Wood Quality… Impact on Product Yields, Grades and Values

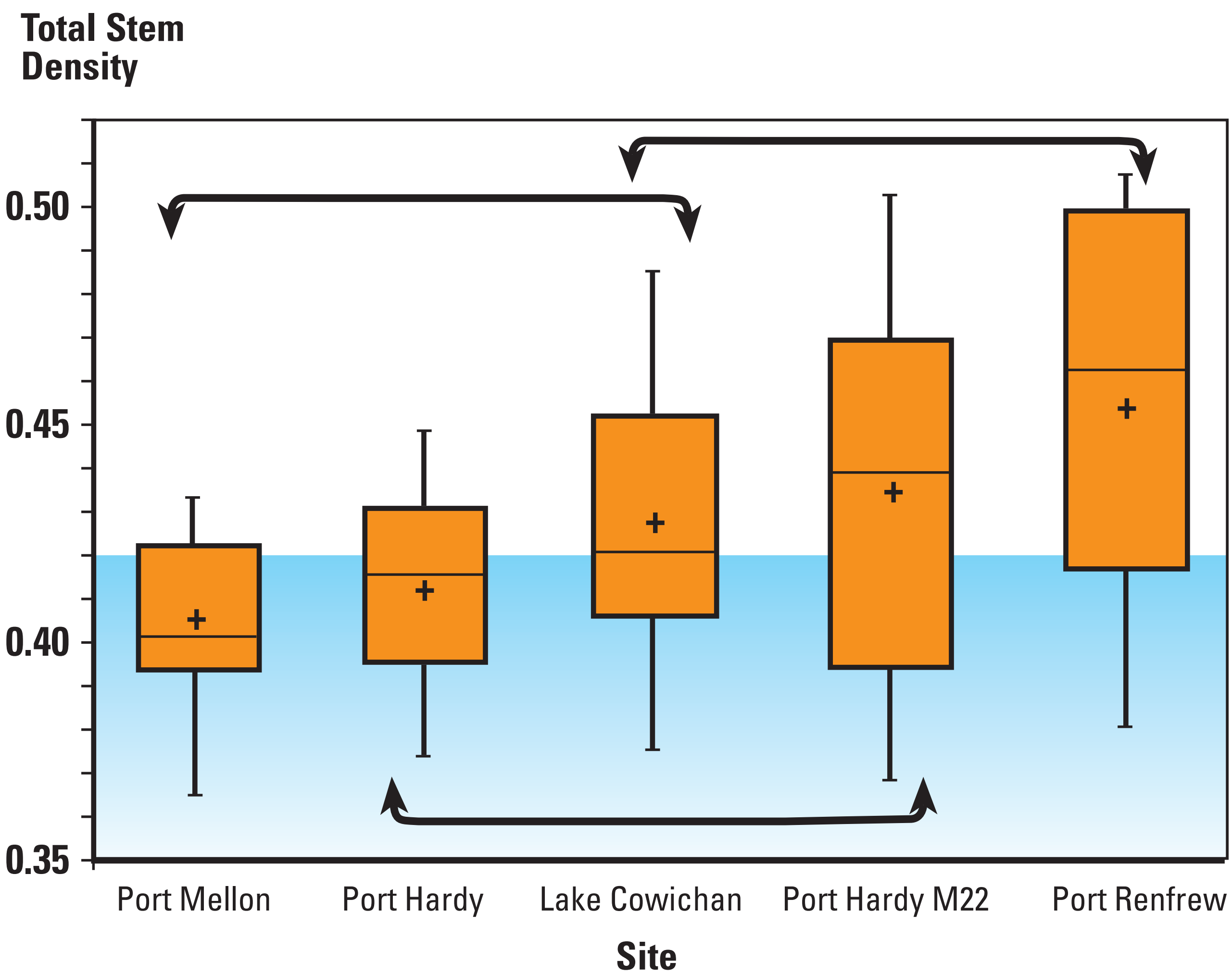
Forest Practices Branch
Ministry of Forests

Canada
CANADA-BRITISH COLUMBIA
PARTNERSHIP AGREEMENT ON
FOREST RESOURCE DEVELOPMENT:
FRDA II

BC

Forintek Canada Corp.

Second Growth Hemlock – Total Stemwood Density Distribution

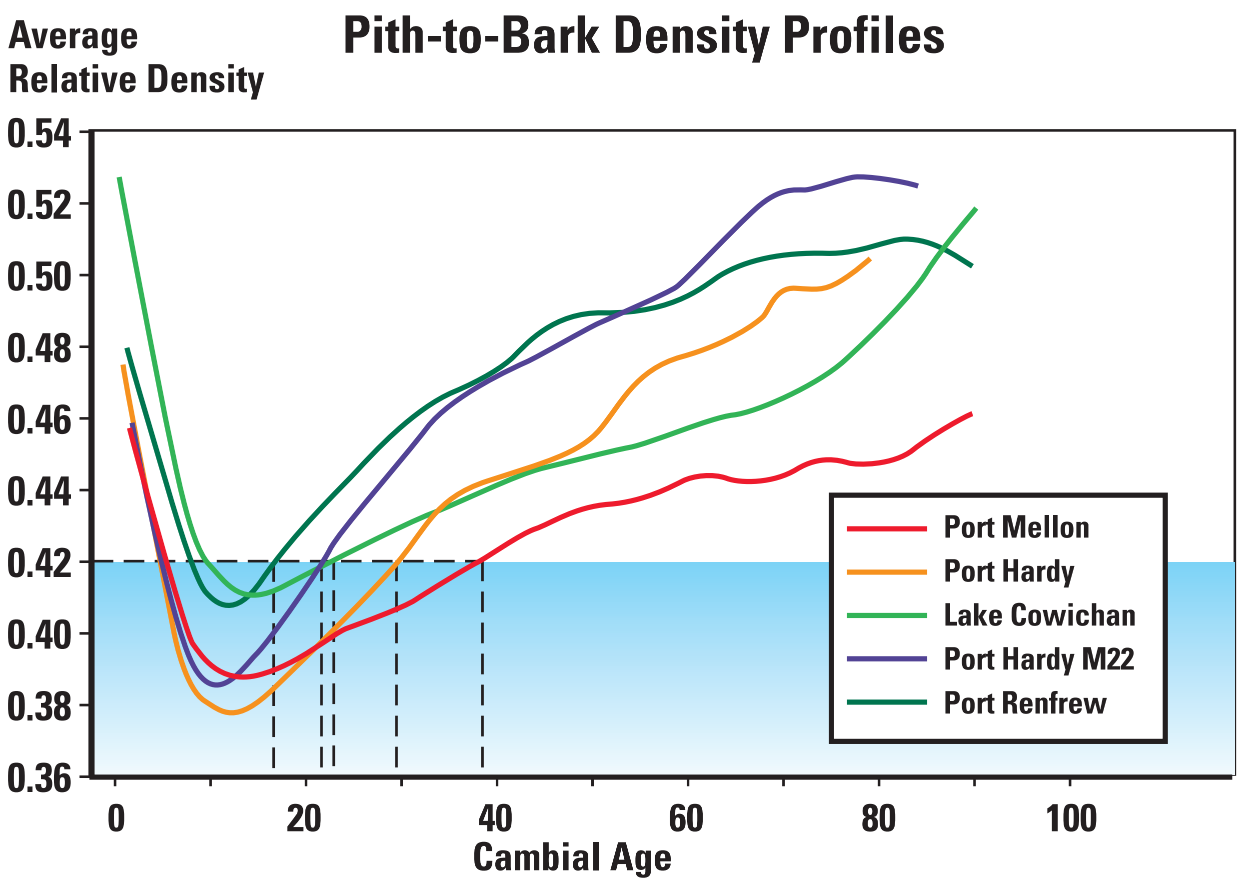


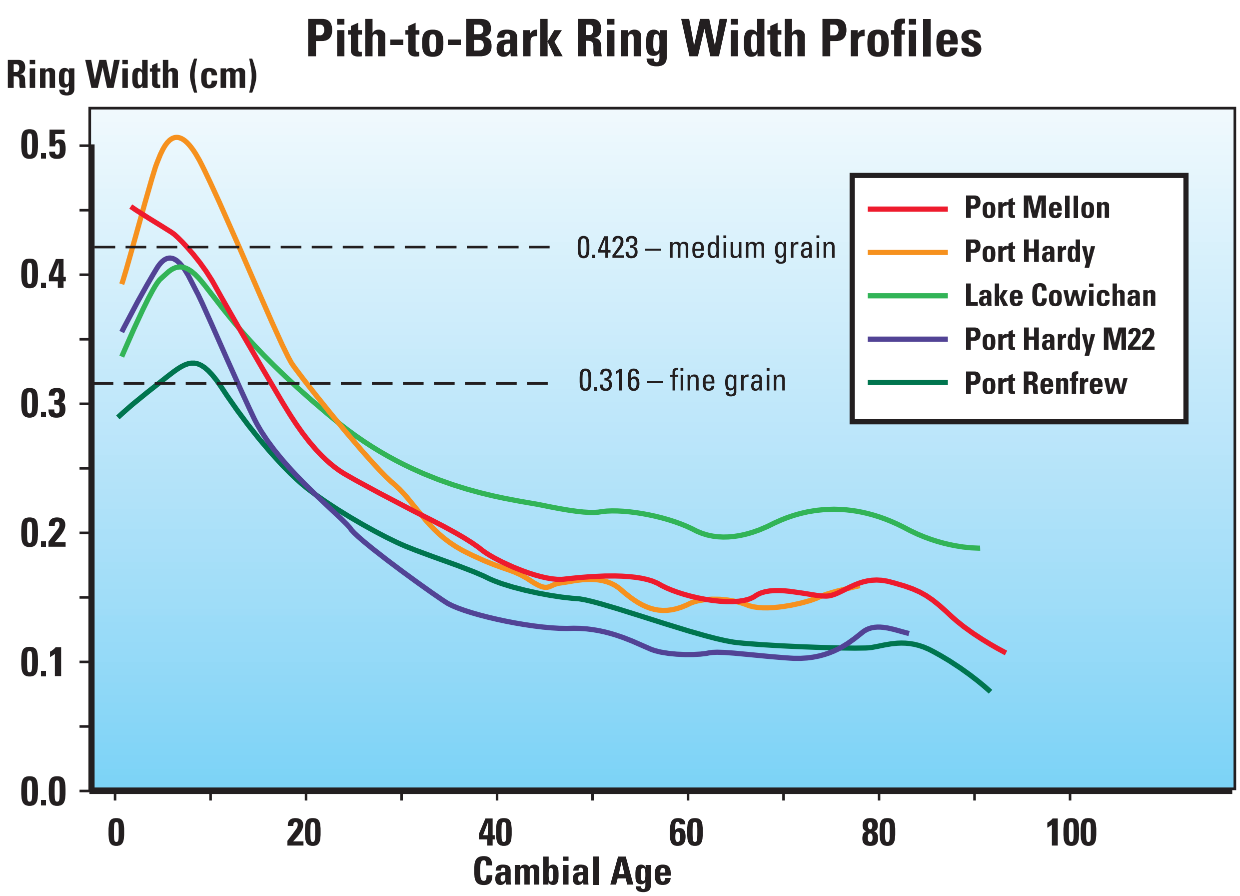
Overhead 81

These box plots show not only the site means ("+"), but also the distribution of the total stemwood density data at each location. The top and bottom edges of the boxes indicate the 75th and 25th percentiles of the sample, respectively. The horizontal lines within the boxes show the sample median, and the vertical lines extending from the boxes indicate the full range of the data. The horizontal brackets show site groupings where no statistically significant differences were found (at 0.05 level).

