Grade recovery and conversion from a Douglas-fir sawing study at Kaingaroa - Douglas-Fir Cooperative Report No . 13

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One hundred and ninety-five unpruned sawlogs were recovered and measured in detail prior to sawing and further processing. Sawlogs including the maximum range of log characteristics available were allocated to each of four saw patterns maximising 100, 150, 200 and 250 x 42 mm green rough sawn dimensions.

Visual and mechanical grade recoveries are presented for a range of log sort combinations according to saw pattern, SED, BIX, log height class, age, density and corewood content.

The data provided from this study has established an extensive Log and Lumber Database. The Database provides the opportunity to produce regression equations linking log characteristics to grade recovery and conversion for predictive purposes .

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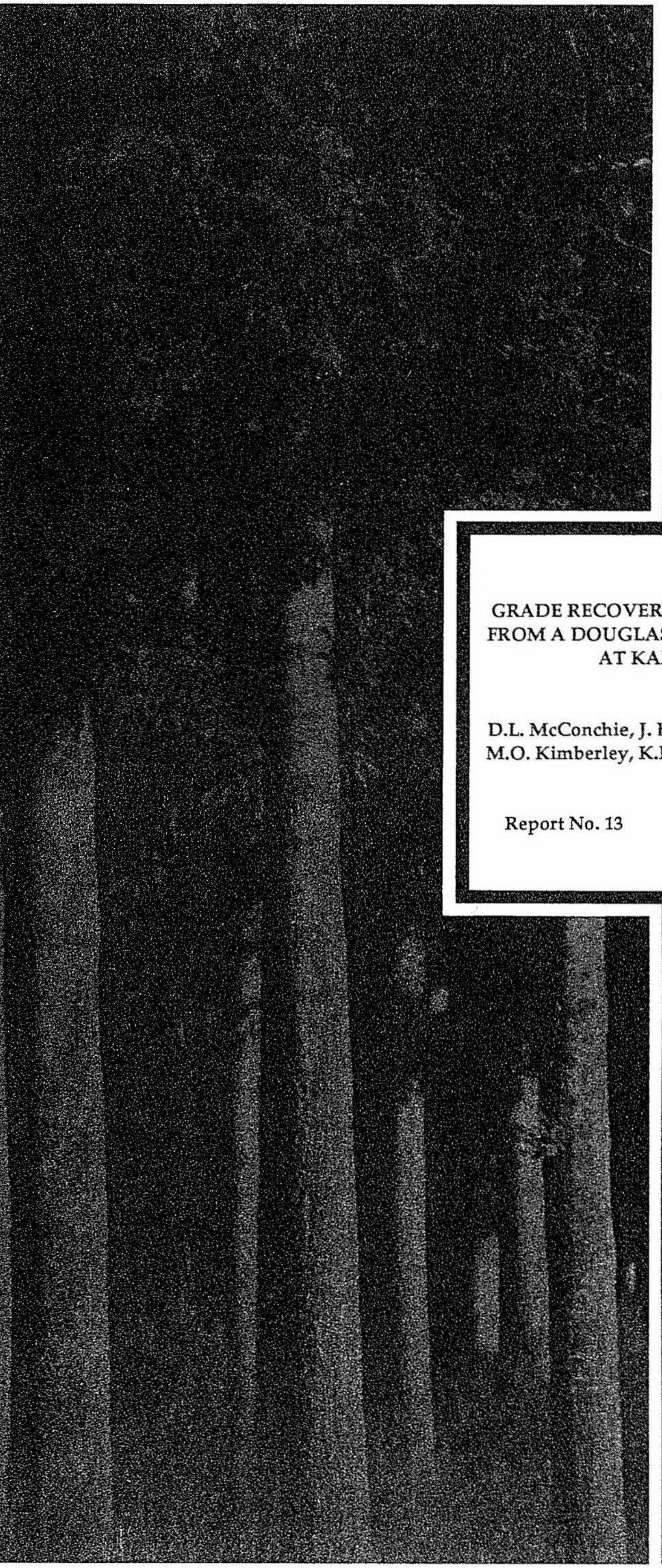

DOUGLAS-FIR

Cooperative

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NZ FRI/INDUSTRY RESEARCH COOPERATIVES

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DOUGLAS-FIR COOPERATIVE

EXECUTIVE SUMMARY

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Four Douglas-fir stands in Kaingaroa Forest were selected to provide unpruned sawlogs covering a wide range of log characteristics. The stands selected were aged 33 years and 59 years and had received a range of silvicultural treatments.

One hundred and ninety-five unpruned sawlogs were recovered and measured in detail prior to sawing and further processing. Sawlogs including the maximum range of log characteristics available were allocated to each of four saw patterns maximising 100, 150, 200 and 250 x 42 mm green rough sawn dimensions.

Visual and mechanical grade recoveries are presented for a range of log sort combinations according to saw pattern, SED, BIX, log height class, age, density and corewood content.

Saw pattern, branch size and corewood content were all shown to have a significant impact on visual and machine grade recoveries. Wood density also influenced machine grade recoveries. Overall NZ visual grade recoveries gave 49% 1F, 30% 2F and 18% Box grade with best recoveries for the 250 x 42 mm saw pattern and small branch (BIX <4 cm) log combinations at 63% 1F and poorest recoveries from the large branch (BIX <4 cm) log combinations at 63% IF and poorest recoveries from the large branch (BIX <4 cm) and highest corewood content (<75%) log combinations at 29% and 30% respectively. Australian visual stress grade recoveries showed similar trends but grade recoveries were considerably higher than NZ visual equivalents averaging 37% F8, 25% F7, 15% F5 and 20% Reject. Best recoveries were again for the 250 x 42 mm saw pattern with 90% F5+ and poorest recoveries for the 100 x 42 mm saw pattern and large branch/log combinations with 61% and 65% F5+ respectively. Overall machine grade recoveries show 25% F8+, 44% F5 and 17% <F5. The best recoveries with regard to F8+ are for the 250 x 42 mm saw pattern — 37%, small branch combination — 35%, and high density logs (density >450 kg/m^3) — 33%. The poorest machine grade recovery with 7% F8 was for the high corewood log combination.

The data provided from this study has established an extensive Log and Lumber Database. The Database provides the opportunity to produce regression equations linking log characteristics to grade recovery and conversion for predictive purposes.

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INTRODUCTION

Douglas-fir is New Zealand's second most important exotic plantation species, although the current planted area at about 65,000 ha only equates to approximately 5% of the total exotic plantation resource. The allocation of research effort to this important structural species has been limited and often fragmented when compared to radiata pine. A number of studies have been undertaken to investigate wood quality aspects: wood density and sawing studies; linking log characteristics to lumber grade recovery and conversion. A comprehensive review of Douglas-fir in New Zealand was carried out in 1974 culminating in FRI symposium No.15, (James 1975;1978). Whiteside *et.al.* (1977) and McConchie *et.al.* (1990) added to the available data linking silviculture to lumber quality. A more recent summary of Douglas-fir wood quality research is given in Cown (1992).

Previous research effort has established a wide range of silvicultural regimes in trials throughout the country. These trials and the older Douglas-fir stands are now reaching maturity and have been or are due to be scheduled for felling in the near future. For this reason there has been a resurgence of interest in Douglas-fir research and the establishment of a Douglas-fir Research Cooperative. The current collaboration with the US. Stand Management Cooperative has provided the opportunity to again review past research and focus current and future research to meet industry requirements.

Old growth Douglas-fir is renowned for the quality of the clear and high strength lumber and in the US has been a major source of structural lumber and plywood and also an important source of appearance and finishing grades. However, second-growth stands of Douglas-fir will contain a higher proportion of juvenile wood and yield negligible amounts of clear lumber when harvested at ages below about 150 years (Middleton and Munroe, 1989).

It is already well established that an increase in the juvenile wood content of Douglas-fir logs is undesirable for strength, stiffness and dimensional stability of structural lumber (Barrett and Kellogg, 1989: Senft *et al* 1989). Nevertheless, the control of juvenile wood through inhibition of diameter growth has generally been rejected as an option in New Zealand plantations due to the associated lengthening of the rotation. On the contrary, forest management practices, including provenance selection, are almost exclusively aimed at increasing stem growth, and where an improvement in wood quality is an objective, thinning and pruning are often recommended. Juvenile wood in North American Douglas-fir has been estimated to extend about 20 growth rings from the pith (Jozsa, 1989: Di Lucca, 1989).

