Handbook for Predicting Slash Weight of Western Conifers

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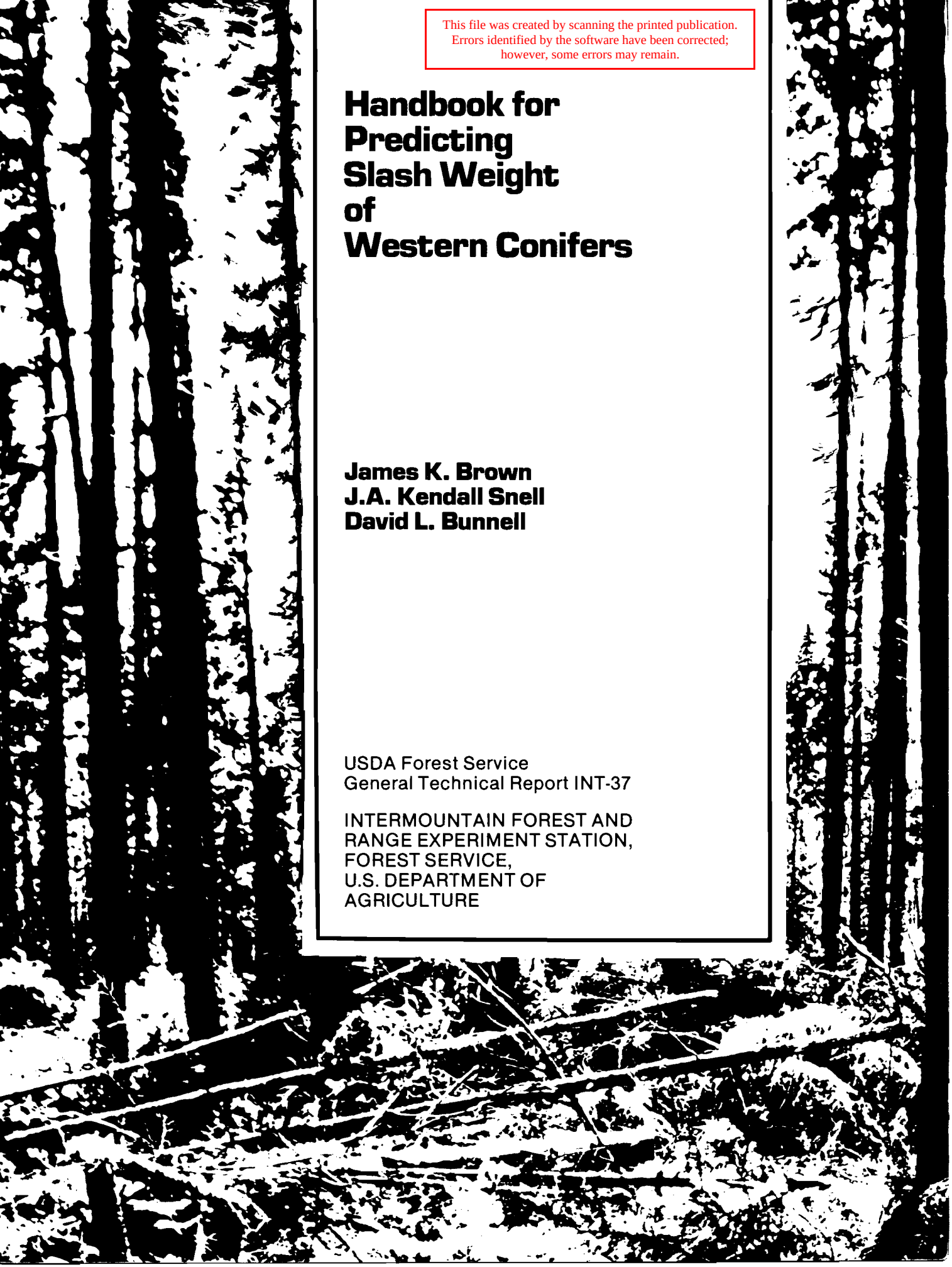

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THE AUTHORS

JAMES K. BROWN received his bachelor's degree from the University of Minnesota in 1960, his master's from Yale University in 1961, and his Ph.D. from the University of Michigan in 1968, all in forestry. From 1961 to 1965 he did research on field measurement of fuel properties and fire-danger rating systems while with the Lake States Forest Experiment Station. In 1965, he transferred to the Northern Forest Fire Laboratory, Missoula, Montana, where he is responsible for research on the physical properties, inventory, and prediction of fuels.

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ABSTRACT

As an aid to managing fuel and woody debris, procedures are provided for predicting weights of slash using tables of either slash weight per tree by d. b.h., or slash weight per square foot of tree basal area by d. b. h. Slash weights include crowns (live and dead foliage and branchwood) and unmerchantable bole tips to 3-, 4-, and 6-inch diameter limits. Slash weights can be predicted for material less than and greater than 3 inches in diameter.

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TABLES

INTRODUCTION

This handbook contains procedures for predicting weights of slash--the needles, branches, unmerchantable bole tips, and broken and defective bole material--that remains after timber cutting or thinning. In the past, inability to quantitatively describe downed woody debris such as logging slash has made it difficult to evaluate and communicate debris problems. The capability to predict quantities of slash permits planning for debris problems before they are created. However, predicting slash does not guarantee easy solutions to slash problems, but rather provides a sound foundation for making decisions and formulating plans. Professional experience and good judgment will continue to play important roles in debris management.

Estimates of slash weights can be useful in the following situations:

1. When communicating the magnitude of fuel and debris problems.
2. When writing and administering debris disposal contracts.
3. When describing fiber potential of woody residue.
4. When selecting among debris treatment alternatives like those developed by Roussopoulos and Johnson (1975).
5. When preparing prescriptions for prescribed burning.
6. When appraising potential fire behavior of fuels.

Slash is produced from three portions of trees: (1) crowns (foliage and branches); (2) unmerchantable bole tips; and (3) defective and broken boles (fig. 1). Different methods are required to predict weight of slash from each source. For crowns, the procedures in this handbook are based on predictive relationships between slash weight and tree d.b.h. that were developed from trees sampled in Montana and Idaho (Brown 1976).[1] The relationships for estimating unmerchantable bole tips were developed by Faurot.[2] The procedure for estimating defective and broken boles relies on estimates of merchantable volume, defect, and breakage supplied by users.

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[1] Brown, James K. Weight and density of crowns of Rocky Mountain conifers. USDA For. Serv. Intermt. For. and Range Exp. Stn. Pap. (in preparation).

[2] Faurot, James L. Tables for estimating stem residues study for ponderosa pine, western larch, Douglas-fir, and lodgepole pine in western Montana. USDA For. Serv. Intermt. For. and Range Exp. Stn. Pap. (in preparation).

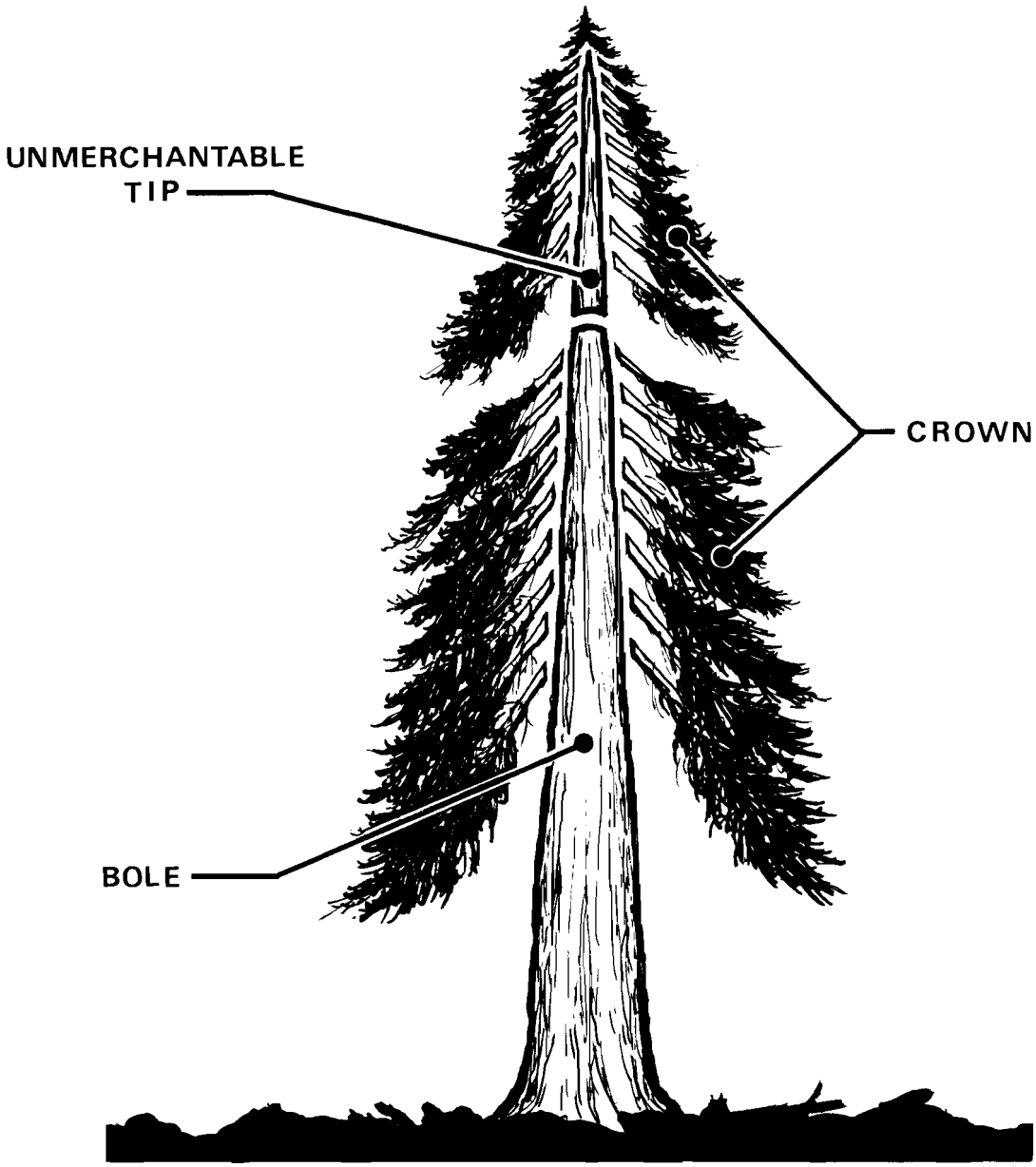


Figure 1.--Different relationships are required to predict weight of slash produced from crowns (foliage and dead and live branchwood), unmerchantable bole tips, and boles (defect and breakage).

