F.R.I. PROJECT RECORD

NO. 2735

TESTING OF LOG QUALITY PREDICTIONS

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Executive Summary

The nature of stands being logged is about to change dramatically, making accurate predictions of log quantity and quality important. This study sets out to test the accuracy of the existing log quality prediction system.

Stands that were indicative of the 'new crop' to be coming out of Kaingaroa Forest had been selected and screened for adequate measurement and treatment histories. There were 43 plots, in 10 treatments. Predictions from the log quality model LOGRAD were compared with MARVL assessments.

Tree diameter and log size predictions were good. The model and the cruise gave similar volume estimates for pruned butt, unpruned saw and residual logs, but **LOGRAD** predicted that most unpruned sawlog material would be **large branched** whereas **MARVL** estimated that it would be **small branched.** As branch size is assessed subjectively during cruising, validation of this aspect of the model would require a detailed climbing or felling study.

Predictions are often needed well before stands are ready for felling. The EARLY and PPM88 growth models predicted growth of these plots very well, with mean error in basal area being less than 1% over 20 years, despite thinnings from initial stockings of up to 5000stems/ha. Growth modelling errors had a compounding effect on log quality prediction error, though in this situation it did not significantly alter the results.

LOGRAD predicts for a single cross-cutting strategy (FRI grades) and the MARVL strategy was set to match. Out-turn was sensitive to cross-cutting strategy. For example with an export log strategy, the pulp estimate from MARVL changed from 10% to 25% of TRV. When PC StandPak is released later this year, users will be able to obtain predictions for their own log specifications.

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1 INTRODUCTION

Logging of old crop stands in New Zealand will soon be finished. The more recent regimes will result in substantial changes in log quality and quantity (Whiteside and Manley, 1985) so that accurate predictions are important.

LOGRAD (Whiteside, McGregor & Manley 1987) is a model FRI produced to predict log quality. The model assigns the logs simulated by program PROD to various grades. Concerns that the model might be under-estimating both the volume of pulp material and the proportion of sawlogs falling into the large branch category have been expressed.

Ideally, a validation exercise would be carried out comparing the model's predictions against actual measurements, when stands of known history are being logged. For this investigation, a more immediate indication was wanted. Pre-harvest inventory with the MARVL system (Deadman & Goulding 1979) is a widely used estimator of log out-turn so predictions from the model were compared with cruise results.

The pre-harvest inventory data, made available by Tasman Forestry Limited, were assessments of permanent sample plots in Kaingaroa forest that had been chosen to be representative of the stands to be logged by the company over the next few years and which had records of treatment and measurement over many years.

This investigation had two parts. In the first stage, LOGRAD predictions were made from actual stand parameters at age of clearfelling. In practice, log quality predictions are often required in advance of when a stand will be felled, in which case LOGRAD relies on growth models to estimate the values of the stand parameters it uses for its own predictions. The second stage of this investigation examined the effect of growth modelling errors on log quality predictions.

2 DATA

Permanent sample plots were used as the sampling units because their treatment and measurement was better documented than production stands and uncertainty about stand history would have confounded the study. So that plots would be indicative of new crop stands that Tasman Forestry Ltd will start logging over the next few years, they had limited selection to those with a final stocking of 200 to 400 stems/ha, achieved at or before age 13 and which were now approaching rotation age.

Three of the plots available were discarded due to treatment or measurement anomalies. Forty three plots, containing 670 stems, were used. Plots came from four experiments in Kaingaroa Forest and covered a range of site qualities and treatments, as summarized in *Tables 1 and 2* below. Additional information is given in *Appendix 1*. Experiment R589 would have been used in the construction of the PPM88 growth model, but the other data can be regarded as an independent data set.