The economic impact of juvenile wood on yield and quality of lumber from young managed plantation stands remains to be evaluated. Previous research in both North America and New Zealand has however shown that young plantation Douglas-fir is likely to be highly variable in quality, (Harris, 1985, Walford, 1985, Smith and Briggs, 1986, Kellogg, 1989).

This sawing study, which has been designed to establish relationships between log characteristics, grade recovery and conversion, is an integral component of a comprehensive series of studies which relate site and silviculture to yield and value of Douglas-fir. The study is modelled on previous research on "young" Douglas-fir (McConchie *et al.* 1990; Fahey *et al.* 1991).

This report presents the actual grade recoveries and conversion achieved for a wide range of log characteristics sawn to maximise the recovery of structural lumber. A second report presents the regression equations relating grade recovery and conversion to log characteristics.

In addition, discs were collected from the ends of all study logs and have been assessed for a wide range of wood properties. A number of wood properties, in particular wood density and the proportions of juvenile wood, are significant variables when interpreting the grade recovery results. A detailed report describing the wood properties of the Douglas-fir stands sampled for the sawing study is also available (McKinley et.al. 1994).

OBJECTIVES

- To complete a comprehensive sawing study of unpruned Douglas-fir sawlogs.
- To provide the basis for the establishment of a Log and Lumber Database for unpruned Douglas-fir sawlogs.
- To ensure that the Database has the required range of sawlogs to allow predictive equations to be developed linking log characteristics (including wood properties) with grade recovery and conversion.
- To provide data on the New Zealand plantation-grown Douglas-fir resource for comparison with Douglas-fir grown in North America (old-growth; second-growth; plantation).

MATERIALS AND METHODS

Log selection and measurement:

Four Douglas fir stands in Kaingaroa Forest were selected to provide the required study logs. Two of these stands were aged 33 years and the other two 59 years. All stands contained a wide range of log characteristics and had received silvicultural treatments. The stand histories are presented in Table 1.

TABLE 1 - STAND HISTORIES (Kaingaroa Forest)

CPT/STAND	DATE	AGE (yrs)	OPERATION
1/02	1960	-	Established at 2500 spha
	1977	17	Waste thinned to 625 spha
	1993	33	Fell study logs
2/02	1960	-	Established at 1600 spha
	1977	17	Waste thinned to 640 spha
	1993	33	Fell study logs
688/01	1934	-	Established at 1600 spha
	1951	17	High prune 0-5.8m 284 spha
	1970	36	Production thin to 680 spha
	1993	59	Fell study logs
694/02	1934	-	Established at 1600 spha
	1957	23	High prune 0-5.8m 268 spha
	1967	33	Production thin to 450 spha
	1993	59	Fell study logs

The two younger stands were established at 2500 and 1600 spha and were both waste-thinned at age 17 years to 625 and 640 spha respectively. The older stands were both established at 1600 spha and had been high pruned and production thinned to 680 and 450 spha respectively.

Prior to final tree selection, a sample of approximately 100 trees for each age class was visually assessed for branching characteristics (large, medium, small), the diameter at breast height was recorded and two outerwood increment cores collected at breast height to assess wood density. From this sample, 60 trees (22 aged 33 years and 38 aged 59 years) were selected to provide the required sawlogs for the sawing study. The trees were selected to cover the range in log characteristics available within the stands and not therefore representative of the actual proportions of log grades present in the plantations. This sampling strategy is a requirement to enable the establishment of good regressions for predictive purposes. Application of the study results to actual forest stands requires inventory data.

All unpruned sawlogs were cut to 4.9m length in the forest and numbered to identify tree and log height class prior to transport to the Timber Industry Training Centre (TITC) sawmill in Rotorua.

At the TITC sawmill all logs were measured for the following external log characteristics according to standard FRI methods:

- * diameter inside bark (SED, LED, cm)
- * sweep (mm/m)
- * branch index (BIX, cm - average of the largest branch/quartile)
- * corewood (juvenile wood) - inner 10 rings and rings 11-20.

Other log characteristics (taper, volume, max. branch) are derived from the above measurements. In addition to normal practice, the corewood (juvenile wood) was painted on the log ends to assist identification of corewood and outerwood in the sawn lumber. Two different colours were used to identify the inner 10 rings and rings 11-20.

Following log measurement, the logs were allocated to one of the four batches for sawing, ensuring that the maximum range of log characteristics was included in each batch. Table 2 shows the log allocation by diameter, log height class, saw pattern and age.

TABLE 2 - LOG ALLOCATION

Log Diam Class mm	Log Height Class	Saw Pattern											
		100x40 mm			150x40 mm			200x40 mm			250x40 mm		
		Age yrs. 33	59	Tot	Age yrs. 33	59	Tot	Age yrs. 33	59	Tot	Age yrs. 33	59	Tot
100-199	Butt	0	0	0									
	2nd	3	0	3									
	Upper	8	12	*20									
200-299	Butt	2	0	2	1	0	1	2	2	4			
	2nd	1	2	3	7	4	11	2	3	5			
	Upper	4	7	*12	3	11	*17	1	2	*4			
300-399	Butt	3	4	7	3	4	7	3	0	3	5	4	9
	2nd	2	1	3	1	2	3	4	4	8	3	3	6
	Upper	0	1	1	0	1	*2	0	5	*7	0	5	5
400+	Butt	1	5	6	0	6	6	1	4	5	1	9	10
	2nd	0	5	5	1	3	4	0	5	5	0	6	6
	Upper	0	0	0	0	0	0	0	1	1	0	2	*4
TOTAL		24	37	62	16	31	51	13	26	42	9	17	40

* Includes an additional 12 logs delivered to the mill as extras. They were batched and sawn but could not linked to an individual stand, tree or log height class.

Prior to sawing, the logs were debarked at the NZ Forestry Corporation Waipa Processing Complex and sorted into the above batches representing the four saw patterns.

Analyses:

The log and lumber data were accumulated in the FRI Log and Lumber Database. The database was subsequently used to provide grade recoveries for a number of log combinations including saw pattern, diameter, branch size, log height class, age, wood density and proportion of corewood. Grade recoveries included NZ visual grades, Australian visual stress grades and machine stress grades using the Australian standards (yellow card).

RESULTS AND DISCUSSION

Log characteristics:

The average log characteristics for selected log combinations are presented in Table 3 and the individual log characteristics sorted by saw pattern, stand age and small end diameter are given in Appendix 1. The log combinations in the table were selected to illustrate the impact of selected saw patterns and log characteristics on subsequent grade recovery and conversion. The selected log characteristics include SED, branch size, log height class, wood density and the proportion of corewood contained in the logs. Stand age is also individually identified.

Appendix 2 documents the overall average log characteristics and shows the range in log characteristics included in the FRI Log and Lumber Database. This appendix clearly shows that the log selection objective to include a wide range of log characteristics in the database has been achieved.

SED ranged from 12.4 cm to 66 cm with an overall average of 33.8 cm. In regard to the selected log combinations, the mean SED values follow expected trends, ie. they increase with increased aim size with regard to saw pattern due to selection criteria, they decrease with increasing log height class, they are higher for the older stands and decrease as the proportion of corewood increases. The mean SED for the smaller branched component ie. BIX <4 cm is slightly higher than for the logs with BIX >4 cm, although the difference is unlikely to have a discernible impact on grade recovery and conversion. The lower density component, <400 kg/m^3 also shows smaller SED (by approximately 6 cm) than the two higher density components.

Sweep levels were generally low, averaging 4 mm/m, although individual logs were recorded as high as 22 mm/m. The butt logs showed the highest average sweep level at 7 mm/m with this level reflected in the larger SED, higher density and lower corewood combinations.

Taper averaged 15 mm/m with a wide range for individual logs from 2 to 36 mm/m. Normal within-tree patterns are evident, with highest levels in the butt logs (mean 20 mm/m) followed by the top logs.