Although the data for predicting crown weight were gathered in Montana and Idaho, the predictions should apply reasonably well to trees throughout the western United States except for some coastal areas where tree species of large d.b.h. are found. For a given species and d.b.h., crown weight per tree varies considerably within individual stands. We suspect that variation in crown weight per tree within stands may be about as much as between major forest regions. Thus, slash predictions may be about as accurate outside of the study area as within the area.

Prediction of slash weights for many different species and tree sizes is a logical job for computers. Computer systems for calculating slash potentials based on individual tree inventory data have been developed for some regions of the USDA Forest Service. Where a timber inventory using individual tree records is processed by computer, debris can be predicted by computers. However, computer systems are not readily available to everyone. The procedures in this handbook are for calculating potential slash weights when access to a computer prediction system is unavailable or inconvenient.

The total amount of downed woody fuel following logging or thinning is the sum of downed woody fuels that exist before cutting and slash fuels added by cutting. Existing fuels can be of major importance for evaluating fire potential. Sometimes, existing downed woody fuels weigh as much as or more than the slash created by cutting. (Weight of existing downed woody fuels can be inventoried using procedures described in "Handbook for Inventorying Downed Woody Material" [Brown 1974].)

PROCEDURES

Slash weights can be predicted for trees cut or trampled using estimates of either (1) trees per acre by species and d.b.h., or (2) basal area per acre by species and d.b.h. Tables of slash weight are provided that include crowns (all live and dead foliage and branches) and unmerchantable bole tips to 3-, 4-, and 6-inch diameters. The tables are designed for calculating total crown material and material less than 3 inches in diameter. Usually, crown weight should be computed using tables for total crown and tip material. However, interpreting fire behavior using mathematical fire models such as described in *Users' Guide to Debris Prediction and Hazard Appraisal* (USDA Forest Service Northern Region) requires material less than 3 inches in diameter; therefore, tables for computing crown material less than 3 inches in diameter are also provided.

Slash weight can be predicted and summarized along with existing downed woody fuels as follows:

1. Gather and summarize tree inventory data.
2. Calculate slash weight from cutting and trampling.
3. Calculate slash weight from defect and breakage.
4. If available, add weight of existing fuels to debris summary.

STEP 1. *For any desired area, summarize tree inventory data as number of trees per acre by species and d.b.h. or basal area per acre by species and d.b.h., whichever form is most convenient.*

If possible, summarize the tree data by l-inch d.b.h. classes as shown on the left-hand side of figure 2. Otherwise, summarize tree data by d.b.h. groups and use the average d.b.h. of each group for determining crown weights. Slash from both cutting and trampling should be considered by including trees in the summary that are expected to be either cut or trampled. (Trampling is the pushing over of small trees by logging equipment.) Trampling probably seldom occurs in thinning operations and may be negligible on many harvesting operations. However, where substantial trampling is expected, its contribution to slash can be predicted by this procedure.

STEP 2. *Select the correct weight table and multiply either the number of trees or basal area per acre times the appropriate table weight for each d.b.h. species category. Sum all weights to obtain the total crown weight per acre (this is shown in the Sample Prediction section, and figure 2).*

For harvest cutting, choose the weight table corresponding to the merchantable tip diameter specified in the timber sale. On sales having mixed merchantable tip diameter specifications use the weight table for either the largest diameter or the diameter associated with the species contributing the most volume.

For precommercial thinning and trampling from harvesting activities, use the tables for a 6-inch merchantable tip diameter. These tables permit calculating crown and total bole weights for trees less than 6 inches d.b.h. For trees larger than 6 inches d.b.h. that might be precommercially thinned or trampled, only crown and bole material less than 6 inches is included in the predictions.

The weight tables are as follows:

Table number	*Information to use tables*	*Amount of crown*	*Merchantable tip diameter (inches)*
1	Trees/acre	All	3
2	Trees/acre	All	4
3	Trees/acre	All	6
4	Trees/acre	Less than 3 in	3 and greater
5	Basal area/acre	All	3
6	Basal area/acre	All	4
7	Basal area/acre	All	6
8	Basal area/acre	Less than 3 in	3 and greater

The lines drawn around the weights in the tables show the range of sample tree data. Species and letter codes used in the table heading are as follows:

GF	Grand fir	*Abies grandis* (Dougl.) Lindl.
WL	Western larch	*Larix occidentalis* Nutt.
ES	Engelmann spruce	*Picea engelmannii* Parry
AF	Subalpine fir	*Abies lasiocarpa* (Hook.) Nutt.
LP	Lodgepole pine	*Pinus contorta* Dougl.
DF	Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
WH	Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.
WP	Western white pine	*Pinus monticola* Dougl.
WC	Western redcedar	*Thuja plicata* Donn
PP	Ponderosa pine	*Pinus ponderosa* Laws.

SLASH WEIGHT SUMMARY

Stand 16 Location Cool Man Ck.
Unit 4 Date 8-26-76 Page 1 of 1

Number of trees /acre from inventory by species							Crown weight/acre (pounds) by species					
DBH	G. Fir	Larch					G. Fir	Larch				
1	300						1590					
2	100						1660					
9												
10	38						9196					
11	30						8070					
12	20	9					6020	1647				
13	16	10					5392	1920				
14	15						5665					
15												
16	10						4710					
17		5						1225				
Total							42293	4792				

SUMMARY OF DEBRIS WEIGHT

(1) Cutting		(2) Trampling		(3) Breakage	
Poundslacre	Tons/acre	Poundslacre	Tonslacre	Poundslacre	Tons /acre
43,835	21.92	3250	1.63	8462	4.23

Predicted weight. (1) + (2) + (3) Tonslacre = 27.8

(4) Existing downed debris. Tonslacre = 18.0

Total debris. (1) + (2) + (3) + (4), Tons/acre = 45.8

Figure 2.--Slash summary form showing a sample estimate of trees expected to be cut and trampled and the resultant slash. Crown weight per acre is the product of number of trees per acre and crown weight per tree from table 3. (A sample form is inserted in the back of this handbook.)

STEP 3. *Estimate slash weight for defect and breakage as:*

$$w = V \times f \times s/2000 \quad (1)$$

where

w = weight of logging residue from defect and breakage, tons/acre
V = merchantable volume of trees' to be cut, ft^3/acre
f = fraction of merchantable volume expected to be left on the ground as defect and breakage
s = density of wood, lb/ft^3

Estimates of merchantable tree volume are obtained from timber cruises or tree inventories. Wood densities for common western species are summarized in table 9. For a mixture of species, densities can be averaged. A wood density value that represents a commonly encountered mixture of western conifer species is 25 pounds per cubic foot.

Slash from defect and breakage is considered to be larger than 3 inches in diameter; thus, weight estimates are needed only when predicting all slash material. The defect and breakage component of slash is far more difficult to predict accurately than weight of crowns and unmerchantable bole tips. Nonetheless, an estimate is possible using experience and knowledge of local harvesting operations. Breakage can vary considerably from negligible in healthy second-growth stands to substantial in defective old-growth stands.

Breakage can be estimated best from local experience with past harvesting operations. In the Northern Rocky Mountains, breakage in old-growth stands is commonly estimated as 10 percent of the cruised merchantable volume and in other stands about 5 percent (opinion of several experienced foresters).

Defect such as rot, crook, sweep, fire scars, butt swell, etc., varies by species and tree size. Most timber sellers have some notion of defect factors (fraction of merchantable volume that is defective) applicable to their area. Not all defect remains on the cutting site because some of it is hauled to the mill. Thus, defect factors must represent the material actually remaining on site. In the Northern Rocky Mountains, about 50 percent of the defective volume remains on an area after cutting (opinion of several experienced foresters).

