Wood Quality… Impact on Product Yields, Grades and Values

Forest Practices Branch
Ministry of Forests

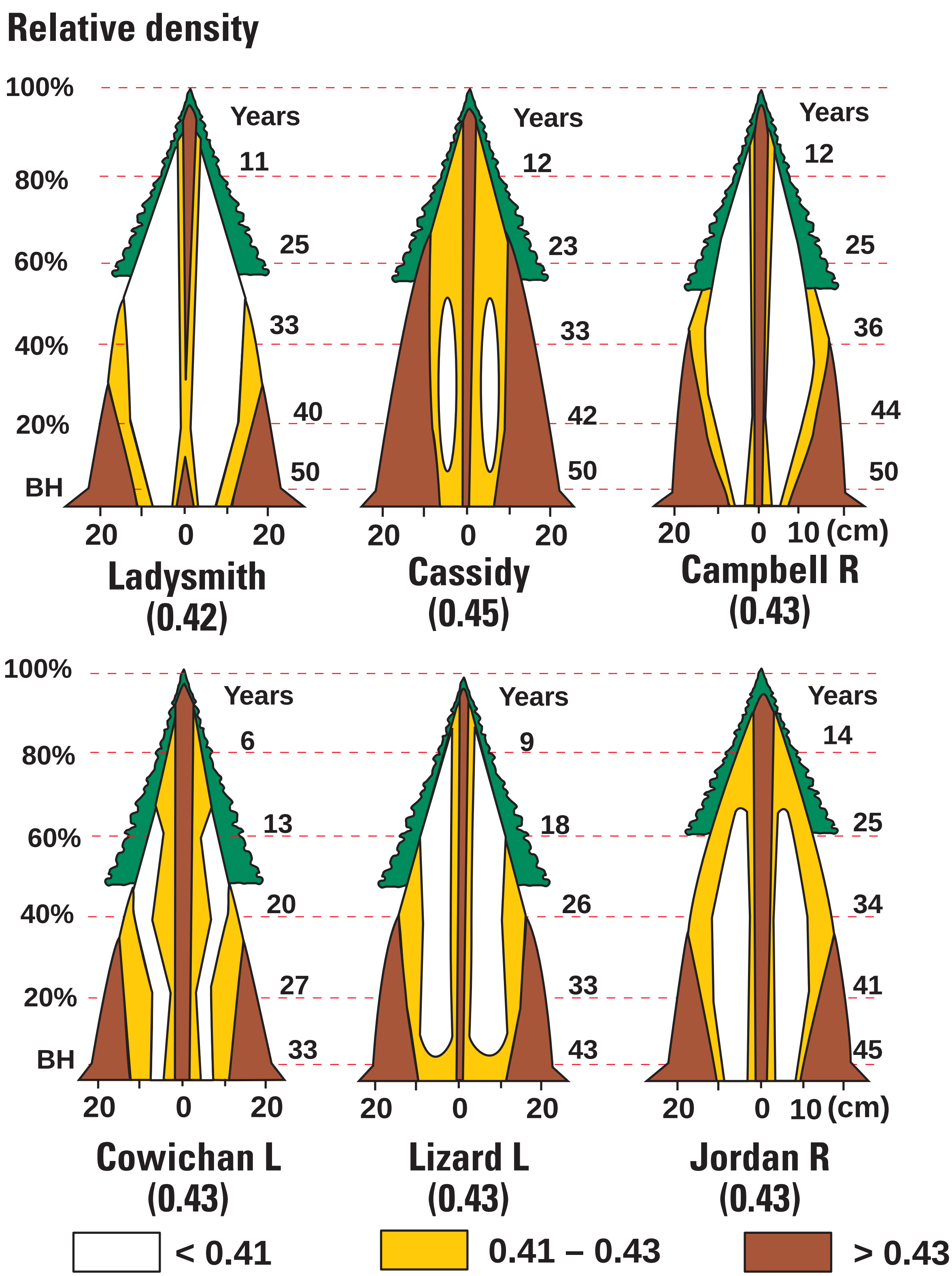
Canada

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

BC

Forintek Canada Corp.

Relative Density Zones in Douglas-fir



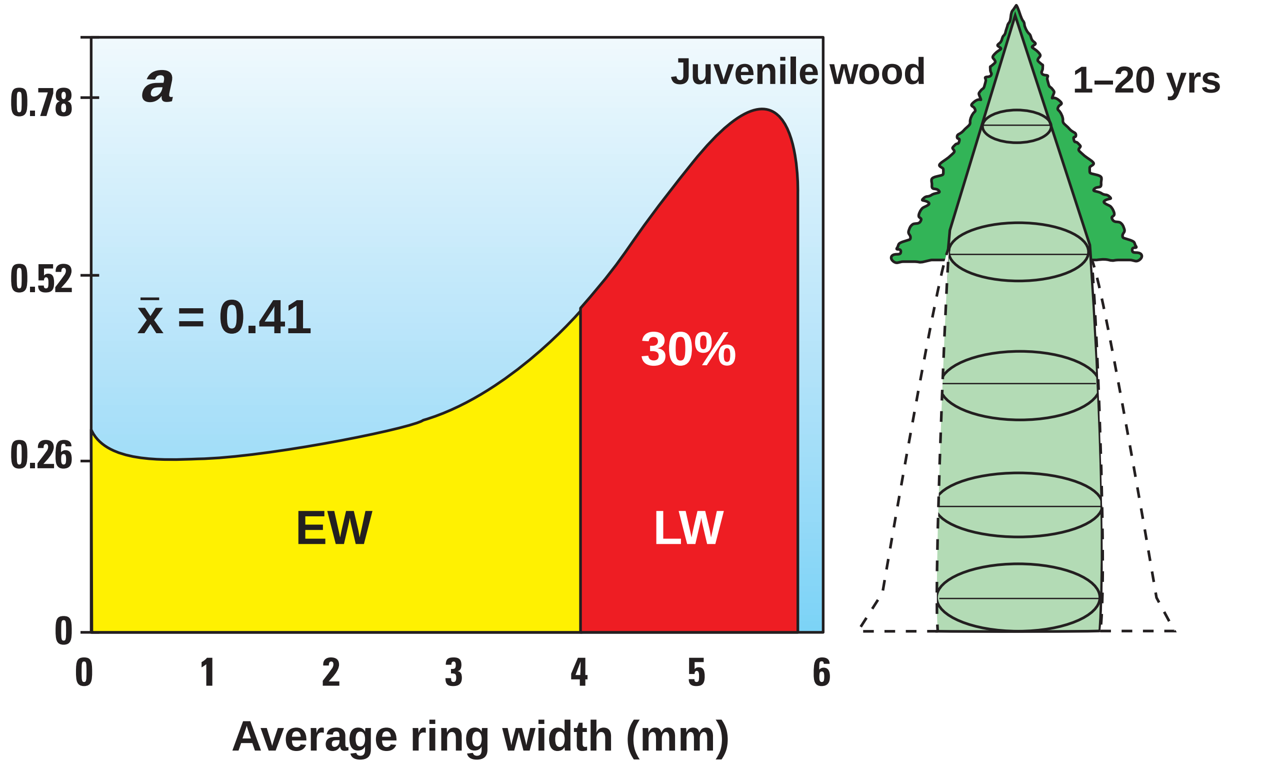
Overhead 61

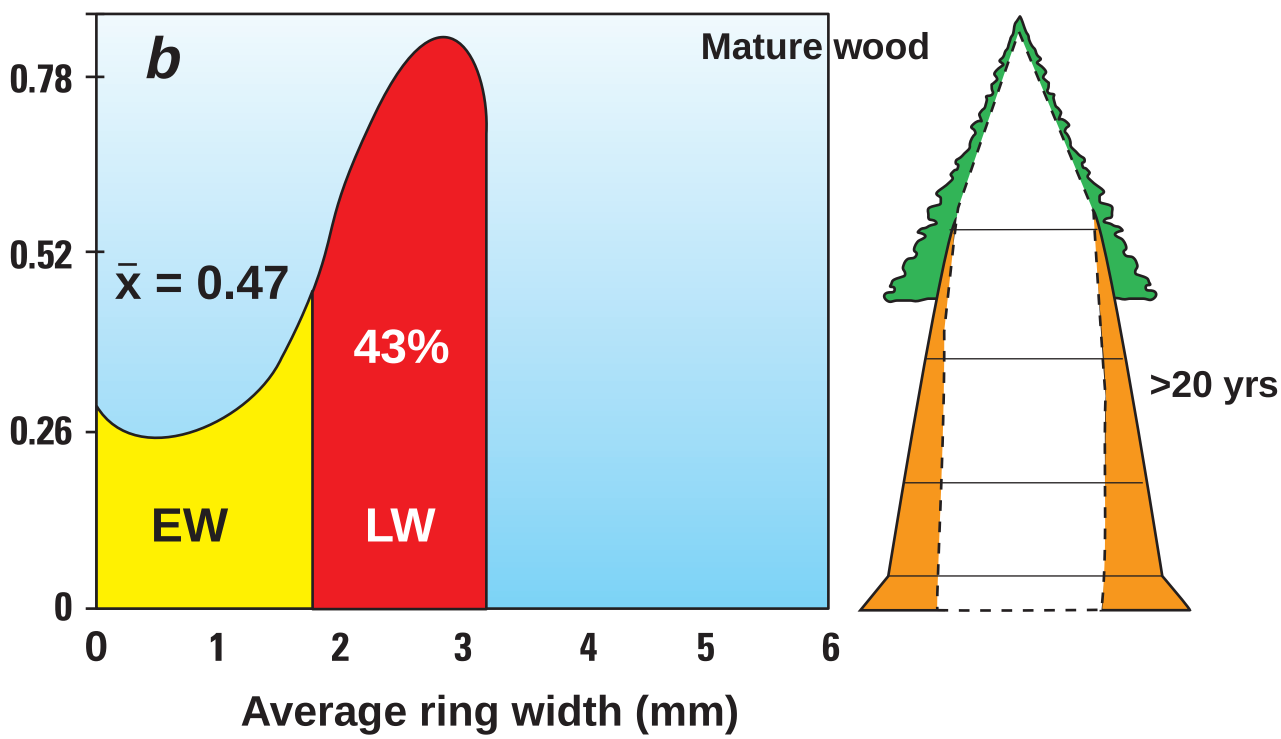
Low-density crown-formed wood surrounds the pith, with the exception of the “unusual” pith-associated high- density wood (definitely juvenile in character).

High density mature wood is below the live crown, surrounding the juvenile cylinder.

Juvenile/Mature Wood Ring Profiles

Relative density





Overhead 62

Intra-ring density profiles show the "coarseness of grain" (number of rings per inch) through the average ring width, and wood density uniformity (homogeneity/heterogeneity) through the density range between earlywood and latewood.

