# Working with Weight Scale:
## *basic information and tenets of the ton(ne)*


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**Timber Measurements Society**
**Tacoma, Washington, April 6-8, 2011**

# What is weight scale

- Can be many things
  - Weight sample scale used to expand volume (evolving ratio)
  - Weight converted to volume via institutionalized factors (set ratio)
  - Weight as the only unit
- For this presentation, we will focus on weight as the unit of measure for payment and what you need to know to manage conversion to volume and value


# What are the strengths of weight?

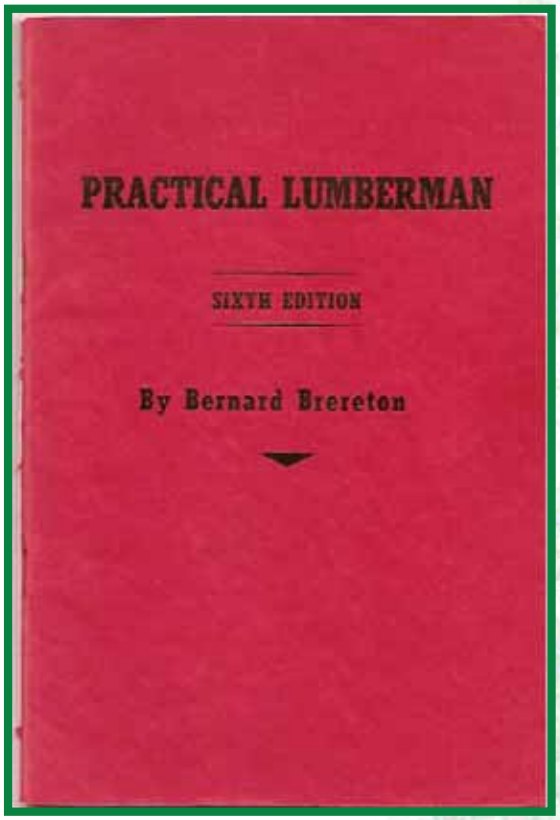
- It is tangible to all
- It is relatively inexpensive
- Good correlation with volume
- Quickly processed
- Often viewed as a “fairer” way of paying for harvest and hauling
- Accountants and auditors love it!

# What are the weaknesses of weight?

- Can be difficult to convert to volume due to:
  - Mixed loads: species/sorts
  - Natural variability within a species/sort
  - Exogenous factors (moisture, dehydration): wood is hydroscopic
- Does not measure all of the key value drivers
  - Diameter, length, species, defects, grade, manufacturing quality
- You still need to physically scale logs to get the most from weight
- You need to have access to a weight scale

# Bernard Brereton…the man, the myth, the visionary

- Wrote extensively about weight/volume relationship of logs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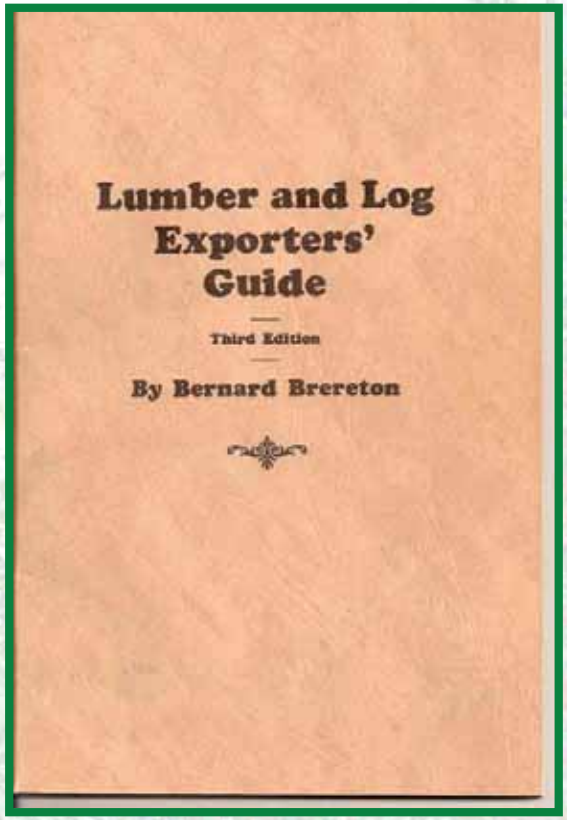


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# Using a log's buoyancy to determine weight

## To Determine the Weight of Floating Logs in Fresh or Salt Water

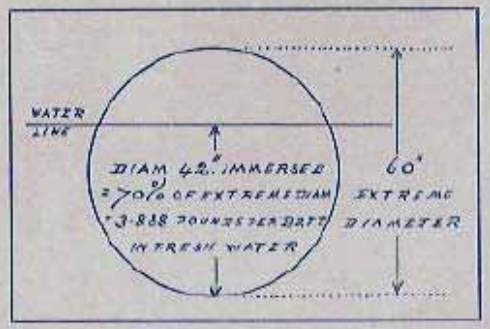
In the export trade, logs are bought, sold and freighted on the Brereton Scale; contents are given in board feet volume or one-twelfth of a cubic foot and measurements are based on the mean of both end diameters inside the bark; but for weight purposes, the extreme diameter, meaning "outside the bark," is used.

To find the weight, the extreme diameter is taken, upon which the volume in board feet is determined. In addition the diameter measurement of the immersed part of the log is taken from outside the bark to the water line.

In the process of computing the weight, it is necessary to find the immersed percentage of the extreme diameter. This is done by dividing the extreme diameter into the immersed diameter. To find the immersed percentage of the extreme diameter add two ciphers to the immersed diameter and divide the result by the extreme diameter.

EXAMPLE: Find the immersed percentage of the extreme diameter of a log, 60 inches extreme diameter, 42 inches of which is immersed.

OPERATION: 60 divided into 4200 equals 70, the immersed percentage.




VOLUME: The diameter system used as a necessary aid to find the weight per board foot having been explained, the next step is to find the volume of the log in board feet. This can be ascertained by the use of the Brereton log scale table, which is based on the following formula:

FORMULA: Multiply the square of the average middle (mean) diameter of the log in inches by 0.7854 and the product by the length in feet, then divide by 12. The result will be the actual content in board feet or one-twelfth of a cubic foot.

To determine the content and weight, the following details are required and the dimensions of an example log, 34 feet long, are included for this purpose.

58 inches extreme diameter, small end.
62 inches extreme diameter, large end.
60 inches mean of extreme diameters.
40 inches immersed diameter, small end.
44 inches immersed diameter, large end.
42 inches mean of immersed diameters.

