Wood Quality...
Impact on Product Yields, Grades and Value

WORK BOOK
Big or Small Trees, Fast or Slow Growing Trees?

Then & Now
Wood Quality... Impact on Product Yields, Grades and Value.

5.0 GLOBAL TRENDS

Population (Billions)

World Population 1850 to 2100

6.0 GLOBAL TRENDS

Global Consumption of Raw Materials by 10.3% of Global Population

Our Forests

Temperate coniferous and mixed forests
Tropical rain forests

Japan, Germany, United Kingdom, France
United States
Wink Sutton holds "The Wedge"; a 1.8 litre piece of wood that represents the average amount of wood used each day by each person on earth.

(Based on FAO figures: total wood harvested / population of earth)

**Annual World Consumption of Wood**

- Industrial Roundwood: 1.7 billion m³
- Fuelwood: 1.8 billion m³

**Global Production of Fibre**

- 3.4 Billions (m³)
- 1.9 Billions (m³)
- 0.56 Billions (m³)

- Saw/veneer logs
- Other industrial roundwood
- Pulpwood
- Fuelwood/charcoal
- Wood-based panels, ROW
- Wood-based panels, U.S.
- Wood-based panels, Canada
- HW lumber, World
- SW lumber, ROW
- SW lumber, Canada

Source: FAO
Global Trends

Softwoods
- Sweden
- Canada/Pacific
- Canada/Interior
- Canada/East
- US/South
- Chile
- New Zealand
- Brazil

Hardwoods
- Sweden
- US/South
- Portugal
- Brazil
- South Africa
- Chile (Euca)

Growth and Mill Delivered Cost of Pulpwood - 1/91

40 30 20 10 0 10 20 30 40 50 60 70 80

(m³/ha/yr) (US $/m³)

IS B.C. BRAZIL OF THE NORTH?
This thinning operation is at age 23. About 3 years later this stand will be clearcut and replanted.

26-year-old Caribbean pine hybrid.

Rapid Early Growth

Pitch Pocket

Sticker
Phenology of Tree Growth

Relative activity


Top/crown growth
Diameter growth
Root growth
Wood Quality... Impact on Product Yields, Grades and Value.

21.0 TREE GROWTH AND TREE PHYSIOLOGY

• Terminal shoot and vigorous last formed portions of the crown foliage produce growth regulating hormones (auxins) and photosynthate.
• Lateral and downward translocation of auxins to reach lower stem.
• In spring radial growth begins first at the top of the tree and proceeds gradually downward = more EW and wider rings in upper crown region near pith.
• Less EW and smaller rings at the base where rings are far from pith.
• Transition to LW occurs first near the base, farthest from the source of auxin supply and proceeds upward.
• The destiny (and density) of an individual fibre is thus determined by its relative position; its distance from the active live crown region and the time of its formation (season).

22.0 TREE GROWTH AND TREE PHYSIOLOGY

Allometry (allocation of photosynthates)
Wood Quality... Impact on Product Yields, Grades and Value.

Wood Structure and Wood Anatomy
Wood Quality... Impact on Product Yields, Grades and Value.

Wood Anatomy

Earlywood

Latewood
Wood Quality: Impact on Product Yields, Grades and Value.

Wood Structure and Wood Anatomy

Western hemlock
True fir (Abies)
White spruce
Western redcedar
Lodgepole pine
Western white pine
Douglas fir
Wood Quality Impact on Product Yields, Grades and Value.

Relative Density of Wood

- Western redcedar
- Subalpine fir
- Interior spruce (Amabilis fir)
- Lodgepole pine
- Western hemlock
- Yellow-cypress
- Douglas-fir
- Western larch

Relative density

Global to Microscopic View of Density Distribution in BC Tree Species

Average Densities

- Western redcedar
- Subalpine fir
- Interior spruce (Amabilis fir)
- Lodgepole pine
- Western hemlock
- Yellow-cypress
- Douglas-fir
- Western larch
Wood Quality... Impact on Product Yields, Grades and Value.

Wood Density Variation within Growth Rings

![Diagram of density variation in Yellow-cypress and Douglas-fir wood samples.](image)

**Wood Density Variation within Growth Rings**

- **Yellow-cypress**
  - Annual ring density range: 0.40 - 0.60
  - Density range: 0.25 - 0.85

- **Douglas-fir**
  - Annual ring density range: 0.40 - 0.60
  - Density range: 0.25 - 0.85
Wood Quality… Impact on Product Yields, Grades and Value.

Juvenile Wood
(wood that is formed in the live crown)

8 20 35 85 (years)
mature wood

Juvenile Wood (JW) and Mature Wood (MW)
Wood Quality... Impact on Product Yields, Grades and Value.

