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Estimating Load Weights With Huber's Cubic Volume Formula: A Field Trial

Dale R. Waddell

Abstract

Log weights were estimated from the product of Huber's cubic volume formula and green density. Tags showing estimated log weights were attached to logs in the field, and the weights were tallied into a single load weight as logs were assembled for aerial yarding. Accuracy of the estimated load weights was evaluated by comparing the predicted with the actual load weights as measured with scales in a helicopter. A total of 110 loads were evaluated. The load weights were accurate (about 10-percent error), and the method was easily applied under difficult logging conditions. The number of aborts caused by inaccurate estimation of load weights was small (six). Increased efficiency provided by accurate estimates of load weights was often negated during the assembly of loads and in the hooking operation. Greater yarding productivity can be achieved when an accurate log weight estimation technique is combined with efficient load assembly and hooking operations.

Keywords: Aerial logging, weight estimation, logging productivity.

Introduction

The Importance of Accurate Log Weight Estimates

Efficient operation of many logging systems depends on accurate estimation of the weight of the logs. Accurate weight estimates are especially valuable for aerial logging systems, such as helicopter, balloon, and some forms of cable yarding, which may be constrained by the weight of each load (Dykstra 1975, Stevens and Clarke 1974, Waddell and others 1984) . The cost of aerial logging is high, and a key factor in producing a profit is an efficient yarding operation (Burke 1973, Dykstra and others 1978). An efficient yarding operation moves loads from the woods to the landing with a minimum number of turns and delays. The load weight will be affected by the capacity of the yarding equipment, the accuracy of the weight estimate, the availability of suitable logs to assemble a load, and various external factors specific to the operating environment of the yarder.

DALE R. WADDELL is a research forester, Forestry Sciences Laboratory, P.O. Box 3890, Portland, Oregon 97208-3890.

A target weight for the yarder is often created to aid in assembling loads. The target weight is generally set as a single value or range of values to reflect a typical payload during the turn. The target weight must be high enough to minimize operational costs (fewer turns per unit area) yet be low enough to minimize wear on the yarder and reduce the possibility of an abort (Burke 1973). Aborts occur when the weight of the payload is greater than the operational lift capacity of the yarder. Operational lift capacity is the ability of an aircraft to lift the load; it differs from the absolute lift capacity because of the amount of fuel in the aircraft at the time of the lifting, the weather conditions, the local terrain, and other factors. Aborts cause delays and increase the number of turns; the result is poor yarding efficiency. After an abort, two loads may be assembled from the original load, but the new loads may not fully use the lifting capacity of the aircraft; the result is reduced efficiency. In addition, aborts can damage logs in the load and the yarding equipment, and may subject the logging crew to safety hazards.

Methods for Estimating Log Weights

Several methods are available for estimating log weights for use in aerial logging (Dykstra 1975, Mann and Lysons 1972). The most common approach is to estimate the cubic volume of the log(s) and multiply that volume by an appropriate green density. Numerous equations (including graphic methods) will estimate the cubic volume of a log (Dilworth 1981, Freese 1973). The equations will differ in the types of log measurements and the degree of complexity they require to calculate the volume (Husch and others 1972). Green density can either be measured (Pong and others 1986, Waddell and others 1984) or be a constant value specific to each tree species and possibly the season (higher values in spring and lower values in summer).

Huber's Formula

The cubic volume is calculated from the measurement of the length of the log and a single diameter measurement on the outside of the bark (dob) from the middle of the log (Freese 1973, Grosenbaugh 1948). Huber's formula for estimating the cubic volume and weight of a log is as follows:

$$V = (L) \times (dob)^2 \times (C) \text{ and} \tag{1}$$
$$W = (V) \times (GD) \text{ ,} \tag{2}$$

where

V = the cubic volume of the log (cubic feet),
L = the length of the log (feet),
dob = the diameter outside of the bark (inches) at a point midway from the ends of the log,
C = 0.005454 (unit conversion factor),
W = green weight of the log (pounds), and
GD = green density of the wood and bark combined (pounds per cubic foot).