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## WEIGHT OF FLOATING LOGS—*Continued*

CONTENTS AND WEIGHT: The volume of a log of the foregoing dimensions, namely, 60 inches mean (middle) diameter and 34 feet long, equals 8011 board feet Brereton scale.

The contents of 8011 board feet, multiplied by 3.888, the fresh water weight given in the weight factor table, as indicated when 70 per cent of the extreme diameter is immersed, equals 31,147 pounds, the weight of the log.

**ONE MINUTE'S TIME: The foregoing clearly demonstrates that when the required dimensions are given and with the aid of the "Brereton Log Scale" and "Weight Factor" tables, the weight of any species of log that floats in fresh or salt water can be accurately determined in about one minute's time.**

### *Weight Factors for Floating Logs*

Fresh Water Weights Are Based on a Specific Gravity of .998 and Salt Water 1.038

| Immersed percentage of extreme diameter | Wt. in pounds per bd. ft. | | Immersed percentage of extreme diameter | Wt. in pounds per bd. ft. | |
|---|---|---|---|---|---|
| | Fresh water | Salt water | | Fresh water | Salt water |
| 40 | 1.942 | 1.980 | 70 | 3.888 | 4.005 |
| 41 | 2.007 | 2.067 | 71 | 3.949 | 4.067 |
| 42 | 2.072 | 2.134 | 72 | 4.008 | 4.128 |
| 43 | 2.138 | 2.202 | 73 | 4.067 | 4.190 |
| 44 | 2.203 | 2.269 | 74 | 4.126 | 4.250 |
| 45 | 2.270 | 2.338 | 75 | 4.184 | 4.310 |
| 46 | 2.335 | 2.405 | 76 | 4.241 | 4.368 |
| 47 | 2.401 | 2.473 | 77 | 4.297 | 4.426 |
| 48 | 2.468 | 2.542 | 78 | 4.352 | 4.483 |
| 49 | 2.534 | 2.610 | 79 | 4.406 | 4.538 |
| 50 | 2.600 | 2.678 | 80 | 4.460 | 4.594 |
| 51 | 2.666 | 2.746 | 81 | 4.512 | 4.647 |
| 52 | 2.732 | 2.814 | 82 | 4.564 | 4.701 |
| 53 | 2.799 | 2.883 | 83 | 4.614 | 4.752 |
| 54 | 2.865 | 2.951 | 84 | 4.663 | 4.803 |
| 55 | 2.930 | 3.018 | 85 | 4.710 | 4.851 |
| 56 | 2.997 | 3.087 | 86 | 4.758 | 4.901 |
| 57 | 3.062 | 3.154 | 87 | 4.803 | 4.947 |
| 58 | 3.128 | 3.222 | 88 | 4.846 | 4.991 |
| 59 | 3.193 | 3.289 | 89 | 4.889 | 5.035 |
| 60 | 3.258 | 3.356 | 90 | 4.929 | 5.077 |
| 61 | 3.322 | 3.422 | 91 | 4.968 | 5.117 |
| 62 | 3.387 | 3.489 | 92 | 5.005 | 5.153 |
| 63 | 3.451 | 3.554 | 93 | 5.040 | 5.191 |
| 64 | 3.515 | 3.620 | 94 | 5.073 | 5.223 |
| 65 | 3.578 | 3.685 | 95 | 5.103 | 5.255 |
| 66 | 3.641 | 3.750 | 96 | 5.130 | 5.284 |
| 67 | 3.704 | 3.815 | 97 | 5.155 | 5.309 |
| 68 | 3.766 | 3.879 | 98 | 5.175 | 5.330 |
| 69 | 3.827 | 3.942 | 99 | 5.191 | 5.347 |

NOTE: Logs sink when their weight per board foot volume (one-twelfth of a cubic foot) exceeds 3.2 pounds in fresh water or 3.356 pounds in salt water.

HOW TO USE TABLE: To find the weight in pounds per board foot of any species of log that floats in fresh or salt water, find the immersed percentage of the extreme diameter by the rule given and opposite the percentage column in the table, the weight will be found.

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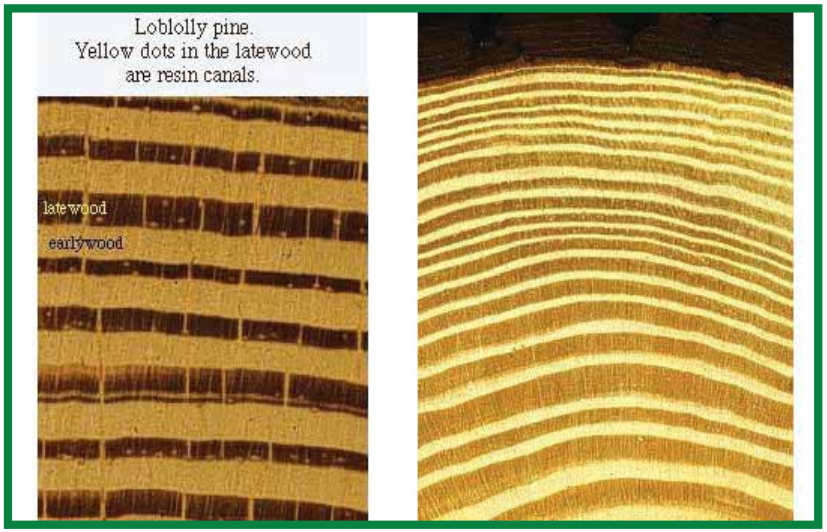
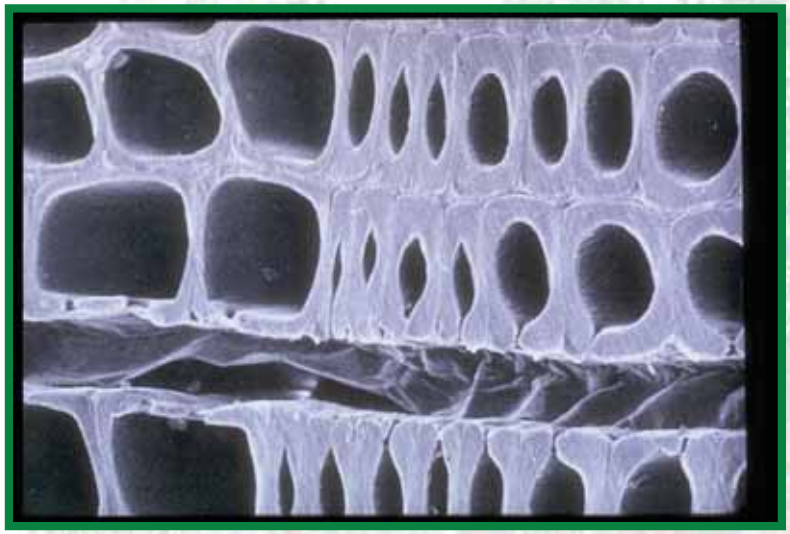
# What drives weight/volume ratios