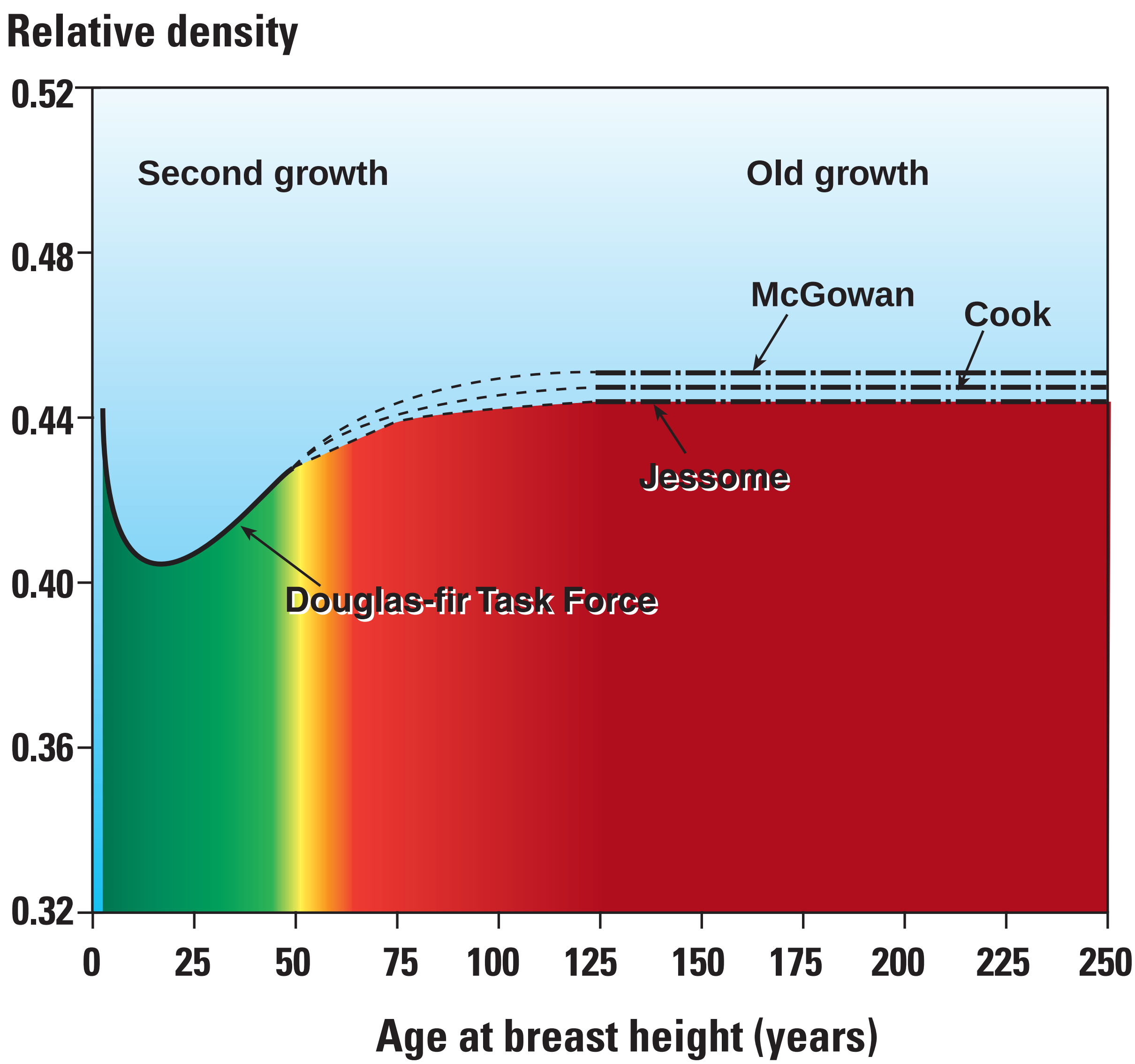
This is a good time to contrast western redcedar and Douglas-fir in terms of average wood density, earlywood/latewood density range and proportion. The main difference between the two species is latewood content!

This overhead shows that on average juvenile wood annual rings are almost 6 mm wide, and they contain 30% latewood by width. Mature wood annual rings are just over 3 mm wide, and they contain 43% latewood. It is interesting that on the absolute scale the juvenile wood annual rings had 1.7 mm wide latewood bands, while the mature wood rings had about 1.3 mm wide latewood.

The range between minimum and maximum density is about the same in juvenile/mature wood. This measure is a good indicator of wood machinability.

Discuss the attributes of old-growth Douglas-fir and show some examples in terms of appearance and density.

Stem-wood Relative Density



Overhead 63

Total stemwood relative density is shown here in terms of age. As the name implies, the difference between second-growth and old-growth and second-growth is simply age.

Three different “snapshots” (wood density surveys) put old-growth average to 0.44–0.45 relative density.

This graph shows that minimum stem density was reached in these second-growth Douglas-fir trees at about age 10–15. At this age stemwood relative density is about 0.36 (not unlike spruce). By age 50 density is at 0.425, approaching the old-growth “standard” of 0.45.

Conclusions:

- These 50-year-old Douglas-fir trees, growing at 530 stems/ha, contained 50% juvenile wood and 50% mature wood.
- At all height levels, the first 20 years of growth "defaulted" to juvenile wood because of wood density, fibre length, and longitudinal shrinkage.
- Juvenile wood is not useless wood.
- Larger knots permitted in wider widths.
- Challenge: find optimum between tree size and branch size at rotation age to maximize value, keeping future trends in mind.

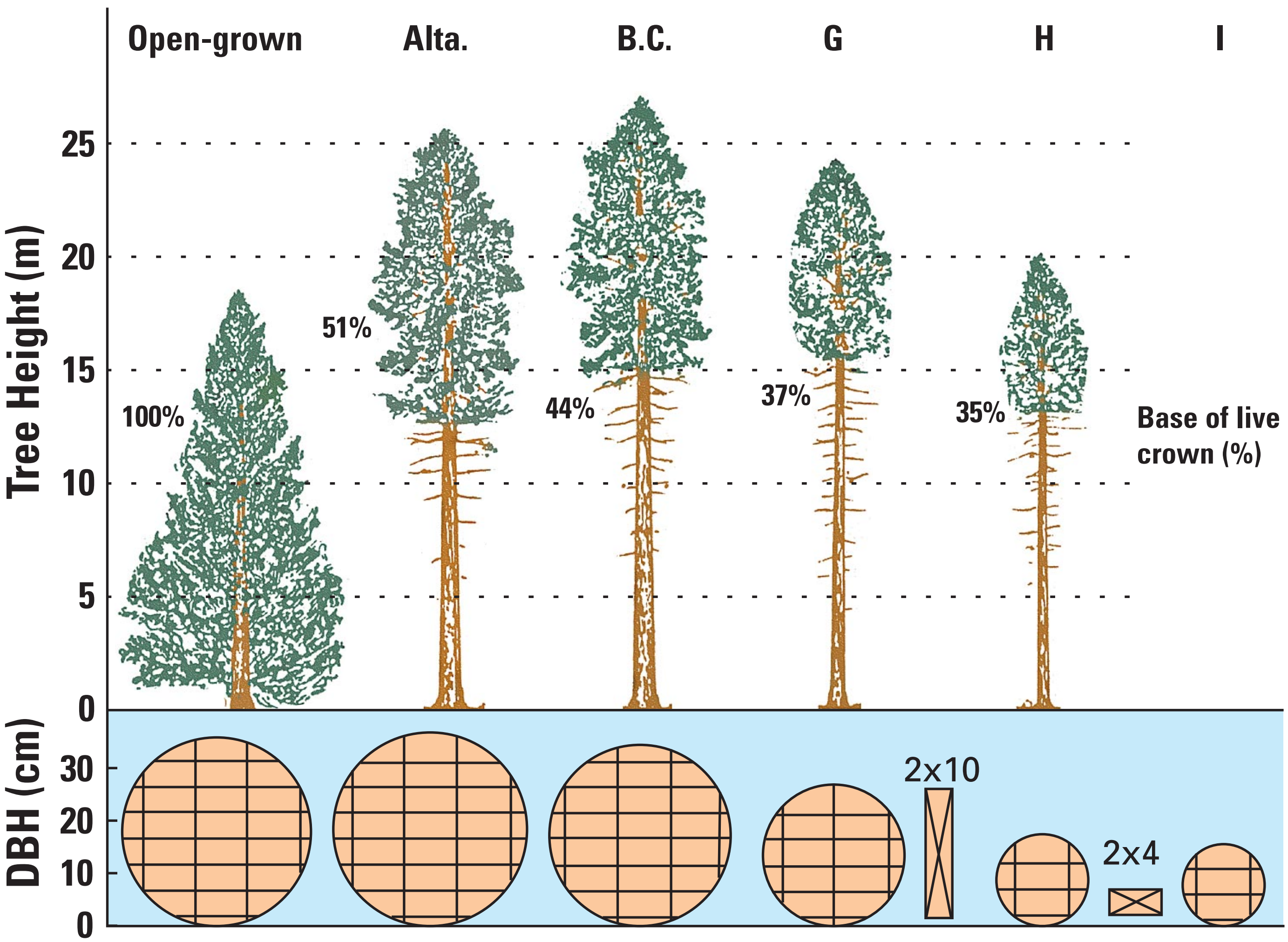
$/ha/yr commercial forestry has to be profitable

- Other non-woody pressures on the land base – social forestry

Overhead 64

This overhead is self explanatory.

Average Dimensions of Small, Medium and Large Diameter Lodgepole Pine Task Force Trees



DBH (cm)	37.0	37.6	35.7	27.5	17.8	17.5
Age (yrs)	71.0	91.0	85.0	121.0	96.0	95.0
Stems/ha	1	600	900	1300	1800	2300
Density BH	0.36	0.37	0.38	0.41	0.43	0.46
Stem Density	0.37	0.37	0.38	0.39	0.40	~0.43
Stem Volume	0.81	1.00	0.92	0.47	0.18	-

Overhead 65

Forintek's efforts in characterizing rapidly grown second-growth tree species in western Canada started in the mid-1980s. Douglas-fir Task Force was the precedent setting study, which was followed by the Jack Pine Task Force in the east, and the Lodgepole Pine Task Force in the west.