Cubic volume estimates from Huber's formula generally are accurate for most log shapes and lengths (Husch and others 1972, Plank and Cahill 1984). The formula has the highest accuracy for logs approaching the form of a truncated parabola. The cubic volume estimate will tend to exhibit a negative bias (underestimation) for logs with a conic form and a positive bias (overestimation) for logs with a cylindrical form (Freese 1973). The practical application of this formula is apparent when the formula is used in a typical logging condition (jackstraw distribution of logs) because it needs only one diameter measurement as compared to most other volume rules that require two or more diameter measurements.

The weight estimates derived from the formula can be displayed in a table with the diameter and log length on the axes. Every species having a different average green density will have a separate table (table 2 in the appendix). The tables can be transferred to cards for use in the field. Alternatives are to use calculators to compute equations or to use hand-held data recorders with the equation in a program.

Objectives

The objectives of this study were (1) to determine the accuracy of Huber's formula for predicting weight, (2) to evaluate the ease of collecting data (measurements) and performing calculations for log and load weights, and (3) to qualitatively assess other factors that may affect yarding productivity during load assembly and yarding in one logging unit in the Rogue River National Forest.

Methods

Study Area

The study area was in the Rogue River National Forest, Applegate Ranger District, in southwestern Oregon. Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii)* was the predominant species with an average diameter at breast height of 28 inches. Other species included a small number of white fir *(Abies concolor* (Gord. and Glend.) Lindl.) and sugar pine *{Pinus lambertiana* Dougl.). The terrain was fairly steep with slopes of 20 to 40 percent. A 24-acre unit was selected for observing the aerial yarding activities conducted by the logging company.

Weight Tending

About 500 trees were felled in the unit and bucked into about 1,900 logs ranging in length from 8 to 41 feet. Weight tenders employed by the logging company identified the species of the log, measured the diameter at the midpoint, recorded the weight on a tag, and attached the tag to the end of each log. The green weight of the log was determined from tables printed on plastic cards (similar to table 2 in the appendix). Each card represented a different tree species with a unique green density. The green density of Douglas-fir logs was 40 pounds per cubic foot; for the white fir logs, it was 58 pounds per cubic foot.

Load Assembly

Choker setters employed by the logging company connected logs with chokers to build loads for yarding (load assembly). The selection of logs for a specific load was accomplished by reading the weight tag on each log and connecting the appropriate logs (weights) together so that the total weight was between 12,000 and 18,000 pounds (target weight). The limitations of reaching a load weight within the target range included the number of logs within reach of the choker, the variety of log weights for a given number of logs, the steepness of the terrain (which affected the reach of the chokers), and the inability to reach preferred logs because of the amount of unmerchantable logging debris in the way. After the chokers were set, each group of logs was labeled with a sequential load number and an estimated load weight (sum of the individual log weights).

Hooking Operation

A Sikorsky S-64 Skycrane helicopter[1] was used to aerial yard. The logging company's strategy for efficient load selection (there may be numerous preassembled loads) was based on the hook tender's ability to match the estimated load weights with the predicted operational lift capacity of the aircraft; for example, on the first turn in a fuel cycle, the helicopter had the least lift capacity (because it was loaded with fuel). The hook tender therefore selected a load with a low estimated weight for the first turn. The hook tender looked for progressively higher estimated load weights as the yarding proceeded through the fuel cycle.[2] Variations of this strategy are used by many aerial logging companies.

As each load was lifted, the estimated weight and the load number was communicated to the helicopter pilot. The weight of the load was then measured with scales in the helicopter (load cells), and the load was transported to the landing. Every turn was recorded on film by using **a** video camera and a soundtrack of the communications between the helicopter pilot and the hook tender.