TABLE 3 - MEAN LOG CHARACTERISTICS

Log Combination	No. of Logs	SED cm	Length m	Sweep mm/m	Taper mm/m	Volume 3D m^3	Branch Index cm	Max. Branch cm	Basic Density kg/m^3	Corewood % 10 rings	Corewood % 20 rings
Saw Pattern											
100 X 40	62	28.3	4.9	4	14	0.436	3.9	4.5	416	29	70
150 X 40	51	32.8	4.9	4	15	0.539	4.0	4.7	417	23	62
200 X 40	42	35.4	4.9	5	14	0.588	3.7	4.4	426	21	59
250 X 40	40	41.8	4.9	4	16	0.810	3.4	4.2	429	18	50
SED (cm)											
<20	20	17.1	4.9	2	13	0.155	3.7	4.3	397	41	86
20 - 30	60	25.8	4.9	4	13	0.313	3.9	4.5	414	29	73
30 - 40	61	34.7	4.9	5	14	0.548	3.7	4.4	423	21	61
>40	54	47.8	4.9	6	17	1.043	3.7	4.5	435	15	42
Branch Index (cm)											
<4	111	34.6	4.9	5	13	0.592	3.0	3.5	429	22	54
>4	84	32.7	4.9	4	16	0.546	4.8	5.7	410	26	71
Log Height Class											
Butt	61	40.8	4.9	7	20	0.822	3.4	4.1	435	16	50
2nd	61	35.2	4.9	4	11	0.580	3.9	4.5	415	25	66
3rd	28	29.4	4.9	3	12	0.423	3.8	4.5	406	32	71
4th	19	26.1	4.9	1	13	0.341	4.2	4.9	416	31	67
5th+	14	21.2	4.9	2	16	0.232	4.6	5.4	423	22	68
Age (yrs)											
33	62	29.4	4.9	4	15	0.430	4.0	4.6	386	33	86
59	121	36.6	4.9	5	15	0.665	3.7	4.4	439	19	49
Basic Density (kg/m^3)											
<400	54	29.7	4.9	3	14	0.437	4.0	4.6	375	32	81
400 - 450	85	36.0	4.9	6	16	0.646	3.9	4.7	424	20	56
>450	44	36.1	4.9	5	14	0.651	3.3	3.9	472	19	48
Corewood (%) 20 rings											
<50	69	42.0	4.9	6	16	0.839	3.4	4.2	440	15	40
50 - 75	69	31.7	4.9	4	14	0.494	3.7	4.4	429	22	60
>75	45	25.9	4.9	3	14	0.337	4.4	5.0	381	39	95
All Logs	195	33.8	4.9	4	15	0.573	3.8	4.5	421	24	61

A wide range in BIX was included in the study, with individual logs ranging from 1.6 cm to 7.1 cm. The overall average BIX was 3.8 cm. The variations in BIX between some of the selected combinations would be expected to impact significantly on the grade recoveries achievable.

The saw pattern combinations show similar BIX for the patterns maximising 100x40 mm and 150x40 mm lumber, 3.9 cm and 4.0 cm respectively, but reduce to 3.7 cm and 3.4 cm for the larger dimensions. The SED combinations also show similar BIX with 3.9 cm for logs below 30 cm SED and 3.7 cm for logs above 30 cm SED. The BIX combinations average 3.0 cm for logs <4 cm and 4.8 cm for logs>4 cm. BIX shows the expected increase with increasing log height class, 3.4 cm for butt logs rising to 4.6 cm for 5th logs and above, and this pattern is also evident in the corewood combinations. BIX averages 3.4 cm for corewood values (20 rings) <50%, corresponding to the high proportion of butt logs and averages 4.4 cm for the logs with corewood values exceeding 75%. Sawlogs from the older stand show a slightly lower BIX than those from the younger stand, 3.7 cm and 4.0 cm respectively and this pattern is also evident in the density combinations. The higher density combinations generally include logs from lower stem levels and have a higher proportion of logs from the higher density older stand.

The maximum branch recorded for each log is also presented in Table 3, with an average for all logs of 4.5 cm (total range from 1.8 cm to 9.5 cm). The average difference between BIX and maximum branch ranged from a minimum of 0.5 cm for the small branched component to a maximum of 0.9 cm for the larger branched component, indicating a generally uniform branching pattern both within and between logs.

Wood density is an important consideration when structural lumber is to be machine stress graded. Sawlog density averaged 421 kg/m^3 with a wide range for individual logs from 337 kg/m^3 to 517 kg/m^3. The sawlog combinations presented in Table 3 show clear differences in wood density in line with the normal patterns of variation within and between trees. Generally, wood density increases with stand age and decreases with increasing height in the stem, in accordance with the normal pattern for softwoods.

The corewood percentage is presented in two ways: the inner 10 growth rings (average 24%; range 6-69%) and the inner 20 growth rings (average 61%; range 18-100%). The pattern of variation for the various log combinations reflects the expected pattern of corewood variation within trees, ie. closely related to age, with higher values for the younger stand, and also closely related to log diameter and log height class with higher levels in the smaller diameter and upper logs.

Conversion:

Table 4 presents the actual conversions achieved at the TITC sawmill for the selected log combinations. Lumber tallies are based on the standard NZ green dimensions and log volumes are presented using both the 3D and Smalian's formulae.

The 3D formula gives consistently lower log volumes and hence higher conversion values than Smalian's, although the patterns of variation with regard to the log combinations are the same. Overall conversion based on the 3D volume is 62% and on Smalian's volume 60%.

The relationship between conversion and saw pattern shows the expected trend with increased conversion corresponding to the recovery of larger dimensions and also with increasing average log size.

TABLE 4 - CONVERSION FROM LOG VOLUME TO LUMBER VOLUME

Log Combination	No. of Logs	Log Volume (m^3)		Lumber Vol. (m^3)	Conversion (%)	
		3D	Smalian's		3D	Smalian's
Saw Pattern						
100 X 40	62	0.436	0.453	0.255	58	56
150 X 40	51	0.539	0.559	0.328	61	59
200 X 40	42	0.588	0.608	0.366	62	60
250 X 40	40	0.810	0.835	0.526	65	63
SED (cm)						
<20	20	0.155	0.161	0.072	47	45
20 - 30	60	0.313	0.326	0.181	58	56
30 - 40	61	0.548	0.572	0.342	62	60
>40	54	1.043	1.071	0.661	63	62
Branch Index (cm)						
<4	111	0.592	0.611	0.368	62	60
>4	84	0.546	0.567	0.335	61	59
Log Height Class						
Butt	61	0.822	0.860	0.496	60	58
2nd	61	0.580	0.592	0.373	64	63
3rd	28	0.423	0.433	0.265	63	61
4th	19	0.341	0.354	0.199	58	56
5th+	14	0.232	0.247	0.131	57	53
Age (yrs)						
33	62	0.430	0.451	0.261	61	58
59	121	0.665	0.686	0.412	62	60
Basic Density (kg/m^3)						
<400	54	0.437	0.454	0.275	63	61
400 - 450	85	0.646	0.669	0.398	62	59
>450	44	0.651	0.671	0.395	61	59
Corewood (%) 20 rings						
<50	69	0.839	0.864	0.526	63	61
50 - 75	69	0.494	0.514	0.301	61	59
>75	45	0.337	0.352	0.198	59	56
All Logs	195	0.573	0.592	0.353	62	60

The greatest range in average conversion is shown for the SED log combinations: the smallest diameter logs (SED <20 cm) yielding 47% conversion and the largest logs (SED >40 cm) yielding 63% conversion. The relationship with SED is also apparent in the age and corewood combinations. The apparently anomalous conversion for the butt logs reflects the higher levels of sweep and taper in this log combination impacting on the SED relationship. Sweep and taper values also influence the mid range and high density combinations.

The conversion results agree well with those achieved in previous sawing studies at the TITC sawmill processing radiata pine but are higher than those described by McConchie et. al. 1990 for an individual log sawing study processing Douglas-fir in a commercial Rotorua sawmill. The Douglas-fir study at the commercial mill showed the same trends, ie for conversion to increase with increasing SED but at consistently lower levels for the three saw patterns tested. (Normal commercial practice in New Zealand is to allow cross-cutting to improve grade, and this can reduce conversion).

The relationships described above and volume recoveries achieved are also consistent with the findings of Fahey et. al. (1991) for young growth Douglas-fir in the US.

Grade recovery:

1) Visual Framing Grades:

The dry-gauged visual lumber grade recoveries to NZS 3631 specifications for the selected log combinations are presented in Table 5. The table clearly shows the important impact of saw pattern and branch size and the relationship between BIX and log height class, corewood percentage and log diameter. The patterns of variation are consistent with those described by Cown et. al. (1987) for visually graded radiata pine and by McConchie et. al. (1990) and Fahey et. al. (1991) for young-growth Douglas fir grown in New Zealand and the US..

