may not represent the mill-specific product. Issues that may "shade" the published price include quality components, experience in the market, quantity available, reputation of the company, and conditions of sale.

Niche Markets

Pricing relevant to niche markets must be carefully evaluated to include the stability of the market, competition, actual end-use requirements, and mode of sale, including delivery. Niche markets are often based on company-to-company communication, and pricing can be linked to mutually acceptable measures of performance.