Analysis

The estimated weights were compared with the scale weights to determine a measure of bias and accuracy. Bias was calculated as the mean of the differences between the measured and the estimated load weights. Accuracy was calculated as the mean of the absolute differences between the actual and the estimated weights. Bias and accuracy equations are as follows:

$$\text{bias} = \sum_{i=1}^{n} (yi - \hat{y}i)/n \quad \text{and} \tag{3}$$

$$\text{accuracy} = \sum_{i=1}^{n} |(yi - \hat{y}i)|/n \, , \tag{4}$$

where

yi = observed load weight, and

$\hat{y}_i$ = predicted load weight.

Results and Discussion

Generally, the load weights estimated by Huber's formula were accurate. Table 1 summarizes the comparison of estimated load weights with that of load cells in the helicopter. Huber's formula tended to slightly underestimate the average load weighed by the helicopter (mean negative bias of 430 pounds) with about a 10-percent error for all loads analyzed (a mean absolute difference of 1,520 pounds). The operator would expect on the average, with a predicted weight of 15,000 pounds, an actual range of load weights from 13,070 to 16,070 pounds.

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[1]The use of trade, firm, or corporation names jn this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U .S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

[2] One of the objectives of this study was to determine if this strategy was actually followed by the hook; tender

Table 1—Load weights recorded by the load cells and compared to estimated log weights

Number of loads[a]	Mean load cell weight[b]	Mean estimated weight[c]	Bias[d]	Bias	Accuracy[e]	Accuracy
----------------------	*Pounds*	----------------------		*Percent*	*Pounds*	*Percent*
104	15,080	14,640	-430	2.9	1,520	10.1

[a] 110 loads were lifted with 6 aborts. Weight estimates for the aborts are not included in the analysis.
[b] Measured with load cells in the helicopter.
[c] Estimated with Huber's formula.
[d] Bias is the mean of the differences between the load cells and the estimated weights. The value is converted to a percentage by dividing the bias by the mean of the weights measured with the load cells.
[e] Accuracy is the mean of the absolute differences between the weight recorded by the load cells and the estimated weights. The value is converted to a percentage by dividing the mean absolute difference by the mean load cell weight.

Six aborts (5.5 percent) occurred and were directly related to inaccurate weight predictions. Turns with aborts caused by equipment failures (mechanical aborts) and not associated with weight overloads were not included in the analysis. This was a low rate of aborts compared to operations that do not incorporate techniques for estimating load weights (Dykstra 1975). Huber's formula is well suited to situations where many logs are concentrated in one area. Alternative methods, requiring more than one measurement of diameter, would not have been feasible because of the jackstraw distribution of logs after the felling and bucking operations. Log ends were frequently covered by other logs and crown material. The rapid method of computation was also enhanced by the tables reproduced on plastic cards. The weight tenders might have had difficulty in operating calculators because of the rugged working terrain and often poor climate.

Additional Observations

Producing optimum load weights was limited not only by accuracy of the load weights but also by the load assembly operation. The problem the choker setters had in reaching the optimum load weight, as discussed above, plus the lack of confidence by the choker setters in the accuracy of the recorded log weights may have had significant impact on the yarding productivity. Loads were often assembled well below the target range even when additional logs were available to add to the load. Choker setters also assembled a few loads above the target range, which resulted in yarding delays.

Yarding productivity was also decreased by the hook tender's selection of loads at various times in a fuel cycle. Hook tenders often would select loads during the first turn of a fuel cycle (lowest operational lift capacity) that were in the upper portion of the target range (17,000 pounds). These turns had the greatest potential for an aboi In addition, delays were observed during the lifting phase as the helicopter struggled to attain an appropriate height for the flight to the landing. This lack of planning ofte led to loads of lesser weights being yarded later in the fuel cycle when the operational lift capacity of the aircraft was greater. The selection of load weights appropriately matched to the current capacity of the yarder might have increased productivity (less turns) and reduced wear on the helicopter.

Yarding Productivity

Yarding productivity can be enhanced by a constant validation of the load weight estimates and feedback of the information to the load assembly and hooking operations. The choker setters and hook tender must have a current assessment of error in the estimated load weights so that acceptable average load weights can be achieved throughout the fuel cycle while the probability of an abort is minimized. Thi can be accomplished by assessing the load weight error through comparisons of estimated load weights and actual load weights as recorded in the helicopter. Adjust ments can be made in the strategy of setting a correct target range for load assembly and selecting appropriate loads for a specific period within a fuel cycle.