38.0 JUVENILE WOOD, CROWN-FORMED WOOD

Douglas-fir
W. larch
W. hemlock
Yellow-cypress
Lodgepole pine
Sitka spruce
Interior spruce
Subalpine fir
W. redcedar

Relative Density at BH of Rapidly Grown B.C. Woods
Wood Quality... Impact on Product Yields, Grades and Value.

Mature wood

Juvenile wood

Compression wood

Second Growth Douglas-fir

Fibre length (mm)

Age (years)
Wood Quality... Impact on Product Yields, Grades and Value.

Western Redcedar

Ethanol-Benzene extractives (%)

Wood fibres from U.V. (ultraviolet) exposure damage from sunlight.
71-year-old open-grown lodgepole pine.
Wood Quality... Impact on Product Yields, Grades and Value.

Compression Wood

Typical Shrinkage Values for "Normal" Wood
% Volumetric Shrinkage at 12% MC

Wood Quality Impact on Product Yields, Grades and Value.
## Wood Quality Impact on Product Yields, Grades and Value

### The Process of Wood Drying

<table>
<thead>
<tr>
<th>Drying Stage</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Moisture Condition:</strong></td>
<td>Above FSP, core still above FSP. Core moisture migrates outward to shell.</td>
<td>Shell below FSP in tension, eventually reaches uniform low EMC.</td>
<td>Core below FSP (flat-grained).</td>
</tr>
<tr>
<td><strong>Stress Condition:</strong></td>
<td>Stress-free</td>
<td>Shell tries to shrink, creates tension across surfaces, squeezes the core into compression. Drying sets shell in oversized condition.</td>
<td>Core now trying to shrink away from oversized shell. Core develops tension, pulls shell into compression.</td>
</tr>
<tr>
<td><strong>Defects:</strong></td>
<td>Defect-free</td>
<td>Surface may check; core may collapse.</td>
<td>Surface is casehardened; core may honeycomb.</td>
</tr>
</tbody>
</table>

---

### Second Growth Douglas-fir Resource


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**Wood Quality...** Impact on Product Yields, Grades and Value

...and Value
Wood Quality… Impact on Product Yields, Grades and Value.
Wood Quality... Impact on Product Yields, Grades and Value.

Size Premium

Random Lengths/Key Price Indicator
January, 1992 Prices

S-P-F-RL-KD  D-Fir-Green-RL

$/1000 fbm

Dollars

Piece Size

Log Value

Processing Cost

Profit

Wood Quality... Impact on Product Yields, Grades and Value.
Wood Quality... Impact on Product Yields, Grades and Value.
50-year-old Douglas-fir

<table>
<thead>
<tr>
<th>Cambial age (years)</th>
<th>Relative density</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.55</td>
<td>Juvenile wood</td>
</tr>
<tr>
<td>0.50</td>
<td>Mature wood</td>
</tr>
<tr>
<td>0.45</td>
<td></td>
</tr>
<tr>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>0.35</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ring width (mm)</th>
<th>6.35 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.23 mm</td>
<td></td>
</tr>
<tr>
<td>3.16 mm</td>
<td></td>
</tr>
</tbody>
</table>

Breast height
- 51% juvenile wood by volume
- 49% mature wood by volume

Juvenile Wood Cylinder
First 20 Years of Growth in 50-year-old Douglas-fir
Wood Quality... Impact on Product Yields, Grades and Value.

Diameter, Taper and Density Distribution in Douglas-fir

Relative Density Zones in Douglas-fir

Relative density
Wood Quality... Impact on Product Yields, Grades and Value.

Juvenile/Mature Wood Ring Profiles

Relative density

![Diagram showing relative density of juvenile and mature wood rings.](image)

Stem-wood Relative Density

Relative density

![Diagram showing stem-wood relative density.](image)
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.

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

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

<table>
<thead>
<tr>
<th>DBH (cm)</th>
<th>Age (yrs)</th>
<th>Stems/ha</th>
<th>Density BH</th>
<th>Stem Density</th>
<th>Stem Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.5</td>
<td>93.0</td>
<td>1,600</td>
<td>0.37</td>
<td>0.37</td>
<td>0.18</td>
</tr>
<tr>
<td>20.0</td>
<td>91.0</td>
<td>1,600</td>
<td>0.37</td>
<td>0.37</td>
<td>0.18</td>
</tr>
<tr>
<td>15.0</td>
<td>95.0</td>
<td>1,600</td>
<td>0.37</td>
<td>0.37</td>
<td>0.18</td>
</tr>
<tr>
<td>10.0</td>
<td>96.0</td>
<td>1,600</td>
<td>0.37</td>
<td>0.37</td>
<td>0.18</td>
</tr>
<tr>
<td>5.0</td>
<td>95.0</td>
<td>1,600</td>
<td>0.37</td>
<td>0.37</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Open-grown Alta. B.C. G H I
Wood Quality Impact on Product Yields, Grades and Value.