- Wood density
- Moisture content
- Seasonal changes in moisture content
- Unmeasured volume that has weight
- Method of assessing volume

# What drives weight/volume ratios

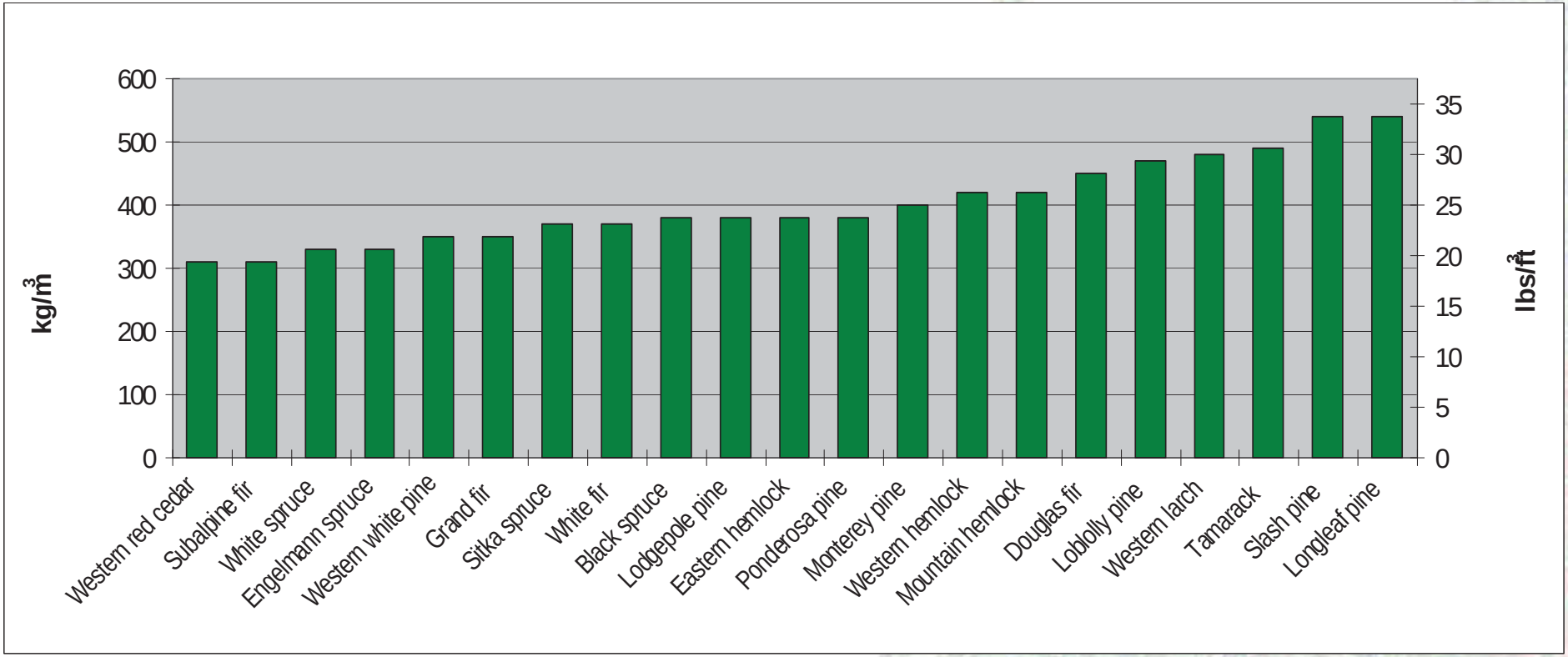
- Wood density (bone dry)
  - Cell wall (tracheid) material of all species is about the same, at 1,560 kg/$m^3$ or 97 lbs/$ft^3$ ($H_2O$ is 1,000 kg/$m^3$ or 62.4 lbs/$ft^3$)
  - What varies is the ratio of cell wall material to cell cavity area (lumen)



# What drives weight/volume ratios

- Wood density of selected species (specific gravity or kg/m$^3$ dry weight, green volume)




Source: USFS Forest Products lab (1999).
Note: to convert kg/m$^3$ to Specific Gravity (SG), divide by 1,000.

To convert kg/m$^3$ to lbs/ft$^3$, divide by 16.

# What drives weight/volume ratios

- Moisture content
  - Freshly cut wood will vary from 30% to more than 200% mcd
  - Sapwood typically has much more moisture than heartwood
  - Some species have higher moisture in the lower bole (butt)
- Seasonality
  - Light season (Montana): July - October
  - Heavy season (Montana): November – June
  - Ponderosa Pine +4.0%, Douglas Fir +4.6%, Western Larch +5.4%, Grand Fir +7.8%: heavy season vs. light season
  - No seasonality noted for AF, ES, LPP, WRC.
  - Unsure if caused by biological, or other causes, e.g., winter logging provenance, ice on logs, dehydration

# What drives weight/volume ratios

- Dehydration
  - Coniferous logs on the ground for twenty days will lose 5.0-6.5% of their weight in the light season and 1.0-1.5% in the heavy season (UK Forestry Commission 1975)

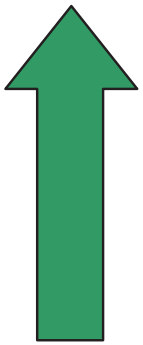
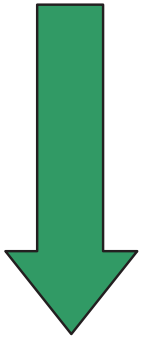
**Southern Yellow Pine Weight Study (Dale Hogg, Arkansas, 2005)**

| | Weeks in Storage | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| **Winter** | 1.0% | 1.5% | 2.0% | 2.7% |
| **Spring** | 1.9% | 3.1% | 5.8% | 6.8% |
| **Summer** | 2.7% | 4.6% | 7.2% | 8.0% |
| **Fall** | 2.7% | 3.7% | 4.4% | 5.1% |