These results show that there is lot of opportunity for exploiting high-density stems for specialty target products. These include MSR lumber and furniture wood.

It is reassuring to the resource manager that even at 440 and 650 live-stems/ha, at age 90, the old-growth reference value of 0.42 was equalled (0.41 and 0.43, respectively).


Pith-to-Bark Density Profiles
Average Relative Density
0.54
0.52
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
0
20
40
60
80
100
Cambial Age
Port Mellon
Port Hardy
Lake Cowichan
Port Hardy M22
Port Renfrew


Pith-to-Bark Ring Width Profiles
Ring Width (cm)
0.5
0.4
0.3
0.2
0.1
0.0
0.423 – medium grain
0.316 – fine grain
0
20
40
60
80
100
Cambial Age
Port Mellon
Port Hardy
Lake Cowichan
Port Hardy M22
Port Renfrew

OVERHEAD 82

(Cover the bottom half of this overhead to facilitate the discussion about wood density trends)

Pith-to-bark yearly ring density trend-lines show a rapidly declining trend from the pith-ring (age 1) to age 10. This comparatively high density wood is juvenile wood (as juvenile as it can get, in fact). The low-point in density (about 0.40) is reached between age 10–15, about 3–7 cm from the pith. These trend-lines were created by summarizing all rings from each of the 12 sampling heights.

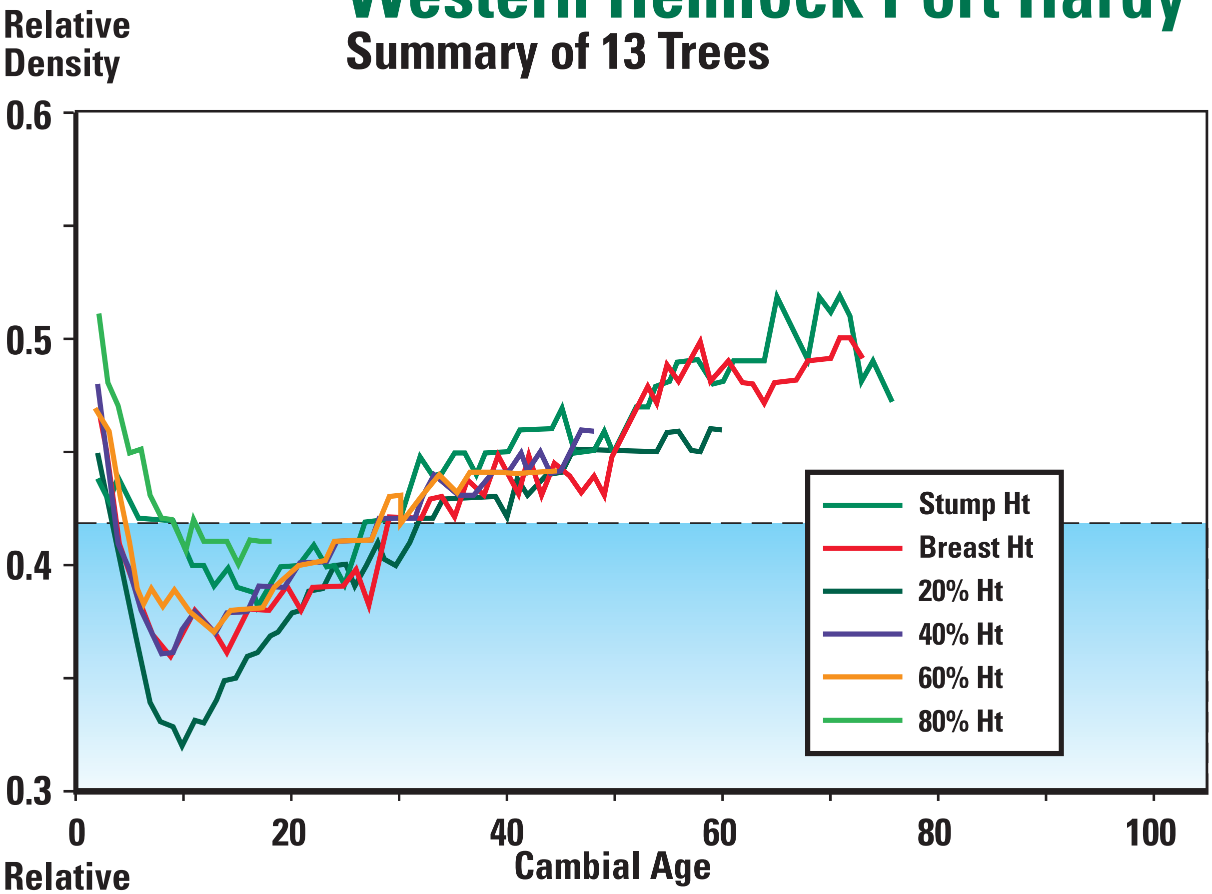
(Show bottom half of overhead for ring width trends)

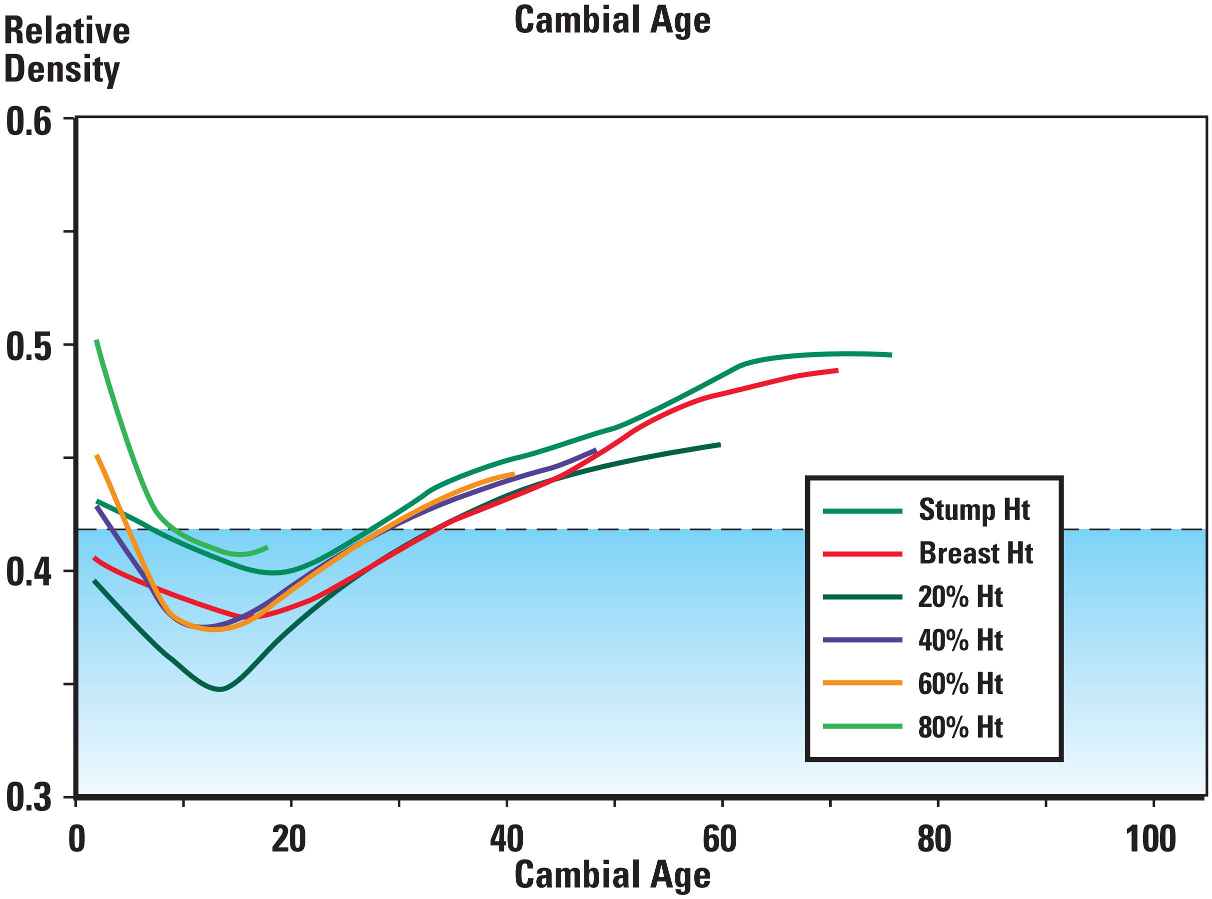
Maximum ring width was reached at all five sites between age 5–10. This was followed by rapid decline in ring width to about age 30. From here on a very gradual decline is evident.

The practical significance of ring width can be related to current NLGA grading rules; top grade in vertical grain door stock requires at least 8 rings/inch, or 3.16 mm wide rings. The next grade requires <4.23 mm in ring width (6 rings per inch).