Conclusion

Hubert formula provided accurate estimates of load weights for use in aerial logging The measurements needed to use the technique can be applied rapidly, even under the adverse conditions often encountered in logging operations. Accurate estimates of load weights allow the average load weights to be increased and the probability o aborts to decrease. This reduces the number of turns needed to harvest a unit, then by resulting in lower operating costs.

Data collected on 110 turns indicated that yarding productivity was affected by the use of weight estimates in both the assembly operation (choker setting) and selectio of appropriate loads during various phases of the fuel cycle (hook tending). The gains in yarding productivity can be increased with consistent use of the log weight estimates in the load assembly operation coupled with a hooking strategy that select loads of increasing weights as the operational lift capacity of the yarder increases during the fuel cycle.

Acknowledgment

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Table 2—Estimated log weights for variable log lengths and middle diameters

	Middle diameter (DOB) (in inches)											
Log lengths (L)	8	9	10	11	12	13	14	15	16	17	18	19
Feet	Pounds											
8	112	141	175	211	251	295	342	393	447	504	565	630
9	126	159	196	238	283	332	385	442	503	567	636	709
10	140	177	218	264	314	369	428	491	558	630	707	788
11	154	194	240	290	346	406	470	540	614	694	778	866
12	168	212	262	317	377	442	513	589	670	757	848	945
13	182	230	284	343	408	479	556	638	726	820	919	1,024
14	195	247	305	370	440	516	599	687	782	883	990	1,103
15	209	265	327	396	471	553	641	736	838	946	1,060	1,181
16	223	283	349	422	503	590	684	785	894	1,009	1,131	1,260
17	237	300	371	449	534	627	727	834	949	1,072	1,202	1,339
18	251	318	393	475	565	664	770	884	1,005	1,135	1,272	1,418
19	265	336	415	502	597	701	812	933	1,061	1,198	1,343	1,496
20	279	353	436	528	628	737	855	982	1,117	1,261	1,414	1,575
21	293	371	458	554	660	774	898	1,031	1,173	1,324	1,484	1,654
22	307	389	480	581	691	811	941	1,080	1,229	1,387	1,555	1,733
23	321	406	502	607	723	848	983	1,129	1,285	1,450	1,626	1,811
24	335	424	524	634	754	885	1,026	1,178	1,340	1,513	1,696	1,890
25	349	442	545	660	785	922	1,069	1,227	1,396	1,576	1,767	1,969
26	363	459	567	686	817	959	1,112	1,276	1,452	1,639	1,838	2,048
27	377	477	589	713	848	995	1,155	1,325	1,508	1,702	1,908	2,126
28	391	495	611	739	880	1,032	1,197	1,374	1,564	1,765	1,979	2,205
29	405	512	633	766	911	1,069	1,240	1,423	1,620	1,828	2,050	2,284
30	419	530	654	792	942	1,106	1,283	1,473	1,675	1,891	2,121	2,363
31	433	548	676	818	974	1,143	1,326	1,522	1,731	1,954	2,191	2,441
32	447	565	698	845	1,005	1,180	1,368	1,571	1,787	2,018	2,262	2,520
33	461	583	720	871	1,037	1,217	1,411	1,620	1,843	2,081	2,333	2,599
34	475	601	742	898	1,068	1,254	1,454	1,669	1,899	2,144	2,403	2,678
35	489	618	764	924	1,100	1,290	1,497	1,718	1,955	2,207	2,474	2,756
36	503	636	785	950	1,131	1,327	1,539	1,767	2,011	2,270	2,545	2,835
37	517	654	807	977	1,162	1,364	1,582	1,816	2,066	2,333	2,615	2,914
38	531	671	829	1,003	1,194	1,401	1,625	1,865	2,122	2,396	2,686	2,993
39	545	689	851	1,029	1,225	1,438	1,668	1,914	2,178	2,459	2,757	3,071
40	558	707	873	1,056	1,257	1,475	1,710	1,963	2,234	2,522	2,827	3,150
41	572	725	894	1,082	1,288	1,512	1,753	2,013	2,290	2,585	2,898	3,229
42	586	742	916	1,109	1,319	1,548	1,796	2,062	2,346	2,648	2,969	3,308
43	600	760	938	1,135	1,351	1,585	1,839	2,111	2,402	2,711	3,039	3,386
44	614	778	960	1,161	1,382	1,622	1,881	2,160	2,457	2,774	3,110	3,465
45	628	795	982	1,188	1,414	1,659	1,924	2,209	2,513	2,837	3,181	3,544
46	642	813	1,004	1,214	1,445	1,696	1,967	2,258	2,569	2,900	3,251	3,623
47	656	831	1,025	1,241	1,477	1,733	2,010	2,307	2,625	2,963	3,322	3,702
48	670	848	1,047	1,267	1,508	1,770	2,052	2,356	2,681	3,026	3,393	3,780
49	684	866	1,069	1,293	1,539	1,807	2,095	2,405	2,737	3,089	3,464	3,859
50	698	884	1,091	1,320	1,571	1,843	2,138	2,454	2,792	3,152	3,534	3,938