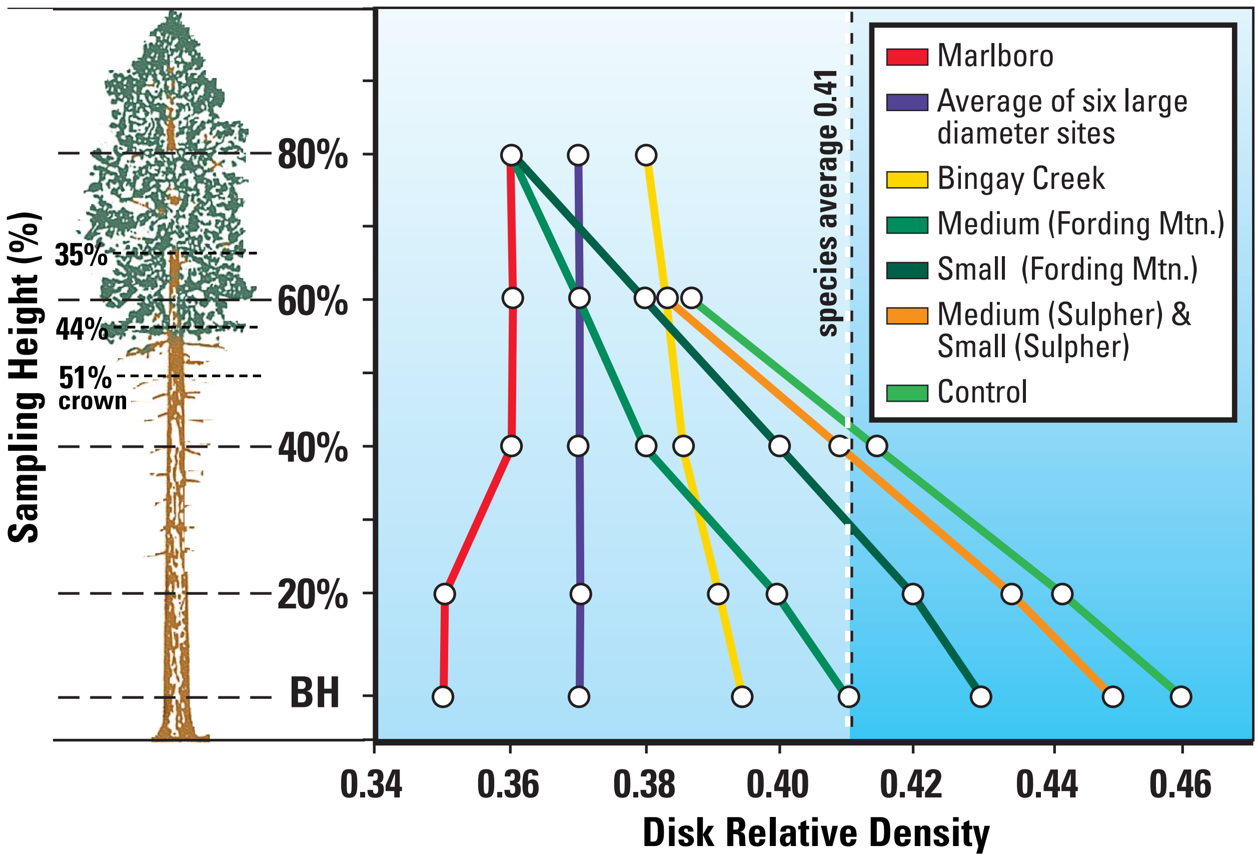
The lodgepole pine study started out with looking at the most rapidly grown stands of lodgepole pine we could find in British Columbia and Alberta. This was accomplished by identifying stands with about 750 live stems per hectare at about age 90. For those of you not familiar with natural lodgepole pine forests, 750 stems/ha is a very open and rare environment (perhaps as little as 1% of the total lpp resource). These stands were required to find lodgepole pine trees up to 40–45 cm DBH at a relatively young age of 90. The rationale was to look for potential problems associated with very rapid growth rates, in terms of product quality, like wood density, lumber strength and stiffness, and dimensional stability.

According to the BC Ministry of Forests, the average lodgepole pine harvested in BC in 1995, was 19 cm DBH, 26 m tall, and 125 years old. Therefore, our targeted tree size and age was "aggressive".

The next phase of the study included tree samples from higher stand densities and one fully open-grown tree.

This overhead shows average tree heights, diameters at BH, and the extent of the live crown. Breast-height disk density, whole stemwood density, and stemwood volume are presented as well.

Average Disk Density at Five Sampling Heights



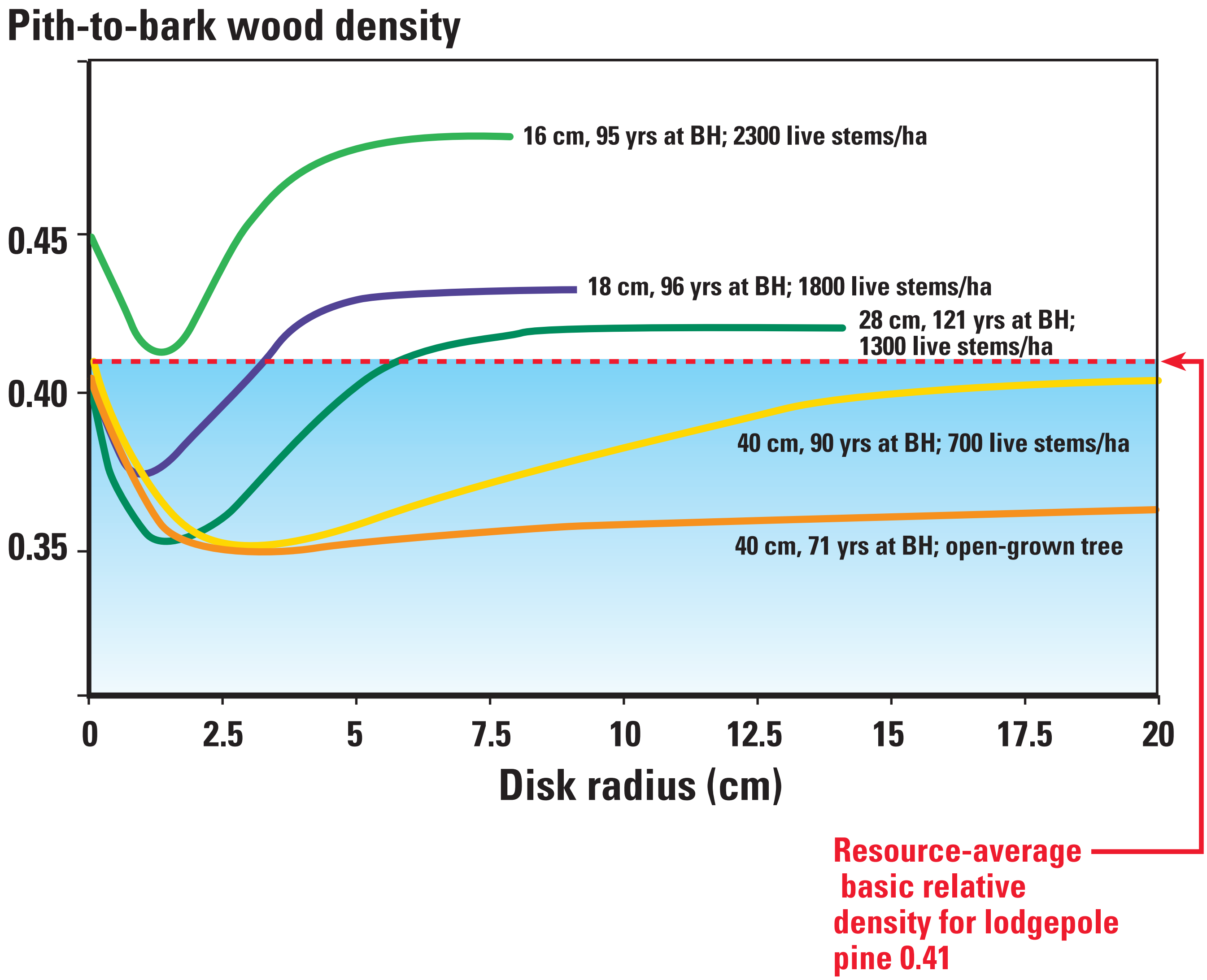
Overhead 66

The large-diameter, relatively open-grown lodgepole pine trees have lower wood density throughout the stem, from BH to 80% tree height, than the species average of 0.41. In fact, the fully open-grown single tree had 0.37 stem density.

Smaller trees (<25 cm DBH) had higher relative density than 0.41, but always in the lower half of the stem. Maximum density was at BH, at stem base. Crown-formed wood had low relative density in all sample trees studied, from the fully open-grown tree to the 600–1800 stems/ha sample trees.

Disk density distribution suggests that log sorting, according to log diameter and log position (butt, mid, top), could be advantageous in segregating logs for specialty products. This segregation could channel high density wood for high grade MSR lumber. In secondary manufacturing (for example, furniture, flooring, etc.) the small-diameter butt logs would yield Douglas-fir-like high density wood.

Pith-to-bark Wood Density and Tree-size Trends as a Function of Stand Density



Overhead 67

The period of juvenility is a function of crown recession, which is dictated by stocking/stand density. Show examples of cross-sections where one can see branch death at 13 years of age (from a high stand density of 2300 stems/ha at age 90) versus 63 years of age (from an open 700 stems/ha stand).

Note the lodgepole pine resource average basic relative density of 0.41. These last two overheads, and the two coming up, should be examined at great lengths by silviculturists and by individuals who are responsible with setting product objectives!

Overhead 67a

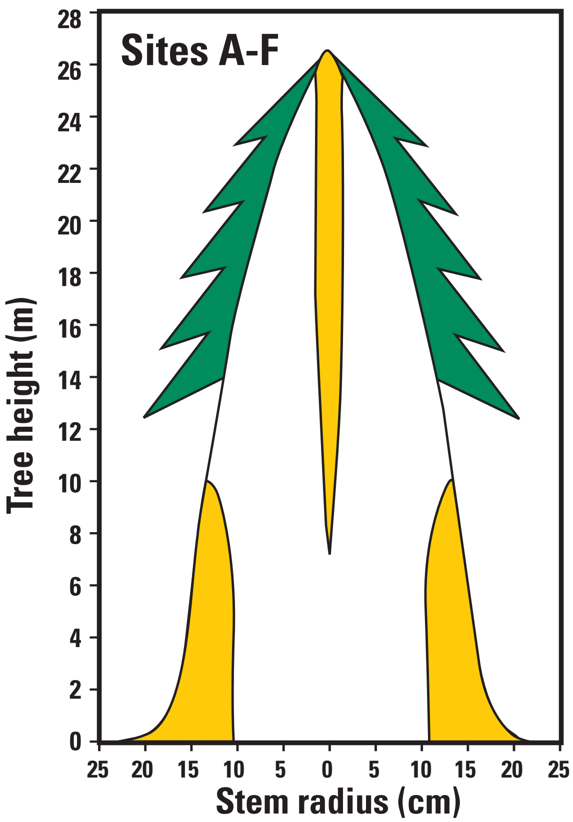
Yearly ring density trends from pith-to-bark, at five sampling heights.

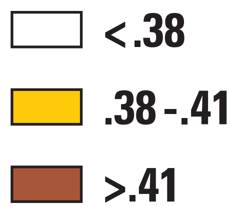
Note the “target” at 0.41, and the weighted average stem densities at 0.37, 0.39, and 0.40.