Average Disk Density at Five Sampling Heights

- Marlboro (average of six large diameter sites)
- Bingay Creek
- Medium (Fording Mtn.)
- Small (Sulpher)
- Control

BH Sampling Height (%)

<table>
<thead>
<tr>
<th>Relative Density</th>
<th>51%</th>
<th>44%</th>
<th>35%</th>
</tr>
</thead>
</table>

Disk Relative Density

Marlboro Average of six large diameter sites

Bingay Creek

Medium (Fording Mtn.)

Small (Sulpher)

Control

Average Disk Density at Five Sampling Heights

Disk Relative Density

<table>
<thead>
<tr>
<th>Sampling Height (%): 51%</th>
<th>44%</th>
<th>35%</th>
</tr>
</thead>
</table>

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

- 16 cm, 95 yrs at BH: 3380 live stems/ha
- 18 cm, 96 yrs at BH: 3000 live stems/ha
- 28 cm, 121 yrs at BH: 1300 live stems/ha
- 40 cm, 90 yrs at BH: 700 live stems/ha
- 60 cm, 75 yrs at BH: 300 open-grown trees

Resource-average basic relative density for lodgepole pine 0.41
Wood Quality... Impact on Product Yields, Grades and Value.

Second Growth Lodgepole Pine Density Distribution

Sites A-F

Sites G

Sites H
Wood Quality... Impact on Product Yields, Grades and Value.

![Graph showing LRF (ft³/m³) vs. Top Diameter Class (cm)]

<table>
<thead>
<tr>
<th>Top Diameter Class (cm)</th>
<th>LRF (ft³/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>15</td>
<td>70</td>
</tr>
<tr>
<td>20</td>
<td>90</td>
</tr>
<tr>
<td>25</td>
<td>110</td>
</tr>
<tr>
<td>30</td>
<td>130</td>
</tr>
<tr>
<td>35</td>
<td>150</td>
</tr>
<tr>
<td>40</td>
<td>170</td>
</tr>
<tr>
<td>45</td>
<td>190</td>
</tr>
<tr>
<td>50</td>
<td>210</td>
</tr>
</tbody>
</table>

![Graph showing Lumber Volume (%) vs. Top Diameter Class (cm)]

<table>
<thead>
<tr>
<th>Top Diameter Class (cm)</th>
<th>Lumber Volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>25</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>35</td>
<td>60</td>
</tr>
<tr>
<td>40</td>
<td>70</td>
</tr>
<tr>
<td>45</td>
<td>80</td>
</tr>
<tr>
<td>50</td>
<td>90</td>
</tr>
</tbody>
</table>

Wood Quality... Impact on Product Yields, Grades and Value.
**Wood Quality... Impact on Product Yields, Grades and Value.**

**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)

**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, ½ max. stress, 30,000,000 times)
**Machine-stress rated lumber yields**

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

<table>
<thead>
<tr>
<th>Density (s/ha)</th>
<th>Frequency (aadf pieces)</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
<tr>
<td>1100</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
<tr>
<td>1900</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Density (s/ha)</th>
<th>Frequency (aadf pieces)</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
<tr>
<td>1100</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
<tr>
<td>1900</td>
<td>Reject: 1650, 2100, 2400</td>
</tr>
</tbody>
</table>
Wood Quality... Impact on Product Yields, Grades and Value.

Western SPF KD Std&Btr Random Lengths - 2x4

MACHINE STRESS RATED (MSR) LUMBER
MSR Lumber—Kiln Dried—8'/20'

2x4 SPF 2x6 SPF

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1650f</td>
<td>$490</td>
<td>$440</td>
<td></td>
</tr>
<tr>
<td>1800f</td>
<td>495</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>2100f</td>
<td>495</td>
<td>465</td>
<td>425</td>
</tr>
<tr>
<td>2400f</td>
<td>520</td>
<td>480</td>
<td>440</td>
</tr>
</tbody>
</table>

*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 - May 24, 1996
Wood Quality... Impact on Product Yields, Grades and Value.