Table 2—Estimated log weights for variable log lengths and middle diameters (continued)

	Middle diameter (DOB) (in inches)											
Log lengths (L)	20	21	22	23	24	25	26	27	28	29	30	31
Feet	Pounds											
8	698	770	845	923	1,005	1,091	1,180	1,272	1,368	1,468	1,571	1,677
9	785	866	950	1,039	1,131	1,227	1,327	1,431	1,539	1,651	1,767	1,887
10	873	962	1,056	1,154	1,257	1,364	1,475	1,590	1,710	1,835	1,963	2,097
11	960	1,058	1,161	1,269	1,382	1,500	1,622	1,749	1,881	2,018	2,160	2,306
12	1,047	1,155	1,267	1,385	1,508	1,636	1,770	1,908	2,052	2,202	2,356	2,516
13	1,134	1,251	1,373	1,500	1,634	1,773	1,917	2,068	2,223	2,385	2,552	2,725
14	1,222	1,347	1,478	1,616	1,759	1,909	2,065	2,227	2,395	2,569	2,749	2,935
15	1,309	1,443	1,584	1,731	1,885	2,045	2,212	2,386	2,566	2,752	2,945	3,145
16	1,396	1,539	1,689	1,847	2,011	2,182	2,360	2,545	2,737	2,936	3,142	3,354
17	1,483	1,636	1,795	1,962	2,136	2,318	2,507	2,704	2,908	3,119	3,338	3,564
18	1,571	1,732	1,901	2,077	2,262	2,454	2,655	2,863	3,079	3,303	3,534	3,774
19	1,658	1,828	2,006	2,193	2,388	2,591	2,802	3,022	3,250	3,486	3,731	3,983
20	1,745	1,924	2,112	2,308	2,513	2,727	2,950	3,181	3,421	3,669	3,927	4,193
21	1,833	2,020	2,217	2,424	2,639	2,863	3,097	3,340	3,592	3,853	4,123	4,403
22	1,920	2,117	2,323	2,539	2,765	3,000	3,244	3,499	3,763	4,036	4,320	4,612
23	2,007	2,213	2,429	2,654	2,890	3,136	3,392	3,658	3,934	4,220	4,516	4,822
24	2,094	2,309	2,534	2,770	3,016	3,272	3,539	3,817	4,105	4,403	4,712	5,032
25	2,182	2,405	2,640	2,885	3,142	3,409	3,687	3,976	4,276	4,587	4,909	5,241
26	2,269	2,501	2,745	3,001	3,267	3,545	3,834	4,135	4,447	4,770	5,105	5,451
27	2,356	2,598	2,851	3,116	3,393	3,681	3,982	4,294	4,618	4,954	5,301	5,661
28	2,443	2,694	2,957	3,231	3,518	3,818	4,129	4,453	4,789	5,137	5,498	5,870