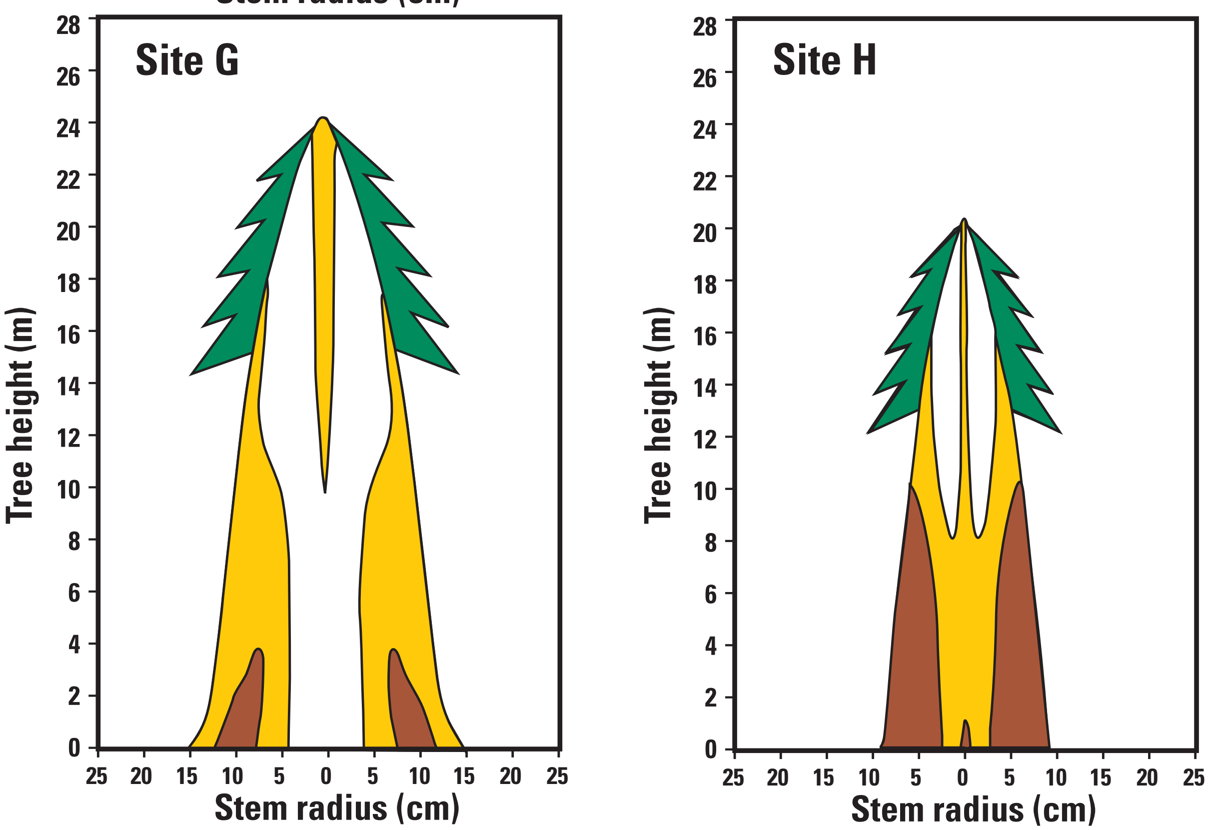
Note the dramatic upswing in density as we shift from the large-diameter trees to the medium-, and small-diameter trees.

Note how the period of juvenility “shrinks” at BH from about 35 years to 15 years from medium to small trees, respectively.

Second Growth Lodgepole Pine Density Distribution



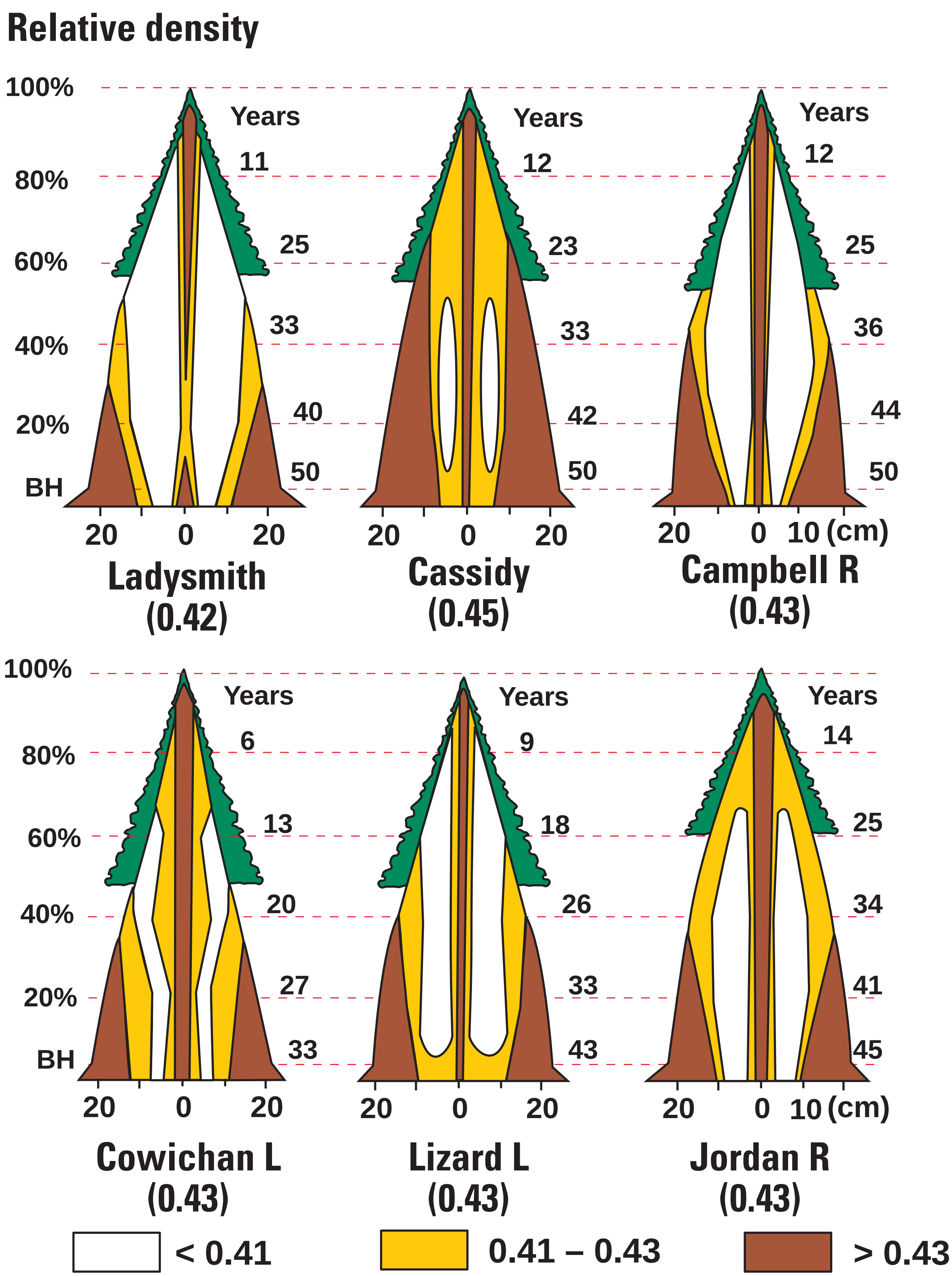




OVERHEAD 68

These stem profiles and density distributions were constructed with the help of trend-lines shown in overhead 71. Log merchandising and product potential for MSR lumber are points to ponder.

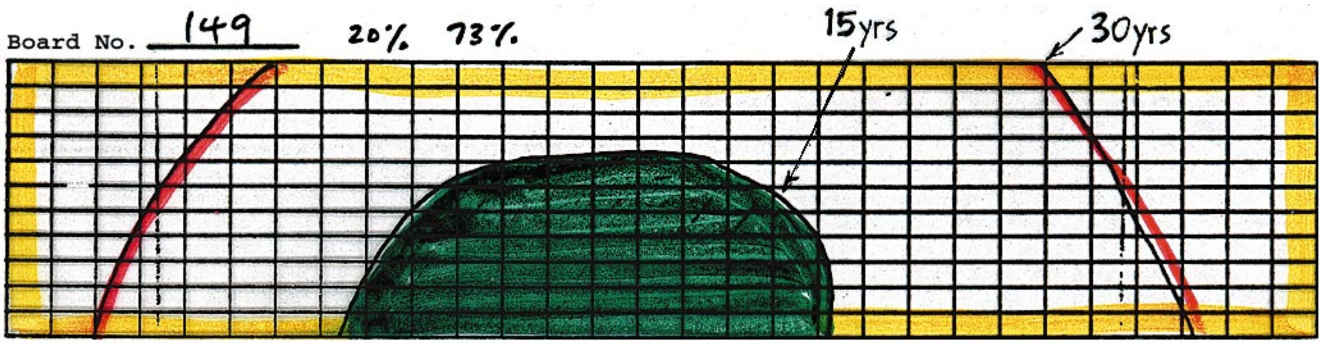
Relative Density Zones in Douglas-fir

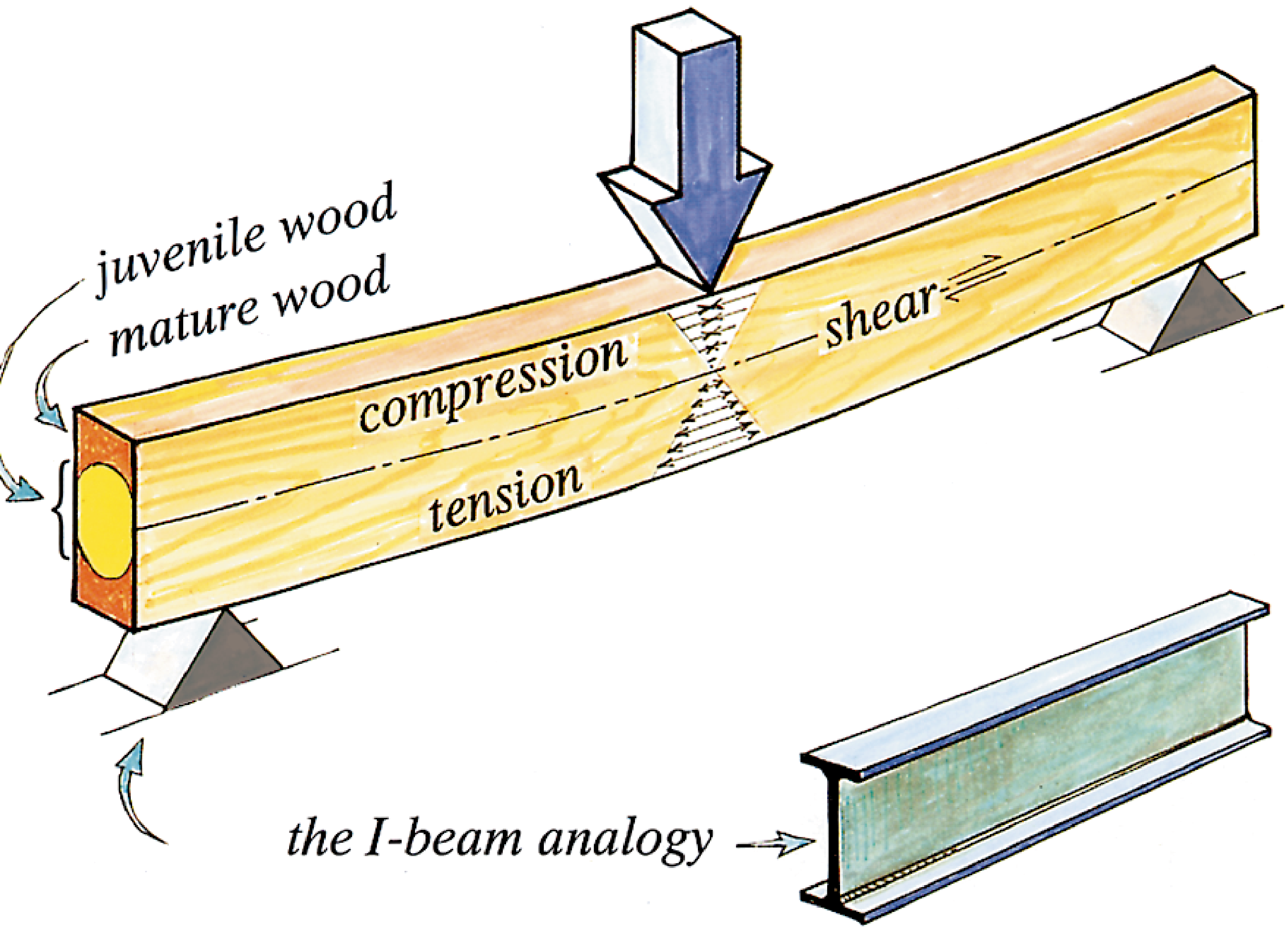


Overhead 69

Rapid increase in lumber recovery factor (fbm/m^3) is evident from 150 to 250 fbm, from 10 to 20 cm top log diameter. The recovery factor levels off at 30 cm diameter.