Western Hemlock Port Hardy

Summary of 13 Trees





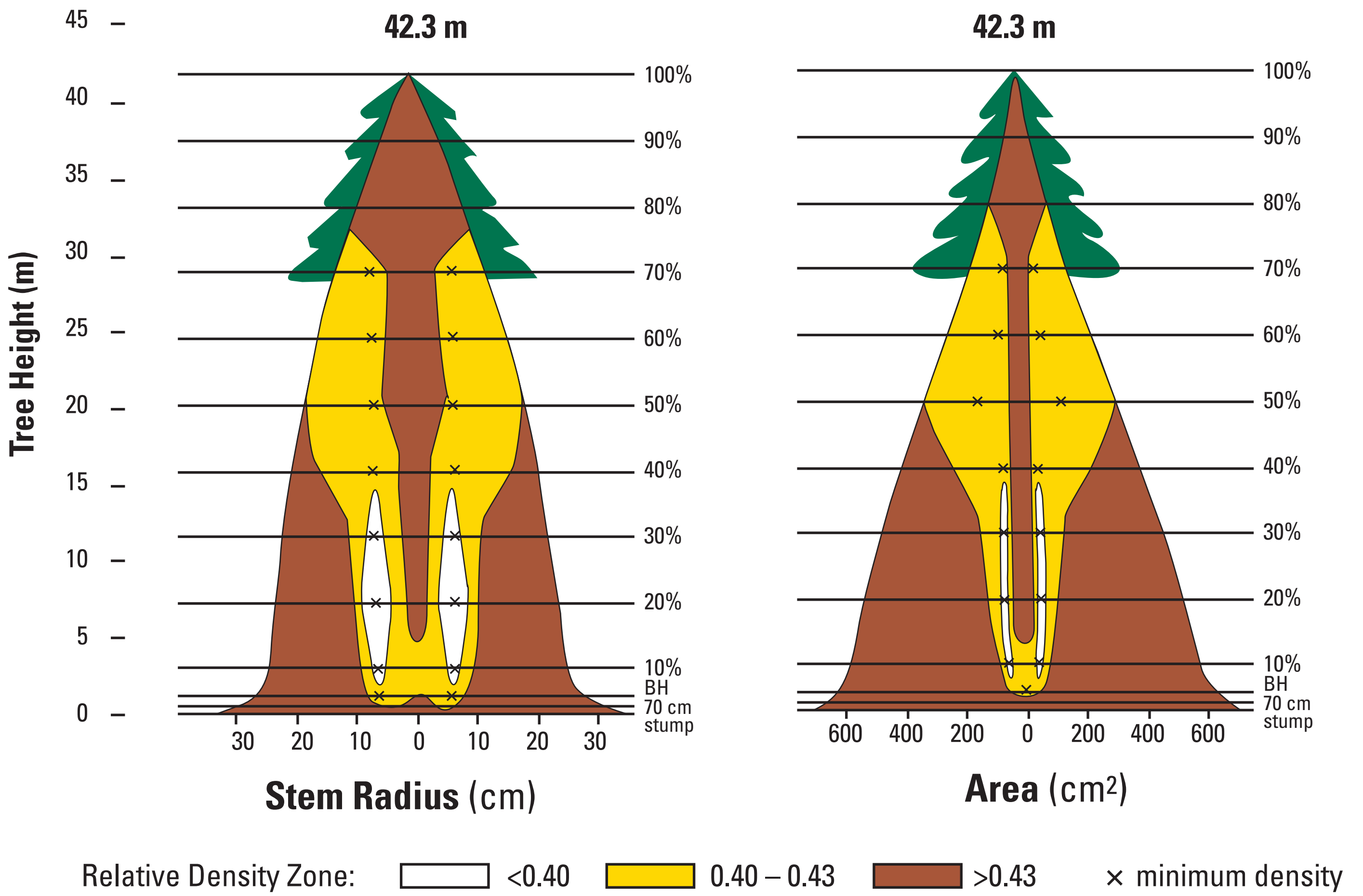
Overhead 83

Yearly ring density trends at six sampling heights are shown for the Port Hardy 650 stems/ha location. We can se that by age 30, at all sample heights, wood density is >0.41, and by age 50 these trees are producing “Douglas-fir-like wood (= and > than 0.45 relative density).

The bottom half of the graph shows “smoothed” trendlines.

Lake Cowichan

Summary of 13 trees (450 stems/ha)



Overhead 84

Average tree-stem profiles and extent of the live crown were drawn with the help of field measurements; tree height, base of live crown, and stem diameters at 12 sampling heights (from stump to 90% tree height). Density zones of "less than species average" (<0.40), "species average" (0.4 0– 0.43), and "higher than species average" (>0.43) were mapped with the use of pith-to-bark trends, as shown in the previous overhead.

Stem profiles and relative density distributions are shown by "stem radius" and by "basal area". Of course, an argument can be made for both versions, but the basal area-weighted depiction shows the relative amounts of wood more realistically. For example, the pith-associated high-density wood gets "equal billing" with the outer wood beneath the bark, of the same radius, by the first version (stem radius). Using the inner 10 cm radius from stump-to-30% tree height, lets calculate the basal area: $10^2 \times 3.14 = 314\ cm^2$. If we calculate the basal area of the next 10 cm in radius, from 10 to 20, we find three times more wood, 942 cm^2.

So much for the rationale of data presentation! Now, what do these stem profiles mean in terms of wood quality and product potential?

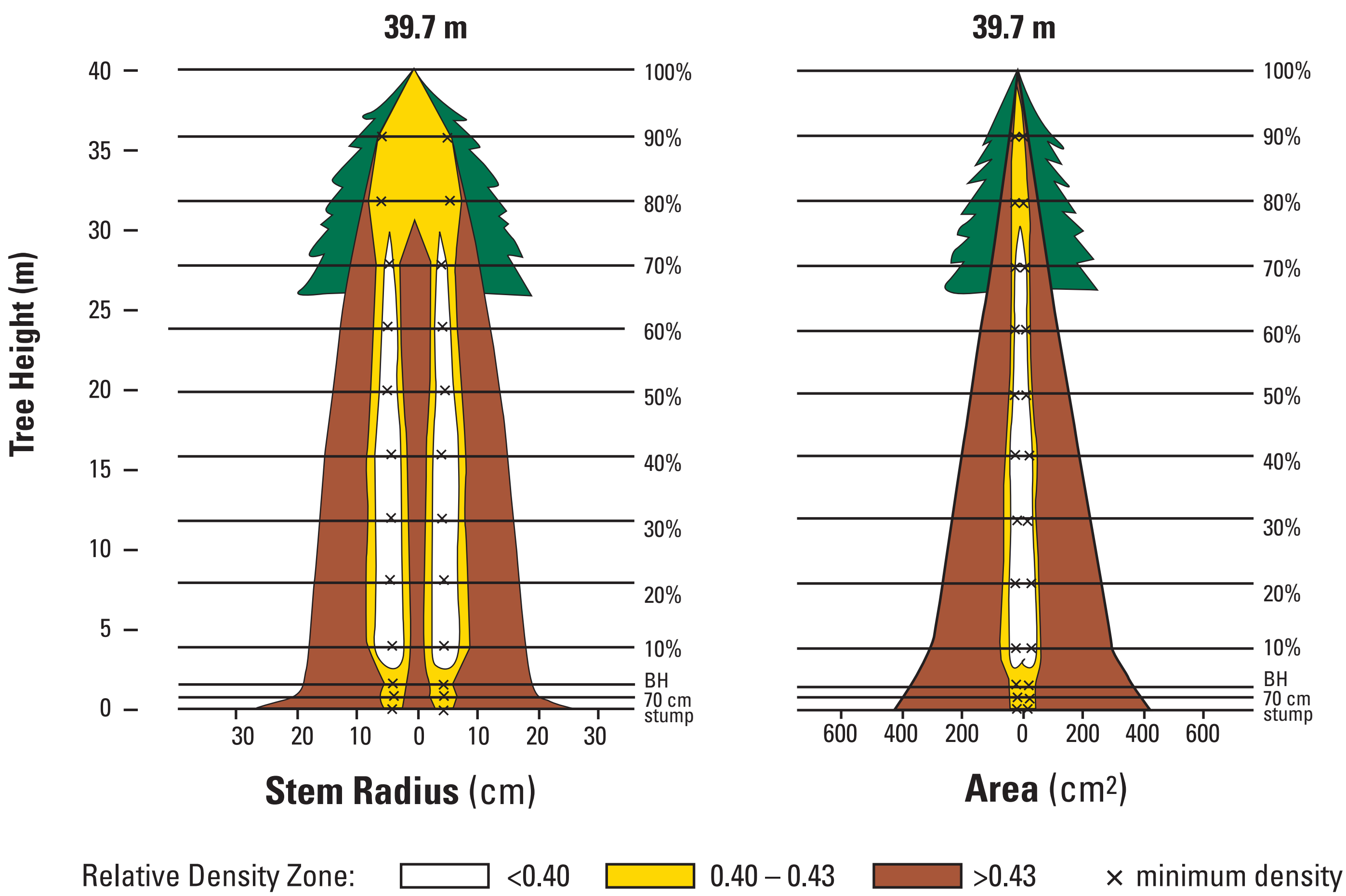
It is encouraging to note that even in the Lake Cowichan sample, with only 450 stems/ha, there is 61% high-density mature wood by volume. (As noted previously, the pith-associated high-density wood is definitely juvenile in nature, because if its high fibril angle, short fibre length, etc.)

This outer mature-wood shell is about 15 cm thick and 17 m long, a lot of wood for producing high-density solid wood products like MSR lumber, laminated veneer lumber (LVL), furniture wood, Parallam, etc. Even the top half of the stem falls within the 0.40–0.43 relative density range; not all that different from the old-growth average of 0.42.

This information will be useful in allocating raw materials for appropriate secondary products manufacturing decisions, for dimensional lumber, composite products, and for pulping.