29	2,531	2,790	3,062	3,347	3,644	3,954	4,277	4,612	4,960	5,321	5,694	6,080
30	2,618	2,886	3,168	3,462	3,770	4,091	4,424	4,771	5,131	5,504	5,890	6,290
31	2,705	2,982	3,273	3,578	3,895	4,227	4,572	4,930	5,302	5,688	6,087	6,499
32	2,792	3,079	3,379	3,693	4,021	4,363	4,719	5,089	5,473	5,871	6,283	6,709
33	2,880	3,175	3,484	3,808	4,147	4,500	4,867	5,248	5,644	6,055	6,479	6,919
34	2,967	3,271	3,590	3,924	4,272	4,636	5,014	5,407	5,815	6,238	6,676	7,128
35	3,054	3,367	3,696	4,039	4,398	4,772	5,162	5,566	5,986	6,422	6,872	7,338
36	3,142	3,464	3,801	4,155	4,524	4,909	5,309	5,725	6,157	6,605	7,068	7,547
37	3,229	3,560	3,907	4,270	4,649	5,045	5,457	5,884	6,328	6,788	7,265	7,757
38	3,316	3,656	4,012	4,385	4,775	5,181	5,604	6,043	6,499	6,972	7,461	7,967
39	3,403	3,752	4,118	4,501	4,901	5,318	5,752	6,203	6,670	7,155	7,657	8,176
40	3,491	3,848	4,224	4,616	5,026	5,454	5,899	6,362	6,841	7,339	7,854	8,386
41	3,578	3,945	4,329	4,732	5,152	5,590	6,047	6,521	7,013	7,522	8,050	8,596
42	3,665	4,041	4,435	4,847	5,278	5,727	6,194	6,680	7,184	7,706	8,246	8,805
43	3,752	4,137	4,540	4,962	5,403	5,863	6,341	6,839	7,355	7,889	8,443	9,015
44	3,840	4,233	4,646	5,078	5,529	5,999	6,489	6,998	7,526	8,073	8,639	9,225
45	3,927	4,329	4,752	5,193	5,655	6,136	6,636	7,157	7,697	8,256	8,835	9,434
46	4,014	4,426	4,857	5,309	5,780	6,272	6,784	7,316	7,868	8,440	9,032	9,644
47	4,101	4,522	4,963	5,424	5,906	6,408	6,931	7,475	8,039	8,623	9,228	9,854
48	4,189	4,618	5,068	5,540	6,032	6,545	7,079	7,634	8,210	8,807	9,425	10,063
49	4,276	4,714	5,174	5,655	6,157	6,681	7,226	7,793	8,381	8,990	9,621	10,273
50	4,363	4,810	5,279	5,770	6,283	6,818	7,374	7,952	8,552	9,174	9,817	10,483

Table 2—Estimated log weights for variable log lengths and middle diameters (continued)