Need large logs to produce wider widths! (e.g., need minimum 25–30 cm top-diameter logs to produce 2 × 10 lumber).

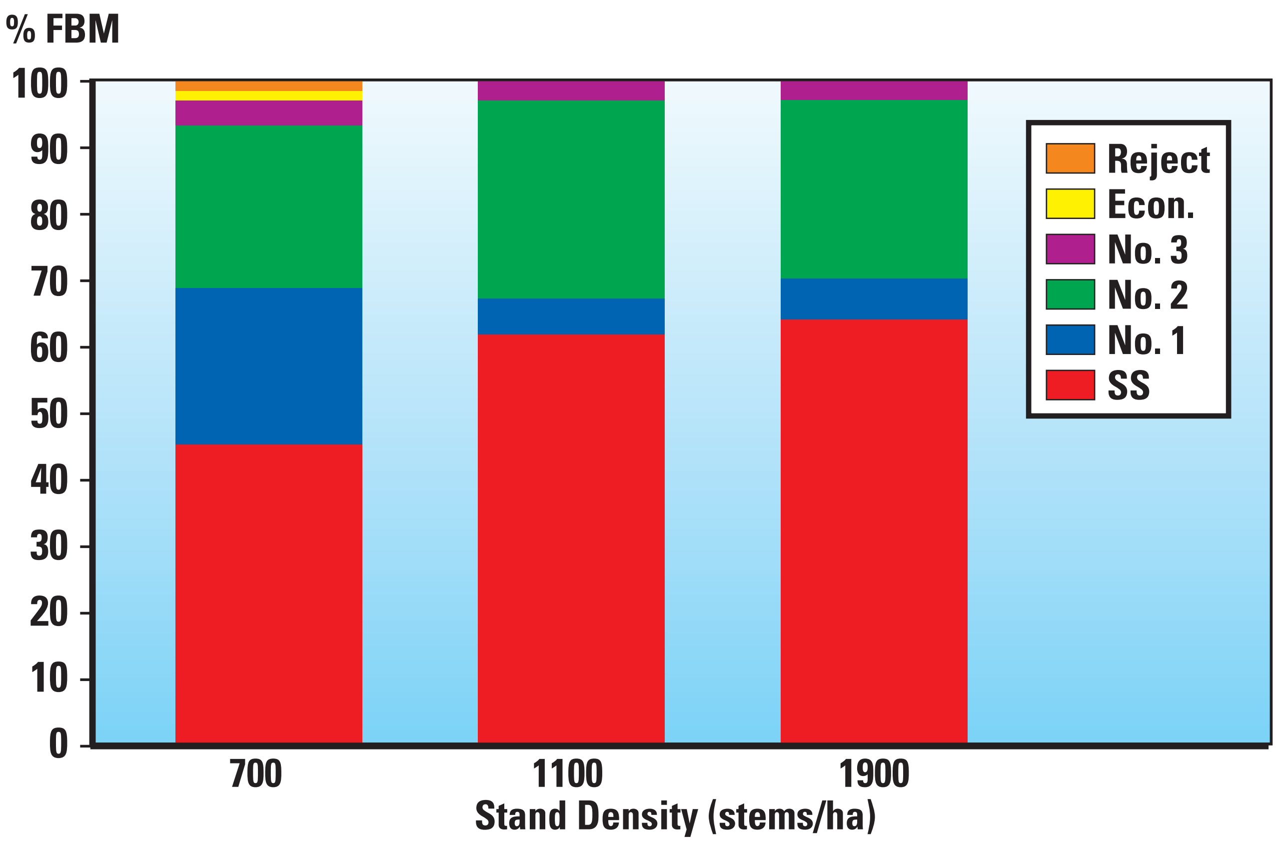

Board No. 149
20% 73%
15yrs
30yrs


juvenile wood
mature wood
compression
tension
shear
the I-beam analogy

Overhead 70

Self explanatory; for additional information please read page 14 of SP No. 34.

Structural Lumber Yields by Visual Grading

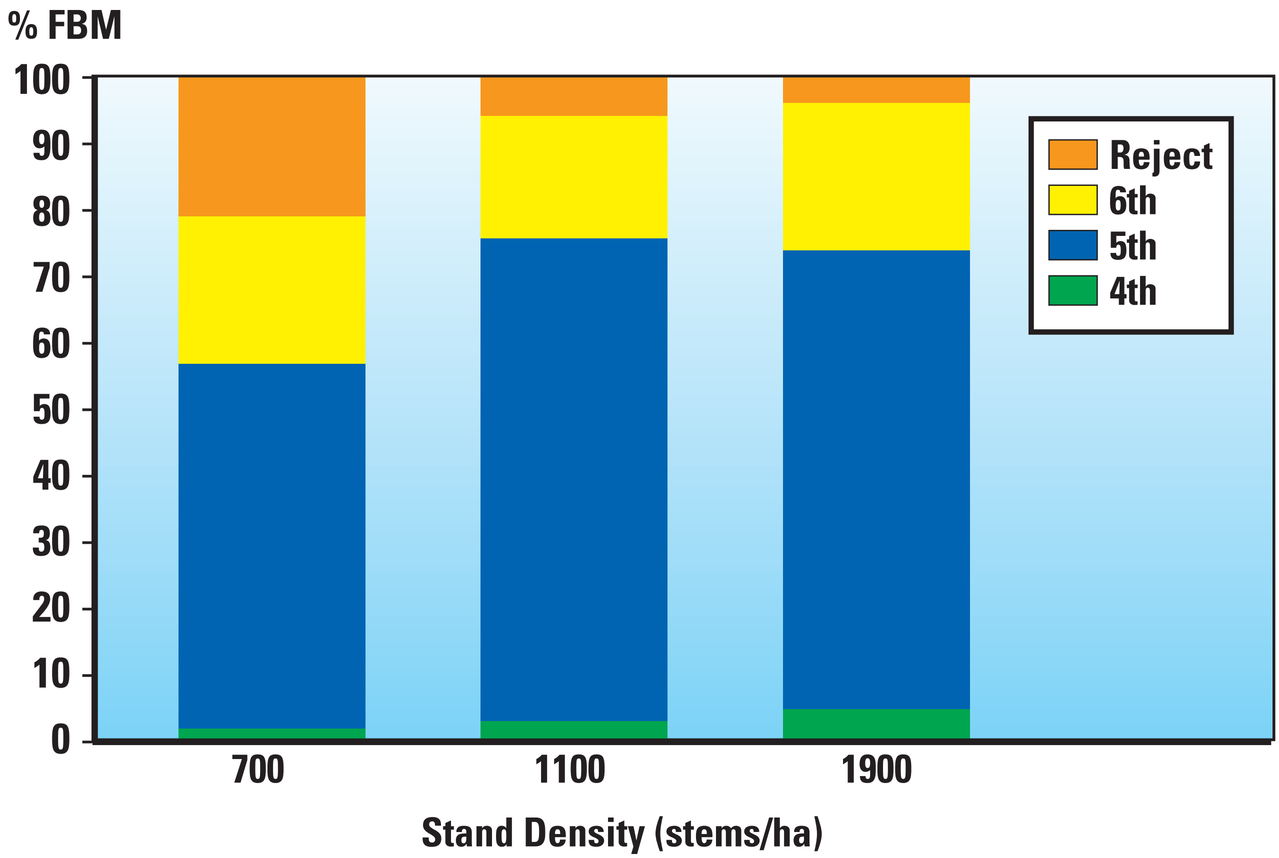


Overhead 71

Even at 700 stems per hectare there is 94% No. 2 and better lumber yield, however, Select Structural yield is up to 65% at the 1100 and 1900 stems/ha (from the 45% at 700 stems/ha).

The first exercise in this type of grade yield and value study is to come up with the weighted average value; that is, combine the value ($/fbm of SS, No. 1, No. 2, etc.) with lumber yields (lumber recovery factor times m^3 of logs from the three stands). There are a number of potential pitfalls. First, what lumber price do we use in our calculations? – in our study we used 10 year average lumber prices (to accommodate periodic fluctuations). Second, it is difficult to get prices for Select Structural, No. 1, and No. 2 separately; usually, prices are quoted as “Standard & Better”.

Door, Window and Furniture-Grade Lumber Yields by Visual Grading



Overhead 72

The top grade is “4th”, followed by “5th” and “6th”. The 1100 and 1900 stems/ha trees produced very similar grade yields (~75% 4th and 5th), while the 700 stems/ha trees yielded ~55% 4th and 5th.

Refer to the maximum knot-size allowances wooden prop (live and dead maximum diameters are shown).