Port Hardy M22

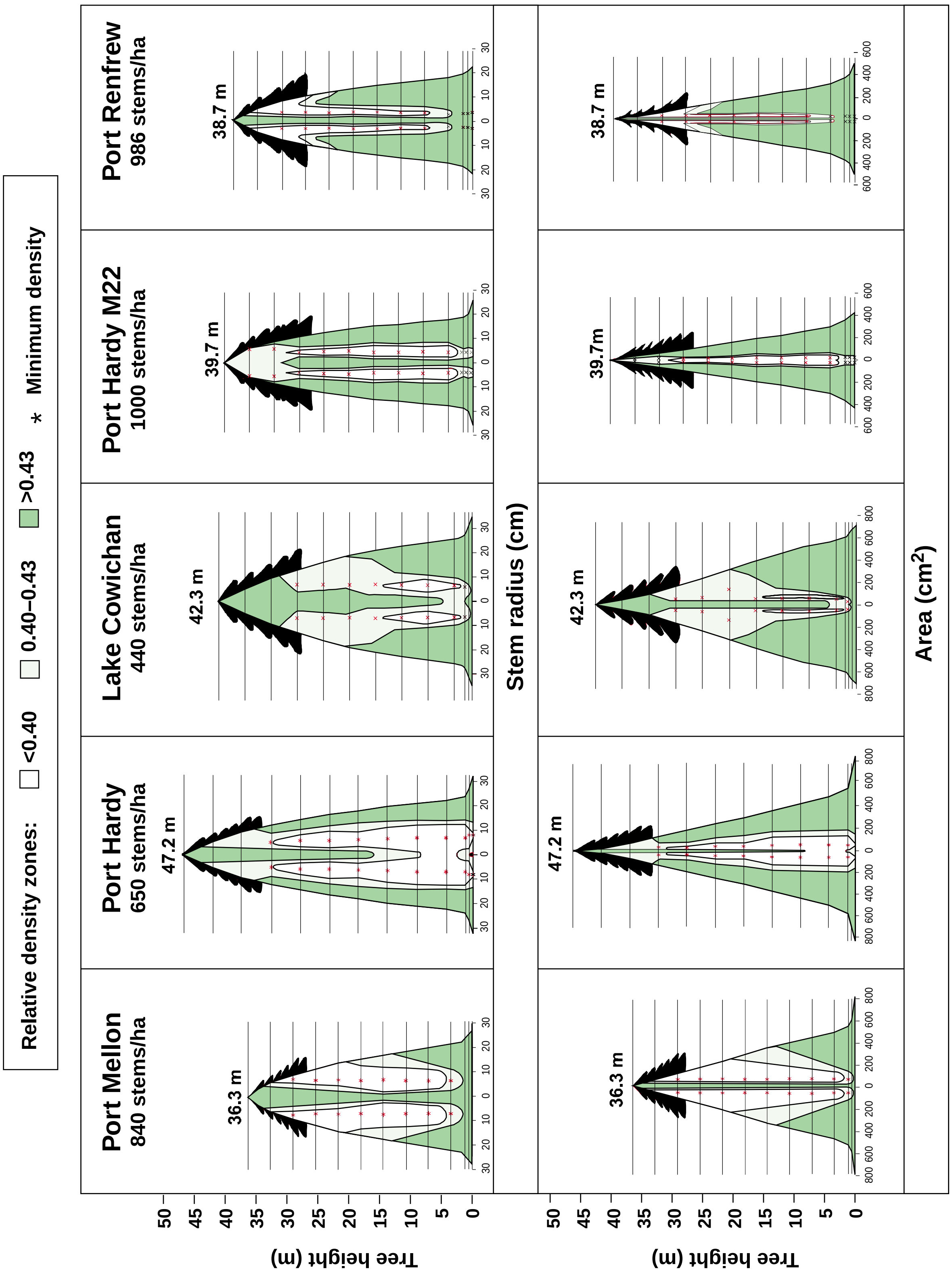
Summary of 13 trees (1000 stems/ha)



Overhead 85

The Port Hardy M22 samples, with 1000 stems/ha has a smaller juvenile-wood cylinder than the Lake Cowichan trees. Here the juvenile-wood cylinder is less than 10 cm in radius, and the high-density mature wood extends up into the live crown.

Based on detailed cruise data, these 90 year old western hemlock trees have produced 16 m^3 of wood per hectare per year.


Relative density zones:
<0.40
0.40–0.43
>0.43
* Minimum density
Port Mellon
840 stems/ha
36.3 m
Port Hardy
650 stems/ha
47.2 m
Lake Cowichan
440 stems/ha
42.3 m
Port Hardy M22
1000 stems/ha
39.7 m
Port Renfrew
986 stems/ha
38.7 m
39.7m
Tree height (m)
Stem radius (cm)
Area (cm²)

Overhead 85a

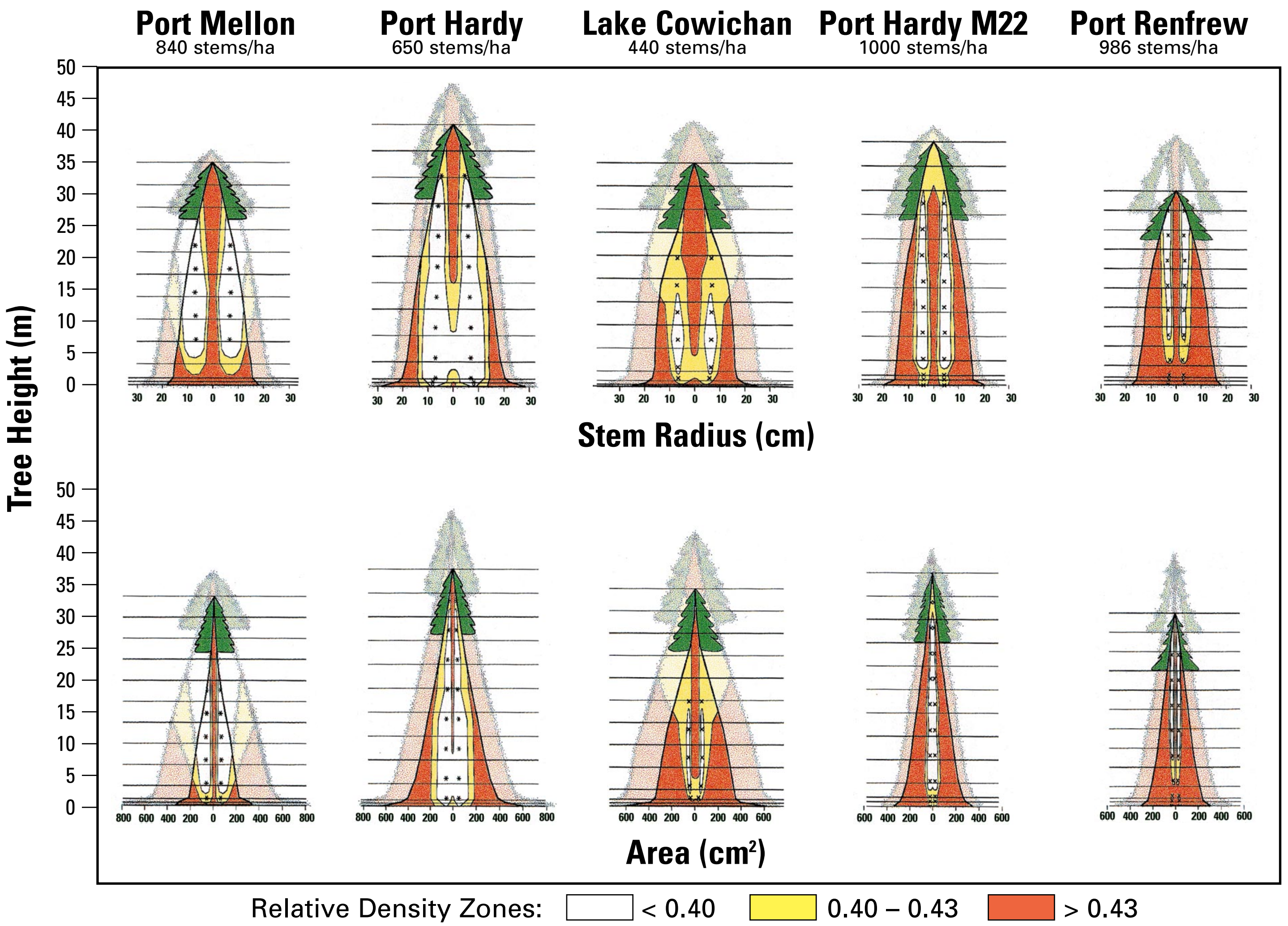
Average tree profiles with the extent of the live crown and stemwood density zones are shown here for the five sampling sites. The same data are shown (as before) by stem radius and by basal area.

The volume-weighted juvenile/mature wood distribution is shown in the bottom half of this overhead. This evaluation identified, left to right, 68, 41, 39, 30, and 30% juvenile wood. In this ranking, the Port Mellon sample appears to be an anomaly, because of the relatively high number of 840 stems/ha at this location.

The Port Mellon samples also had the least amount of outer mature wood, >0.43 relative density. This anomaly caused a lot of concern, and led to a follow-up study at the Haney Research Forest, where Western hemlock trees were planted at the same location to different densities (3 × 3, 9 × 9, and 12 × 12 feet spacing).