The visual grade recovery results also reflect the impact of the grade requirements which allow holes and all knots (other than spike knots), singly or in groups, to cover 1/3rd of the cross section for 1F grade in lumber sizes 150 mm wide or less. In lumber sizes exceeding 150 mm wide, (for the purposes of this study 200 and 250x40 mm) the rules specify 1/4 of the cross section. These rules therefore allow knots to average 33 mm for the two faces in 100x40 mm lumber, 50 mm in the 150x40 mm and 200x40 mm lumber, and 62 mm in the 250x40 mm dimension to achieve 1F grade.

In conjunction with branch size, cross grain was also identified as having a significant impact on degrade. Cross grain was invariably associated with knots and the effect of the cross grain increased with knot size. The relationship between knot size, cross grain and grade recovery has been previously reported by Whiteside (1978) following intensive investigations of the quality of Douglas fir from Kaingaroa Forest.

TABLE 5 - DRY GAUGED VISUAL LUMBER GRADE RECOVERY (NZS 3631)

Log Combination	No. of Logs	Dry, Gauged, Visual Grade Recovery (%)			
		1F	2F	Box	Boards
Saw Pattern					
100 X 40	62	35	38	24	3
150 X 40	51	44	33	20	4
200 X 40	42	51	26	19	4
250 X 40	40	63	23	12	2
SED (cm)					
<20	20	45	39	11	6
20 - 30	60	40	36	17	6
30 - 40	61	50	32	15	3
>40	54	51	26	21	2
Branch Index (cm)					
<4	111	63	24	10	3
>4	84	29	38	30	3
Log Height Class					
Butt	61	58	23	17	2
2nd	61	42	33	22	3
3rd	28	43	37	16	4
4th	19	34	41	20	5
5th+	14	31	46	16	7
Age (yrs)					
33	62	48	32	16	4
59	121	49	29	19	3
Basic Density (kg/m^3)					
<400	54	49	33	15	3
400 - 450	85	47	30	20	3
>450	44	50	27	20	3
Corewood (%) 20 rings					
<50	69	54	26	17	2
50 - 75	69	46	31	19	3
>75	45	30	43	23	4
All Logs	195	49	30	18	3

Overall, the results show 49% 1F, 30% 2F and 18% Box grade with the remaining 3% recovered as 25 mm boards.

The effect of saw pattern is clearly illustrated with 35% 1F grade for the pattern maximising the smallest dimension, 100x40 mm structural, and rising to 63% for the largest dimension, 250x40 mm. As discussed above the grading rules have an important impact on this result as do log diameter and associated log characteristics. A higher proportion of larger logs are included as aim size increases, refer Table 2. The larger logs are generally from the lower log height classes and the older and higher density stands.

The impact of SED is not immediately apparent due to the compounding effect of saw pattern, but the data clearly show that the proportion of boards (25 mm) increases for the smaller diameter logs. This is also illustrated by the 4th and 5th log height classes. The lowest recovery of 1F grade at 40% was for the 20-30 cm SED class which also recorded the highest average BIX. The other SED combinations averaged 45% to 51% 1F grade.

On the other hand, the critical impact of branch size is illustrated by the two BIX combinations representing logs with BIX <4 cm and >4 cm. Average BIX for the small branch combination was 3.0 cm (average maximum branch 3.5 cm) and for the large combination 4.8 cm (average maximum branch of 5.7 cm). Recovery of 1F grade was 63% and 29% for the small and large branch combinations respectively. Mean SED's for the two combinations were similar at 35 cm and 33 cm, although the sample representing the larger branches has higher corewood which will influence recovery as will the saw pattern mix.

The grade recovery pattern with log height class follows the expected pattern, closely linked to log characteristics. Mean SED decreases and mean BIX and corewood % increase with increasing log height class. The larger dimensions and hence saw pattern effect are more influential in the lower log height classes. The patterns described show grade recovery to decrease from 58% 1F grade for butt logs to 31% for the 5th logs and above.

The grade recovery results for the age and density combinations are all similar as both these criteria have little impact on visual grade recoveries. Interrelationships between BIX, corewood % and saw pattern have combined to produce 1F grade recoveries between 47% and 50%.

The final log combination is corewood %, based on the inner 20 growth rings. The three combinations are <50%, 50-75% and >75%, with corresponding grade recoveries of 54%, 46% and 30% 1F grade. The corewood combinations also show expected relationships with SED (42 cm, 32 cm and 26 cm) and BIX (3.4 cm, 3.7 cm and 4.4 cm) as corewood percentage increases. Saw pattern allocation will again have had an impact on grade recovery.

The interaction and impact of the various log characteristics will be discussed in more detail in a further report which covers the establishment of multiple regression equations linking log characteristics and grade recovery. That report will also identify those parts of the FRI Log and Lumber Database which require additional data to enhance predictions.

2) Australian Visual Stress Grades:

Table 6 presents the Australian visual stress grade recoveries for the selected log combinations. The pattern of variation is generally the same as that described for the NZ. visual grades, although the recovery of F5 and better (F5+) is considerably higher than the recovery of 1F grade. The range in grade recovery within groups is also generally less, the most notable being the small and large branch combinations showing a difference of 20% for Australian visual stress grade F5+ and 34% for the NZ. 1F grade.

TABLE 6 - AUSTRALIAN VISUAL STRESS GRADE RECOVERY
(AS 2858)

Log Combination	No. of Logs	Australian Visual Stress Grade (%)				
		F8	F7	F5	Reject	Boards
Saw Pattern						
100 X 40	62	16	24	22	36	3
150 X 40	51	26	25	19	26	4
200 X 40	42	42	26	13	15	4
250 X 40	40	58	25	7	8	2
SED (cm)						
<20	20	9	34	28	22	6
20 - 30	60	23	27	22	22	6
30 - 40	61	36	29	17	15	3
>40	52	43	21	11	23	2
Branch Index (cm)						
<4	111	50	24	11	11	3
>4	84	18	27	20	33	3
Log Height Class						
Butt	61	45	21	12	20	2
2nd	61	31	28	16	23	3
3rd	28	35	29	16	16	4
4th	19	18	32	25	20	5
5th+	14	10	35	19	29	7
Age (yrs)						
33	62	34	26	18	19	4
59	121	38	25	14	21	3
Basic Density (kg/m^3)						
<400	54	36	28	16	17	3
400 - 450	85	36	25	16	21	3
>450	44	38	24	12	23	3
Corewood (%) 20 rings						
<50	69	43	23	12	20	2
50 - 75	69	34	27	17	19	3
>75	45	14	31	22	29	4
All Logs	195	37	25	15	20	3

Overall F5+ gave 77% which compares with 49% 1F. This result reflects the close association between branch size and the knot dimensions allowed in the respective lumber grades. The best Australian visual stress grade recoveries were achieved from the log combinations maximising the largest dimension (250x40 mm) and the small branch group. Recovery of F5+ was 90% and 85% respectively. At the lower end of the scale, the saw pattern maximising the smallest dimension, (100x40 mm), and the large branch group show 62% and 65% recovery of F5+ respectively.

When comparing the two visual grading assessments, (F5+ and 1F grades) a number of factors are important. Firstly, No. 1F equates to approximately an F6 rating and therefore falls midway between F5 and F7 groupings. Secondly, the grading specifications have different criteria relating to strength. The Australian visual stress grade specifications downgrade all lumber containing pith or in the immediate proximity of the pith, but allow larger knots provided that they are contained within the central portion of the cross section being assessed. The NZ rules are tighter on spike knots and more restrictive on slope of grain. The impact of cross grain has already been mentioned with regard to degrade in Douglas fir.

The results of the Australian visual stress grading assessment are consistent with the findings in previous studies of radiata pine, (Cown and McConchie, 1986; McConchie et. al., 1986; 1989). All these studies show that the Australian visual stress grades generally give higher recoveries of the better grades (F5+) than equivalent recoveries of No. 1F.

3) Machine Stress Grades:

The machine stress grade recoveries achieved using the Australian yellow card are presented in Table 7 for the selected log combinations. Overall results show a recovery of 69% F5+ with a range from a maximum of 81% for the saw pattern producing the largest dimension (250x40 mm) to a minimum of 59% F5+ for the large branch combination. The overall recovery of F8 was 23% and F11 2%. The impact of wood density is most apparent when viewed in conjunction with the F8 and F11 recoveries, although confounding with BIX and saw pattern prevent direct comparison.

The trends described previously for the visual grade recoveries are again presented in Table 7 with regard to machine grade recoveries. The levels of variation are however less than those presented for the visual grades and are also linked to wood density.