![Wood Quality Diagram]

Breast Height Relative Density

<table>
<thead>
<tr>
<th>Location</th>
<th>D.b.h. Class (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur Springs (MS) = SS</td>
<td>20 25 30 35 40</td>
</tr>
<tr>
<td>Wells (ESSF) = WE</td>
<td>25 30 35 40 45</td>
</tr>
<tr>
<td>Jamieson Creek (MS) = JC</td>
<td>20 25 30 35 40</td>
</tr>
<tr>
<td>Likely (IDF) = LI</td>
<td>25 30 35 40 45</td>
</tr>
<tr>
<td>Modeste Lake (SBS) = ML</td>
<td>20 25 30 35 40</td>
</tr>
</tbody>
</table>

**Legend:**
- Red: Sulphur Springs (MS) = SS
- Yellow: Wells (ESSF) = WE
- Blue: Jamieson Creek (MS) = JC
- Green: Likely (IDF) = LI
- Orange: Modeste Lake (SBS) = ML
## WESTERN HEMLOCK BASIC WOOD PROPERTIES

<table>
<thead>
<tr>
<th>Property</th>
<th>Heartwood/Sapwood/M.C.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative density</td>
<td>90%</td>
</tr>
<tr>
<td>Longitudinal shrinkage</td>
<td>80%</td>
</tr>
<tr>
<td>Spiral grain</td>
<td>70%</td>
</tr>
<tr>
<td>Compression wood</td>
<td>60%</td>
</tr>
<tr>
<td>Breast ht.</td>
<td>50%</td>
</tr>
<tr>
<td>Stump ht.</td>
<td>40%</td>
</tr>
<tr>
<td>Brown stain</td>
<td>30%</td>
</tr>
<tr>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>10%</td>
<td>Breast ht. 70 cm</td>
</tr>
</tbody>
</table>
| Sampling plan for basic wood properties characterization of second-growth western hemlock.
### Second-growth Western Hemlock

**Disk Densities at 12 Heights for Five Sites**

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Relative Density</th>
<th>% of Tree Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Mellon</td>
<td>0.48</td>
<td>0</td>
</tr>
<tr>
<td>Port Hardy</td>
<td>0.48</td>
<td>10</td>
</tr>
<tr>
<td>Lake Cowichan</td>
<td>0.46</td>
<td>20</td>
</tr>
<tr>
<td>Port Hardy M22</td>
<td>0.44</td>
<td>30</td>
</tr>
<tr>
<td>Port Renfrew</td>
<td>0.42</td>
<td>40</td>
</tr>
</tbody>
</table>

#### Second Growth Hemlock -
**Total Stemwood Density Distribution**

![Box plot showing total stemwood density distribution for different sites](image-url)
Wood Quality Impact on Product Yields, Grades and Value.

Lake Cowichan
Summary of 13 trees (450 stems/ha)

Port Hardy M 22
Summary of 13 trees (1000 stems/ha)
Average Tree Stem Profiles and Density Distributions

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

<table>
<thead>
<tr>
<th>Site</th>
<th>Stems/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Mellon</td>
<td>840</td>
</tr>
<tr>
<td>Port Hardy</td>
<td>650</td>
</tr>
<tr>
<td>Lake Cowichan</td>
<td>440</td>
</tr>
<tr>
<td>Port Hardy M 22</td>
<td>1000</td>
</tr>
<tr>
<td>Port Renfrew</td>
<td>986</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative Density Zones:</th>
<th>&lt; 0.40</th>
<th>0.40 – 0.43</th>
<th>&gt; 0.43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height (m)</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Stem Radius (cm)</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Area (cm²)</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>
Wood Quality... Impact on Product Yields, Grades and Value.

Global to Microscopic View of Density Distribution in Western Hemlock

Western Hemlock Log Grade Old-growth Second-growth

<table>
<thead>
<tr>
<th>Small Ø D log-length</th>
<th>$10,000</th>
<th>$4,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 - 36 in. H 18 - 24'</td>
<td>12,000</td>
<td>8,000</td>
</tr>
<tr>
<td>15 - 36 in. I 12 - 14'</td>
<td>12,000</td>
<td>15,000</td>
</tr>
<tr>
<td>4 - 11 in. J 16 - 20'</td>
<td>5,000</td>
<td>20,000</td>
</tr>
<tr>
<td>4 - 14 in. K 10 - 15'</td>
<td>6,000</td>
<td>4,000</td>
</tr>
<tr>
<td>4 - 36 in. Y &lt;6'</td>
<td>5,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Total</td>
<td>$50,000</td>
<td>$55,000</td>
</tr>
</tbody>
</table>

- Stand volume in second-growth 150 – 200m³ higher than in old-growth

WFPL - North Vancouver Island
Global to Microscopic View of Density Distribution in BC Tree Species

Western Hemlock
Lodgepole Pine
Douglas-fir
Western Redcedar
Yellow Cypress

Geographic Tree-to-tree Pith-to-bark Within-annual-ring Microscope

Solid Cell Wall Relative Density 1.1

0 0.2 0.4 0.6 0.8 1.0

0 0.2 0.4 0.6 0.8 1.0
Wood Quality is Related to Measurable Stand...