

# Lumber Recovery From Small-Diameter Ponderosa Pine From Flagstaff, Arizona

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**Abstract**—Thousands of acres of densely stocked ponderosa pine forests surround Flagstaff, AZ. These stands are at high risk of fire, insect, and disease outbreak. Stand density management activity can be expensive, but product recovery from the thinned material could help defray removal costs. This project evaluated the yield and economic return of lumber recovered from small-diameter, suppressed ponderosa pine. A sample of 150 trees ranging from 6 to 16 inches in diameter at breast height was selected. Half of the sample was sawn into dimension lumber and the other half into appearance grade lumber. This study yielded about 25 percent No. 2 and Better Common for appearance lumber with the majority of lumber (66 percent) graded No. 3 Common. About 50 percent of the dimension lumber was No. 2 and Better, with very little of the highest grade, Select Structural, produced. Volume recovery was slightly higher for dimension lumber, yet the lumber from the logs sawn for appearance grade was worth significantly more than that from the logs sawn for dimension lumber.

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## Introduction

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In 1998 it was estimated that 40 million acres of National Forest were at high risk of fire, disease, and insect outbreak because of increased stand density (Dombeck 1998). This acreage does not include forest land under other ownership. Some researchers believe that past forest management practices, such as fire suppression and livestock grazing, have altered forest conditions in ways that may increase these hazards (Sackett and others 1996). This is of special concern at the urban-wildland interface because of the risk of property damage and threats to public safety. A representative case study in northern Arizona (Mast and others 1999) found a rise in forest density from 60 trees/ha in 1876 to 3,000 trees/ha in 1992. This case study prescribed a forest restoration plan to return the forests to presettlement conditions. The plan involves thinning the dense understory of

stands to allocate more resources to overstory trees and thereby restore stand vigor and health. Costs for this type of management activity are high, and information regarding revenue from use of the extracted resource is minimal.

Historically, ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) was a commercially important species in the Southwestern United States. Past research (Ernst and Pong 1985; Fahey and others 1986; Fahey and Sachet 1993) to evaluate product recovery from this resource generally is not specific to suppressed stands and is limited to a few grading options not suitable for evaluating use in engineered structural products such as metal plate wood trusses, I-joists, and glulam beams. Erickson and others (2000) recently completed a grade yield study on small-diameter trees sampled from northern and central Idaho that provides some information on structural framing and machine stress rated (MSR) lumber yields for ponderosa pine sawn into 2 by 4s. The ponderosa pine trees sampled for this study were removals from densely stocked stands that were about 45 years old and thinned from below. The trees removed were smaller, 9-inches diameter at breast height (d.b.h.) or less, that were not dominant or codominant in the forest canopy. The lumber produced from these trees had poor yields in the higher visual grades and would not be suitable for production of MSR lumber. It should be noted, however, that grade yields from these thinnings might not be typical of small-diameter ponderosa pine that were dominant or codominant trees in a stand. Previous studies also have documented that drying degrade is a major cause of grade reduction with younger trees (Arganbright and others 1978; Blake and Voorhies 1980; Mackay and Rumball 1972; Markstrom and others 1984). Even though these past studies have shown that lumber cut from young-growth, small-diameter, ponderosa pine trees is prone to warp during drying, the extent of the problem in lumber from suppressed stands is not entirely clear.

To begin evaluating products from this resource, some basic information on lumber recovery, grade yield, and mechanical properties is needed. The Ecologically Sustainable Production of Forest Resources (ESP) team at the Pacific Northwest Research Station has been conducting product recovery studies for over 40 years. Since the early 1990s, the focus of the team's work in this area has been to quantify the types of wood products that might result from treatments designed to alter structural conditions and development trajectories in densely stocked, small diameter stands. The objective of these studies was to determine the value of these wood products and to incorporate this information into planning tools used to design treatments for these management activities (Fight 1997). Although many people tend to think of small trees as being young growth,

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it became evident that many trees from densely stocked stands were older (usually at least 60 years old), slow growing, and had small branches or knot indicators. Small diameter is defined differently depending on land management objectives. The d.b.h. range of trees (Douglas-fir, *Pseudotsuga menziesii* [Mirb.] France; western larch, *Larix occidentalis* Nutt.; and lodgepole pine, *Pinus contorta* Dougl. Ex. Loud.) from a previous study in northern Idaho was 6 to 14 inches. Results from this work (Lowell and others 2000; Willits and others 1997) showed that the quality (volume and grade yield) of this resource was similar to that found in larger diameter trees. Economic gains could be realized by using the lumber as a raw material for a variety of end **uses**, including engineered and value-added products.