MSR Summary

Uses of MSR Lumber

- Primarily for roof trusses, I-joists, laminating stock for glulam
- Parallel chord floor trusses – new market (ease of handling, longer spans, ready openings for wiring, plumbing and ductwork)

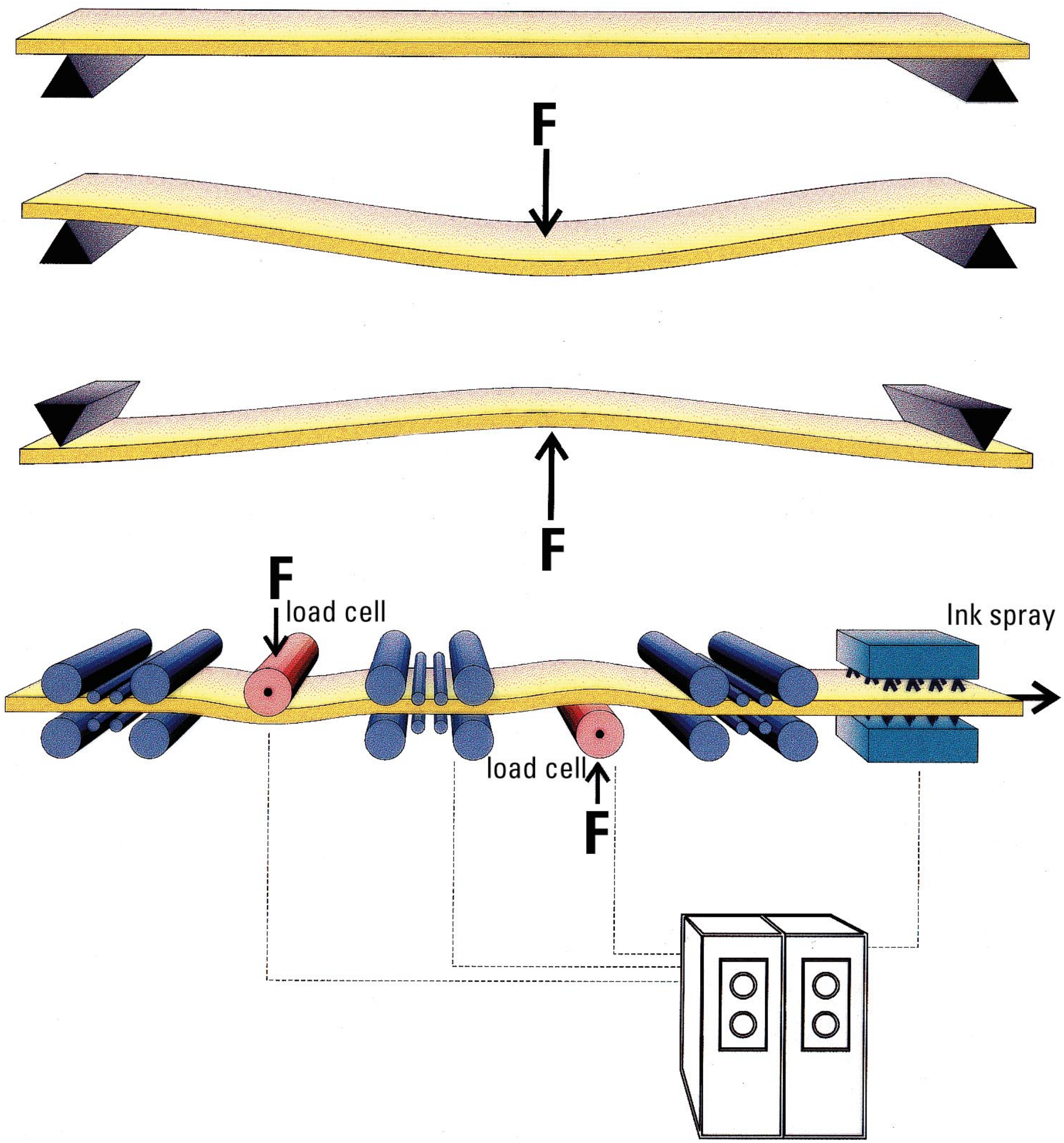
Advantages of MSR Lumber

- better consistency because of E rating (more uniform "links")
- quality control in the plant – none with visually graded
- lumber can be cut from small logs (no need for very wide widths)
- reduced variability = reliability and exactness
- reduced waste (2% vs 10%)
- uniformity across "species boundaries" (fewer grades)
- **Profit** (marketability)

Overhead 73

Machine Stress Rated (MSR) lumber is going to be more and more common in the future in structural applications. There is a global “push” by structural engineers for MSR lumber grades because of the greater reliability in terms of design and performance (when compared with visual grades). In spite of the great potential for MSR lumber, in 1996 little more than 5% of all lumber cut in North America was MSR’d.

MSR Grading System



Overhead 74

MSR grades are determined in the sawmill at production speeds, about 1000 feet/minute. This schematic shows the concepts and the main elements. Each piece of lumber is “flexed” from both top and bottom (not unlike the instructor standing in the middle of an 8' 2 × 4, supported on the two ends on chairs). Although the piece of lumber is loaded on the wide face, the strength and stiffness result is equally valid for the narrow face as well. Computer assisted photocells determine the beginning and the end of each stick of lumber.

(It might be a good time to quiz students if they know the difference between strength and stiffness. Which one of the two measurements is the more important one?)

It is very important to put in perspective MSR lumber production, not only in BC, but elsewhere as well. Experts tell me that if we were to take atypical BC interior S-P-F mill that pulls MSR lumber, the following is the average yield: About 80% of the lumber gets a spray mark. In other words, 80% of the pieces going through the machine are stiff-enough. However, only about one half of these pieces will pass the visual inspection that looks for large edge knots and excessive wane. Therefore, just because a sawmill cuts MSR lumber not all lumber will pass the machine and visual override; typically, only 40% gets the MSR stamp. The next challenge is, what are we to do with 60% of the lumber that did not make it?

Strength of wood

is the resistance to forces deforming it.

- There are still other things besides relative density that affect the strength of wood.
- These include knots, slope of grain, compression wood, the relative amounts of earlywood and latewood, moisture content, temperature (above 65°C), and fibril angle (the part of the tree, near the pith, or farther out from which the piece was cut).
- A few basic terms in wood mechanics:

  force: push, pull and shear

  stress: force per unit area (psi)

  strain: unit deformation

  stiffness (elasticity)**:** stress/strain

  creep: continuously stressed in bending,"flow","sag"

  fatigue: loss in wood property due to repeated force application (bending back and forth, 1/3 max. stress, 30,000,000 times)

Overhead 75

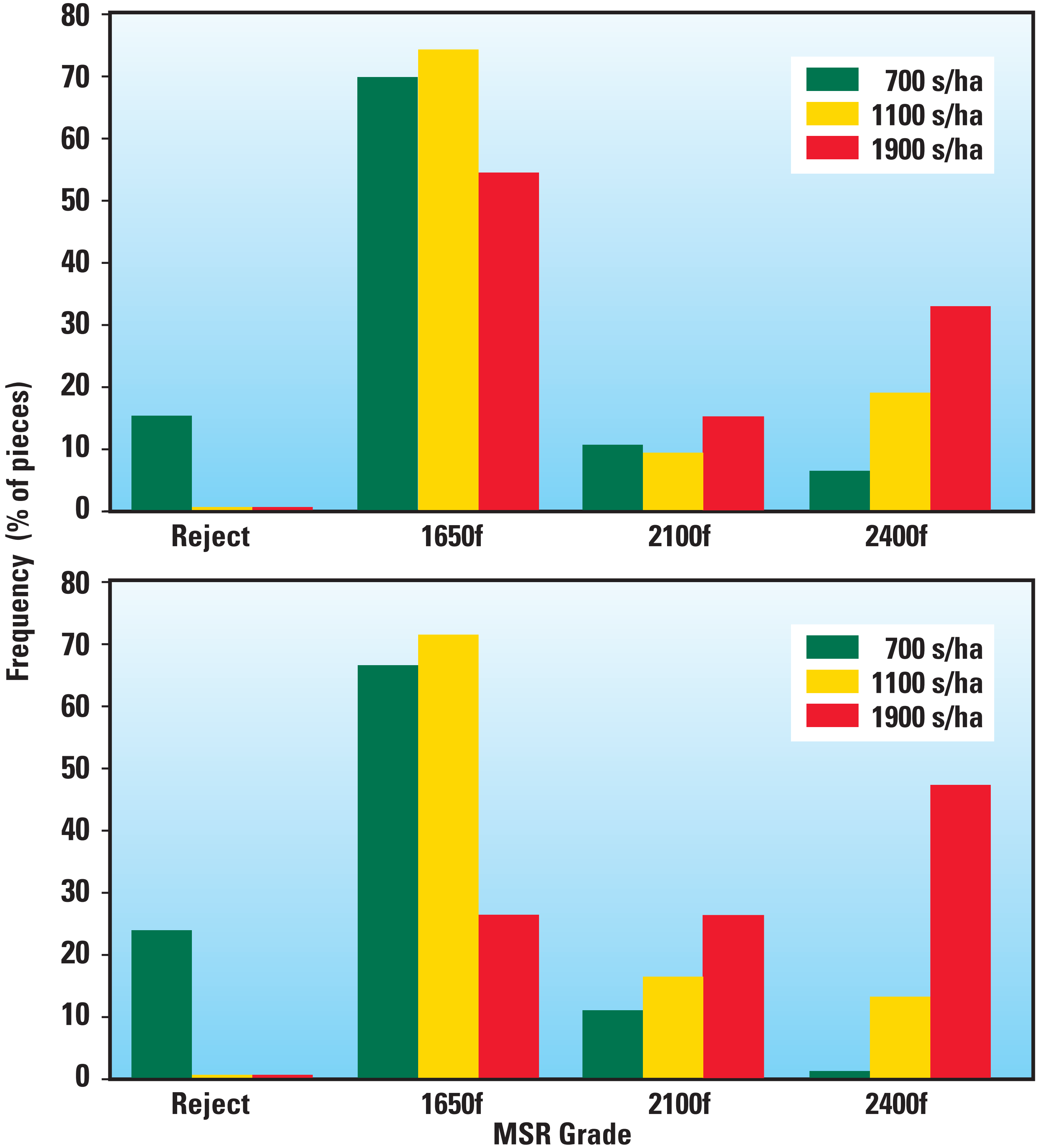
One reason that wood is often neglected by architect and engineers for many construction applications is its great variability in strength properties within visual grades. For this reason there is an international movement that insists on MSR structural lumber grades.

Machine stress rating consists of a collection of machinery, methods, and rules which make use of a nondestructive measurement of certain physical properties to classify lumber for use in structures, where their performance must meet minimum standards.

To get in the right frame of mind, we will review some of the basic terms that describe the strength properties of wood. We will use the “popular” meanings to avoid confusion.

Machine-stress rated lumber yields

Distribution of MSR Grades for 2x4's by Stand Density



Distribution of MSR Grades for 2x6's by Stand Density

Overhead 76

Machine Stress Rated Lumber Yields are discussed in great detail in Forintek's Special Publication No. Sp-35 (p. 46–53).

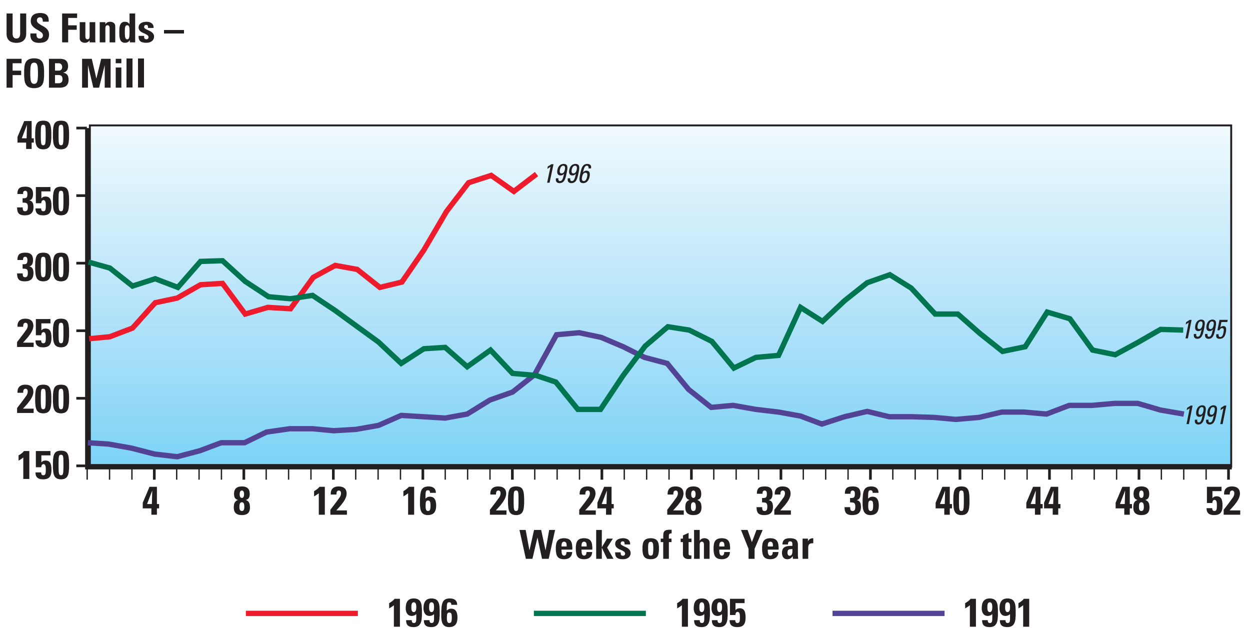
Visual **"over-ride"** is used to eliminate potential problem pieces that could include large edge knots, excessive wane **(truss manufacturing can not use waney lumber because the metal-connecting plate staples do not stick too well to air!)**, decay, etc.