Average Tree Stem Profiles and Density Distributions

(summary of 13 trees per site at age 60 superimposed onto 90 year old trees)

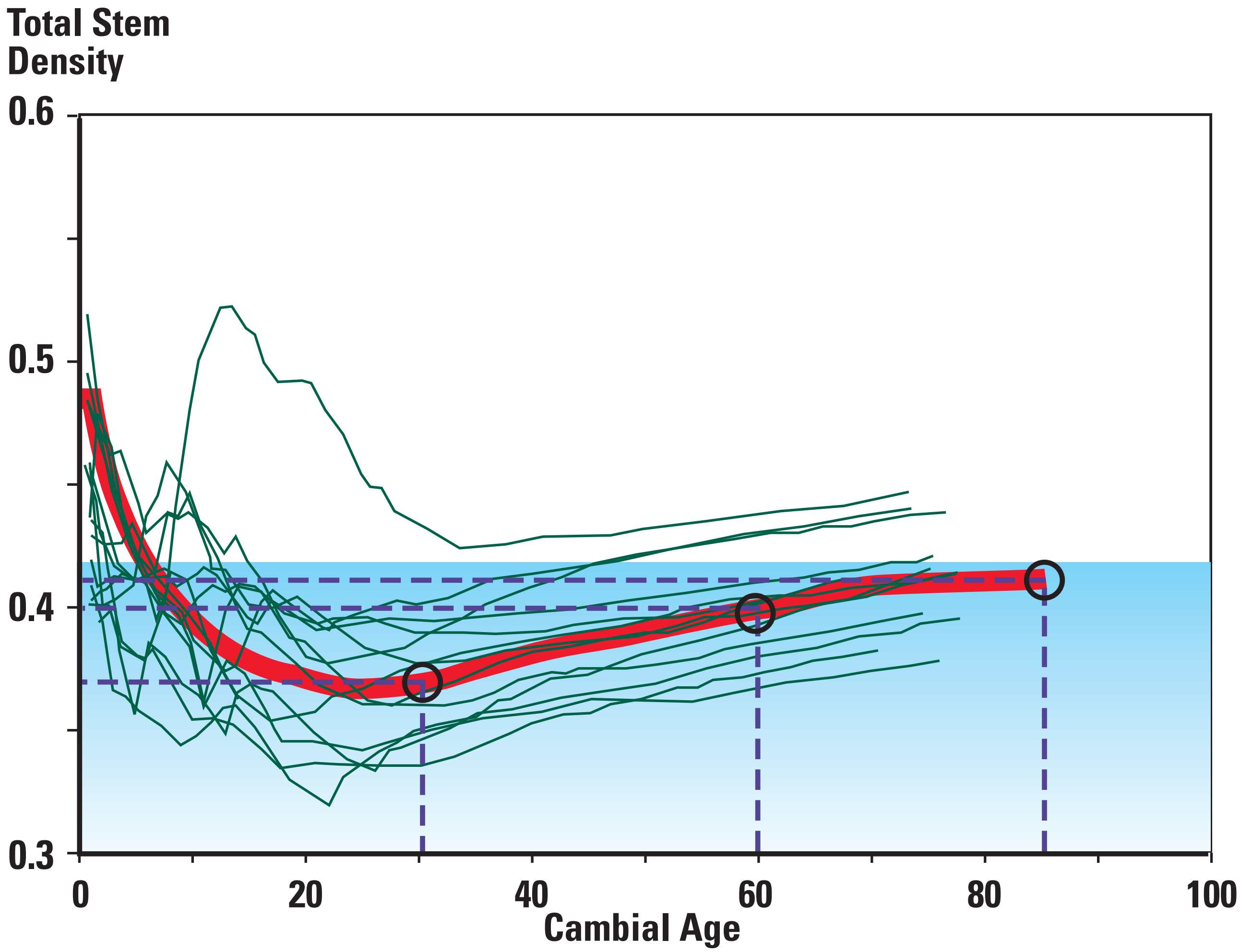


Overhead 86

At Forintek we have a very strong client pull for investigating basic wood properties at much younger tree ages. For example, for western hemlock the financial rotation (as opposed to biological rotation) was estimated at 35–38 years of age. Actually this train of thought starts to make some sense when one looks at a large number of cross-sections from second-growth western hemlock.

In response to membership client-pull we “terminated tree growth” at age 60, to show how these 90 year old trees looked back then. The difference in tree height and diameter is at the expense of high-density mature wood.

Western Hemlock Port Hardy



Overhead 87

Through the integration of tree height measurements and X-ray densitometric ring width and ring density measurements, weighted average stemwood densities can be calculated on a yearly basis. This overhead shows the relationship between total stemwood density and total stemwood volume for the Port Hardy (650 stems/ha) sample. Note that although the smallest tree, with 1.3 m^3 total stem volume is also the most dense (0.44 relative density), the largest tree, with 5 m^3 stem volume, is not the least dense.

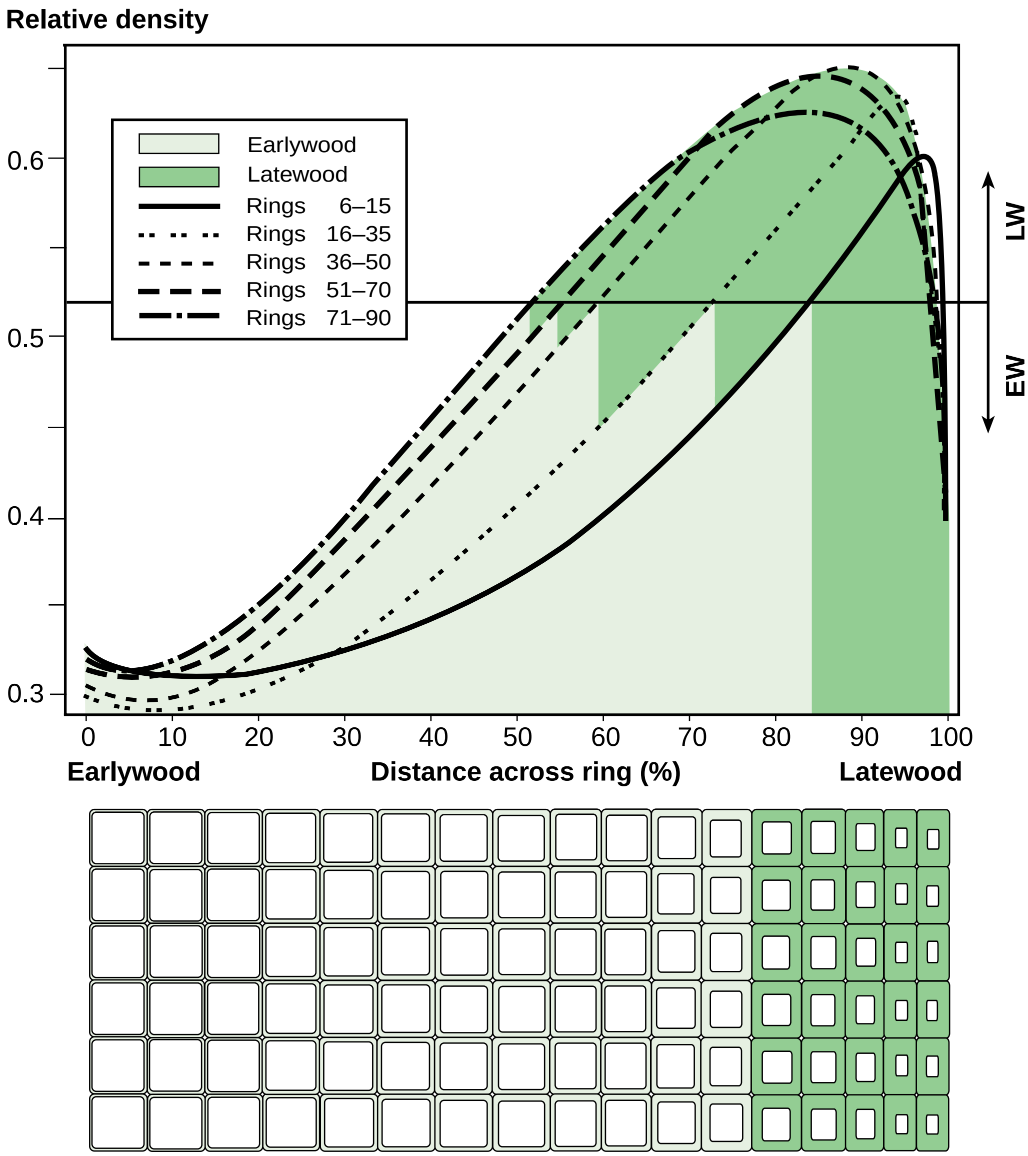
Also shown is total stemwood density from age one to age 80. Minimum stemwood density of 0.37 was reached at age 30. By age 60 stemwood density is 0.40, and by age 80 it is 0.41. The difference or range between the most and least dense tree is about 0.07 density units.

Overhead 87a

Intra-ring density profiles are shown for Port Hardy (650 stems/ha) and Port Hardy M22 (1000 stems/ha) tree samples for all 12 sampling heights. In addition to the yearly profiles, average profiles were prepared at each sampling height by summarizing all the rings from pith-to-bark.

Yearly minimum density values in the earlywood zone show a declining trend from pith to age 10, then level off and range mostly between 0.25 and 0.30. Maximum ring density values show little change from pith-to-bark, and range between 0.6 and 0.7. Therefore, because the lower and upper of density are well defined in a narrow range, it is the proportion of latewood that will determine the relative density of each annual ring.

The average ring density profiles show a decreasing trend in latewood width from the stump to the 90% tree height. This supports the decreasing disk density trends from stump to top, as discussed earlier.



Schematic of one annual ring (approximately 230 times magnification)