STEP 4. *To estimate weight of total downed debris, add weight of downed woody material before cutting to predicted weight of slash.*

Sample Prediction

To illustrate procedures for predicting slash, consider a partial cutting of grand fir and larch. The merchantable tip diameter limit is 6 inches and number of trees per acre is used to calculate weight for all slash material. Weights summarized by source of material are:

Source	*Weight (tons/acre)*
Cutting: Trees to be cut are grand fir (10 to 16 in d.b.h.); and larch (12 to 17 in d.b.h.). Number of trees per acre (recorded in figure 2) multiplied times crown weights per tree (from table 3) provided the slash weights shown in figure 2.	21.92
Trampling: Trees expected to be trampled were 1 and 2 in d.b.h. Weights were calculated using table 3	1.63
Defect and breakage: w = 3,385 × 0.10 × 25/2,000. A timber cruise showed a volume of 3,385 ft^3, of which 80 percent was grand fir. A wood density of 25 lb/ft^3, was determined by weighting the densities of grand fir and larch from table 9 by their percentages of total timber volume: (80 percent × 23.1 + 20 percent × 32.4)/100 = 25.0. Breakage was judged to be about 5 percent and defect left on site was 5 percent. Thus, the f in equation (1) is 0.05 plus 0.05 or 0.10.	4.23
Predicted slash	27.8
Domed woody material: Inventory of existing downed debris yielded 18 tons/acre	18.0
Total	45.8

Other Species and Crown Classes

These procedures can be used with unknown but probably acceptable accuracy on species having branch forms similar to species that are listed. To indicate accuracy of prediction, crown weight for species in this handbook that have similar branch forms, such as the firs and spruce, were compared. On the average, one species was within about 20 percent of the other. For some d.b.h.'s, differences were as high as 50 percent. The following combinations of species are probably similar enough to yield reasonably accurate slash predictions when considered alike:

Listed in tables	*Not listed in tables*
Lodgepole pine	White barked pine, limber pine
Grand fir	Pacific red fir

The tables in this handbook were developed from data for trees having dominant and codominant crown classes. Brown (see footnote 1) found that for shade-tolerant species, crown weight of intermediate crowns is not significantly different from dominant and codominant crowns. However, for shade-intolerant species, weight of intermediate crowns is significantly less than for dominant and codominant crowns. Thus, in stands of intolerant species where a large proportion of the trees have intermediate crowns, an adjustment of the crown weight based on dominant and codominant crowns may be desirable.

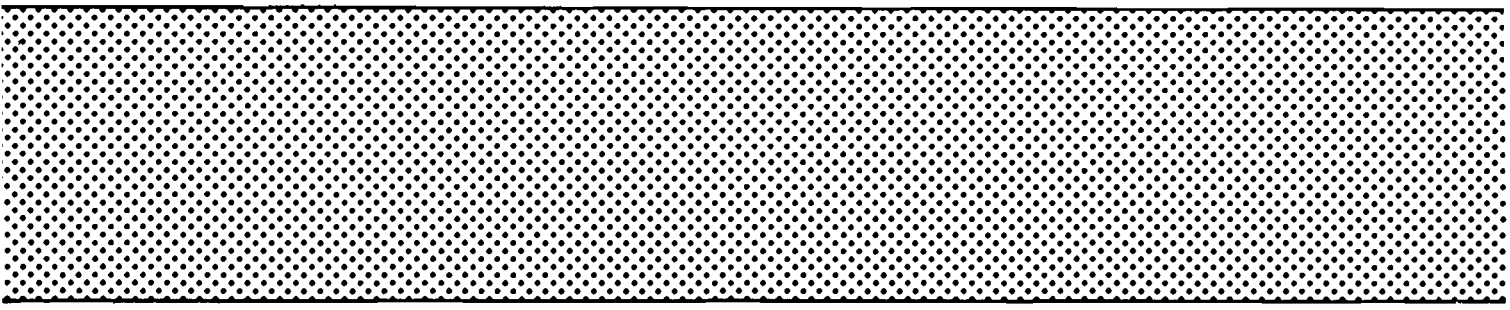
We recommend adjusting crown weights only for ponderosa pine, lodgepole pine, and western larch. When these species dominate the composition and have a high proportion of intermediate crowns, adjusted crown weights can be calculated as follows:

D. b. h.	*Equation*	
Less than 7.5 in	$D' = D(1 - 0.5\ f_I)$	(2)
7.5 in and greater	$D' = D(1 - 0.4\ f_I)$	(3)

where

D' = crown weight per acre adjusted for intermediate crowns
D = crown weight per acre based on dominant and codominant crowns
f_I = fraction of trees per acre having intermediate and suppressed crowns

Slash Weight (lbs) per TREE



WEIGHT PER TREE--TOTAL CROWN AND TIP

TABLE 1.--Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top

3-INCFI TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
4	35	29	31	40	45	37	34	40
5	48	36	36	51	60	47	44	53
6	66	46	43	64	77	61	56	69
7	87	59	52	80	97	79	70	87
8	113	74	62	97	120	100	86	108
9	143	92	72	116	146	125	104	131
10	177	112	84	137	175	154	124	156
11	216	133	97	160	207	187	145	183
12	259	155	110	184	242	226	168	213
13	307	179	125	210	281	269	193	246
14	359	205	140	239	324	319	220	280
15	416	233	156	269	370	375	249	317
16	478	262	173	301	422	437	280	357
17	544	293	190	334	477	489	312	399
18	616	325	209	380	538	546	347	444
19	692	360	228	429	587	607	383	492
20	774	396	248	482	637	671	421	542
21	861	433	268	537	688	739	462	596
22	953	473	289	597	741	809	504	652
23	1,050	513	311	659	796	883	549	712
24	1,150	556	334	725	852	960	595	775
25	1,260	600	357	795	909	1,040	644	841
26	1,370	645	382	869	968	1,120	695	911
27	1,490	693	406	946	1,030	1,210	748	985
28	1,620	741	432	1,030	1,090	1,300	804	1,060
29	1,750	792	458	1,110	1,150	1,400	862	1,140
30	1,890	844	485	1,200	1,220	1,490	922	1,230
31	2,030		513	1,290	1,280		985	1,320
32	2,180		541	1,390	1,350		1,050	1,410
33	2,330		570	1,490	1,420		1,120	1,510
34	2,490		600	1,600	1,490		1,190	1,610
35	2,660		630	1,710	1,560		1,260	1,720
36	2,830		661	1,820	1,630		1,340	1,830
37	3,010		693	1,940	1,700		1,410	1,950
38	3,200		725	2,060	1,780		1,500	2,070
39	3,390		758	2,190	1,850		1,580	2,200
40	3,590		792	2,320	1,930		1,670	2,330

TABLE 2.--*Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top*

4-INCH TOP

D.b.h. (inches)	Species							
	PP	*LP*	*WL-WP*	DF	GF	AF	WC-WH	ES
	Pounds							
5	67	55	60	70	77	62	61	68
6	82	62	63	81	92	74	70	82
7	101	72	69	94	111	90	83	99
8	126	86	77	110	132	110	98	118
9	154	103	87	128	157	134	115	140
10	188	122	98	148	185	162	134	165
11	226	142	109	170	217	195	155	192
12	268	164	122	194	252	233	177	222
13	315	187	136	220	290	276	202	253
14	367	213	151	248	333	325	229	288
15	424	240	166	277	379	381	257	325
16	485	269	183	309	430	444	288	364
17	552	299	200	342	486	495	320	406
18	623	332	218	388	546	552	354	451
19	699	366	237	437	595	613	390	498
20	780	401	257	489	645	677	428	549
21	867	439	277	544	696	744	469	602
22	959	478	298	603	749	814	511	658
23	1,060	518	320	666	803	888	555	718
24	1,160	561	342	732	859	965	602	781
25	1,270	605	366	802	916	1,050	650	847
26	1,380	650	390	875	975	1,130	701	917
27	1,500	697	414	952	1,040	1,220	754	990
28	1,620	746	440	1,030	1,100	1,310	810	1,070
29	1,760	796	466	1,120	1,160	1,400	868	1,150
30	1,890	848	493	1,210	1,220	1,500	928	1,230
31	2,030		520	1,300	1,290		990	1,320
32	2,180		549	1,400	1,360		1,060	1,420
33	2,340		578	1,500	1,420		1,120	1,510
34	2,500		607	1,600	1,490		1,190	1,620
35	2,660		637	1,710	1,560		1,270	1,720
36	2,840		668	1,830	1,640		1,340	1,840
37	3,020		700	1,950	1,710		1,420	1,950
38	3,200		732	2,070	1,780		1,500	2,080
39	3,390		766	2,200	1,860		1,580	2,200
40	3,590		799	2,330	1,940		1,670	2,340

TABLE 3.--*Weight per tree by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top*

6-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	3.3	2.5	3.5	5.5	5.3	10.6	4.0	5.1
2	10.5	10.2	11.3	16.5	16.6	17.3	13.4	15.3
3	22.8	24.4	27.7	33.1	34.4	31.5	28.7	29.1
4	40	45	56	55	60	56	51	46
5	64	73	99	82	93	93	80	66
6	93	107	162	113	136	145	118	88
7	181	158	173	176	187	151	157	165
8	195	158	167	182	200	163	163	177
9	216	165	166	192	218	182	173	193
10	243	177	169	206	242	205	187	213
11	276	191	175	223	269	235	204	236
12	315	207	183	243	301	270	223	262
13	359	227	192	266	337	311	245	292
14	408	249	203	291	377	358	270	324
15	462	273	216	318	421	412	296	359
16	521	299	230	348	471	472	325	397
17	586	328	245	379	525	523	355	437
18	655	358	261	423	584	579	388	481
19	730	391	278	471	632	638	423	527
20	810	425	296	522	681	701	460	576
21	896	461	315	576	731	767	500	629
22	987	499	335	634	783	837	541	684
23	1,080	538	356	696	837	910	585	743
24	1,180	580	377	761	892	987	630	805
25	1,290	623	399	830	949	1,070	678	871
26	1,400	667	423	902	1,010	1,150	729	940
27	1,520	714	446	979	1,070	1,240	781	1,010
28	1,650	761	471	1,060	1,130	1,330	836	1,090
29	1,780	811	497	1,140	1,190	1,420	893	1,170
30	1,910	862	523	1,230	1,250	1,520	953	1,250
31	2,060		550	1,320	1,320		1,020	1,340
32	2,200		577	1,420	1,390		1,080	1,440
33	2,360		606	1,520	1,450		1,150	1,530
34	2,520		635	1,630	1,520		1,220	1,640
35	2,680		665	1,740	1,590		1,290	1,740
36	2,860		695	1,850	1,660		1,360	1,860
37	3,040		726	1,970	1,740		1,440	1,970
38	3,220		758	2,090	1,810		1,520	2,100
39	3,410		791	2,220	1,890		1,610	2,220
40	3,610		824	2,350	1,960		1,690	2,360