Considerable variation in the recovery of F5+ is shown for the saw pattern combinations. Lowest recoveries are produced by the 150x40 mm pattern at 60% F5+ and a maximum of 81% F5+ for the 250x40 mm dimension. The combined influence of BIX and wood density are contributing factors in these results, with larger branches and lower density for the 100 and 150x40 mm patterns. Wood density becomes a more important grade determinant as lumber dimensions increase.

The saw pattern allocation within the SED combinations has a significant impact on recoveries. This point is illustrated by the grade recovery for the <20 cm SED combination (78% F5+) which were all sawn to 100x40 mm lumber indicating that many of the larger logs sawn to this dimension gave particularly low grade recoveries.

The BIX combinations show 77% and 59% F5+ for the small and large branch combinations respectively. The small branch combination is higher in density with lower corewood and produced 35% F8+ which includes 4% F11 compared to 11% F8 for the large branch combination. This result clearly illustrates the significant impact of branch size on grade recovery.

There is no clear pattern in grade recovery with log height class although recoveries show similarities with the SED combinations. The density trend is also not clear due to the log selection criteria, with different numbers of logs in the various height classes although BIX and corewood follow expected trends and increase with increasing log height class. The lowest recoveries are for the 2nd logs, 64% F5+ and Butt logs, 70% F5+ with best recoveries for the 5th logs at 79% F5+. All log height classes gave 24-27% F8+. Saw pattern selection had a significant impact on the grade recoveries.

The logs recovered from the younger stand had larger average BIX and lower average SED with wood properties consistent with normal age patterns, ie. higher levels of corewood and lower wood density. The lower average SED indicates that a higher proportion of logs were sawn to produce the smaller dimensions. Grade recoveries show 73% F5+ for the logs from the younger stand compared with 68% from the older stand. The younger stand however produced only 14% F8 compared to 25% F8 and 3% F11 from the older stand.

The density combinations all show similar recoveries of F5+ ranging from 68 to 70%. The recovery of F8 and F8+ increased in line with the increase in density, with the low density combination producing 15% F8 and the high combination 27% F8 and 6% F11. In addition to the saw pattern selection, log characteristics which probably influenced the grade recoveries were the SED and corewood values for the low density combination and the considerably lower BIX for the high density combination.

The final set of log combinations are those for corewood percentage. The corewood combinations show a close relationship with SED and are hence influenced by saw pattern allocation, and wood density, ie. as corewood levels increase both SED and density decrease. BIX also shows an increase with increased corewood percentage. The recovery of F5+ was 69 or 70% for all combinations although the recovery of F8+ decreased from 31% for the low corewood combination to 7% for the logs with corewood >75%.

Verification of the machine grade settings was undertaken by destructively sampling approximately 100 pieces of each of the main aim sizes, (100, 150, 200 and 250x40 mm). This testing indicated that the settings used (yellow card), gave lumber which met the required stress levels. The sampling procedure applied for selection of test pieces was to evenly sample across the quality range. Table 7 indicates that the F11 grade had insufficient pieces for adequate data analysis. This testing to validate the MSG grade settings will be presented in detail in a further report under the PNW Cooperative Research Agreement.

Whiteside et. al. (1977) reported that for all stands sampled from the Kaingaroa forest resource, grade recoveries were much better with machine grading than with visual grading to NZ. specifications. However, the rating of stands by visual grade results (ie. patterns of variation) correlated very closely with machine stress grade ratings. The results presented in Table 7 support these findings.

4) Grade Comparisons:

Comparisons between dry visual grade (NZ. specifications) and Australian visual stress grade and machine stress grade are presented in Table 8 A and B. Table 8 C presents a comparison between Australian visual stress grade and machine stress grade. It should be noted that the number of lumber lengths assessed for the visual grade comparison is greater than the number for comparison with machine grades due to the removal of lengths <3.0 m prior to machine grading.

Table 8A shows that the top NZ. visual grade Engineering, equates to 100% F8 under Australian visual stress grade specifications. 1F grade equates to 72% F8, 24% F7, 4% F5 and 1% Reject. This result is in line with the fact that 1F in theory should represent approximately an F6 grade. The reject recovery would most likely reflect lumber with small knots but containing pith. The 2F visual grade has a wider distribution with 6% F8, 44% F7, 33% F5 and 17% Reject. Much of the Reject would again constitute 2F containing pith. The visual Box grade equates largely to Reject although 17% F5 and 2% F7 are achieved. These latter grades reflect the more generous knot and cross grain allowances in the Australian visual stress grade specifications. Overall 49% 1F (includes <1% Engineering grade), 32% 2F and 20% Box grade equate to 38% F8+, 26% F7, 15% F5 and 21% Reject.

The comparison between NZ. visual grade and machine stress grade shows that overall, 47% 1F+, 32% 2F and 21% Box grade equates to 25% F8+, 45% F5, 16% F4 and 14% Reject. Individually the better visual grades record higher percentages of the better machine grades. The visual Box grade contains the highest level of Reject with 40%, but still contains 31% F5+. These lengths of lumber will generally be from the higher density logs where density compensates for the larger knot dimensions.

TABLE 8 - GRADE COMPARISONS

A) Dry visual grade / Australian visual stress grade						
Dry visual grade	Australian visual stress grade F8 %	F7 %	F5 %	Reject %	Total Pieces	%
Engineering	100	-	-	-	8	-
1F	72	24	4	1	1154	49
2F	6	44	33	17	750	32
Box	-	2	17	81	468	20
Total pieces	811	590	390	589	2380	
%	38	26	15	21		100

B) Dry visual grade / Machine stress grade						
Dry visual grade	Machine stress grade F8+ %	F5 %	F4 %	Reject %	Total Pieces	%
Engineering	75	25	-	-	3	-
1F	41	48	8	3	1026	47
2F	15	54	21	10	704	32
Box	4	27	28	40	445	21
Total pieces	554	975	348	301	2178	
%	25	45	16	14		100

C) Australian visual stress grade / Machine stress grade						
Aust. visual stress grade	Machine stress grade F8+ %	F5 %	F4 %	Reject %	Total Pieces	%
F8	49	44	5	2	709	33
F7	21	56	17	6	550	25
F5	10	52	30	9	370	17
Reject	5	31	24	40	549	25
Total pieces	554	975	348	301	2178	
%	25	45	16	14		100

The final grade comparison (Table 8C), is between the Australian visual stress grades and the machine stress grades. The top Australian visual stress grade (F8), shows a higher recovery than the equivalent machine grade although the recovery of F5+ is similar for both ie 75% and 70% for the Australian visual and machine stress grades respectively. Within a given visual stress grade there is a range of machine grades with the general trend showing the lower visual stress grades producing higher proportions of the lower machine grades.

The following points need to be considered when interpreting this comparison:

- Machine grading allows each piece of lumber to be graded on actual stiffness irrespective of the presence of pith or the maximum knot dimensions.
- The Australian visual stress grades exclude pith, thus ensuring that the lowest density portion of the logs, whether of high or low density are excluded.
- The visual stress grade Reject, which totalled 25%, contained 31% F5 and 5% F8 when machine graded. This result again reflects the upgrading effect of wood density in lumber containing pith.

GENERAL COMMENT

It must be borne in mind that the results presented in this report can not be directly related to the stands from which the sawlogs were selected, as the unpruned sawlogs where selected to cover the range of log characteristics available, and not as a representative sample. The selection criteria adopted is a prerequisite for good regression analysis. A subsequent report will deal with the application of the study results to stand assessment.

The grade recovery results presented in this report are lower than would be the case in normal industry practice. Study procedure requires docking for wane only and therefore slightly higher conversions are achieved at the expense of grade. This factor is important when considering the overall grade recoveries.

CONCLUSIONS

1. The study has been successful in the selection and processing of unpruned Douglas-fir sawlogs covering a wide range of log characteristics. It has provided the comprehensive data required to establish a Douglas-fir Log and Lumber Database and enables regression equations to be developed linking log characteristics to grade recovery and conversion for predictive purposes.

2. Branch size was identified as the most important log characteristic with regard to both visual and machine grade recoveries. The proportion of corewood (juvenile wood) was also identified as a significant contributor to grade recovery for all grading criteria, and wood density with regard to machine grade recovery. These findings are consistent with previous studies completed in both NZ. and North America, Whiteside et.al. (1977, 1978), McConchie et.al. (1990), Kellogg, R.M. (1989) and Fahey et.al. (1991).

3. Saw patterns are shown to have a significant impact on grade recovery, reflecting current grading specifications with regard to knot size, knot location and associated cross grain. This relationship will be an important consideration as processors endeavour to optimise value from the Douglas fir resource.