This study was part of a larger project designed to evaluate product potential of the ponderosa pine resource and to determine if certain kiln drying techniques reduce drying defect. The objective of the portion of the study reported here was to determine the yield of structural and nonstructural lumber grades from small-diameter (in this case 6 to 16 inches d.b.h.), suppressed ponderosa pine and to compare the volume and value recovery of dimension versus appearance grade lumber from this resource.

## Procedures

### Tree Selection

Trees were selected from the Fort Valley demonstration project, Flagstaff, AZ. The demonstration project was set up in three experimental blocks with four treatment plots each. The experimental blocks represented different initial stand conditions; black jack (young-growth) pine, yellow pine (old growth) and a mixture of the two age groups. The treatments within the blocks were different thinning prescriptions designed to return stands to presettlement conditions. This involved thinning from below where the larger, older trees are retained. Trees to be left had been marked but no treatments had been applied prior to sample selection for this study. Sample trees came from three of the four treatment plots in the mixed age block.

A sample of trees ranging from 6 to 16 inches d.b.h. was selected by using a matrix consisting of six L-inch diameter classes. Trees selected were those that would have been removed under the silvicultural prescription. The sample was randomly divided into two subsamples, one to be sawn for dimension lumber and the other for appearance grade lumber.

### Logging

A crew from the ESP team was present during tree falling to record measurements from both the standing tree and bucked logs. Woods-length logs had a preferred length of 36 and 40 feet. Measurements included d.b.h., total height, age at stump height, length and diameter of all woods-length logs, length of breaks, and unutilized tops. Woods-length logs **were** tagged with a number that identified the tree and position in the tree from which it came. Logs were hauled to the cooperating mill for both long-log and short-log scaling.

## Log Measurements

After all woods-length logs were delivered to the mill, they were rolled out and scaled as presented. Logs were scaled by a Forest Service check scaler according to rules in the National Forest log scaling handbook (U.S. Department of Agriculture 1985) and by the Forest Service cubic scaling rules (U.S. Department of Agriculture 1991). Scaling deductions were itemized to show cause, location, and amount of each defect. Logs also were graded by using an appropriate log grading rule. The official scales for the study were cubic and Scribner. After scaling, woods-length logs were bucked into sawmill lengths (short logs) and scaled again, recording bucked lengths and diameters (to the nearest 0.1 inch). An ESP team member participated in scaling to ensure that all necessary data were collected.

## Log Processing

As the study logs were brought into the mill they were assigned a consecutive sawing number that was matched to the original tree number and log within that tree. One-half the sample was sawn into 2-inch dimension lumber (nominal sizes 2 by 4 and 2 by 6) with some 1-inch jacket boards sawn from the outer portion of the logs. The other half of the sample was sawn for 1-inch boards. Green lumber measurements were taken to enable calculation of the rough-green cubic volume of lumber, sawdust, and chips. Scientists from the Forest Products Laboratory (FPL) also measured warp on the green lumber.

## Board Data

After kiln drying, the lumber was surfaced to standard dressed dry dimensions. Each board grade, length, and width was tallied after the grading station. A Western Wood Products Association inspector graded the dimension lumber under the structural light framing grades; Select Structural, No. 1, No. 2, No. 3, and Economy (Western Wood Products Association 1998) and the type of grade-limiting defect was recorded. The appearance boards were graded under the board grades; #1 Common, #2 Common, #3 Common, #4 Common and factory lumber grades; Moulding, #3 Clear, 1 Shop, and 2 Shop (Western Wood Products Association 1998).

The 2 by 4 lumber was shipped to the University of Idaho for inclusion in an ongoing cooperative study between the FPL and the University of Idaho on mechanically grading lumber from small-diameter trees of Inland West species (Green and others 1997). An associate inspector of the Western Wood Products Association graded this subsample of lumber using the light framing (Construction, Standard, Utility), structural light framing (Select Structural, No.1, No.2, No.3), lamstock, and machine stress rated systems. Final grade assignment for the lamstock and MSR grades required determination of physical and mechanical properties. Results from this portion of the study will be reported separately.

The FPL determined the warp characteristics of lumber kiln dried in a conventional way and then determined the effect of presteaming and top loading, separately and in

combination, on warp. These results also will be reported separately.

## Analysis

Regression analysis was used to determine volume and value recovery of ponderosa pine by log small-end diameter. The best fitting model was selected on the basis of coefficient of determination ( $R^2$ ) and standard deviation about the regression ( $s_{yx}$ ). Models were developed by using a transformation of log small-end diameter as the independent variable. The dependent variable for volume was either percentage of cubic recovery or cubic volume of lumber per gross cubic log volume expressed as a percentage. Dollars per 100 cubic feet of log scale (\$/CCF) was the variable used for lumber value because it is a preferred measure of tree value. It is calculated by dividing the total value of lumber produced by the cubic scale (gross or net) of the log multiplied by 100. The results are dependent on the pricing structure in place at the time. Dollars per 100 cubic feet can be highly correlated with log diameter because log quality tends to increase with log size.