TABLE 4.--*Weight per tree by d.b.h. of material less than 3 inches diameter for crowns and bole tips*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	3.1	2.4	3.4	5.3	5.2	10.4	3.9	4.9
2	9.8	9.4	10.5	15.5	15.9	16.6	12.5	14.4
3	16.3	14.2	16.1	22.8	25.9	22.9	19.0	22.9
4	35	29	31	40	45	37	34	40
5	48	36	36	51	60	47	44	53
6	66	46	43	64	77	61	56	69
7	87	59	52	80	97	79	70	87
8	111	74	62	97	120	100	86	108
9	139	92	72	116	146	125	104	131
10	170	112	84	137	175	154	124	156
11	205	133	96	160	207	187	145	183
12	243	155	109	184	242	226	168	213
13	284	179	122	210	281	269	193	246
14	328	205	137	239	324	319	220	280
15	376	233	152	268	370	375	249	317
16	426	262	168	299	422	437	280	357
17	480	293	184	332	477	489	312	399
18	536	325	201	377	538	546	347	444
19	596	360	219	425	587	607	383	492
20	658	396	238	476	637	671	421	542
21	723	433	257	530	688	739	462	596
22	790	473	277	588	741	809	504	652
23	861	513	298	649	796	883	549	712
24	933	556	320	713	852	960	595	775
25	1,010	600	342	781	909	1,040	644	841
26	1,090	645	364	852	968	1,120	695	911
27	1,170	693	388	926	1,030	1,210	748	985
28	1,250	741	412	1,000	1,090	1,300	804	1,060
29	1,330	792	436	1,090	1,150	1,400	862	1,140
30	1,420	844	462	1,170	1,220	1,490	922	1,230
31	1,510		488	1,260	1,280		985	1,320
32	1,600		514	1,350	1,350		1,050	1,410
33	1,690		542	1,450	1,420		1,120	1,510
34	1,780		570	1,550	1,490		1,190	1,610
35	1,880		598	1,660	1,560		1,260	1,720
36	1,980		627	1,760	1,630		1,340	1,830
37	2,080		657	1,880	1,700		1,410	1,950
38	2,180		688	1,990	1,780		1,500	2,070
39	2,280		719	2,120	1,850		1,580	2,200
40	2,380		751	2,240	1,930		1,670	2,330

Slash Weight (lbs) by BASAL AREA

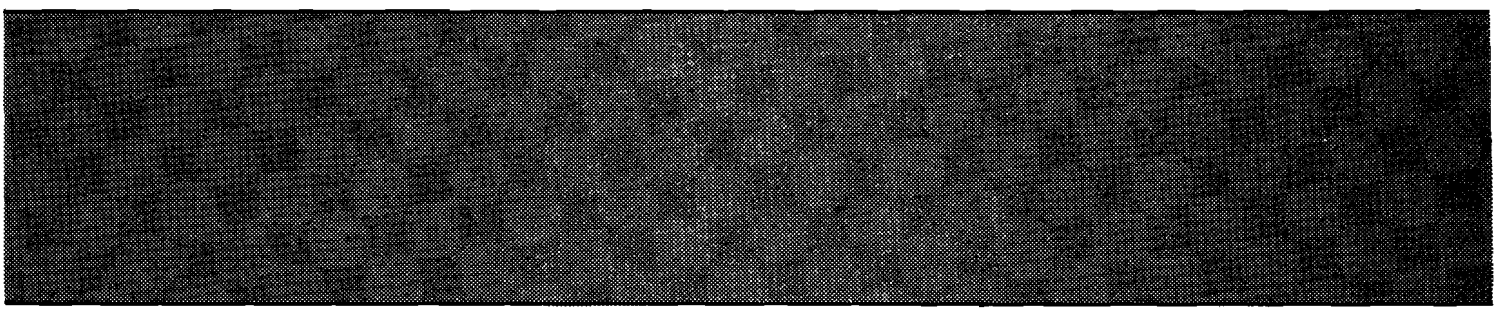


TABLE 5.--*Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 3-inch top*

3-INCH TOP

D.b.h. inches	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
4	402	332	355	463	520	419	390	455
5	353	264	266	375	438	346	321	387
6	334	235	221	328	392	312	284	349
7	326	220	195	298	364	294	262	325
8	324	212	177	277	344	286	246	308
9	324	208	164	262	330	282	235	295
10	325	206	154	251	320	282	227	286
11	327	201	147	242	313	284	220	278
12	330	198	141	234	308	287	214	272
13	333	194	135	228	305	292	210	266
14	336	192	131	223	303	298	206	262
15	339	190	127	219	302	305	203	259
16	342	188	124	215	302	313	200	256
17	345	186	121	212	303	310	198	253
18	349	184	118	215	305	309	196	251
19	352	183	116	218	298	308	195	250
20	355	181	113	221	292	308	193	249
21	358	180	111	223	286	307	192	248
22	361	179	110	226	281	307	191	247
23	364	178	108	228	276	306	190	247
24	367	177	106	231	271	306	189	247
25	370	176	105	233	267	305	189	247
26	373	175	103	236	263	305	188	247
27	376	174	102	238	259	305	188	248
28	379	173	101	240	255	305	188	248
29	382	173	100	242	251	304	188	249
30	384	172	99	245	248	304	188	250
31	387		98	247	245		188	251
32	390		97	249	242		188	253
33	393		96	251	239		188	254
34	395		95	253	236		188	256
35	398		94	256	233		189	257
36	401		94	258	231		189	259
37	403		93	260	228		189	261
38	406		92	262	226		190	263
39	409		91	264	223		190	265
40	411		91	266	221		191	267

TABLE 6.--*Weight per square foot of basal area: by d.b.h. of all material for crowns and unmerchantable bole tips to a 4-inch top*

4-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
5	493	400	438	516	563	452	446	500
6	416	314	322	412	468	375	359	417
7	379	271	260	352	413	335	310	369
8	360	247	222	315	379	314	280	339
9	350	233	197	290	356	303	260	318
10	345	224	179	271	340	297	245	303
11	342	215	166	258	328	295	234	291
12	342	208	156	247	320	297	226	282
13	342	203	148	238	315	300	219	275
14	344	199	141	232	311	304	214	269
15	345	195	136	226	309	310	210	264
16	348	192	131	221	308	318	206	261
17	350	190	127	217	308	314	203	258
18	352	188	123	220	309	313	200	255
19	355	186	120	222	302	311	198	253
20	358	184	118	224	296	310	196	251
21	360	182	115	226	289	309	195	250
22	363	181	113	229	284	309	194	249
23	366	180	111	231	278	308	192	249
24	369	178	109	233	273	307	192	248
25	372	177	107	235	269	307	191	248
26	374	176	106	237	264	306	190	249
27	377	175	104	239	260	306	190	249
28	380	174	103	242	256	306	189	250
29	383	174	102	244	253	305	189	250
30	385	173	100	246	249	305	189	251
31	388		99	248	246		189	252
32	391		98	250	243		189	254
33	393		97	252	240		189	255
34	396		96	254	237		189	256
35	399		95	256	234		190	258
36	401		95	258	231		190	260
37	404		94	261	229		190	262
38	406		93	263	226		191	264
39	409		92	265	224		191	266
40	412		92	267	222		192	268

TABLE 7.--*Weight per square foot of basal area by d.b.h. of all material for crowns and unmerchantable bole tips to a 6-inch top*

6-INCH TOP

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	605	464	635	1,001	972	1,937	736	936
2	482	467	519	757	759	791	615	702
3	464	497	564	674	701	642	585	593
4	458	519	641	628	683	640	580	527
5	469	534	730	599	682	682	588	484
6	474	546	824	578	691	741	602	448
7	678	590	646	660	698	565	588	618
8	559	453	478	520	573	468	467	506
9	489	374	376	434	495	411	393	437
10	446	324	310	377	443	377	343	390
11	419	289	265	338	408	356	309	358
12	401	264	232	309	383	343	285	334
13	389	246	209	288	365	337	266	316
14	381	233	190	272	353	335	252	303
15	376	222	176	259	343	335	241	292
16	373	214	165	249	337	338	233	284
17	372	208	155	241	333	332	225	277
18	371	203	148	240	331	327	220	272
19	371	198	141	239	321	324	215	268
20	372	195	136	239	312	321	211	264
21	373	192	131	239	304	319	208	261
22	374	189	127	240	297	317	205	259
23	375	187	123	241	290	315	203	258
24	377	184	120	242	284	314	201	256
25	379	183	117	243	278	313	199	255
26	381	181	115	245	273	312	198	255
27	383	179	112	246	268	311	196	255
28	385	178	110	248	264	310	196	255
29	388	177	108	249	259	309	195	255
30	390	176	106	251	255	309	194	256
31	392		105	253	252		194	256
32	395		103	254	248		193	257
33	397		102	256	245		193	258
34	399		101	258	241		193	260
35	402		99	260	238		193	261
36	404		98	262	235		193	263
37	406		97	263	233		193	264
38	409		96	265	230		193	266
39	411		95	267	227		194	268
40	414		94	269	225		194	270