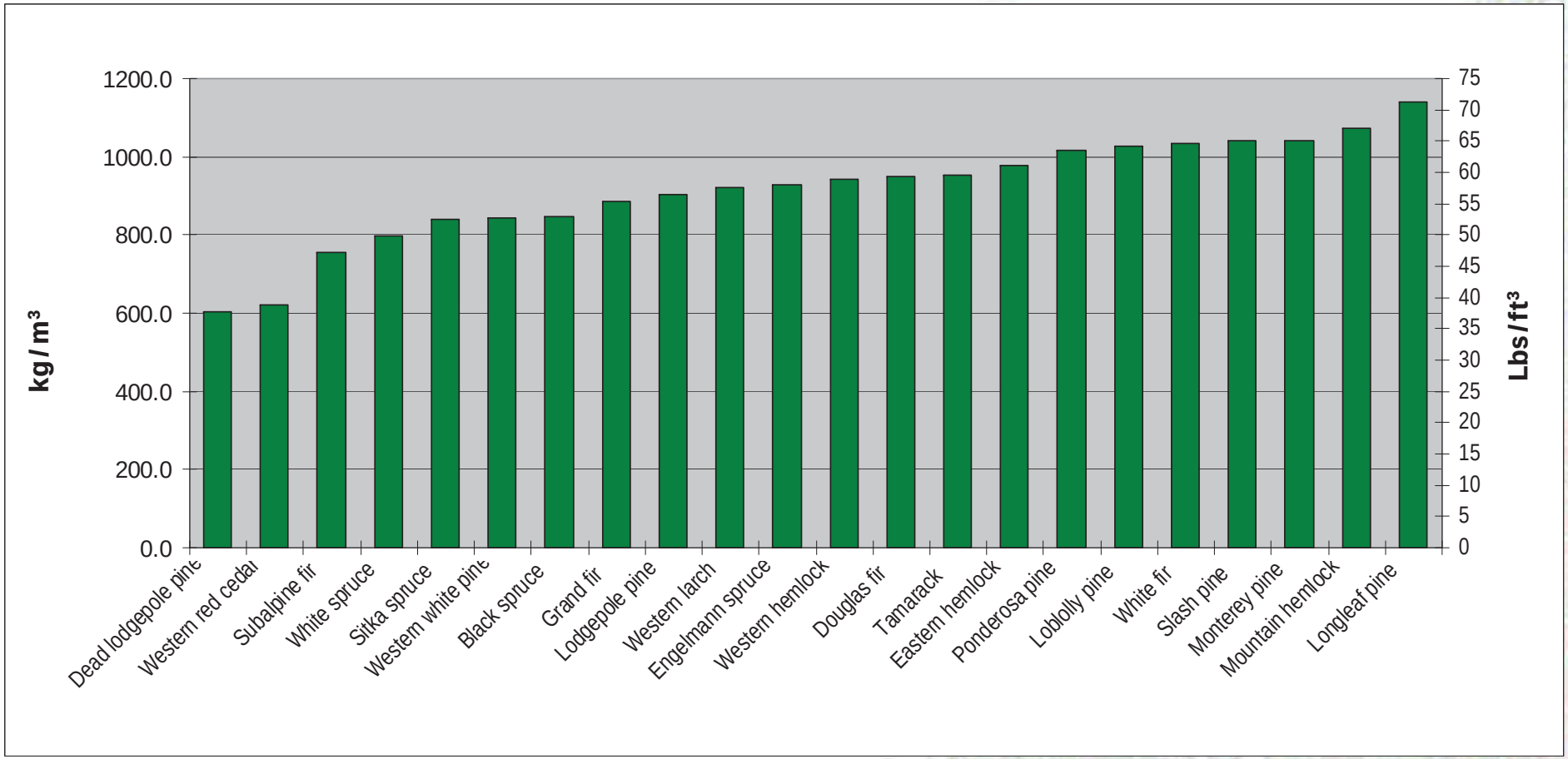
# What drives weight/volume ratios

- Unmeasured volume that has weight
  - Bark: typically 5% (LPP) to 15% (MH) of the weight and volume (w/bark) of a log (average is about 10%)
  - Defect: rot, crook, checks, etc., weigh but volume is deducted
  - Trim allowance: typically 2.5-3.5% of volume (USFS, Alberta)
  - Diameter: rounding bias is 2-4% understatement of volume (short log Scribner, USFS cubic)
  - Butt flare (significant in some species, e.g., WRC, SS, WL, RW)

# What drives weight/volume ratios

| Natural drivers | HEAVY | Exogenous drivers |
|---|---|---|
| winter<br>small diameter<br>young<br>thick sapwood<br>high specific gravity<br>thick bark<br>butt cut<br>defective |  | freshly felled<br>full trim allowance<br>knot bumper and bucker<br>poor cutting for scale |
| low defect<br>second and top cuts<br>thin bark<br>low specific gravity<br>thin sapwood<br>old<br>big diameter<br>summer |  | cutting for scale<br>log processor<br>reduced trim allowance<br>stump to mill delivery delay |
| Natural drivers | LIGHT | Exogenous drivers |

# Weight to volume ratios
## (true wood volume, green averages) by species

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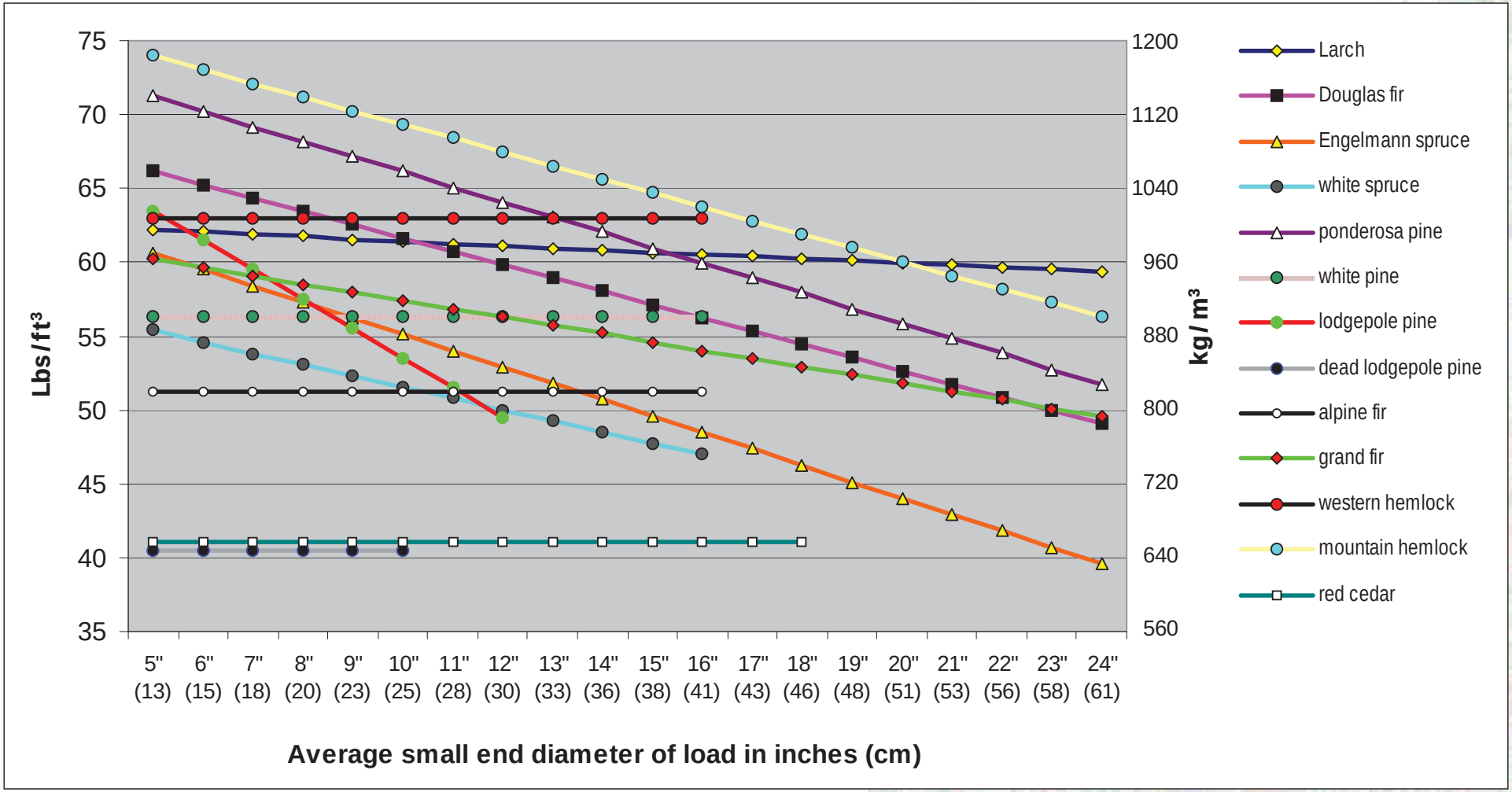
# Weight to volume ratio (gross, USFS cubic)