Refer to the lumber display, showing different grades, including down-graded pieces (with the blue or red paint streak).

Overhead 76A

This graph shows the total tensile loads allowed by present design rules for different grades and dimensions. Note how the visual grades suffer, especially with the wider widths, when compared with MSR lumber.

Western SPF KD Std&Btr Random Lengths – 2x4



As reported by Madison's Canadian Lumber Reporter – **May 24, 1996**

MSR Lumber—Kiln Dried—8'/20'

	2x4 SPF		2x6 SPF	
1650f	$490	{450}	$440	{400}
1800f	495	{455}	n/a	n/a
2100f	495	{460}	465	{425}
2400f	520	{480}	480	{440}

*Prices are in U.S. funds, F.O.B. Chicago
Prices in () are f.o.b. Vancouver

As reported by Madison's Canadian Lumber Reporter

Overhead 77

The author keeps track of Canadian lumber prices through reading Madison's Canadian Lumber Reporter.

Showing the top half of this overhead gives a good example of the volatility of lumber prices over a two-and-a-half-year-period. The price shown is for random length S-P-F 2 × 4, Standard & Better grade. We can see a selling-price of about $350 (USA) in the 20th week of 1996. This price is being shown as a reference point in terms of MSR lumber price premiums (reveal the bottom half of the overhead).

We can see about $100–150 premium for MSR lumber. Herein lies the incentive for Mechanical Stress Rating. Examine and discuss price differences between different strength classes, and between 2 × 4 and 2 × 6. Why would a sawmill manager want to cut 2 × 6 dimension when 2 × 4 is selling at a higher price/thousand?

Overhead 77a

Data shown here is based on actual laboratory measurements of 1 371 pieces of 2 × 4 lumber. Note that the high- strength pieces (2400f-2.0E) have high basic-relative-density.

Note the lodgepole pine species average density of 0.41 correspond to 1800f.

Superimpose our large-diameter and open-grown tree average densities; 0.38 and 0.36, respectively.

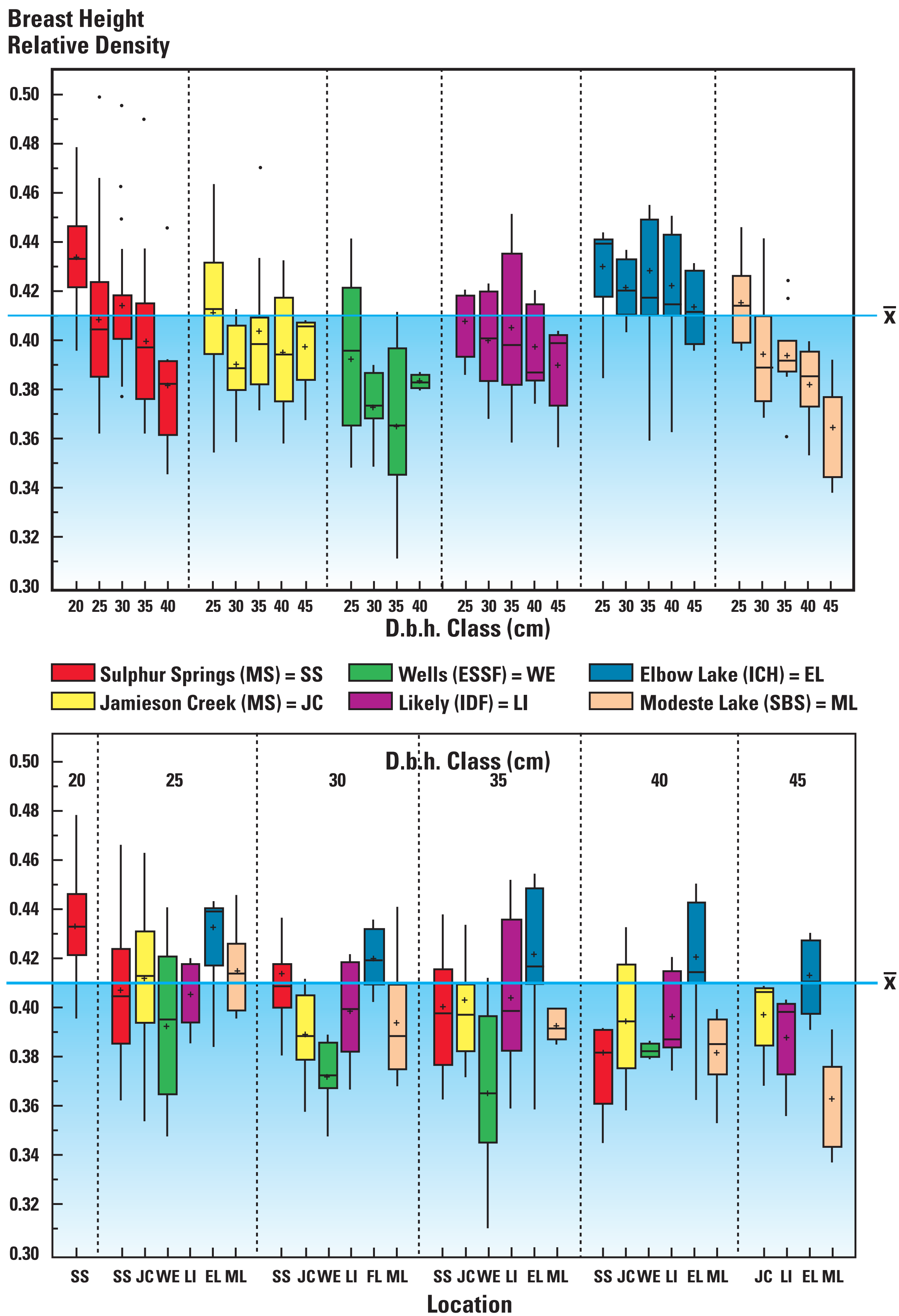
This graph demonstrates that low-density woods, such as subalpine fir (0.33), will yield little MSR lumber.

Re-emphasize an earlier point— a typical interior S-P-F mill that makes MSR lumber will have the following “batting average”; although 80% of the lumber will get sprayed, only one half will pass the visual check. Therefore, 40% of the lumber will receive the proud MSR stamp, however what will happen to the 60% that did not make the grade? Answering this question will be a challenge to mills with low-density wood, who will not be lobbying for MSR standardization— they will be more than happy with the visual grades.

Overhead 77b

Look this table up in SP No. 35 and read background information, and necessary qualifications.

The main point here is that the middle of the road seems the best, using today’s product prices and expectations (good-grade lumber is more valuable): at 700 stems/ha the problem is with quality, in terms of visual SS top grade, and MSR yields from the big “pumpkins”; at 1900 stems/ha sawlog volumes were lower.

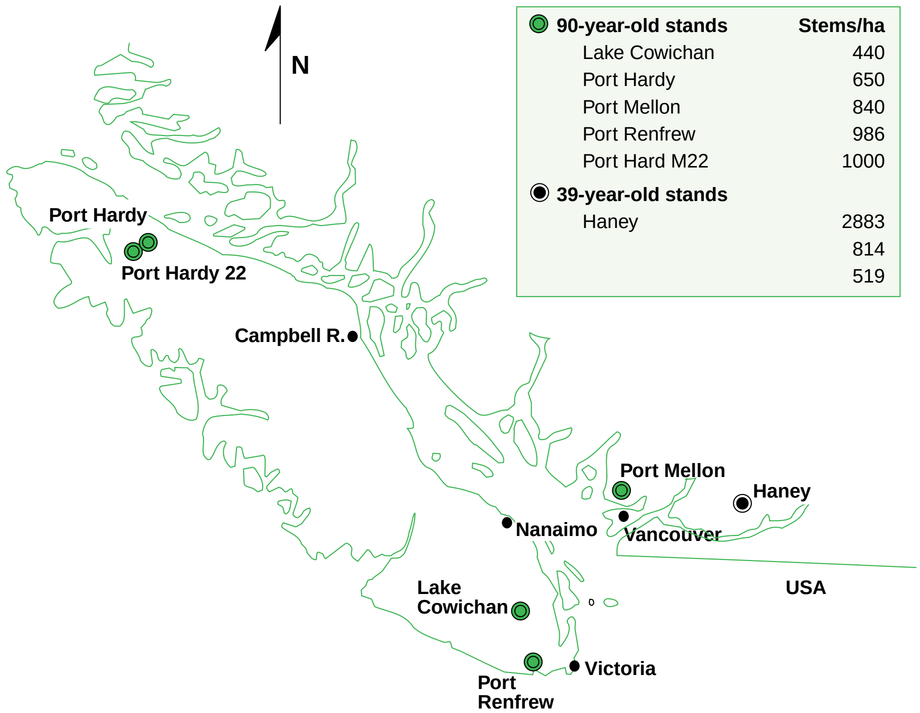

Breast Height
Relative Density
0.50
0.48
0.46
0.44
0.42
0.40
0.38
0.36
0.34
0.32
0.30
20 25 30 35 40
25 30 35 40 45
25 30 35 40
25 30 35 40 45
25 30 35 40 45
25 30 35 40 45
D.b.h. Class (cm)
x̄
Sulphur Springs (MS) = SS
Jamieson Creek (MS) = JC
Wells (ESSF) = WE
Likely (IDF) = LI
Elbow Lake (ICH) = EL
Modeste Lake (SBS) = ML
D.b.h. Class (cm)
20
25
30
35
40
45
SS
SS JC WE LI EL ML
SS JC WE LI FL ML
SS JC WE LI EL ML
SS JC WE LI EL ML
JC LI EL ML
Location

Overheads 78

This overhead should be shown first with the bottom-half covered up. Forintek's special publication No. SP- 36 should be read for background information, particularly the "Wood Density" heading on page 13.

The main point of the **Regional Comparisons of Wood Density and Knot Size in Low Stand Density Lodgepole Pine** report was that it confirmed the study results of the Lodgepole Pine Task Force, carried out in the SE corner of BC. In other words, the results are valid throughout the province.