TABLE 8.--*Weight per square foot of basal area by d.b.h. of material less than 3 inches diameter for crowns and bole tips*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	569	440	624	972	954	1,907	715	899
2	450	431	482	711	730	762	574	661
3	333	290	328	465	528	467	388	449
4	402	332	355	463	520	419	390	455
5	353	264	266	375	438	346	321	387
6	334	235	221	328	392	312	284	349
7	324	220	195	298	364	294	262	325
8	318	212	177	277	344	286	246	308
9	314	208	164	262	330	282	235	295
10	312	206	154	251	320	282	227	286
11	310	201	145	242	313	284	220	278
12	309	198	138	234	308	287	214	272
13	308	194	133	228	305	292	210	266
14	307	192	128	223	303	298	206	262
15	306	190	124	218	302	305	203	259
16	305	188	120	214	302	313	200	256
17	304	186	117	211	303	310	198	253
18	303	184	114	213	305	309	196	251
19	302	183	111	216	298	308	195	250
20	302	181	109	218	292	308	193	249
21	301	180	107	221	286	307	192	248
22	299	179	105	223	281	307	191	247
23	298	178	103	225	276	306	190	247
24	297	177	102	227	271	306	189	247
25	296	176	100	229	267	305	189	247
26	295	175	99	231	263	305	188	247
27	293	174	98	233	259	305	188	248
28	292	173	96	235	255	305	188	248
29	291	173	95	237	251	304	188	249
30	289	172	94	239	248	304	188	250
31	288		93	241	245		188	251
32	286		92	242	242		188	253
33	285		91	244	239		188	254
34	283		90	246	236		188	256
35	281		90	248	233		189	257
36	280		89	250	231		189	259
37	278		88	251	228		189	261
38	276		87	253	226		190	263
39	275		87	255	223		190	265
40	273		86	257	221		191	267

TABLE 9.--*Density of wood for selected western species. (Density values from U.S. Forest Products Laboratory (1974))*

Species	Density (lb/ft^3)
CONIFERS	
Cedar	
Western redcedar *(Thuja plicata)*	20.0
Incense cedar *(Libocedrus decurrens)*	23.1
Alaska cedar *(Chamaecyparis nootkatensis)*	27.5
Douglas-fir *(Pseudotsuga menziesii)*	
Coastal (Washington and Oregon)	30.0
Northern Rocky Mountains	30.0
Southern Rocky Mountains	28.7
Fir	
Grand fir *(Abies grandis)*	23.1
California red fir *(Abies magnifica)*	23.7
Noble fir *(Abies procera)*	24.3
Pacific silver fir *(Abies amabilis)*	26.8
White fir *(Abies concolor)*	24.3
Subalpine fir *(Abies lasiocarpa)*	20.0
Western hemlock *(Tsuga heterophylla)*	28.1
Western larch *(Larix occidentalis)*	32.4
Pine	
Lodgepole pine *(Pinus contorta)*	25.6
Ponderosa pine *(Pinus ponderosa)*	25.0
Sugar pine *(Pinus lambertiana)*	22.5
Western white pine *(Pinus monticola)*	23.7
Redwood *(Sequoia sempervirens)* Old growth	25.0
Spruce	
Engelmann spruce *(Picea engelmannii)*	21.8
White spruce *(Picea glauca)*	25.0
Sitka spruce *(Picea sitchensis)*	25.0
HARDWOODS	
Quaking aspen *(Populus tremuloides)*	23.7
Black cottonwood *(Populus trichocarpa)*	21.8

ACCURACY

Accuracy of predictions can vary considerably, depending upon species, stand conditions, and accuracy of the timber stand inventory. Sources of variation affecting predictions include equations for estimating live crown weight, dead crown weight, unmerchantable tip volume, and bark density; estimates of defect and breakage factors; and accuracy of tree inventory data. Equations for predicting live branches and foliage, which account for a major portion of the total crown weight, have standard errors of the estimate ranging from 30 to 64 percent of mean values. When weight is predicted for many trees and summed, errors for individual trees tend to balance out; thus, estimates for stand averages are expected to be more accurate than estimates for individual trees.

A test to validate predictions was conducted in three small stands dominated by a single species--ponderosa pine, Douglas-fir, and lodgepole pine. Crown weights were predicted before cutting. After cutting, the slash was intensively inventoried using the planar intersect method (Brown and Roussopoulos 1974).

For slash less than 3 inches in diameter, predicted weights were less than inventoried weights by 15, 22, and 37 percent of inventoried values. For all slash, predicted weights varied from 4 percent more, to 15 percent less than inventoried weights. Some of the discrepancies were traced to biases in the test; thus, differences between predicted weights and actual weights would be less than indicated by our test.

Considering the sources of variation inherent in predicting slash weights and a validation test, we believe that most estimates of slash weight from crowns and unmerchantable bole tips should be within 20 percent of the true mean. Occasionally, estimates can be expected to deviate from the true mean by as much as 50 percent.

FUEL APPRAISAL

Appraising potential fire behavior of fuels is often termed fuel appraisal and is the process of (1) describing fuel characteristics such as quantity and size; and (2) interpreting the fuel in terms of fire behavior; for example, rate of spread, fireline intensity, and flame length. Thus, the appraisal process attempts to answer the question: What is the expected fire behavior for different fuels, given steepness of slope and weather conditions? The question is difficult to answer, partly because the answer is made up of different elements of fire behavior (Anderson 1974): rate of spread, intensity, crowning potential, spotting potential, and duration of heat. One or more of these elements may have to be appraised when a specific fuel management situation is being evaluated.

Potential fire behavior of downed woody debris can be appraised by (1) mathematical modeling, and (2) experienced judgment. Mathematical modeling of rate of spread, fireline intensity, and flame length, for example, offers the most objective means of appraising potential fire behavior. However, this approach may not be readily available to some land managers.

Experienced judgment is an important means of appraising fuels because an experienced person can integrate many factors that elude quantification. Even when more sophisticated methods are available, judgment is still important. One way of using experienced judgment is to establish a reference (tons per acre) that can be used to compare against other fuel loadings. The reference loading should represent fuels for which a consensus of land managers experienced in control of fire can agree upon a rating. Ratings, for example, might be for low, medium, or high fire intensity potential, or either acceptable or unacceptable regarding the ability of an initial attack crew to gain control. After setting a reference loading, fuels are appraised on a relative basis. For example, for material less than 3 inches in diameter, if a loading of 10 tons per acre is established as a reference, then a loading of 20 tons per acre would exhibit approximately twice the potential fire behavior.

How Much Fuel Is Acceptable?

Fire managers commonly want to know the tonnages of fuel that are acceptable. This question is difficult to answer because fire behavior depends not only on fire potential at one location but also on other factors, such as distribution of fuels and fire behavior potential over surrounding areas that may cover one or more drainages. Acceptable fuel loading depends on resource values, management objectives for the land, pattern of land ownership, and suppression capability. In some stands, acceptable load depends on resistance of trees to crown scorch and cambium kill. Professional judgment is certainly needed to determine acceptable fuel tonnages.

Decision steps.--To decide how much fuel is acceptable requires that one must integrate many factors (fig. 3). This can be done systematically as follows:

1. Consider management objectives and values at risk. For the latter, resource values and risk of a fire during a high fire-danger period causing damage are jointly considered.

2. Appraise fuels by (a) describing fuels from inventory and prediction; and (b) interpreting fire behavior potential such as rate of spread, flame length, intensity, and scorch height.

3. Consider other fire-related factors such as fuel and fire behavior potential on adjoining areas, suppression capability, frequency and severity of historical fires, and fire's ecological role.

Acceptable fuel loadings can depend to a high degree on factors in item 3. For example, a heavier fuel loading would be acceptable on a unit surrounded by sparse fuels with little chance of ignition than on a unit surrounded by heavy fuels with a high chance of ignition.

Fuel loading standards.--No single fuel loading may be acceptable for a large administrative area. Herein lies the dilemma of setting fuel standards. Establishing standards would permit the setting of clear objectives for residue management and provide benchmarks with which to measure accomplishments. However, standards could easily circumvent professional judgment for determining the maximum acceptable level of fuel for specific sites. One approach to determining acceptable fuel levels is to develop different standards for each of the major decision circumstances encountered on a large administrative unit. To accomplish this, the factors in figure 3 should be evaluated for the different management circumstances found on a large administrative unit.

Acceptable loadings of debris also depend on requirements of other disciplines for attaining land management objectives. Thus, even if fuel standards are set, the final decision on how much downed debris is acceptable should be coordinated among land management interests.