Table 1: Experiment number, Number of replicates and Number of trees (in brackets) by Treatment

Age last thinned (years)	Final Stocking (stems/ha) 200	250	300	400
7	R695 4(78)		R695 4(119)	R695 4(155)
8	R681 4(32)		R681 4 (48)	
9	R680 4(32)	R589 6(89)	R681 3 (36)	
12	R680/681 6(48)			
13	R680 4(32)			

Table 2: Experiment summary

Experiment number	Cmpt number (Kaingaroa)	Age	Site index
R589/2	917	23.8	30.2
R680	1119	29.8	29.4
R681	48	28.8	32.0
R695	84	25.8	30.5

3 METHOD

First a review of the way that the modelling system predicts log quality:
A set of stand parameters is taken at some start point then growth models are used to predict growth through to the clearfelling age, taking account of silviculture. This new set of parameters is used to predict the diameter distribution and height/diameter curve, from which the height and diameter of individual trees can be estimated. Using tree volume and taper equations, the form of each tree is calculated. The user specifies a log cutting strategy and the resulting logs are allocated to FRI grades based on SED and branch size.

Assuming that the starting values and silvicultural records were accurate the next possible source of error was from the growth models. The primary objective of this study was to look at the performance of the log grading module itself. In the first stage of the study basal area and height predictions were corrected by using actual measurements so that growth modelling errors did not confound testing of the LOGRAD module. In the second stage of the study, growth was not adjusted, so that the effect that growth modelling errors had on log quality prediction was demonstrated.

The same tree volume and taper equations were used in both the MARVL and LOGRAD, so any error due to form, shape would not affect the comparison.

So that the model and cruise would be compared on a similar basis, MARVL was run with log specifications that matched the single cutting pattern available in the log grading module. The log grades proposed by FRI (Whiteside & Manley 1987) were used for both. See *Table 3* below.

Table 3: FRI Log Grades

	Minimum SED (mm)				
Branch size (cm)	400	300	200	150	100
0	P1	P2			
<6	S1	S2	S3	S4	
6-14	L1	L2	L3	L4	
>14					R

3.1 Cruise Estimates

Plots were cruised by FRI staff using Tasman Forestry Limited's coding system and were processed using program MARVL on the Institute's VAX network.

The MARVL log cutting strategy was tailored to match the specifications that LOGRAD uses. MARVL segregated out-turn by both SED and branch size into sawlog grades and a residual grade. For pruned trees the butt log length was assigned to the average pruned height of that element minus stump height. Unpruned logs with an SED of less than 200mm were cut to variable lengths. Other unpruned logs were cut to fixed 5.5m lengths.

Table 4: Cross cutting strategy specified for MARVL analysis

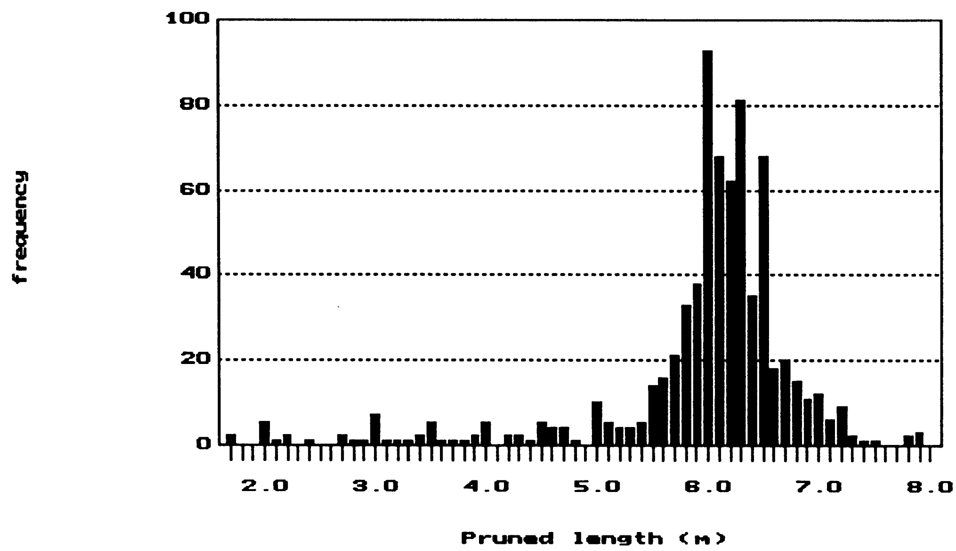
Log type	Length (m)		SED (mm)		$/m³	Quality codes
	min	max	min	max		*(refer Appendix 3)*
P1	2.4	7.2	400	990	155	ABZ
P2	2.4	7.2	300	400	104	ABZ
S1	5.5	5.5	400	990	99	ABZKL
S2	5.5	5.5	300	400	72	ABZKL
S3	5.5	5.5	200	300	29	ABZKL
S4	3.5	6.1	150	200	22	ABZKL
L1	5.5	5.5	400	990	85	ABZKLND
L2	5.5	5.5	300	400	58	ABZKLND
L3	5.5	5.5	200	300	13	ABZKLND
L4	3.5	6.1	150	200	11	ABZKLND
R	3.5	6.1	100	990	9	ABZKLNDCEGHJMQRSYPV