Overhead 87b

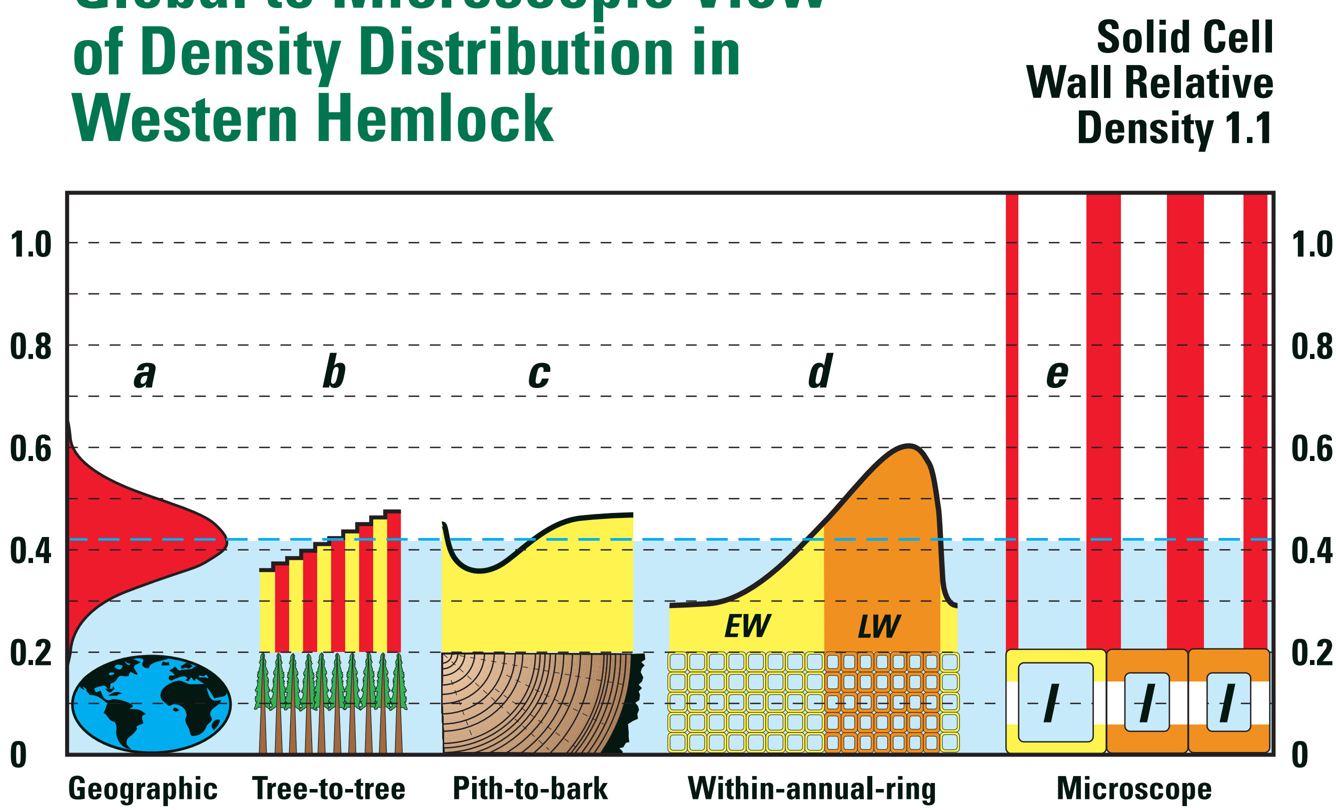
This illustration shows intra-ring density profiles for the BH samples of 166 trees from five locations of 90 year old western hemlock trees. To help with orientation, the schematic of one complete annual ring is shown at the bottom of the graph. The superimposed intra-ring density profiles were produced by summarizing rings 6–16 (juvenile zone), 16–35 (transitional zone), 36–50, 51-70, and 71-90 (the last three intervals from the mature zone). Ring width was standardized for ease of comparison of density range (between earlywood and latewood) and percent latewood width. For these interval summaries minimum ring density ranges between 0.29 and 0.32, while maximum latewood density is between 0.58 and 0.65.

The first interval, rings 6–15, the average ring contains only 15% latewood, and it was 3.92 mm wide. Latewood width increases from pith-to-bark from 15% to 28, 40, 45, and 48% from rings 6–15 to rings 16–35, 36–50, 51–70, and 71–90, respectively. For the same time intervals average ring width was 3.92, 2.64, 1.92, 1.44, and 1.1 mm

The most important feature of these western hemlock intra-ring density profiles explains the excellent machinability property of the species; there is very little low density earlywood and high density latewood. Note how from the very beginning of the annual ring, there is an immediate gradual increase in density. In other words, there is no substantial amount of low density earlywood, as one might find in Douglas-fir and western redcedar. This “robust” transitional earlywood will make the wood tougher to wear-and-tear in furniture, panelling, doors, windows, etc.

Density homogeneity will help in veneer peeling and wood turnings as well.

Global to Microscopic View of Density Distribution in Western Hemlock



Overhead 88

This overhead should be shown and discussed by revealing the five panels one-by-one.

First, **geographic/global** average stemwood basic relative density of these 90 year old second-growth western hemlock trees was 0.426, compared with the old-growth standard of 0.42.

Second, **tree-to-tree** average stemwood density ranged from 0.36 to 0.51 for the 65 trees. This variability in stemwood density is very similar to the old-growth western hemlock norm of 10% coefficient of variation (mean 0.42, range 0.34–0.50).

Third, **pith-to-bark** yearly average ring density trendline is similar to a check-mark, as was shown in Overheads 82 and 83. This has implications for earlier harvests, such as in commercial thinnings or partial cuts; if trees are harvested at a younger age, stemwood density will be lower than the 0.42 old-growth standard.

Fourth, **within-annual-ring** density trends (as discussed in Overhead 87b).

Fifth, **microscopic** density distribution; in this realm, basic relative density ranges from the absolute minimum of zero (in the lumen), to 1.1 in the solid wood substance of the cell wall material.

(A good mental exercise: discuss and rationalize the density difference of the solid wood substance in the oven-dry (1.53) and the fully water saturated condition (1.1). Of course, this implies that a solid block of oven-dry wood-substance, with no air in it, will sink in water more readily than a wet one.)

Western Hemlock

Log Grade			Old-growth	Second-growth
small Ø	D	log length	$ 10,000	$ 4,000
12 – 36 in.	H	16 – 24'	12,000	8,000
15 – 36 in.	I	12 – 14'	12,000	15,000
4 – 11 in.	J	16 – 24'	5,000	20,000
4 – 14 in. 15 – 36 in.	X	8 – 14' 8 – 10'	6,000	4,000
4 – 36 in.	Y	< 8'	5,000	4,000
Total			**$ 50,000**	**$ 55,000**

- Stand volume in second-growth 150 – 200m^3 higher than in old-growth

WFPL – North Vancouver Island

Overhead 89

Some of the naturally regenerated second-growth western hemlock stands are extremely productive. Total wood production of 15–20 m^3 of wood/ha/yr is not uncommon. For example, the 85 year old M22 site at Port Hardy had a total volume of 1 372 m^3. Yearly average wood volume production was 16 m^3/ha. At another location, near Port McNeill, FERIC and MacMillan Bloedel were doing commercial thinning in 50 year old western hemlock. Productivity rates in five different plots were 17.2–23 m^3/ha/yr. Site index was 31-33 m (at age 50). Number of trees per hectare ranged from 956 to 1678. Average height over diameter ratio was 102–124. From the same general area (north Vancouver Island) Western Forest Products found similar productivity rates.

This picture was taken by Dr. Hamish Kimmins. On the left-hand side of the picture we can see a vigorous second-growth, while on the right-hand of the picture there is an old-growth western hemlock stand.

Overhead 90

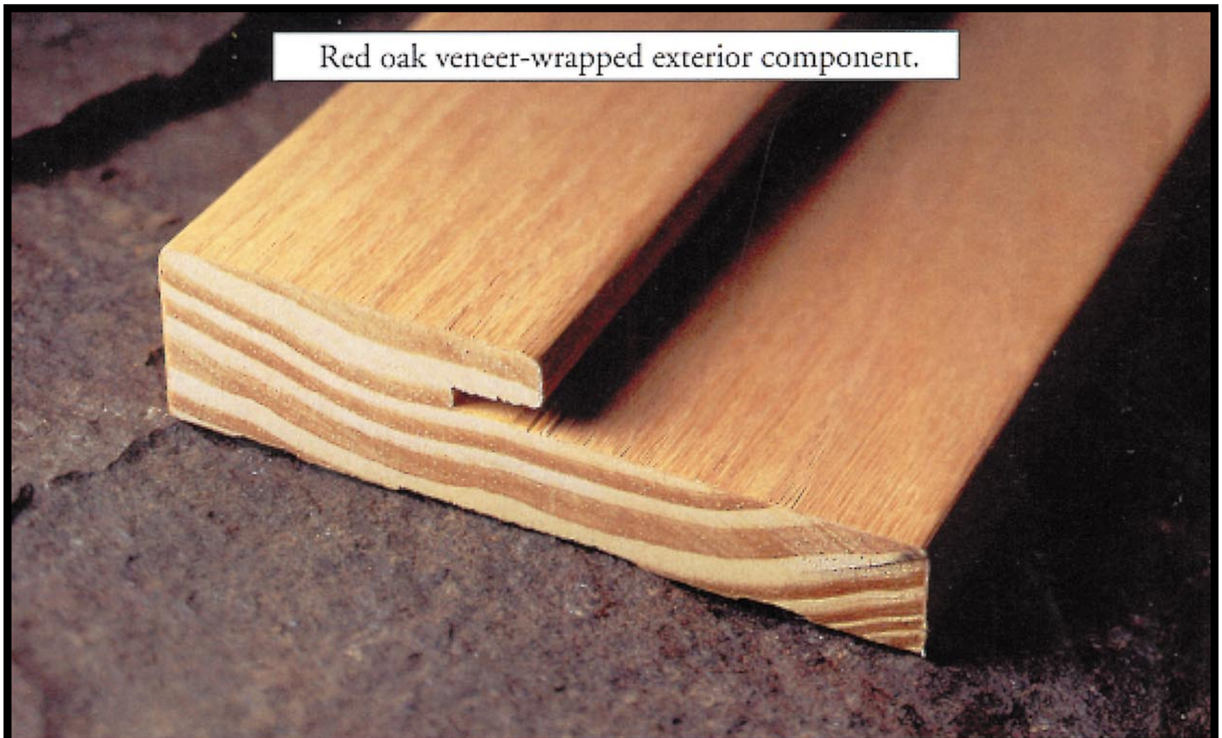
Engineered wood products—which can be defined simply as any wood that has been taken apart and reassembled in a manner that will yield a useful product with predictable engineered properties at competitive value—-**are the fastest growing segment of the building materials industry in North America and the world.**

The evolution of **composite products and engineered wood products** in North America over the last 60 years began with the introduction of plywood in the 1930s. This was followed by fibre cement board in the late 1940s, particle board in the late 1950s, oriented strand board or wafer board (OSB) in the early 1960s, and medium density fibreboard (MDF) in the 1970s. Laminated veneer lumber (LVL) and I-joists ("silent floor") were introduced in the late 1970s, but they did not get the wide public acceptance until the 1990s. Finger-jointing green lumber at industrial production speeds was developed by my colleagues at Forintek in the mid 1970s. Parallam® (parallel strand lumber) was developed in the early 1980s. One of the most recent development was Timberstrand® (laminated strand lumber), in the 1990s.