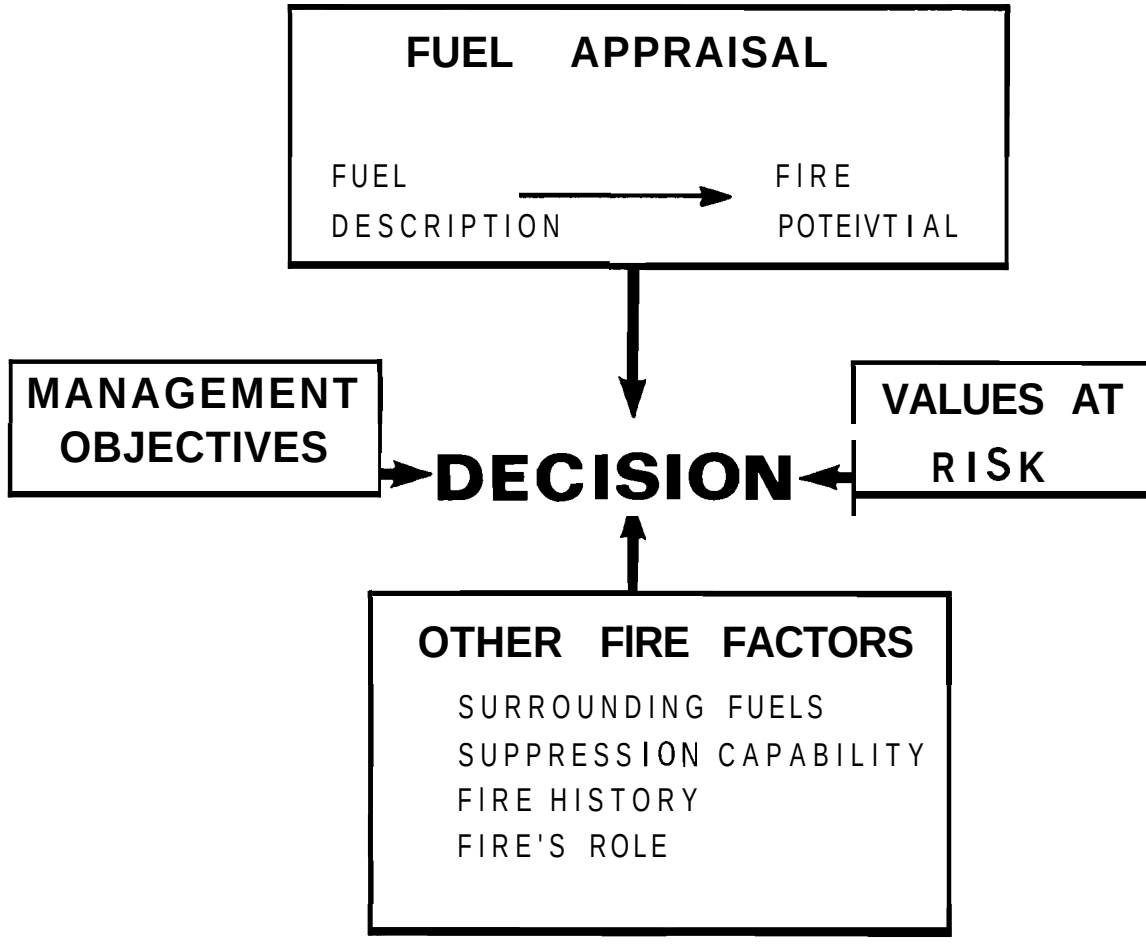


Figure 3.--Factors to consider when deciding how much fuel is acceptable.

BASIS FOR TABLES

Weights in the tables are expressed on an ovendry basis. Fractions for converting material less than 3 inches in diameter to all material and converse conversions are in appendix I.

Tables 1 through 8 show combined weights of crowns and unmerchantable tips. Relationships for estimating only crown weights for live and dead material are summarized by Brown (see footnote 1). Tables for predicting crown weights without unmerchantable tips are in appendix II. Fractions for dividing crown weights into foliage and branchwood diameter classes of 0 to 0.24 in, 0.25 to 0.99 in, 1.0 to 2.99 in, and 3.0+ in are in appendix III.

Unmerchantable tip and bole weights were computed using two methods. Brown's equations for total tree bole weight, including bark, were used for trees above the dashed lines in tables 3, 4, 7, and 8. For trees below the dashed line, weight of wood was estimated by means of unmerchantable tip volume equations developed by Faurot (see footnote 2) and wood densities from U.S. Forest Products Laboratory (1974). Bark weight was estimated from bark volumes and densities. Bark volume was calculated from ratios of bark thickness-to-stem thickness as described in appendix IV.

Faurot's equations for volume of unmerchantable tips require d.b.h. and height as independent variables. For constructing the tables, height was estimated using height-d.b.h. regressions developed by Brown (see footnote 1). Tables of tip weights and equations for tip volume and tree height are included in appendix IV.

The tables based on weight-per-square-foot of tree basal area were constructed from tables of weight per tree by d.b.h. For each d.b.h., weights per tree were divided by the basal area corresponding to that d.b.h.

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APPENDIX I

Fraction of Crowns and Tips 3 Inches and Larger

The fractions in table 10 above the dashed lines drawn at 2, 4, and 6 inches d.b.h. are based on weights that include entire boles. These fractions apply to slash from precommercial thinning and trampling where entire trees are left on the ground. Below the lines, the fractions are based on weights that include unmerchantable tips and apply to slash from harvesting operations.

TABLE *10.--Fractions of crowns and unmerchantable bole tips that are 3 inches in diameter and larger*

D.b.h. (inches)	Species									
	PP	LP	WL	DF	GF	AF	WC	WP	WH	ES
				3-INCH TOP						
2	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0
8	0.02	0	0	0	0	0	0	0	0	0
10	.04	0	0	0	0	0	0	0	0	0
12	.06	0	0.02	0	0	0	0	0	0	0
14	.09	0	.02	0	0	0	0	0	0	0
16	.ll	0	.03	0.01	0	0	0	0	0	0
18	.13	0	.04	.01	0	0	0	0	0	0
20	.15	0	.04	.01	0	0	0	0	0	0
22	.17	0	.04	.01	0	0	0	0	0	0
24	.19	0	.05	.02	0	0	0	0	0	0
26	.21	0	.05	.02	0	0	0	0	0	0
28	.23	0	.05	.02	0	0	0	0	0	0
30	.25	0	.05	.02	0	0	0	0	0	0
32	.27		.05	.03	0		0	0	0	0
34	.28		.06	.03	0		0	0	0	0
36	.30		.06	.03	0		0	0	0	0
38	.32		.06	.03	0		0	0	0	0
40	.34		.06	.04	0		0	0	0	0

[con.)

TABLE 10.--*Continued*

D.b.h. (inches)	Species									
	PP	LP	WL	DF	GF	AF	WC	WP	WH	ES
					4-INCH TOP					
2	0.07	0.08	0.08	0.06	0.04	0.04	0.06	0.07	0.07	0.06
4	.24	.39	.45	.29	.25	.31	.32	.40	.33	.21
6	.18	.24	.32	.19	.15	.15	.16	.25.	.22	.15
8	.11	.13	.21	.11	.09	.08	.10	.16	.13	.09
10	.09	.08	.15	.07	.06	.05	.06	.11	.09	.05
12	.09	.05	.12	.05	.04	.03	.04	.08	.06	.04
14	.11	.03	.10	.04	.03	.02	.03	.06	.04	.03
16	.12	.02	.09	.03	.02	.01	.02	.05	.03	.02
18	.14	.02	.08	.03	.02	.01	.02	.04	.03	.01
20	.16	.01	.08	.03	.01	.01	.01	.03	.02	.01
22	.18	.01	.08	.03	.01	.01	.01	.03	.02	.01
24	.19	.01	.07	.03	.01	.01	.01	.02	.01	.01
26	.21	.01	.07	.03	.01	0	.01	.02	.01	.01
28	.23	.01	.07	.03	.01	0	.01	.02	.01	.01
30	.25	0	.07	.03	.01	0	.01	.02	.01	0
32	.27		.07	.03	.01		0	.01	.01	0
34	.29		.07	.03	.01		0	.01	.01	0
36	.30		.07	.03	0		0	.01	.01	0
38	.32		.07	.04	0		0	.01	.01	0
40	.34		.07	.04	0		0	.01	0	0
					6-INCH TOP					
2	.06	.08	.08	.06	.04	.04	.06	.07	.07	.06
4	.31	.51	.58	.38	.33	.40	.42	.53	.43	.27
6	.34	.59	.74	.46	.44	.56	.56	.69	.50	.28
8	.42	.52	.65	.46	.39	.38	.41	.57	.50	.38
10	.30	.36	.53	.33	.27	.25	.29	.45	.37	.26
12	.23	.25	.43	.24	.19	.16	.21	.36	.28	.19
14	.19	.17	.35	.18	.14	.11	.15	.28	.21	.13
16	.18	.13	.29	.14	.11	.07	.12	.23	.16	.10
18	.18	.09	.25	.11	.08	.06	.09	.19	.13	.08
20	.19	.07	.21	.09	.07	.04	.07	.15	.10	.06
22	.20	.05	.19	.07	.05	.03	.06	.13	.08	.05
24	.21	.04	.17	.06	.05	.03	.05	.11	.07	.04
26	.23	.03	.15	.06	.04	.02	.04	.09	.06	.03
28	.24	.03	.14	.05	.03	.02	.03	.08	.05	.03
30	.26	.02	.13	.05	.03	.02	.03	.07	.04	.02
32	.28		.12	.05	.03		.02	.06	.04	.02
34	.29		.11	.05	.02		.02	.06	.03	.02
36	.31		.11	.05	.02		.02	.05	.03	.01
38	.32		.10	.05	.02		.02	.04	.02	.01
40	.34		.10	.05	.02		.01	.04	.02	.01

APPENDIX II

Crown Weight Tables

TABLE 11.--Crown weight per *tree*[1/]