Explanation of some aspects of the cutting strategy is given below:

1. Pruned length

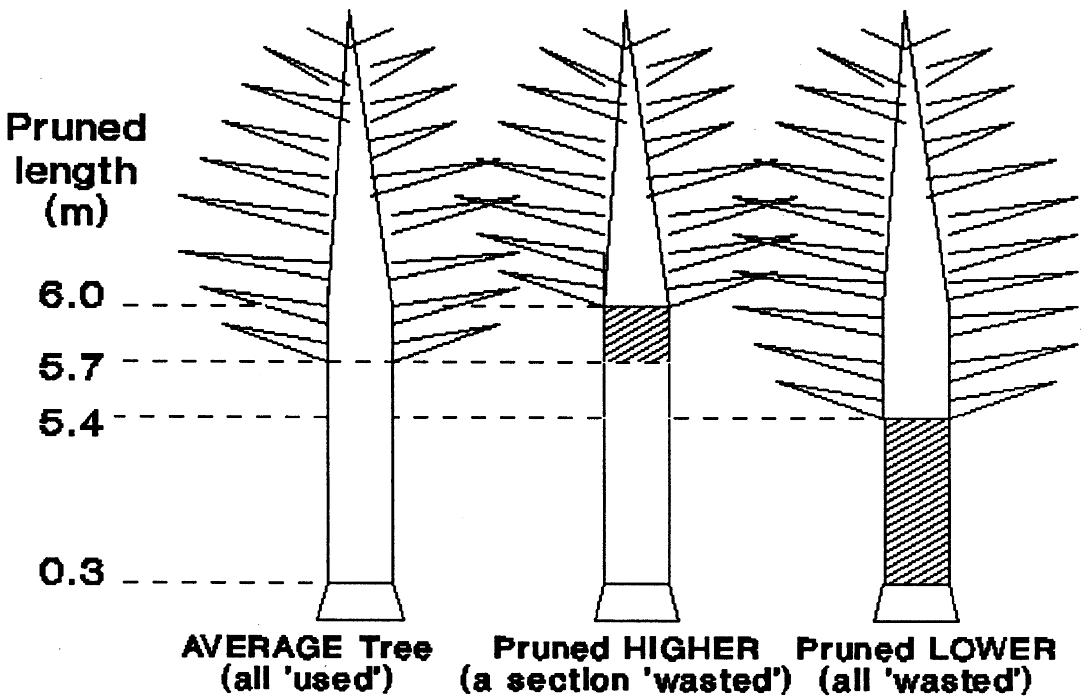
Most log making operations cut pruned logs to variable lengths in order to increase recovery of value. LOGRAD also maximises the recovery of pruned logs, by making the assumption that within each pruned element, butt log length equals the mean pruned height of the element (less stump height). In fact pruned length of stems within a stand will be variable, as shown in *Figure 1*. The trees that are pruned higher than average were offset by others that were pruned lower. The use of average length in LOGRAD was expected to give a good estimate of the pruned volume.

Figure 1: Distribution of pruned lengths



Unlike the modelling system, which operates at the stand level, MARVL 'cuts' individual trees and any choice of fixed pruned log length would result in an under-estimate of pruned volume of a stand (*Figure 2*). A variable length for pruned logs of 2.4-7.2m was used in the MARVL cutting strategy, in order to put the estimate of merchantable pruned volume on a similar basis to both reality and the model's predictions.