These were the major product lines, but there were other incremental developments as well, like in finger jointing, edge-gluing, and veneer-wrapping MDF, lower grade woods, plastics, and even metals.

Recent research and development has produced many viable products combining wood with other materials. Wood fibre-plastic composites are used extensively in the automobile industry as a substrate for interior door panels, roof headliners, seat backs, rear decks, and trunk liners (vinyl, carpeting and other coverings are applied over the substrate). Reinforced glued laminated timber beams utilize high-strength fibre additives in a thin plastic matrix, which are added with the gluing procedure. The new product has economic advantages because the reinforcement allows smaller cross sections than conventional glulam timbers.

What about the future? While North America formerly led in the development of plywood, Malaysia and Indonesia now dominate in this area. Europe was and is the leader in developing particleboard, MDF and fibre-cement board. Currently, North America leads in the production of OSB, LVL, Parallam® and I-joists. Market conditions are, however, changing very rapidly in the face of global technology, changes in wood supply economics due to plantations and new hybrid species, and highly mobile capital.



Red oak veneer-wrapped exterior component.

Flat-laminated skylight frame.

Overhead 91

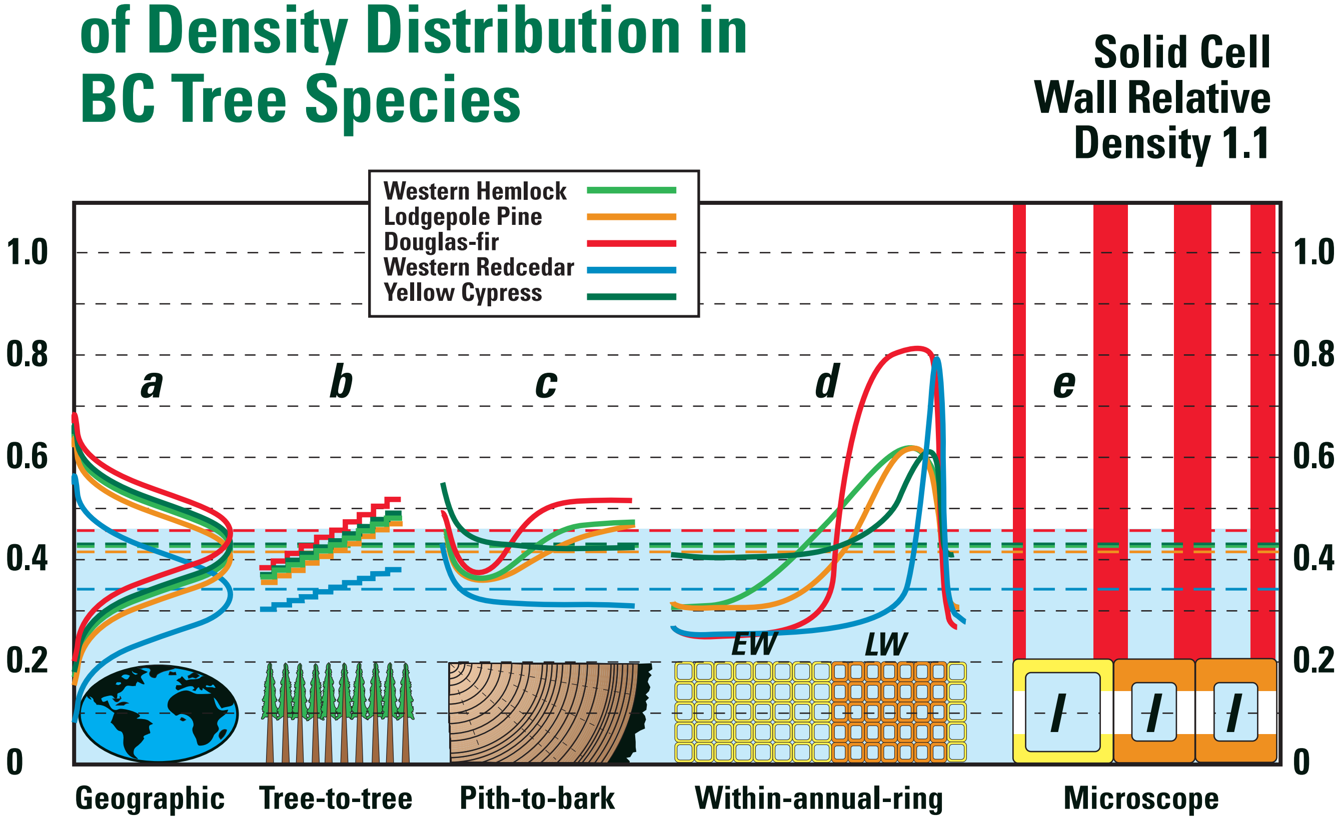
After explaining the overhead, show some examples of MDF moldings (paired with their wooden equivalents and appropriate prices!), “silent floor”, finger joints, Parallam®, edge-glued pine shelving, etc.

From time-to-time there were serious problems with some composite products. These problems arose usually because of poor quality control. In the early to mid 1970s large glulam beams were showing signs of delamination. The problem was traced back to uneven heating and extremely hot heating platens. Latent heat in the wood (transferred from the platens) was used to accelerate curing of the glue. Overheating weakened the wood surface (the bonding sites), reducing sheer strength to critical levels. In retrospect, not enough testing and quality control was carried out with that project. Other problems include the fire retardant treated plywood roof decking that “cooked apart” in the New York summer heat. More recently, some composite siding products were experiencing difficulties in the USA Northeast; OSB siding got saturated with water and got swollen up (not a good thing to do). More resin and testing could have prevented a $50 000 000 lawsuit.

Ask the workshop participants for their own company’s and personal experiences with composite products. Where do they see the future trends and markets?

In closing our discussion on composite wood products, it is well to remember that the groundwork for the technology that underlies the development of engineered wood products was established long ago. The wood science and technology community was at work developing new products long before the crisis surrounding harvest limitations developed. It has been very fortuitous that as old-growth timber has become less available, new engineered wood products have been developed to meet the demands of the 21st century.

Global to Microscopic View of Density Distribution in BC Tree Species



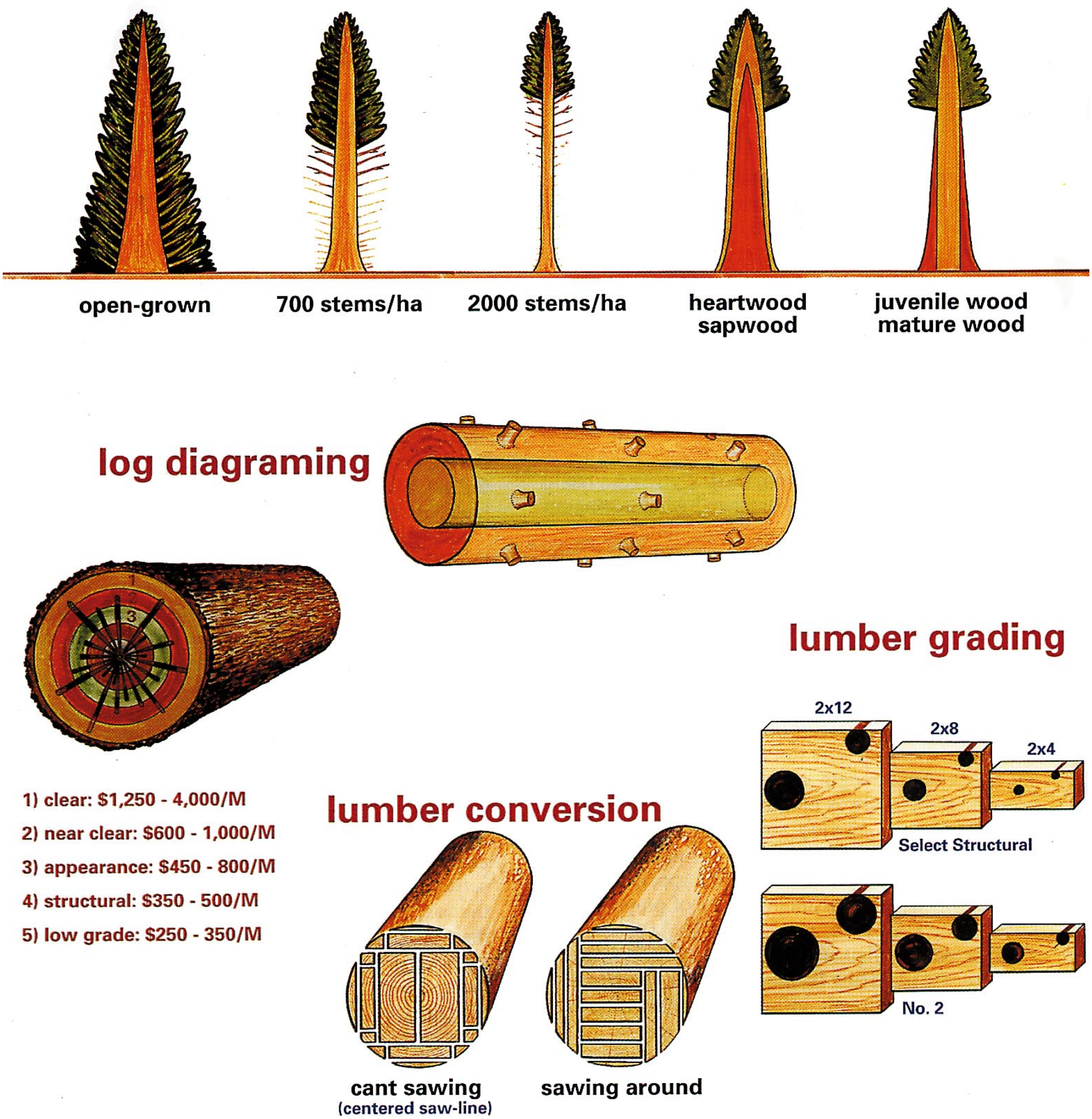
OVERHEAD 92

We have come to the end of our wood quality workshop. We started out with an overview of global trends in wood supply and demand, and concluded with composite products. Central to our discussion was always wood. Different kinds of wood. About half a dozen tree species were discussed in some detail, from the global to the microscopic perspective.