Analysis of covariance was used to determine if significant differences existed in volume and value recovery between logs sawn for appearance and dimension lumber.

## Results and Discussion

Tree and log data for each sample are given in table 1. The average age of the trees was 90 years old (range of 50 years to 120 years). Both samples of trees had very little scaled defect, less than 1.5 percent of the total cubic log volume.

### Volume Recovery

The percentage of cubic volume recovered as lumber was similar for logs sawn for dimension and appearance grade products (fig. 1). Table 2 contains the analysis of covariance (ANCOVA) statistics and table 3 presents the models and statistics for the volume recovery curves. The logs sawn for dimension lumber had a slightly higher volume recovery. This can be partially explained by the fact that fewer pieces of lumber were produced from each log. Fewer saw cuts were made so there was less loss to saw kerf, fewer boards means less overall loss to shrinkage during kiln drying, and there would be correspondingly less loss in planer shavings. About 10 percent of the volume of lumber produced from the dimension logs were 1-inch boards sawn from the outside portion of the log (table 4). The mean cubic recovery

Table 1—Sample statistics by the type of lumber product produced in this study.

Item	Appearance	Dimension
Number of trees	76	76
D.B.H. range (inches)	6-16	6-16
Avg. small diameter of log (inches)	7.0	7.0

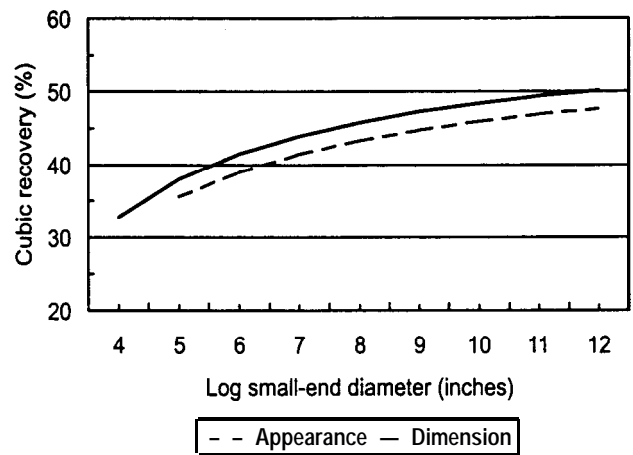


Figure 1—Percentage of cubic volume recovery (based on gross cubic log volume) by log small-end diameter from logs sawn for appearance and dimension products.

from logs sawn for dimension products was 42.7 percent while logs sawn for appearance lumber recovered 40.4 percent.

### Value Recovery

As illustrated in figure 2 (tables 3 and 5 show the models and ANCOVA, respectively), value of lumber differed significantly between the two product types, with appearance lumber worth more than the dimension lumber in the log diameter range sampled. The mean value of the appearance grade lumber was \$268 per 100 cubic feet (gross log scale), while the dimension lumber was only \$215 per 100 cubic feet. Prices used were from the Western Wood Products Association (1999) report summary through November 1999. No manufacturing costs are included in these values; so the real difference between the products thus would be less because manufacturing and handling costs for appearance lumber are greater owing to the larger number of pieces being produced.

Value recovery depends on both the volume and the lumber grade recovered from a log. Lumber grade recovery is important, with higher grades of lumber commanding higher prices. This study yielded about 25 percent No. 2 and Better Common for appearance lumber with the majority of lumber (66 percent) graded No. 3 Common (table 6). About 50 percent of the dimension lumber was No. 2 and Better (table 4), with very little of that in the highest grade.

Table 2—Analysis of covariance for percent cubic volume recovery.

Source	df	MSE	F-value	P-value
1/log SD <sup>a</sup>	1	6172.67	73.45	0.0001
Lumber product <sup>b</sup>	1	513.52	6.11	0.0139
Error	350	84.04		

<sup>a</sup>SD = Log small-end diameter.

<sup>b</sup>Appearance and dimension lumber

**Table 3**—Models for volume and value recovery curves shown in figures 1 and 2.

Dependent variable	Product	Model	R2
Cubic volume recovery	Appearance	$56.44 - (104.59*(1/SD))^a$ (2.02) <sup>b</sup> (12.2)	0.18
	Dimension	$58.66 - (104.59*(1/SD))$ (1.99)	
Dollars/CCF	Appearance	$342.92 - (2953.22*(1/SDSQ))^c$ (28.25) (-6.80)	0.25
	Dimension	$244.40 - (1161.41*(1/SDSQ))$ (22.95) (-3.09)	

<sup>a</sup>SD = Log small-end diameter.  
<sup>b</sup>Numbers in parentheses are standard errors of estimates.  
<sup>c</sup>DSQ = Log small-end diameter squared.