4. The study has demonstrated that a wide range of log qualities (internal and external) are available in the current resource. These qualities result from a range of management strategies and from the quality of initial establishment. Relationships between log qualities, and grade recovery and conversion established from the results of this study will enable values to be applied to the influential log characteristics, in particular branch size, wood density and juvenile wood content.

5. Study results suggest that stand management practices could have a significant impact on final crop value. Regimes that promote growth rates at the expense of branch control, with the objective of reducing rotation age, will also increase the proportion of juvenile wood, reduce wood density and significantly impact on grade recovery irrespective of the grading criteria applied. To optimise value, future regimes must carefully balance the advantages and disadvantages of the silvicultural treatments applied.

REFERENCES

AS 2858 - 1986: Lumber - Softwood - Visually stress graded for structural purposes. Standards Association of Australia.

Barrett, J.D. and Kellogg, R.M. 1989: Strength and stiffness of dimension lumber. In Second growth Douglas-fir: Its management and conversion for value. Forintek Canada Corp. SP-32: 50-58.

Cown, D.J., McConchie, D.L. 1986: Sawing radiata pine unpruned logs to export sizes. Forest Research Institute, Project Record No. 1078.

Cown, D.J., Kimberley, M.O. and Whiteside, I.D. 1987: Conversion and Lumber Grade Recoveries From Radiata Pine Logs. Proceedings of the Conversion Planning Conference. NZ. Ministry of Forestry, FRI Bulletin No. 128 pp 147 - 161.

Cown, D.J. 1992: New Zealand radiata pine and Douglas fir: Suitability for processing. Ministry of Forestry, FRI Bulletin No. 168. 74 pp.

Di Lucca, C.M. 1989: Juvenile-mature wood transition. In Second growth Douglas-fir: Its management and conversion for value. Forintek Canada Corp. SP-32: 23-38

Ellis, J.C. 1982: A three-dimensional formula for coniferous log volumes in New Zealand. NZ Forest Service, FRI Bulletin No. 20.

Fahey, T.D., Cahill, J.M., Snellgrove, A. and Heath, L.S. 1991: Lumber and veneer recovery from intensively managed young-growth Douglas-fir. USDA, Forest Service, Research Paper PNW-RP-437.

Grant, D. 1987: The grading of lumber using the Computermatic Stress Grading Machine. Forestry Commission of New South Wales, Australia.

Harris, J.M. 1985: Effects of site and silviculture on wood density of Douglas fir grown in Canterbury Conservancy. New Zealand Journal of Forestry 30 (1):121-132.

James, R.N. 1975: A review of Douglas fir in New Zealand. New Zealand Journal of Forestry, 20 (1): 107-128.

James, R.N. 1978: Editor - A review of Douglas fir in New Zealand. FRI Symposium No. 15

Jozsa, l., 1989: Relative density. In Second growth Douglas-fir: Its management and conversion for value. Forintek Canada Corp. SP-32: 5-22.

Kellogg, R.M. 1989: Second growth Douglas-fir: Its management and conversion for value. Forintek Canada Corp. SP-32. 171 pp.

McConchie, D.L., McKinley, R.B. and Kimberley, M.O. 1989: Live sawing unpruned radiata pine to domestic and export sizes. Forest Research Institute, Project Record No. 2434.

McConchie, D.L., McKinley, R.B., Rowles, C.J., Butler, R.M. and Kimberley, M.O. 1986: Extension of the FRI Log and Lumber Data Bank for saw pattern 7. (100 mm cant maximising 100x40 mm framing). Forest Research Institute, Project record No. 1520.

McConchie, D.L., McKinley, Turner, J.C.P., Kimberley, M.O. and Cown, D.J. 1990: Investigation of Central North Island Douglas fir. Part 1: A sawing study of Douglas fir grown in Kaingaroa Forest. Forest Reassert Institute, Project record No. 2516.

McKinley, R.B., McConchie, D.L., Lausberg, M., Gilchrist, K.F. and Skipwith, J, 1994: Relating site and silviculture to the yield and value of Douglas fir: Part 1 - Wood Properties. NZ FRI Project Record No. 4310

Middleton, G.R. and Munroe, B.D. 1989: Log and lumber yields. In second growth Douglas-fir: Its management and conversion for value. Forintek Canada Corp. SP-32: 5-22.

NZS 3631, 1988: New Zealand Lumber Grading Rules. Standards Association of New Zealand.

Senft, J.F., Quanci, M.J. and Bendtsen, B.A. 1989: Property profile of 60-year-old Douglas-fir. In Juvenile Wood: What does it mean to Forest Management and Forest Products? Forest Products Research Society.

Smith, W.R. and Briggs, D.G. 1986: Juvenile wood: has it come of age? In Juvenile Wood: What does it mean to Forest Management and Forest Products? Forest Products Research Society.

Walford, G.B. 1985: The mechanical properties of New Zealand grown Douglas fir. New Zealand Ministry of Forestry, FRI Bulletin No. 94.

Whiteside, I.D., Wilcox, M.D. and Tustin, J.R. 1977: New Zealand Douglas fir lumber quality in relation to silviculture. New Zealand Journal of Forestry, 22(1): 24-44.

Whiteside, I. D., 1978: Machine stress grading studies and grading rules for Douglas fir. In - A Review of Douglas Fir in New Zealand. NZ. Forest Service, FRI. Symposium No. 15
pp 273-287.

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter.

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern: Maximise 100x40mm													
Stand Age 33 years													
44	2	11	3	12.4	4.6	2	15	0.094	2.8	2.8	351	65	100
30	2	12	3	13.1	4.9	0	10	0.098	2.9	3.3	376	69	100
34	1	1	4	17.0	4.9	2	2	0.120	5.9	6.3	359	57	100
46	2	24	3	17.7	4.9	4	14	0.169	3.9	4.3	348	59	100
31	1	11	4	18.1	4.9	3	20	0.194	5.0	5.5	386	59	100
11	2	12	2	18.1	4.9	0	8	0.154	2.8	2.8	381	40	100
42	1	5	3	18.8	4.9	0	18	0.198	4.1	4.8	358	51	100
26	1	2	4	19.0	4.6	0	20	0.192	4.9	5.3	337	57	100
29	2	11	2	19.2	4.9	0	7	0.170	2.6	2.8	361	42	100
27	1	18	4	20.4	4.3	0	19	0.194	5.4	5.8	388	57	100
39	1	12	3	20.5	4.9	0	10	0.201	4.3	5.3	349	47	100
17	2	30	4	20.5	4.9	0	19	0.230	4.4	4.8	387	55	100
38	2	11	1	22.8	4.9	11	11	0.246	1.8	1.8	397	20	72
35	1	12	2	25.5	4.9	14	9	0.291	3.8	4.3	362	33	85
8	2	4	2	25.6	4.9	2	9	0.292	3.4	3.8	403	35	85
21	1	18	3	28.6	4.9	0	15	0.385	4.8	5.3	411	40	100
24	2	30	3	29.7	4.9	0	16	0.415	4.5	4.8	384	36	100
28	1	12	1	29.8	4.9	19	17	0.426	3.4	4.3	407	23	64
45	2	3	2	30.9	4.9	3	8	0.411	4.6	5.8	431	33	90
1	1	5	1	34.2	4.9	2	23	0.571	4.1	4.8	380	20	68
6	1	8	1	35.4	4.9	0	19	0.592	3.6	4.3	398	22	73
4	1	11	2	36.4	4.9	3	12	0.583	5.3	5.8	406	26	79
40	2	17	1	37.5	4.9	14	12	0.617	4.4	5.3	428	28	79
37	1	11	1	42.2	4.9	8	19	0.817	3.1	3.3	431	20	62
Stand Age 59 years													
62	688	52	5	15.2	4.9	0	11	0.124	3.6	3.8	401	24	57
9	688	99	6	15.5	4.6	4	19	0.139	4.1	4.8	433	28	100
47	694	3	5	15.5	4.9	4	8	0.121	2.0	2.5	432	32	75
63	688	77	5	17.0	4.9	0	10	0.145	4.0	6.8	457	31	66
32	688	80	5	17.6	4.0	0	12	0.126	3.5	3.8	467	24	65
50	688	113	4	18.0	4.9	3	11	0.165	3.1	4.0	456	28	74
10	688	39	5	18.3	4.9	0	17	0.187	4.6	4.8	407	15	60
56	694	2	3	18.7	4.9	10	18	0.195	4.1	5.8	410	34	79
53	694	3	4	19.5	4.9	0	8	0.178	2.1	2.5	424	30	66
36	688	80	4	22.5	4.9	2	10	0.235	2.8	3.3	475	26	51
54	688	113	3	23.9	4.9	8	12	0.271	3.6	4.8	440	27	66
18	688	99	5	24.1	4.9	3	12	0.276	4.5	5.8	446	18	59