Show this overhead by covering up panels **b, c,** and **d**. By revealing **a** and **e** only, review the basic premise that all solid wood substance has a basic relative density of 1.1. Therefore, the species-to-species differences in average density , shown in

panel a, must be the result of the proportion solid wood substance to air spaces in the wood. Proceed with revealing the other three panels one-by-one, summarizing and contrasting species-to-species differences (refer to SP No. 34 for additional detail).

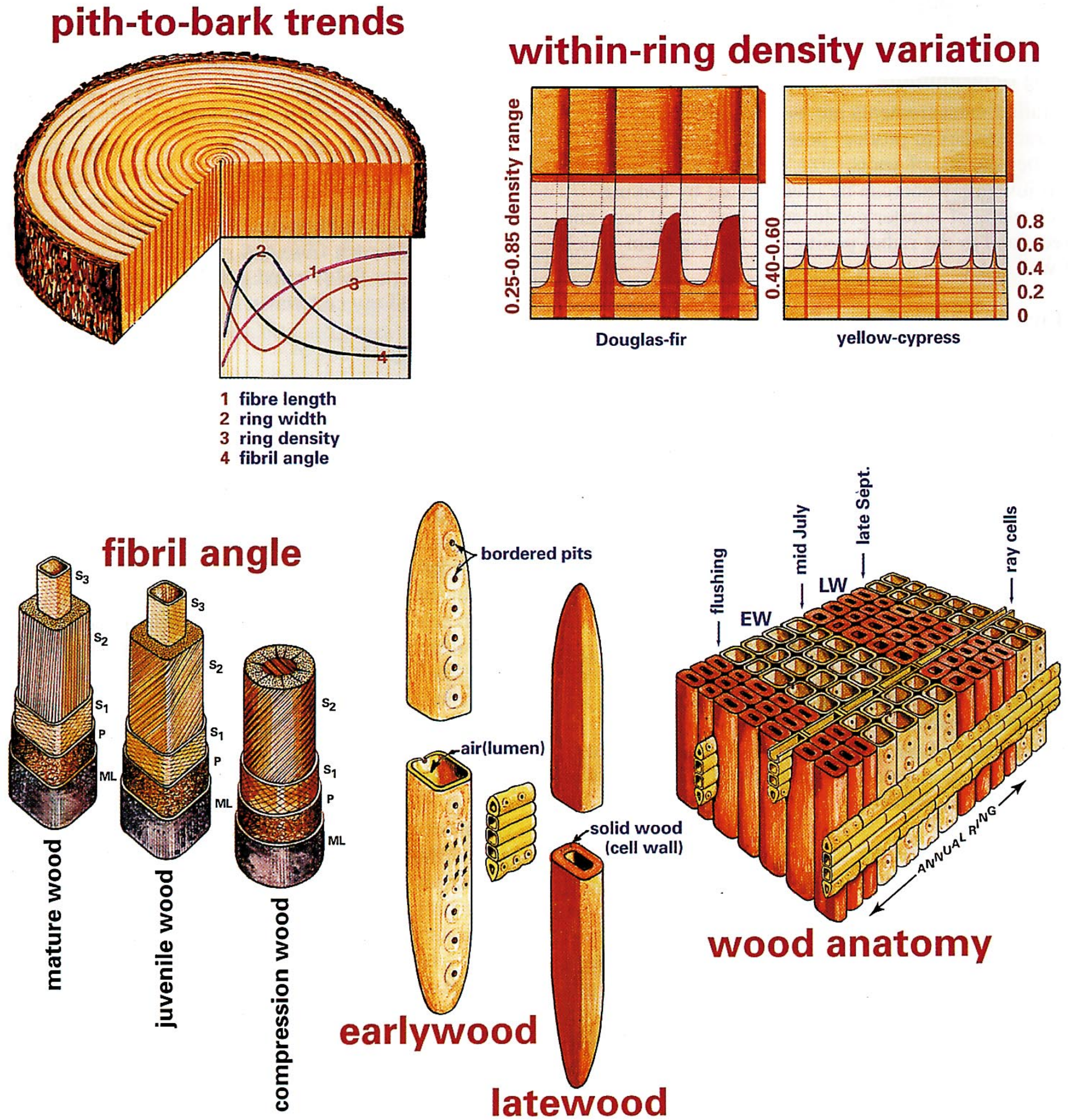
Wood Quality is Related to Measurable Stand…



Overhead 93

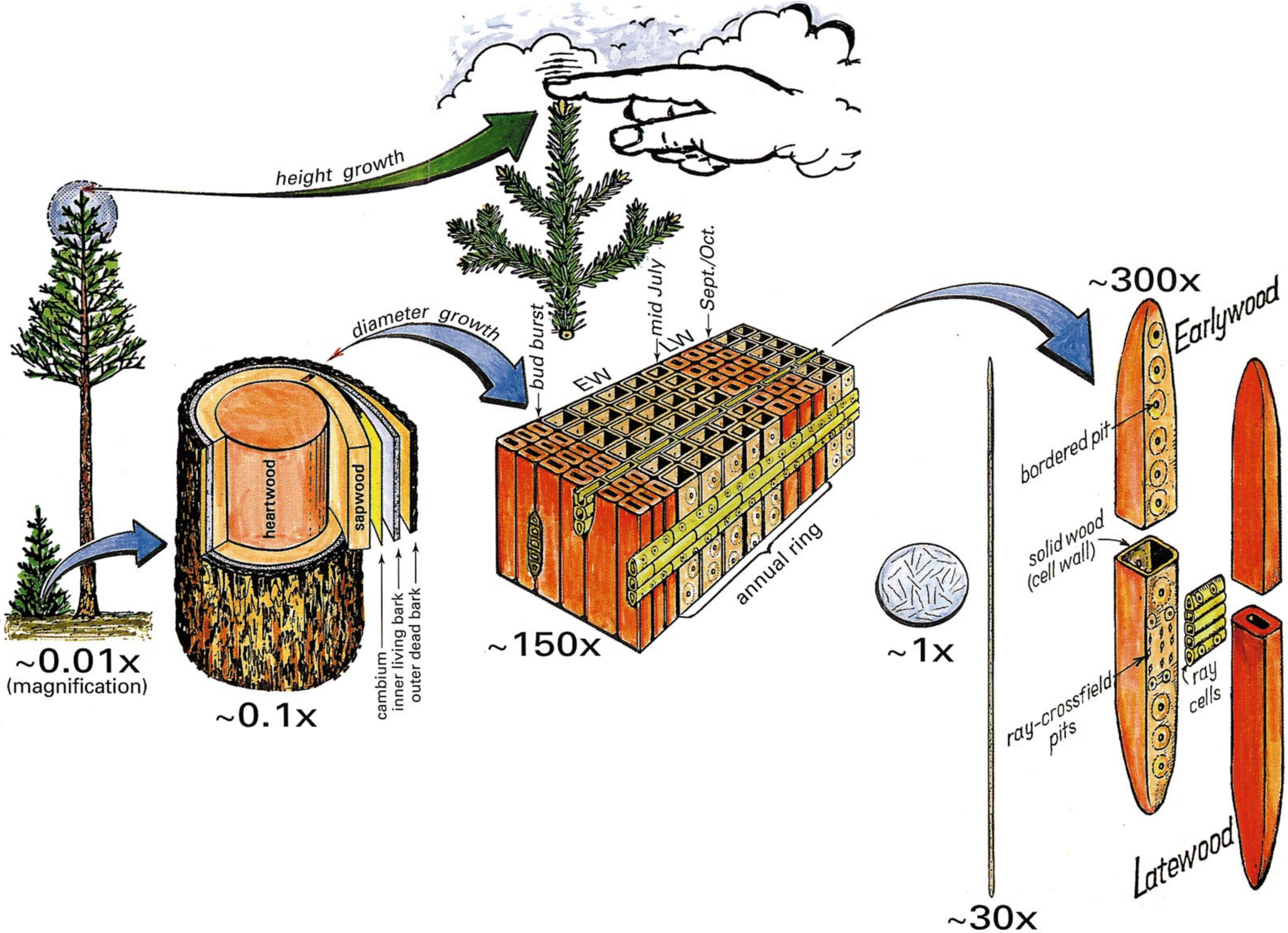
This workshop has demonstrated that wood quality is related to measurable stand, tree, log, lumber, and fibre characteristics. We have seen the impact of stocking and stand density on stem size, taper, branch size, crown size, rate of crown recession, and wood juvenility. We talked about the major tissue types in a tree stem and related their importance to the forest products industry (both solid wood products and the pulp and paper sector). Log diagramming, lumber conversion, and lumber grading was referred to a number of times, as these concepts relate to the resource. We talked about commodity products, and higher value products in the context of MSR lumber, truss manufacturing, pressure treatment with preservatives, secondary manufacturing, and the ever increasing need for proper lumber drying.

...Tree, Log, Lumber and Fibre Characteristics



Overhead 94

Special attention was paid to characterizing the extent of juvenile wood (crown-formed wood) through examining pith-to-bark trends in fibre length, extractives, ring width, ring density, fibril angle, and longitudinal shrinkage. We emphasized that not all species have low-density juvenile wood, but all species have shorter fibres, larger fibril angles, and dimensional stability problems near the pith. The microscopic structure and fibre morphology of earlywood and latewood were discussed in terms of strength and stiffness, machining properties, and paper sheet formation.


height growth
diameter growth
~0.01x
(magnification)
heartwood
sapwood
cambium
inner living bark
outer dead bark
~0.1x
bud burst
EW
mid July
LW
Sept./Oct.
annual ring
~150x
~1x
~30x
~300x
Earlywood
bordered pit
solid wood
(cell wall)
ray-crossfield
pits
ray
cells
Latewood

Overhead 95

You were teased (and perhaps insulted) about the basics like: How do trees grow? When do trees grow? What are tree rings? What are the major tissue types and their role in a tree stem? Why can't we see wood fibres with the naked eye? Why should we concern ourselves with wood structure, tree growth, and wood quality?

We established time and again that qualities of wood that we appreciate in various end-uses differ by species, and are linked to basic properties. Because silvicultural practices can alter these properties, we have an obligation to explore and understand all of the linkages involved. Only then can we hope to ensure that the quality of wood from managed stands remains equal to that of our natural forests.

Thank you for your attention and patience!