Log lengths (L)	Middle diameter (DOB) (in inches)										
	32	33	34	35	36	37	38	39	40	41	42
Feet	*Pounds*										
8	1,787	1,901	2,018	2,138	2,262	2,389	2,520	2,655	2,792	2,934	3,079
9	2,011	2,138	2,270	2,405	2,545	2,688	2,835	2,986	3,142	3,301	3,464
10	2,234	2,376	2,522	2,672	2,827	2,987	3,150	3,318	3,491	3,667	3,848
11	2,457	2,613	2,774	2,940	3,110	3,285	3,465	3,650	3,840	4,034	4,233
12	2,681	2,851	3,026	3,207	3,393	3,584	3,780	3,982	4,189	4,401	4,618
13	2,904	3,088	3,279	3,474	3,676	3,883	4,095	4,314	4,538	4,767	5,003
14	3,128	3,326	3,531	3,741	3,958	4,181	4,410	4,645	4,887	5,134	5,388
15	3,351	3,564	3,783	4,009	4,241	4,480	4,725	4,977	5,236	5,501	5,773
16	3,574	3,801	4,035	4,276	4,524	4,779	5,040	5,309	5,585	5,868	6,157
17	3,798	4,039	4,287	4,543	4,807	5,077	5,355	5,641	5,934	6,234	6,542
18	4,021	4,276	4,539	4,810	5,089	5,376	5,670	5,973	6,283	6,601	6,927
19	4,245	4,514	4,792	5,078	5,372	5,675	5,985	6,305	6,632	6,968	7,312
20	4,468	4,752	5,044	5,345	5,655	5,973	6,300	6,636	6,981	7,335	7,697
21	4,691	4,989	5,296	5,612	5,937	6,272	6,615	6,968	7,330	7,701	8,082
22	4,915	5,227	5,548	5,879	6,220	6,571	6,931	7,300	7,679	8,068	8,466
23	5,138	5,464	5,800	6,147	6,503	6,869	7,246	7,632	8,028	8,435	8,851
24	5,362	5,702	6,053	6,414	6,786	7,168	7,561	7,964	8,377	8,801	9,236
25	5,585	5,939	6,305	6,681	7,068	7,467	7,876	8,296	8,726	9,168	9,621
26	5,808	6,177	6,557	6,948	7,351	7,765	8,191	8,627	9,075	9,535	10,006
27	6,032	6,415	6,809	7,216	7,634	8,064	8,506	8,959	9,425	9,902	10,391
28	6,255	6,652	7,061	7,483	7,917	8,363	8,821	9,291	9,774	10,268	10,775
29	6,478	6,890	7,314	7,750	8,199	8,661	9,136	9,623	10,123	10,635	11,160
30	6,702	7,127	7,566	8,017	8,482	8,960	9,451	9,955	10,472	11,002	11,545
31	6,925	7,365	7,818	8,285	8,765	9,258	9,766	10,286	10,821	11,369	11,930
32	7,149	7,602	8,070	8,552	9,048	9,557	10,081	10,618	11,170	11,735	12,315
33	7,372	7,840	8,322	8,819	9,330	9,856	10,396	10,950	11,519	12,102	12,700
34	7,595	8,078	8,575	9,086	9,613	10,154	10,711	11,282	11,868	12,469	13,084
35	7,819	8,315	8,827	9,354	9,896	10,453	11,026	11,614	12,217	12,835	13,469
36	8,042	8,553	9,079	9,621	10,178	10,752	11,341	11,946	12,566	13,202	13,854
37	8,266	8,790	9,331	9,888	10,461	11,050	11,656	12,277	12,915	13,569	14,239
38	8,489	9,028	9,583	10,155	10,744	11,349	11,971	12,609	13,264	13,936	14,624
39	8,712	9,265	9,836	10,423	11,027	11,648	12,286	12,941	13,613	14,302	15,009
40	8,936	9,503	10,088	10,690	11,309	11,946	12,601	13,273	13,962	14,669	15,393
41	9,159	9,741	10,340	10,957	11,592	12,245	12,916	13,605	14,311	15,036	15,778
42	9,383	9,978	10,592	11,224	11,875	12,544	13,231	13,936	14,660	15,403	16,163
43	9,606	10,216	10,844	11,492	12,158	12,842	13,546	14,268	15,009	15,769	16,548
44	9,829	10,453	11,096	11,759	12,440	13,141	13,861	14,600	15,358	16,136	16,933
45	10,053	10,691	11,349	12,026	12,723	13,440	14,176	14,932	15,708	16,503	17,318
46	10,276	10,929	11,601	12,293	13,006	13,738	14,491	15,264	16,057	16,869	17,702
47	10,500	11,166	11,853	12,561	13,289	14,037	14,806	15,596	16,406	17,236	18,087
48	10,723	11,404	12,105	12,828	13,571	14,336	15,121	15,927	16,755	17,603	18,472
49	10,946	11,641	12,357	13,095	13,854	14,634	15,436	16,259	17,104	17,970	18,857
50	11,170	11,879	12,610	13,362	14,137	14,933	15,751	16,591	17,453	18,336	19,242