Data From straight species loads in Montana, Idaho and Alberta

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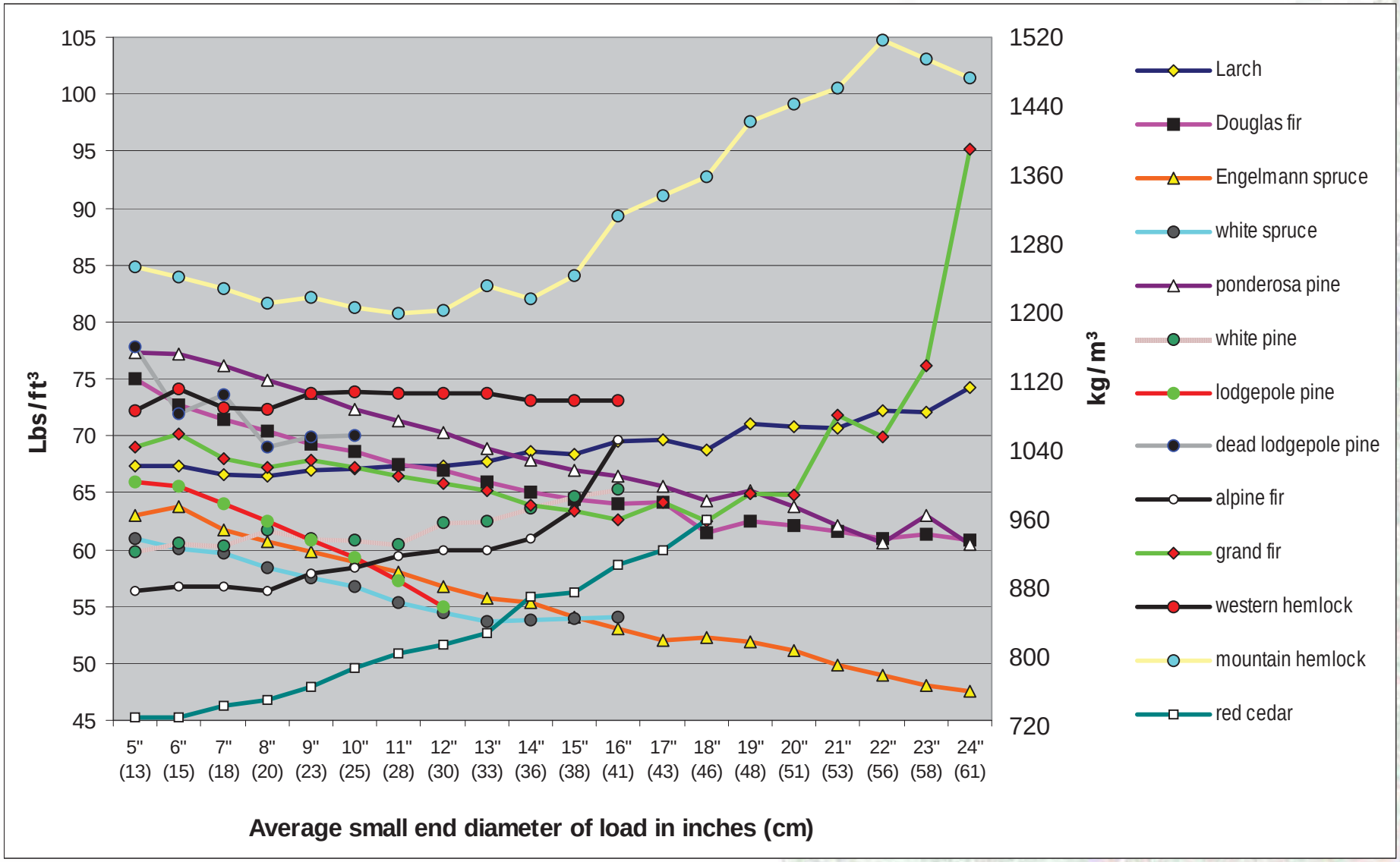
# Weight to volume ratio (net, USFS cubic)