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	1.3	1.1	1.8	3.1	3.7	8.6	2.2	2.8
2	5.7	4.3	5.5	9.4	11.3	12.4	7.3	9.3
3	13.3	9.4	10.7	18.0	21.9	18.8	14.5	18.6
4	24	17	17	29	35	28	24	30
5	39	26	24	41	51	40	35	45
6	58	37	33	55	69	55	48	61
7	80	51	42	71	90	73	63	80
8	106	67	53	89	113	94	79	101
9	137	85	64	109	139	119	97	125
10	171	106	76	130	168	149	117	150
11	210	127	89	153	200	182	139	178
12	254	150	103	178	236	221	162	208
13	302	174	117	204	275	265	188	240
14	354	200	133	233	317	314	215	275
15	411	228	149	263	364	370	244	312
16	473	258	166	295	416	433	274	352
17	540	289	183	329	471	485	307	395
18	611	322	202	375	532	542	341	439
19	688	356	221	424	581	603	378	487
20	770	392	241	476	631	667	416	538
21	856	430	261	532	683	735	456	591
22	949	469	283	591	736	805	499	648
23	1,050	510	305	654	790	879	543	708
24	1,150	553	328	720	846	957	590	771
25	1,260	597	351	790	903	1,040	639	837
26	1,370	642	375	864	962	1,120	690	907
27	1,490	690	400	941	1,020	1,210	743	980
28	1,620	739	426	1,020	1,080	1,300	799	1,060
29	1,750	789	452	1,110	1,150	1,390	857	1,140
30	1,880	841	479	1,200	1,210	1,490	917	1,220
31	2,030		506	1,290	1,280		980	1,310
32	2,170		535	1,390	1,340		1,040	1,410
33	2,330		564	1,490	1,410		1,110	1,500
34	2,490		593	1,590	1,480		1,180	1,610
35	2,660		624	1,700	1,550		1,260	1,720
36	2,830		655	1,820	1,620		1,330	1,830
37	3,010		686	1,930	1,700		1,410	1,950
38	3,190		719	2,060	1,770		1,490	2,070
39	3,390		752	2,190	1,850		1,570	2,200
40	3,580		786	2,320	1,920		1,660	2,330

1/ Numbers within the lined space are within limits of data sampled.

TABLE 12.--*Crown weight per square foot of basal area*

D.b.h. (inches)	Species							
	PP	LP	WL-WP	DF	GF	AF	WC-WH	ES
	Pounds							
1	244	207	333	573	680	1,577	411	519
2	260	196	254	432	520	568	333	425
3	271	192	218	367	446	382	296	379
4	280	190	195	328	402	319	272	349
5	287	189	180	302	372	291	256	328
6	293	190	168	282	351	278	244	313
7	299	191	159	267	335	271	234	300
8	304	192	151	256	324	269	226	290
9	309	193	145	246	315	270	220	282
10	314	195	140	238	308	272	215	275
11	319	193	135	232	303	276	211	270
12	323	191	131	226	300	281	207	265
13	327	189	127	222	298	287	204	261
14	331	187	124	218	297	294	201	257
15	335	186	121	214	297	302	198	255
16	339	185	119	211	298	310	196	252
17	342	183	116	209	299	308	195	250
18	346	182	114	212	301	307	193	249
19	349	181	112	215	295	306	192	247
20	353	180	110	218	289	306	191	247
21	356	179	109	221	284	305	190	246
22	359	178	107	224	279	305	189	245
23	363	177	106	227	274	305	188	245
24	366	176	104	229	269	305	188	245
25	369	175	103	232	265	304	187	246
26	372	174	102	234	261	304	187	246
27	375	173	101	237	257	304	187	247
28	378	173	100	239	253	304	187	247
29	381	172	98	241	250	304	187	248
30	384	171	98	244	247	303	187	249
31	386		97	246	244		187	251
32	389		96	248	241		187	252
33	392		95	250	238		187	253
34	395		94	253	235		188	255
35	397		93	255	232		188	257
36	400		93	257	230		188	259
37	403		92	259	227		189	261
38	405		91	261	225		189	263
39	408		91	263	223		190	265
40	411		90	266	220		190	267

APPENDIX III

Crown Component Fractions

TABLE 13.--*Fraction of crown (live and dead branchwood and foliage) comprised of foliage and branchwood by size class*

D.b.h. (inches)	Species									
	PP	WL	DF	GF	AF	ES	LP	WP	WC	WH
					FOLIAGE					
0- 0.9	0.57	0.40	0.52	0.62	0.62	0.62	0.52	0.52	0.62	0.62
1- 2.9	.49	.32	.46	.59	.55	.55	.46	.51	.58	.51
3- 4.9	.44	.29	.43	.54	.49	.50	.41	.47	.55	.47
5- 6.9	.39	.27	.41	.50	.45	.47	.37	.43	.51	.43
7-10.9	.33	.23	.37	.44	.37	.42	.32	.38	.46	.38
11-14.9	.27	.20	.32	.37	.29	.36	.28	.32	.40	.33
15-18.9	.21	.17	.28	.30	.22	.31	.24	.27	.35	.28
19-22.9	.17	.14	.25	.27	.19	.25	.20	.23	.30	.23
23-26.9	.14	.12	.22	.25	.16	.21	.16	.20	.26	.20
27-30.9	.11	.10	.20	.23	.14	.18	.13	.17	.22	.17
31-34.9	.09	.08	.18	.22		.15		.14	.19	.14
35-38.9	.07	.07	.16	.20		.12		.12	.16	.12
					BRANCHWOOD 0 to 0.25 INCH					
0- 0.9	.14	.42	.27	.26	.26	.26	.27	.27	.26	.26
1- 2.9	.08	.37	.24	.23	.26	.26	.29	.26	.14	.26
3- 4.9	.06	.35	.23	.21	.25	.26	.29	.25	.13	.25
5- 6.9	.05	.33	.21	.20	.24	.25	.28	.24	.12	.23
7-10.9	.04	.30	.20	.18	.22	.23	.26	.23	.11	.20
11-14.9	.03	.27	.17	.15	.20	.22	.23	.22	.10	.17
15-18.9	.02	.24	.16	.12	.19	.20	.22	.21	.08	.14
19-22.9	.01	.21	.14	.10	.17	.18	.21	.21	.07	.12
23-26.9	.01	.18	.13	.09	.15	.17	.20	.20	.06	.10
27-30.9	.01	.16	.12	.08	.13	.15	.19	.19	.05	.08
31-34.9	.01	.14	.11	.07		.14		.18	.05	.07
35-38.9	.01	.13	.10	.07		.13		.17	.04	.05

(con.)

TABLE 13.--*Continued*

D.b.h. (inches)	Species									
	PP	WL	DF	GF	AF	ES	LP	WP	WC	WH
					BRANCHWOOD 0.25 *to* 1 INCH					
0- 0.9	0.29	0.18	0.21	0.12	0.12	0.12	0.21	0.21	0.12	0.12
1- 2.9	.36	.31	.30	.19	.19	.19	.25	.23	.28	.23
3- 4.9	.37	.32	.31	.20	.24	.22	.29	.26	.29	.25
5- 6.9	.38	.33	.32	.23	.27	.23	.32	.28	.30	.25
7-10.9	.38	.33	.33	.27	.34	.25	.34	.29	.30	.26
11-14.9	.36	.33	.33	.31	.41	.27	.29	.30	.29	.27
15-18.9	.34	.33	.31	.34	.47	.28	.26	.31	.27	.27
19-22.9	.31	.33	.28	.32	.49	.29	.25	.31	.25	.26
23-26.9	.27	.32	.24	.28	.50	.30	.25	.31	.23	.25
27-30.9	.23	.31	.20	.25	.51	.29	.25	.31	.21	.24
31-34.9	.18	.30	.17	.21		.29		.32	.18	.23
35-38.9	.13	.28	.13	.17		.28		.31	.16	.22
					BRANCHWOOD 1 *to* 3 INCHES					
0- 0.9	0	0	0	0	0	0	0	0	0	0
1- 2.9	.07	0	0	0	0	0	0	0	0	0
3- 4.9	.13	.04	.03	.03	.02	.02	.01	.02	.03	.03
5- 6.9	.18	.07	.06	.07	.04	.05	.03	.05	.07	.09
7-10.9	.22	.14	.10	.11	.07	.10	.08	.10	.13	.16
11-14.9	.27	.18	.18	.17	.10	.15	.20	.16	.21	.23
15-18.9	.31	.23	.24	.24	.12	.21	.28	.21	.30	.31
19-22.9	.35	.28	.32	.31	.15	.28	.34	.25	.38	.39
23-26.9	.39	.33	.39	.38	.19	.32	.39	.29	.45	.45
27-30.9	.42	.38	.46	.44	.22	.38	.43	.33	.52	.51
31-34.9	.45	.42	.51	.50		.42		.36	.58	.56
35-38.9	.48	.46	.58	.56		.47		.39	.64	.61
					BRANCHWOOD 3+ INCHES					
1- 2.9	0	0	0	0	0	0	0	0	0	0
3- 4.9	0	0	0	0	0	0	0	0	0	0
5- 6.9	0	0	0	0	0	0	0	0	0	0
7-10.9	.03	0	0	0	0	0	0	0	0	0
11-14.9	.07	.02	0	0	0	0	0	0	0	0
15-18.9	.12	.03	.01	0	0	0	0	0	0	0
19-22.9	.16	.04	.01	0	0	0	0	0	0	0
23-26.9	.19	.05	.02	0	0	0	0	0	0	0
27-30.9	.23	.05	.02	0	0	0	0	0	0	0
31-34.9	.27	.06	.03	0		0		0	0	0
35-38.9	.31	.06	.03	0		0		0	0	0

APPENDIX IV

Unmerchantable Tip Weights

Weights of unmerchantable bole tips (table 14) were determined by adding together separate estimates of wood and bark. Wood weight was determined using Faurot's (see footnote 2) equations to estimate volume and wood densities from table 9 to convert volume to weight.