One pleasant surprise was the Interior Cedar Hemlock (ICH) biogeoclimatic zone— here even the >30 cm DBH trees had equal or higher density than the target 0.41. Most likely explanation is soil moisture availability during the summer months (July and August) when the latewood is laid down, and the tree can keep-on growing (instead of suffering from soil-moisture-deficit). Further work in the ICH zone will determine if the higher wood density and smaller branch sizes resulted from the slow 30 year growth rate (a stand effect), or from specific zonal growing conditions (as hypothesized above).

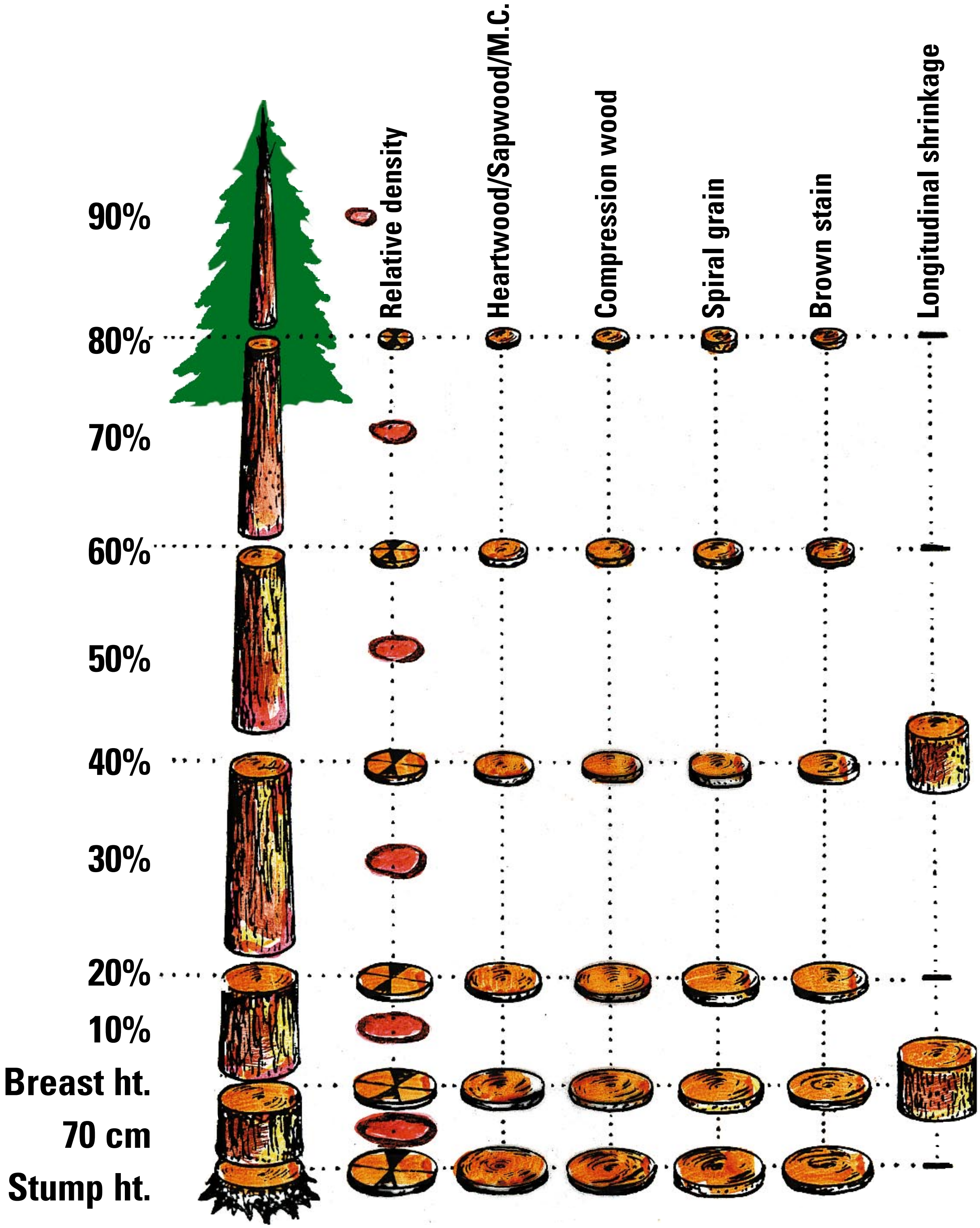


N
90-year-old stands
Stems/ha
Lake Cowichan 440
Port Hardy 650
Port Mellon 840
Port Renfrew 986
Port Hard M22 1000
39-year-old stands
Haney 2883
814
519
Port Hardy
Port Hardy 22
Campbell R.
Port Mellon
Haney
Nanaimo
Vancouver
USA
Lake
Cowichan
Victoria
Port
Renfrew

Overhead 78a

Map of sampling locations for western hemlock basic wood properties study. Ninety year old trees were sampled at five locations, from 450 to 1000 stems/ha.

Thirty-nine year old trees from Haney provided a controlled sample set for examining stocking density effects on stemwood density at 3×3, 9×9, and 12×12 feet spacings.



Sampling plan for basic wood properties characterization of second-growth western hemlock.

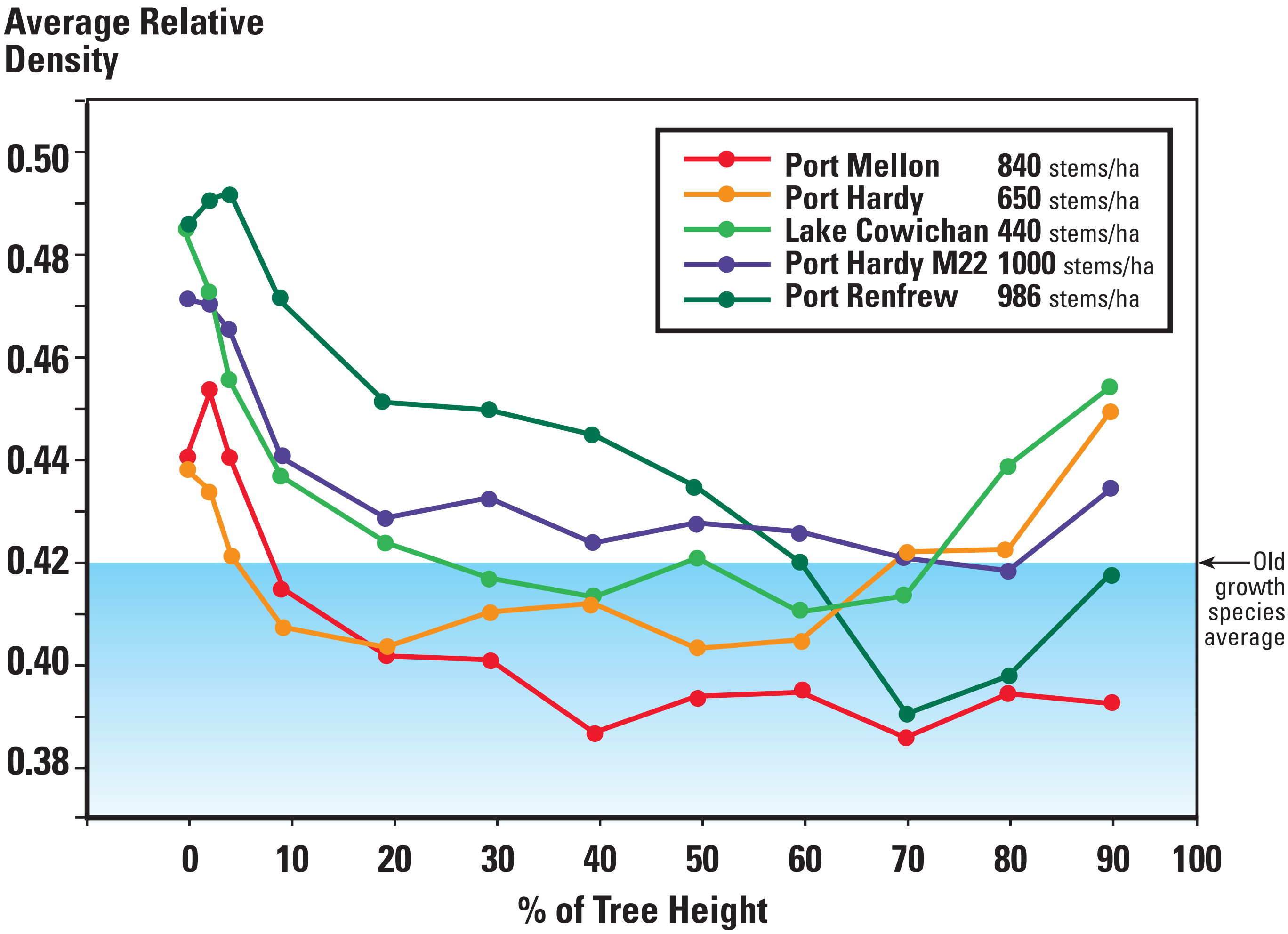
Overhead 79

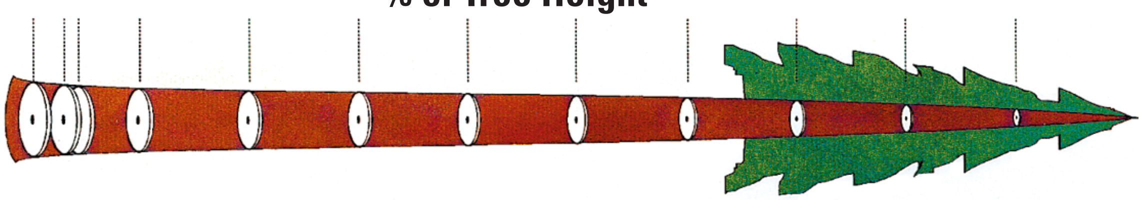
Sampling plan for basic wood properties characterization of 90 year old second-growth western hemlock. To accommodate the BC Ministry of Forests Research Branch needs, we increased the sampling intensity for yearly pith-to-bark relative density measurements from five height levels (@ BH, 20, 40, 60, and 80%) to 12, adding the stump, 70 cm, 10, 30, 50, 70, and 90% height disks. This additional “resolution” was required for modelling tree growth for TASS and other applications.

Outline the need for the basics in terms of the six variables, and relate to old-growth “standards” whenever possible (e.g., Strength/stiffness, permeability, dimensional stability, and appearance).

Second-growth Western Hemlock

Disk Densities at 12 Heights for Five Sites





OVERHEAD 80

Disk densities, in relation to the 0.42 old-growth reference standard, show that these 90 year old western hemlock trees are producing "good wood". In fact, we can state that the bottom 10% of the stem, on average, is Douglas-fir-like in terms of relative density. The 50 year old Douglas-fir Task force trees had a BH disk density of 0.46, while at 20, 40, 60, and 80% relative density of disks were 0.44, 0.41, 0.41, and 0.42, respectively (overhead 63 b). Equally intriguing is the wide diversity in relative density of the top wood, at 70, 80, and 90% height levels.

The Port Mellon sample, at 850 stems/ha, seems the "odd-ball" in this comparison. More on this later, when we describe the "Haney trees".