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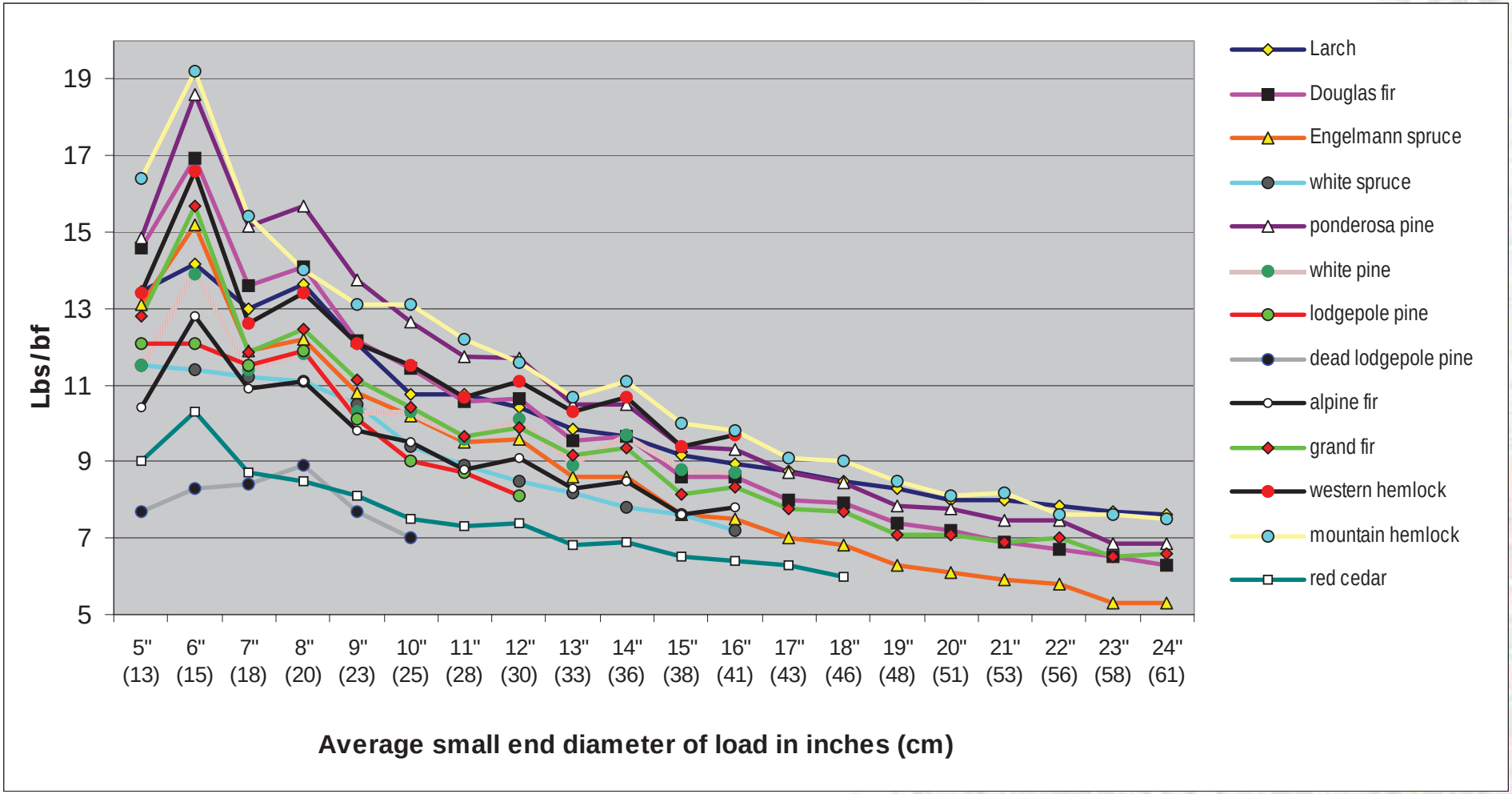
# Weight to volume ratio (gross, Scribner east)

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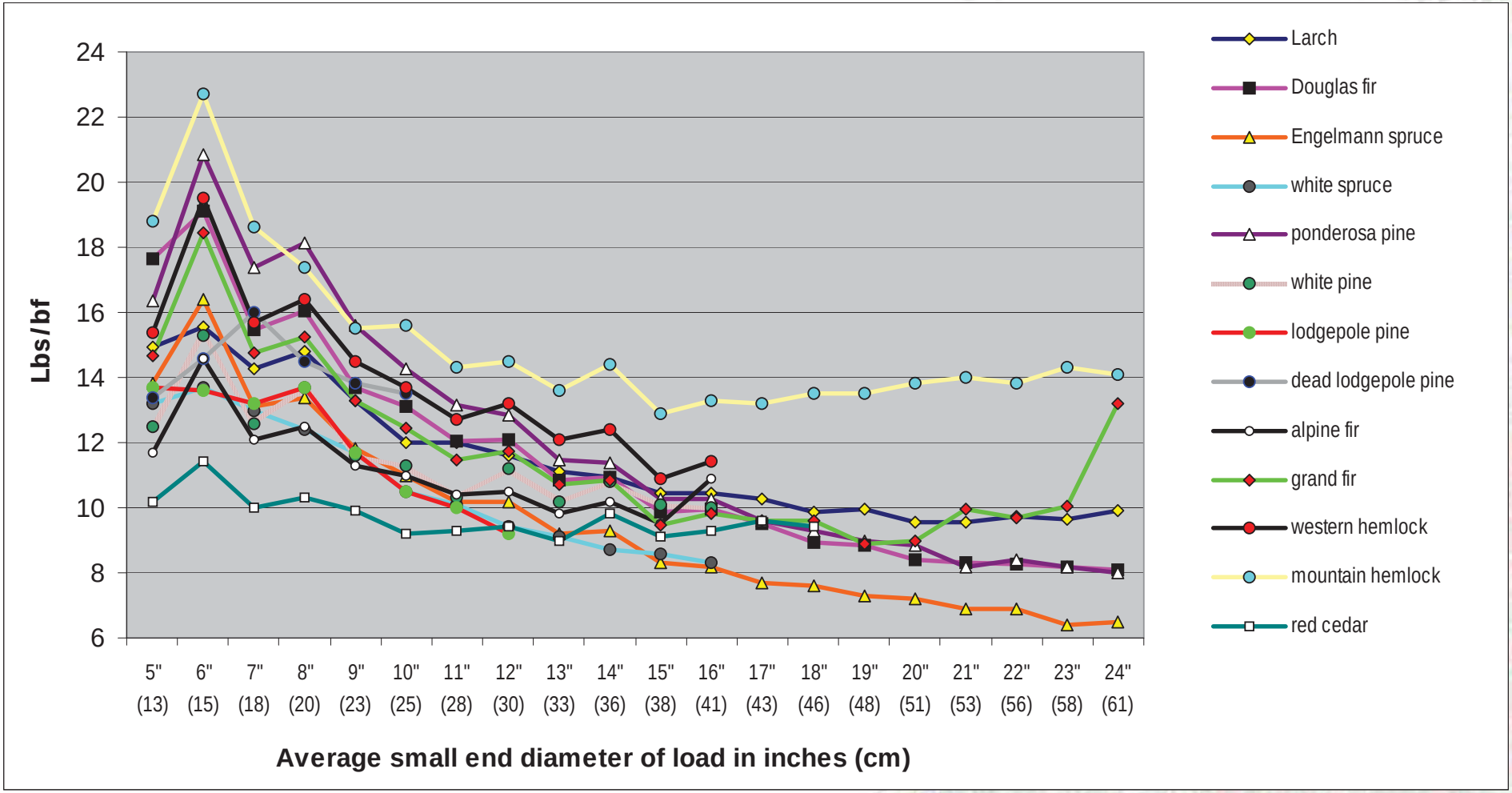
# Weight to volume ratio (net, Scribner east)

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# Weight to volume ratios

- There is no substitute for local knowledge: locally developed empirical data is best
- You will most likely need good cruise data or other information on what you are buying to insure you are getting what you expect
- Be very careful when using published ratios, as many use theoretical not empirical data
- Value is not directly linked to green weight, so how do you assess diameter, length, species, grade and manufacturing quality?