Faurot's equations were developed for lodgepole pine, ponderosa pine, western larch, and Douglas-fir. Comparisons of volumes among species showed that differences were small and that volume estimates for Douglas-fir were intermediate among the four species studied. On this basis, Douglas-fir volume equations were chosen to represent species not included in Faurot's work.

Solution of Faurot's equations required an estimate of height, which was provided by the equations in table 15. To avoid unreasonable extension of Faurot's equations, tip weights for trees 24 inches d.b.h. or larger are assumed to be the same.

TABLE 14.--Weight of unmerchantable bole tips including wood and bark

D.b.h. (inches)	Species									
	PP	LP	WL	DF	CF	AF	WC	WP	WH	ES
					3-INCH TIP					
4	10.7	12.4	18.1	12.6	11.0	8.7	8.2	11.0	12.6	9.5
6	8.0	8.8	13.1	9.6	8.7	6.7	6.3	8.7	9.8	7.4
8	6.8	7.0	10.9	8.1	7.6	5.7	5.4	7.7	8.6	6.3
10	6.0	6.0	9.7	7.3	7.1	5.1	4.9	7.1	7.8	5.8
12	5.5	5.2	9.0	6.8	6.7	4.8	4.6	6.7	7.4	5.4
14	5.2	4.7	8.5	6.4	6.5	4.5	4.4	6.4	7.0	5.1
16	4.9	4.3	8.1	6.1	6.4	4.3	4.2	6.3	6.8	4.9
18	4.7	3.9	7.9	5.9	6.3	4.1	4.1	6.1	6.6	4.8
20	4.6	3.7	7.7	5.8	6.3	4.0	4.1	6.1	6.5	4.7
	4.4	3.4	7.5	5.7	6.2	3.9	4.0	6.0	6.4	4.6
	4.3	3.2	7.4	5.6	6.3	3.9	4.0	6.0	6.4	4.5
					4-INCH TIP					
4	34.2	35.2	56.9	37.9	33.0	26.4	24.7	33.0	37.7	28.6
6	24.1	24.4	38.4	27.2	24.5	19.0	17.8	24.7	27.8	20.9
8	19.3	19.1	30.5	22.1	20.6	15.5	14.6	20.7	23.1	17.3
10	16.5	15.9	26.1	19.2	18.4	13.5	12.8	18.4	20.4	15.1
12	14.7	13.8	23.4	17.3	17.0	12.2	11.7	16.9	18.6	13.7
14	13.3	12.2	21.6	16.0	16.1	11.2	10.9	15.9	17.4	12.7
16	12.3	11.0	20.2	15.0	15.4	10.5	10.3	15.1	16.4	12.0
18	11.5	10.1	19.2	14.2	14.9	9.9	9.9	14.5	15.7	11.4
20	10.9	9.3	18.5	13.6	14.5	9.5	9.5	14.0	15.2	11.0
22	10.4	8.7	17.9	13.1	14.2	9.1	9.3	13.6	14.7	10.6
24	10.0	8.1	17.4	12.7	14.0	8.8	9.1	13.3	14.3	10.3
					6-INCH TIP					
6	119.0	128.5	198.6	130.6	118.3	91.3	85.5	119.6	134.6	100.4
8	88.8	91.3	143.5	98.9	92.8	69.3	65.3	93.5	104.2	77.1
10	71.9	70.5	114.2	81.1	78.5	56.9	54.2	78.7	87.0	64.0
12	61.2	57.4	96.0	69.9	69.5	49.0	47.2	69.2	76.0	55.5
14	53.8	48.3	83.8	62.1	63.4	43.5	42.4	62.6	68.3	49.6
16	48.4	41.7	75.0	56.3	58.9	39.4	38.9	57.8	62.7	45.3
18	44.2	36.7	68.4	52.0	55.5	36.3	36.3	54.0	58.4	42.0
20	40.9	32.8	63.2	48.5	52.9	33.8	34.3	51.1	54.9	39.3
22	38.3	29.6	59.1	45.7	50.8	31.8	32.6	48.7	52.2	37.2
24	36.0	27.0	55.7	43.4	49.1	30.1	31.3	46.8	49.9	35.4

TABLE 15.--*Height-d.b.h. relationships for trees from a variety of site indexes and stand densities*

Species	Number of trees	Function[1]	R^2	Standard error of estimate
Ponderosa pine	39	$h = -43.86 + 39.31\ d^{0.4040}$	0.90	12.0
Western larch	52	$h = -51.01 + 49.10\ d^{0.4065}$	.92	11.7
Lodgepole pine	51	$h = 327.76 - 333.52\ d^{-0.1124}$	.92	5.2
Western white pine	48	$h = -37.75 + 35.98\ d^{0.4961}$	.97	7.7
Grand fir	40	$h = -23.11 + 22.51\ d^{0.6166}$	.95	11.4
Douglas-fir	43	$h = -26.68 + 29.42\ d^{0.4697}$	.94	8.3
Western redcedar	37	$h = -15.40 + 18.80\ d^{0.6039}$	.98	6.1
Western hemlock	35	$h = -35.84 + 35.44\ d^{0.4775}$	.95	10.1
Engelmann spruce	34	$h = -37.84 + 34.49\ d^{0.4551}$	.93	10.8
Subalpine fir[2]	82	$h = -38.43 + 37.08\ d^{0.4167}$	.91	10.4

[1] d = d.b.h., inches; h = height, feet.
[2] This equation is based on data for Douglas-fir, ponderosa pine, and subalpine fir.

Bark weight was determined by multiplying ratios of bark weight-to-wood weight (R) times estimates of wood weight. The ratios R were calculated from:

$$R = \rho_b \left(\frac{\pi d_o^2 \ell}{4} - \frac{\pi d_i^2 \ell}{4}\right) \Big/ \rho_s \left(\frac{\pi d_i^2 \ell}{4}\right) = \frac{\rho_b}{\rho_s}\left(\frac{d_o^2}{d_i^2} - 1\right) \qquad (4)$$

where

ρ_b = density of bark, lb/ft^3
ρ_s = density of wood, lb/ft^3
d_o = diameter outside bark, ft
d_i = diameter inside bark, ft
ℓ = length of cylindrical tree piece, ft

Data on diameters inside and outside bark were supplied by Faurot and James Brickell, USDA Forest Service, Intermountain Forest and Range Experiment Station. Measurements along the entire tree length were used in the analysis. Values of R varied substantially. Average R was greater for tip sections than entire trees; however, values for entire trees were used to represent tips because the values seemed more reliable than those from the limited data for tip sections.

Values of bark density were obtained from Smith and Kozak (1971). Values used to calculate the ratios R are in table 16.

TABLE 16. --*Wood densities, bark densities, bark volume to stem volwne ratios, and bark weight to stem weight ratios used in estimating weights of unmerchantable bole tips*

Species	Wood density	Bark density	Bark volume[1] / Stem volume	Bark weight[2] / Stem weight
	Lb/ft^3	*Lb/ft*^{3}		
Ponderosa pine	25.0	21.8	0.24	0.209
Lodgepole pine	25.6	26.5	.11	.114
Western white pine	23.7	26.2	.21	.232
Douglas-fir	30.0	[3]27.4	[3].19	.174
Subalpine fir	20.0			.260
Grand fir	23.1	37.4	.20	.324
Western larch	32.4	24.3	.24	.180
Western hemlock	28.1	31.2	.18	.200
Western redcedar	20.0	23.1	.15	.173
Engelmann spruce	21.8	30.6	.19	.267

[1] $(d_o^2/d_i^2)-1$ from equation (4).

[2] R from equation (4).

[3] Considered same as Douglas-fir.

SLASH WEIGHT SUMMARY

Stand _____ Location _____

Unit _____ Date _____ Page ___ of ___

Number of trees /acre from inventory by species							Crown weight/acre (pounds) by species					
DBH												
						Total						

SUMMARY OF DEBRIS WEIGHT

(1) Cutting		(2) Trampling		(3) Breakage	
Poundslacre	Tonslacre	Poundslacre	Tonslacre	Poundslacre	Tons /acre

Predicted weight, (1) + (2) + (3) Tonslacre = _____

(4) Existing downed debris, Tonslacre - _____

Total debris, (1) + (2) + (3) + (4), Tons/acre = _____

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Brown, James K., J. A. Kendall Snell, and David L. Bunnell
1977. Handbook for predicting slash weight of western conifers. USDA For. Serv. Gen. Tech. Rep. INT-37, 35 p. Intermountain Forest & Range Experiment Station, Ogden, Utah 84401.

As an aid to managing fuel and woody debris, procedures are provided for predicting weights of slash using tables of either slash weight per tree by d.b.h., or slash weight per square foot of tree basal area by d.b.h. Slash weights include crowns (live and dead foliage and branchwood) and unmerchantable bole tips to 3-, 4-, and 6-inch diameter limits. Slash weights can be predicted for material less than and greater than 3 inches in diameter.

KEYWORDS: slash, forest fuels, tree biomass

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KEYWORDS: slash, forest fuels, tree biomass

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