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter (Contd)

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern Maximise: 100x40mm (Contd)													
Stand Age 59 years (Contd)													
60	694	6	2	24.1	4.9	8	4	0.245	2.1	2.3	473	29	61
52	694	3	3	24.3	4.9	2	9	0.267	2.5	2.8	448	27	58
61	688	110	5	26.2	4.9	12	26	0.372	7.1	8.3	444	19	66
16	688	39	4	26.5	4.9	0	10	0.319	4.1	5.3	426	16	47
19	688	78	2	26.9	4.9	0	10	0.325	2.8	3.3	402	22	49
57	688	105	5	27.0	4.9	3	22	0.378	6.0	7.3	399	18	100
5	688	37	5	28.2	4.9	6	13	0.367	4.9	5.8	373	18	52
49	688	88	2	31.1	4.9	0	10	0.426	2.9	3.3	415	27	60
7	688	77	1	32.3	4.9	19	21	0.509	2.4	2.8	472	16	42
2	688	37	4	34.5	4.9	0	10	0.515	3.9	4.8	389	16	45
59	688	116	1	35.5	4.9	10	18	0.589	5.4	5.8	452	11	41
12	688	80	1	35.7	4.9	12	22	0.614	2.8	3.3	517	18	46
33	688	88	1	36.0	4.9	13	19	0.608	3.4	3.8	417	21	54
25	688	40	2	41.3	4.9	7	13	0.750	2.9	3.3	390	19	33
23	688	20	2	43.8	4.9	0	12	0.829	4.3	4.8	461	18	49
58	688	108	2	44.2	4.9	9	14	0.857	4.8	5.8	425	16	48
22	688	91	1	45.0	4.9	2	22	0.946	2.8	3.3	493	15	40
48	688	111	1	46.3	4.9	0	19	0.977	3.6	3.8	437	17	51
13	688	34	2	47.7	4.9	8	13	0.990	3.1	3.8	440	13	34
41	688	20	1	49.6	4.9	8	34	1.126	3.5	3.8	461	11	38
15	688	68	2	55.0	4.9	10	22	1.388	4.9	6.3	420	17	46
55	688	46	1	56.2	4.9	9	21	1.435	3.9	4.8	460	12	40
51	688	110	1	63.0	4.9	10	15	1.730	5.1	5.8	475	12	47
Extra Logs													
3	*	*	*	14.3	4.9	0	20	0.138	4.8	5.0	*	*	*
43	*	*	*	19.0	4.9	0	15	0.191	3.9	4.2	*	*	*
14	*	*	*	20.5	4.9	0	18	0.229	4.0	4.2	*	*	*
Sawpattern: Maximise 150x40 mm													
Stand Age 33 years													
129	2	1	2	26.7	4.9	0	6	0.305	3.3	3.3	390	32	100
135	1	17	2	27.2	4.9	0	10	0.332	2.5	2.8	377	35	71
132	2	22	2	27.4	4.9	0	16	0.361	5.1	5.8	374	35	100
146	1	5	2	27.5	4.9	10	14	0.355	4.6	5.8	360	33	100
114	1	1	3	28.3	4.9	0	20	0.398	5.4	6.8	358	35	100
115	1	2	3	28.3	4.9	0	11	0.363	4.4	4.8	346	38	100
149	1	11	3	28.5	4.6	0	17	0.364	5.8	6.3	398	36	100

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter (Contd)

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern: Maximise 150x40mm (Contd)													
Stand Age 33 years (Contd)													
113	2	24	1	32.4	4.9	10	20	0.509	4.3	5.8	394	27	73
131	2	18	2	32.8	4.6	0	12	0.449	5.3	5.3	382	29	100
124	2	22	1	35.2	4.9	8	23	0.604	4.8	5.3	399	20	72
145	1	18	1	39.6	4.9	6	26	0.762	3.6	4.3	413	19	63
122	2	30	1	43.8	4.9	0	30	0.947	3.9	4.3	402	16	54
Stand Age 59 years													
117	688	37	6	20.0	4.9	2	17	0.215	5.5	5.8	381	21	63
144	688	52	4	20.4	4.9	0	7	0.187	2.5	3.3	411	26	50
109	688	8	4	22.0	4.9	0	10	0.226	2.6	3.3	473	25	59
104	688	20	5	23.5	4.0	0	21	0.230	4.5	6.0	456	20	56
103	688	52	3	23.6	4.9	3	5	0.239	2.0	2.3	418	24	49
105	688	19	5	23.7	4.9	0	11	0.265	4.5	5.3	409	23	65
133	688	103	5	25.0	4.9	0	16	0.309	4.9	5.5	416	24	74
102	688	77	3	25.9	4.9	4	5	0.283	2.8	3.3	463	29	59
142	688	8	3	26.7	4.9	0	8	0.311	2.5	2.8	483	25	53
130	694	2	2	27.3	4.9	6	13	0.349	4.5	4.8	416	28	71
128	688	77	2	28.4	4.9	2	8	0.351	2.4	3.3	468	24	54
118	694	3	2	28.7	4.9	3	8	0.358	2.8	3.3	474	28	55
139	688	113	2	29.8	4.9	4	11	0.396	3.5	4.3	425	25	64
107	688	70	1	30.4	4.9	8	17	0.438	2.4	2.8	463	17	44
112	688	20	4	31.0	4.9	0	9	0.419	4.5	5.5	461	20	53
111	694	3	1	32.6	4.9	12	14	0.485	2.6	2.8	498	20	48
121	694	2	1	33.9	4.9	19	17	0.534	4.9	5.3	433	12	47
150	688	113	1	35.0	4.9	12	27	0.617	3.6	4.8	434	10	44
126	688	47	2	36.9	4.9	4	12	0.600	4.4	5.3	422	20	51
141	688	105	4	38.0	4.9	7	26	0.710	6.4	7.3	411	12	53
143	688	110	4	38.9	4.9	6	14	0.676	6.4	7.8	432	17	51
106	688	58	2	39.9	4.9	0	7	0.664	2.9	3.3	395	16	39
147	688	19	1	41.0	4.9	11	24	0.805	4.0	5.3	463	14	38
137	688	37	2	42.5	4.9	0	9	0.762	3.4	3.8	387	16	39
148	688	47	1	42.9	4.9	4	16	0.821	4.5	6.8	436	12	39
136	694	8	1	45.5	4.9	12	22	0.961	2.3	2.8	421	12	34
138	688	103	2	46.4	4.9	0	14	0.942	5.5	5.8	411	18	54
134	688	109	1	49.0	4.9	0	19	1.089	3.0	4.3	430	9	33
101	688	27	2	50.5	4.9	6	11	1.088	3.5	4.3	385	14	37
151	688	105	1	64.5	4.9	6	15	1.887	5.1	6.3	468	9	31
119	688	68	1	66.0	4.9	6	21	1.975	3.6	4.3	431	11	38

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter (Contd)