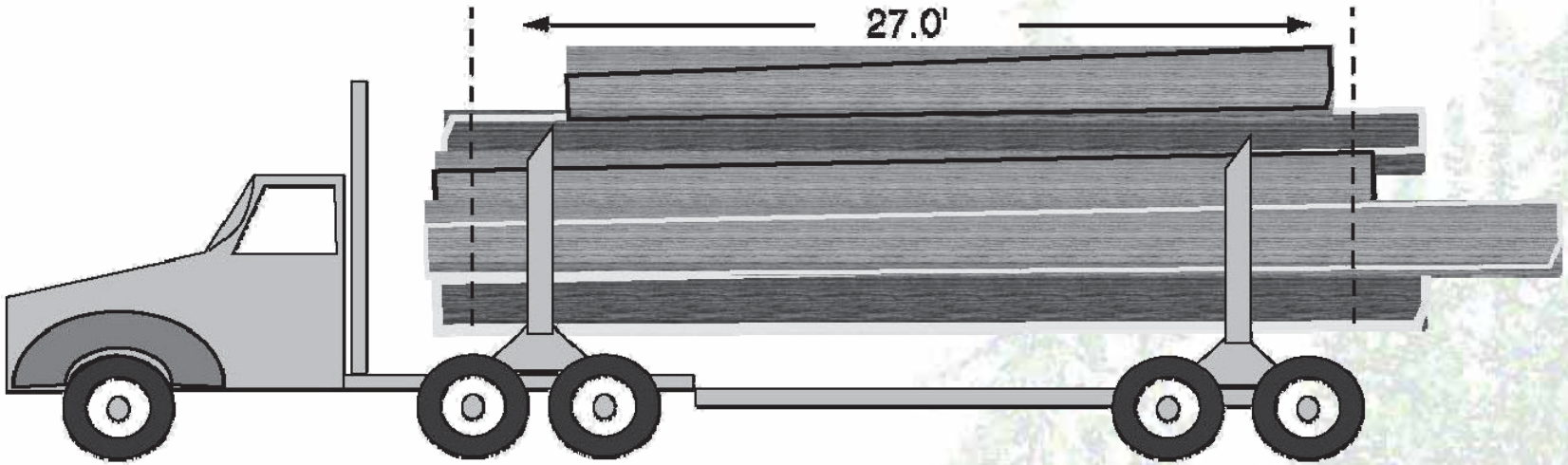
# How do you manage value determiners when buying/selling by weight

- Most still scale and use the data to assess/extrapolate what they are getting and inform supplier if there are any issues (past tense control)
- Purchase agreement that spells out specifications, payment classification and defect deductions procedures (if any)
- In general, diameter is the most critical assessment as it is the biggest driver of value for most
- Personnel at weight scale or unloading that can assess load attributes and affect payment in the present tense
- lbs/lineal foot (kg/lineal metre) works well where weight ratios are consistent and timber is fairly homogeneous

# Pounds per lineal foot / kilograms per lineal meter: big log example

**Load A**

Net weight = 54,000 lbs (24,490 kg), average log length 27.0' (8.23 m), log count = 20,
average lbs per $ft^3$ for Southern yellow pine = 68.6 (1098.9 $kg/m^3$), total load volume 7.87 ccf (22.29 $m^3$)




**Imperial**

54,000 ÷ (20 × 27) = 100 lbs per LF; 100 ÷ 68.6 = 1.458; (1.458 ÷ 0.7854) × 144 = 267.31; √267.31 = **16.35"**

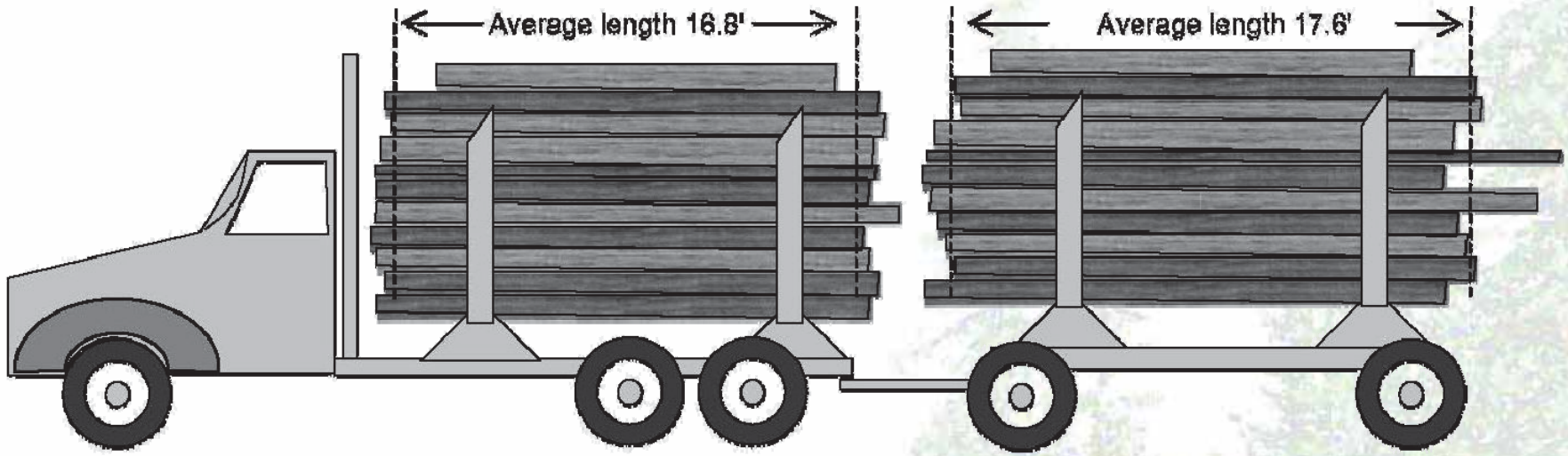
**Metric**

24,490 ÷ (20 × 8.23) = 148.8 kg per m; 148.8 ÷ 1098.9 = 0.1354; (0.1354 ÷ 0.7854) × 10,000 = 1724;
√1724 = **41.5 cm**