ıble 2—Estimated log weights for variable log lengths and middle diameters ;ontinued)

.og lengths (L)	Middle diameter (DOB)							
	43	44	45	46	47	48	49	50
₣eet	Pounds							
8	3,227	3,379	3,534	3,693	3,855	4,021	4,190	4,363
9	3,630	3,801	3,976	4,155	4,337	4,524	4,714	4,909
10	4,034	4,224	4,418	4,616	4,819	5,026	5,238	5,454
11	4,437	4,646	4,860	5,078	5,301	5,529	5,762	5,999
12	4,841	5,068	5,301	5,540	5,783	6,032	6,286	6,545
13	5,244	5,491	5,743	6,001	6,265	6,534	6,809	7,090
14	5,647	5,913	6,185	6,463	6,747	7,037	7,333	7,636
15	6,051	6,335	6,627	6,924	7,229	7,540	7,857	8,181
16	6,454	6,758	7,068	7,386	7,711	8,042	8,381	8,726
17	6,857	7,180	7,510	7,848	8,193	8,545	8,905	9,272
18	7,261	7,602	7,952	8,309	8,674	9,048	9,428	9,817
19	7,664	8,025	8,394	8,771	9,156	9,550	9,952	10,363
20	8,068	8,447	8,835	9,233	9,638	10,053	10,476	10,908
21	8,471	8,870	9,277	9,694	10,120	10,555	11,000	11,453
22	8,874	9,292	9,719	10,156	10,602	11,058	11,524	11,999
23	9,278	9,714	10,161	10,617	11,084	11,561	12,047	12,544
24	9,681	10,137	10,603	11,079	11,566	12,063	12,571	13,090
25	10,084	10,559	11,044	11,541	12,048	12,566	13,095	13,635
26	10,488	10,981	11,486	12,002	12,530	13,069	13,619	14,180
27	10,891	11,404	11,928	12,464	13,012	13,571	14,143	14,726
28	11,295	11,826	12,370	12,926	13,494	14,074	14,666	15,271
29	11,698	12,248	12,811	13,387	13,976	14,577	15,190	15,817
30	12,101	12,671	13,253	13,849	14,457	15,079	15,714	16,362
31	12,505	13,093	13,695	14,310	14,939	15,582	16,238	16,907
32	12,908	13,515	14,137	14,772	15,421	16,085	16,762	17,453
33	13,311	13,938	14,579	15,234	15,903	16,587	17,285	17,998
34	13,715	14,360	15,020	15,695	16,385	17,090	17,809	18,544
35	14,118	14,783	15,462	16,157	16,867	17,592	18,333	19,089
36	14,522	15,205	15,904	16,619	17,349	18,095	18,857	19,634
37	14,925	15,627	16,346	17,080	17,831	18,598	19,381	20,180
38	15,328	16,050	16,787	17,542	18,313	19,100	19,904	20,725
39	15,732	16,472	17,229	18,003	18,795	19,603	20,428	21,271
40	16,135	16,894	17,671	18,465	19,277	20,106	20,952	21,816
41	16,538	17,317	18,113	18,927	19,759	20,608	21,476	22,361
42	16,942	17,739	18,555	19,388	20,240	21,111	22,000	22,907
43	17,345	18,161	18,996	19,850	20,722	21,614	22,523	23,452
44	17,749	18,584	19,438	20,312	21,204	22,116	23,047	23,998
45	18,152	19,006	19,880	20,773	21,686	22,619	23,571	24,543
46	18,555	19,428	20,322	21,235	22,168	23,121	24,095	25,088
47	18,959	19,851	20,763	21,696	22,650	23,624	24,619	25,634
48	19,362	20,273	21,205	22,158	23,132	24,127	25,143	26,179
49	19,766	20,696	21,647	22,620	23,614	24,629	25,666	26,725
50	20,169	21,118	22,089	23,081	24,096	25,132	26,190	27,270

Green density is 40 pounds per cubic foot (Douglas-fir).
Log weight = 40*(L)*(DOB)^2*(0.005454)