**Table 4**—Lumber grade recovery from logs sawn for dimension grade products.

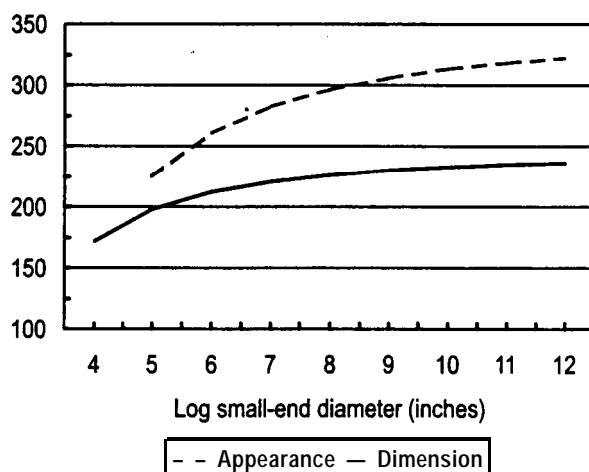
Board grade	Lumber volume
	Percent
#1 Common	<1
#2 Common	2
#3 Common	5
#4 Common	2
Moulding	<1
3 Clear	<1
1 Shop	<1
2 Shop	<1
Select Structural	<1
#1	4
#2	46
#3	31
Economy	9

**Table 5**—Analysis of covariance for value recovery (dollars per 100 cubic feet).

Source	df	MSE	F-value	P-value
1/log SDSQ <sup>a</sup>	1	219487.43	5.14	0.0001
Lumber product <sup>b</sup>	1	158961.34	37.22	0.0001
Product*SDSQ	1	41622.89	9.75	0.0019
Error	349	4270.43		

<sup>a</sup>DSQ = Log small-end diameter squared.  
<sup>b</sup>Appearance and dimension lumber.

Lumber grades are dependent on a variety of board characteristics. Appearance grades (Factory lumber and Boards) are based on characteristics such as stain, pitch pockets, unsound wood, slope of grain, knot size, and wane. Structural lumber is graded on characteristics that affect its strength. Knot type and placement becomes a factor under grading systems for structural lumber. The amount of juvenile wood can also affect the mechanical properties of lumber graded for structural applications. Dimension lumber that can be graded for structural applications (either visually or mechanically) commands a higher price. The research conducted by Erikson and others (2000) indicated



**Figure 2**—Value in dollars per 100 cubic feet (CCF) by log small-end diameter from logs sawn for appearance and dimension products.

**Table 6**—Lumber grade recovery from logs sawn for appearance grade products.

Board grade	Lumber volume
	Percent
#1 Common	3
#2 Common	22
#3 Common	66
#4 Common	7
Moulding	<1
3 Clear	<1
1 Shop	1
2 Shop	1

that the lumber manufactured from their ponderosa pine sample yielded a very small proportion of lumber suitable for structural applications. The lumber sawn for this study indicated that just by producing a different primary product (appearance lumber), a gain in value was realized.

Previous work (Lowell and others 2000) shows that there are opportunities to increase the value of appearance lumber through further processing into cut-stock material. The study found boards graded No. 3 Common had the largest increase in value when comparing value as a single piece of lumber versus value as cut-stock material. Board width also influenced yield and value of clear cuttings with 6-inch wide boards being higher in value as cut-stock than lumber. The resource from Flagstaff, AZ, used in this study had a high yield of appearance lumber graded #3 Common and about 60 percent of the boards were 6 inches or greater in width. While the Flagstaff study did not involve evaluation of cut-stock production, there may be an opportunity to recover more value from this material with further processing into secondary products.

## Conclusion

Old-growth ponderosa pine traditionally has been used in appearance applications. The results of this study indicated that lumber from small-diameter ponderosa pine growing in densely stocked stands in the Flagstaff, AZ, area has characteristics that make it more valuable as appearance grade lumber than dimension lumber. Results from this study indicated that the wood characteristics of small-diameter ponderosa pine growing in densely stocked stands have sufficient value to warrant its processing for primary products and also may have the potential for secondary processing as a resource for the moulding and millwork industries. This information can be used with new technology and emerging processes to direct this resource to an appropriate end use, where as much value as possible may be captured from the resource to offset restoration costs.

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