# Pounds per lineal foot / kilograms per lineal meter: small log example

**Load B**

Net weight = 54,000 lbs (24,490 kg), average log length (16.8 + 17.6) ÷ 2 = 17.2' (5.24 m), log count = 90, average lbs per $ft^3$ for Southern yellow pine = 68.6 (1098.9 $kg/m^3$), total load volume 7.87 ccf (22.29 $m^3$)




**Imperial**

54,000 ÷ (90 × 17.2) = 34.88 lbs per LF; 34.88 ÷ 68.6 = 0.508; (0.508 ÷ 0.7854) × 144 = 93.14; √93.14 = **9.65"**

**Metric**

24,490 ÷ (90 × 5.24) = 51.90 kg per m; 51.90 ÷ 1098.9 = 0.04723; (0.04723 ÷ 0.7854) × 10,000 = 601.35; √601.35 = **24.52 cm**

# Assessing defect /quality at the scales

**Ton reductions**

| diameter inches | Per lineal foot length deduction | squared deduction |
|---|---|---|
| **5** | 0.00 | 0.01 |
| **6** | 0.01 | 0.01 |
| **7** | 0.01 | 0.01 |
| **8** | 0.01 | 0.02 |
| **9** | 0.02 | 0.02 |
| **10** | 0.02 | 0.02 |
| **11** | 0.02 | 0.03 |
| **12** | 0.03 | 0.04 |
| **13** | 0.03 | 0.04 |
| **14** | 0.04 | 0.05 |
| **15** | 0.04 | 0.06 |
| **16** | 0.05 | 0.06 |
| **17** | 0.06 | 0.07 |
| **18** | 0.06 | 0.08 |
| **19** | 0.07 | 0.09 |
| **20** | 0.08 | 0.10 |
| **21** | 0.09 | 0.11 |
| **22** | 0.09 | 0.12 |
| **23** | 0.10 | 0.13 |
| **24** | 0.11 | 0.14 |
| **25** | 0.12 | 0.16 |
| **26** | 0.13 | 0.17 |
| **27** | 0.14 | 0.18 |
| **28** | 0.15 | 0.20 |
| **29** | 0.16 | 0.21 |
| **30** | 0.18 | 0.22 |

SYP at 71.8 lbs/ft$^3$

**Tonne reductions**

| diameter cm | Per lineal metre length deduction | squared deduction |
|---|---|---|
| **12** | 0.01 | 0.01 |
| **14** | 0.01 | 0.02 |
| **16** | 0.02 | 0.02 |
| **18** | 0.02 | 0.03 |
| **20** | 0.03 | 0.04 |
| **22** | 0.04 | 0.05 |
| **24** | 0.04 | 0.05 |
| **26** | 0.05 | 0.06 |
| **28** | 0.06 | 0.07 |
| **30** | 0.07 | 0.09 |
| **32** | 0.08 | 0.10 |
| **34** | 0.09 | 0.11 |
| **36** | 0.10 | 0.12 |
| **38** | 0.11 | 0.14 |
| **40** | 0.12 | 0.15 |
| **42** | 0.13 | 0.17 |
| **44** | 0.15 | 0.18 |
| **46** | 0.16 | 0.20 |
| **48** | 0.17 | 0.22 |
| **50** | 0.19 | 0.24 |
| **52** | 0.20 | 0.26 |
| **54** | 0.22 | 0.28 |
| **56** | 0.23 | 0.30 |
| **58** | 0.25 | 0.32 |
| **60** | 0.27 | 0.34 |
| **62** | 0.29 | 0.37 |

DF at 954 kg/m$^3$

- Typically, weight of defect is deducted by weigh-master using a table that lists estimated weight rather than volume
- Table weights based on volume x weight ratio
- Weigh-master can provide more value than is typically expected

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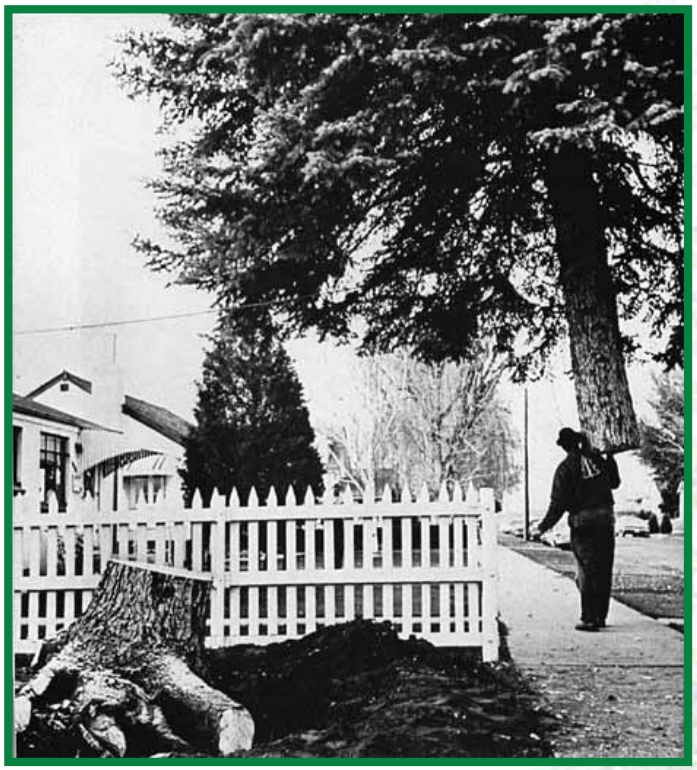
# Conclusions…

- Weight works best when:
  - Timber is homogenous
  - Loads are delivered in like-valued sorts
  - Control of harvest and utilization is strong, e.g., stumpage sales or long term sourcing agreements
  - Scaling is used to establish volume and value
  - The purchaser and seller understand it well and use cubic rather than board feet
  - Coupled with controls at the weight scale and elsewhere

# Conclusions…(continued)

- Potential benefits:
  - The perceived risk associated with log measurement is borne by those with the most knowledge and experience
  - Purchaser has more latitude to specify log manufacture, e.g., preferred length, without regard to effect on scale (no trim studs, 40’ logs, etc.)
  - Harvest and hauling contractors are usually motivated to minimize stump to mill time (reducing degrade)
  - Purchaser/seller more conscious of value utilization by using same unit as other wood users, e.g., sawlog vs. pulp
  - When used thoughtfully, stronger correlation to product yield than most board feet rules

# Weight scale - it’s not as heavy as you might think…

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