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern: Maximise 150x40mm (Contd)													
Extra Logs													
127	*	*	*	24.0	4.9	4	13	0.275	4.0	4.4	*	*	*
108	*	*	*	24.6	4.9	0	15	0.296	4.5	5.0	*	*	*
116	*	*	*	25.5	4.9	0	10	0.294	4.2	4.5	*	*	*
123	*	*	*	32.5	4.9	3	9	0.458	2.2	2.9	*	*	*
Sawpattern: Maximise 200x40mm													
Stand Age 33 years													
226	1	4	3	26.4	4.9	6	15	0.336	4.5	5.3	353	38	100
225	1	8	2	27.5	4.9	0	16	0.364	5.4	7.3	351	29	100
207	2	1	1	29.7	4.9	2	8	0.382	2.0	2.8	427	19	71
203	2	17	2	29.8	4.9	5	16	0.419	4.6	4.8	413	43	100
232	2	4	1	29.8	4.9	10	15	0.417	1.8	1.8	445	18	64
222	2	8	2	32.9	4.9	9	12	0.484	3.6	4.3	389	34	100
220	1	2	2	33.8	4.9	4	14	0.520	4.5	5.3	357	32	100
217	1	4	2	33.9	4.9	7	11	0.507	4.0	4.3	354	29	100
209	2	3	1	34.8	4.9	7	15	0.550	2.9	3.3	452	21	70
213	1	1	2	38.0	4.9	0	15	0.650	5.0	5.8	349	24	78
239	2	18	1	38.5	4.9	0	19	0.688	4.1	4.3	417	19	72
219	2	8	1	38.9	4.9	22	19	0.702	3.1	3.8	403	19	69
218	1	2	1	40.9	4.9	10	15	0.749	3.5	4.3	382	20	60
Stand Age 59 years													
227	688	52	2	26.2	4.9	0	6	0.295	2.3	2.3	453	26	49
235	694	6	1	26.3	4.9	12	14	0.329	2.9	4.8	487	20	50
214	688	70	2	26.8	4.9	2	7	0.312	2.6	3.8	424	21	49
201	688	80	3	27.2	4.9	0	7	0.318	2.8	2.8	465	27	48
241	688	116	2	28.5	4.9	10	14	0.381	6.0	6.8	427	20	62
208	688	52	1	29.3	4.9	12	16	0.405	2.9	3.8	466	20	42
221	688	19	4	29.3	4.9	0	10	0.382	4.3	4.8	423	23	53
216	688	99	4	30.1	4.9	0	11	0.405	4.4	5.3	446	17	48
229	688	8	2	30.4	4.9	6	7	0.396	2.4	2.8	500	20	48
231	688	80	2	30.5	4.9	9	11	0.414	2.5	2.8	485	27	52
242	688	3	2	30.5	4.9	6	10	0.411	3.1	3.3	447	21	44
236	694	8	4	32.6	4.9	2	10	0.463	2.9	3.3	392	18	51
212	688	103	4	33.0	4.9	0	17	0.509	4.3	5.0	425	22	63
215	688	99	3	35.5	4.6	0	8	0.498	3.9	4.8	460	20	44
210	688	99	2	39.0	4.9	0	8	0.642	3.0	3.3	484	22	45
240	688	109	2	40.5	4.9	8	17	0.747	5.0	7.8	442	19	54
223	688	103	3	41.0	4.9	0	8	0.707	5.2	5.5	417	22	58

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter (Contd)

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern: Maximise 200x40mm (Contd)													
Stand Age 59 years (Contd)													
204	688	91	2	41.4	4.9	4	7	0.715	3.4	3.8	475	21	48
211	688	44	2	42.6	4.9	0	7	0.750	2.9	3.3	429	15	40
205	688	58	1	43.4	4.9	3	19	0.864	2.3	2.8	420	12	34
238	688	37	1	46.8	4.9	4	33	1.090	2.8	4.3	423	12	29
228	688	46	2	47.9	4.9	7	17	1.024	4.4	4.8	428	16	44
202	688	100	2	49.5	4.9	14	11	1.048	3.6	4.3	415	18	44
234	688	105	3	50.8	4.9	8	13	1.117	5.4	5.8	424	12	46
230	688	108	1	50.9	4.6	12	27	1.145	5.3	6.8	424	6	27
224	688	103	1	53.2	4.9	0	33	1.390	4.5	4.8	428	8	40
Extra Logs													
206	*	*	*	27.0	4.9	8	11	0.331	3.8	5.0	*	*	*
237	*	*	*	30.0	4.9	0	5	0.374	3.0	3.5	*	*	*
233	*	*	*	34.0	4.6	0	11	0.475	3.1	3.5	*	*	*
Sawpattern: Maximise 250x40mm													
Stand Age 33 years													
304	1	24	1	30.2	4.9	11	24	0.465	4.5	5.3	402	31	81
328	2	2	2	31.0	4.9	0	17	0.455	3.9	4.8	356	25	100
318	1	17	1	32.1	4.9	0	13	0.465	2.5	2.8	407	29	60
331	1	3	1	32.2	4.9	0	23	0.515	3.4	3.8	396	31	81
315	1	18	2	35.8	4.9	6	8	0.543	4.8	5.8	416	30	85
313	2	30	2	37.3	4.9	0	13	0.618	4.1	4.8	391	28	100
320	2	2	1	39.3	4.9	0	13	0.684	2.6	3.8	403	14	61
329	1	4	1	39.4	4.9	2	18	0.714	2.8	3.8	369	15	59
317	1	1	1	45.3	4.9	0	19	0.937	3.9	4.3	369	16	61
Stand Age 59 years													
326	688	39	3	31.6	4.9	0	10	0.440	2.4	2.8	446	21	42
303	688	78	1	31.7	4.9	4	17	0.474	2.8	4.3	415	15	42
319	688	8	1	34.0	4.9	0	23	0.565	2.1	2.8	516	13	37
323	688	19	3	34.3	4.9	4	7	0.495	3.6	4.8	425	22	48
339	688	3	1	35.4	4.9	8	26	0.626	5.4	9.5	444	16	37
311	688	73	2	35.9	4.9	7	3	0.520	3.8	4.3	437	29	58
301	688	39	2	36.6	4.9	0	8	0.566	3.1	3.8	457	21	41
327	694	8	3	37.3	4.9	2	9	0.594	2.4	2.8	388	17	43
316	688	73	1	37.6	4.9	12	21	0.671	3.5	3.8	447	18	53
324	688	19	2	37.7	4.9	5	7	0.593	3.8	4.3	425	20	45

Appendix I: Individual Log Characteristics Sorted by Saw Pattern, Stand Age and Diameter (Contd)

Log No.	Cpt.	Tree No.	Log Height Class	SED (cm)	Length (cm)	Sweep (mm/m)	Taper (mm/m)	Volume (m^3)	Branch Index (cm)	Max. Branch (cm)	Basic Density (kg/m^3)	Corewood % 10 Rings	Corewood % 20 Rings
Sawpattern: Maximise 250x40mm (Contd)													
Stand Age 59 years (Contd)													
307	688	37	3	39.2	4.9	0	7	0.640	3.0	3.3	392	18	43
312	688	39	1	40.4	4.9	9	26	0.791	2.9	3.3	475	13	37
338	688	111	2	41.0	4.9	0	11	0.724	4.8	5.3	442	31	65
336	688	20	3	41.5	4.9	0	5	0.700	4.0	4.5	459	20	52
305	694	8	2	41.7	4.9	8	8	0.728	2.3	2.8	395	16	38
306	688	99	1	43.0	4.9	6	12	0.799	3.1	4.3	483	16	40
310	688	72	2	43.7	4.9	3	12	0.827	4.0	4.8	481	19	50
309	688	100	3	44.5	4.9	10	7	0.822	3.1	4.0	390	20	49
321	688	44	1	45.8	4.9	0	24	0.987	2.1	2.3	453	10	32
322	688	110	3	46.0	4.9	8	15	0.932	6.5	8.3	417	16	48
325	688	40	1	47.8	4.9	0	22	1.059	2.4	3.3	410	12	28
314	688	72	1	49.6	4.9	13	24	1.151	3.5	3.8	483	14	51
337	688	110	2	53.2	4.9	3	20	1.281	5.3	6.3	454	16	52
330	688	34	1	54.3	4.9	12	36	1.469	3.1	3.8	447	7	26
335	688	100	1	55.1	4.9	15	15	1.327	3.4	3.8	436	10	31
340	694	11	2	55.2	4.6	8	9	1.193	3.1	3.8	449	10	24
302	688	27	1	56.0	4.9	4	31	1.513	2.8	3.3	410	8	26
308	688	105	2	57.3	4.9	12	15	1.429	5.1	5.8	442	14	42
332	694	11	1	59.5	4.9	0	28	1.670	2.4	2.8	478	7	18
Extra Logs													
334	999	M	*	40.0	4.6	0	9	0.633	1.6	1.8	*	*	*
333	999	K	*	44.0	4.9	3	6	0.796	2.7	3.5	*	*	*

APPENDIX 2 - OVERALL MEAN AND RANGE OF LOG CHARACTERISTICS INCLUDED IN THE LOG AND TIMBER DATABASE

Log Characteristic	Mean	Minimum	Maximum
SED (cm)	33.8	12.4	66.0
Sweep (mm/m)	4	0	22
Taper (mm/m)	15	2	36
Volume 3D (m^3)	0.573	0.094	1.975
Vol. Smalians (m^3)	0.592	0.094	1.964
Branch Index (cm)	3.8	1.6	7.1
Max. Branch (cm)	4.5	1.8	9.5
Basic density (kg/m^3)	421	337	517
Corewood- 20rings(%)	61	18	100
Corewood- 10rings(%)	24	6	69