Figure 2: Effect of using fixed pruned length in MARVL on pruned volume



2. Variable length for small logs

LOGRAD was constructed so that it 'cuts' unpruned sawlogs to a strict 5.5m length. A varying proportion of volume in each SED and log height class is then assigned to the different log grades. This approach can be used to predict log grades at the stand level.

MARVL operates at the stem level. Applying a fixed length log cutting strategy to all log grades would give unrealistic indications of volume by log grade. For example, where cruising had recorded even just a short length of defect in the upper logs, the program degrades the whole 5.5m length to 'R' grade. Variable log lengths were used for S4 and L4 grade logs in this analysis.

3. Log prices

Because MARVL was designed to maximise tree value when 'cutting' the stem, relative prices for the various grades needed to be realistic. Actual values could not be used due to the commercially sensitive nature of price information. Prices used in this study were based on an earlier study by Bruce Manley (pers. com.) and which, when adjusted for inflation, did not appear to be unreasonable today.

4. Rounding length and stump height

So as to minimise rounding error, a rounding length of 0.1m was chosen. Stump height was set at 0.3m.

3.2 Model Predictions

Development of each plot was simulated using STANDPAK on FRI's VAX network. The start point for each simulation was at the time of the first measurement (usually at around first pruning), and tending was modelled according to actual measurements (eg. of pruned height or stocking) or where this was not possible, from the plot history sheets. The responses made during each simulation were chosen to imitate what a forest manager would select if modelling this situation. Details of the values that did not change between plots are given in *Appendix 2.* The volume and taper equations were the same as those used in the MARVL.

Simulations began in the EARLY growth model and switched to PPM88 after the last pruning. For some plots, reduction to final stocking had not been until age 13, so in these cases the last thinning was simulated in the later growth model.

As a first stage the effect of growth model errors was minimised by correcting the predictions wherever possible using actual measurements from the permanent sample plot system, so that errors in growth modelling would not confound testing of the LOGRAD module. *Appendix 4* contains details of how these corrections were made.

In the second stage no adjustments were made, so that any effect of growth model errors on log quality prediction would be apparent.

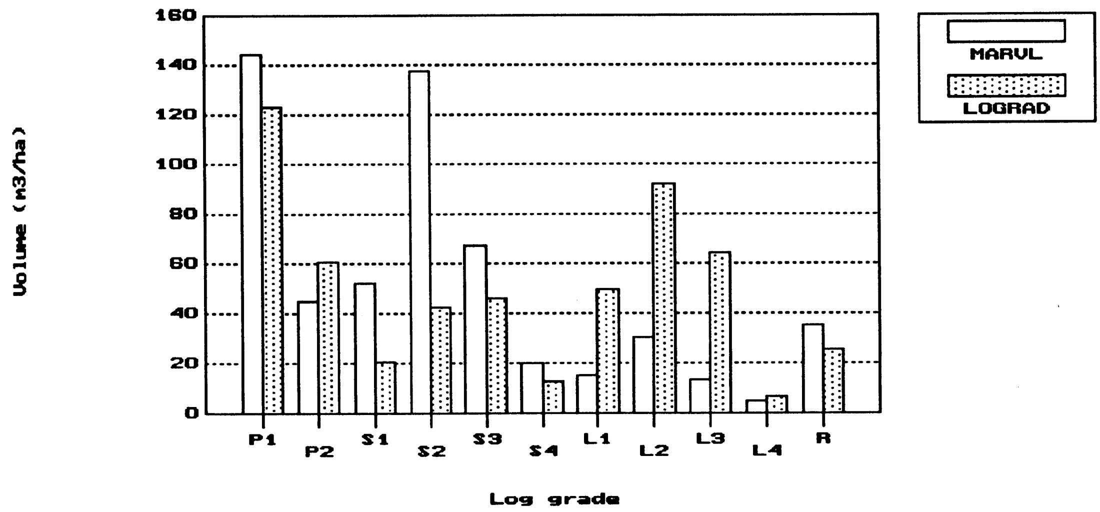
4 RESULTS

4.1 Stage One: Excluding Growth Model Errors

Predictions from the model were compared with cruise estimates for each plot. Results were then grouped by treatment and compartment and examined for trends. None were found, so results for all plots were combined.

In *Figure 3* below, each bar represents the mean volume of that grade averaged over all plots.

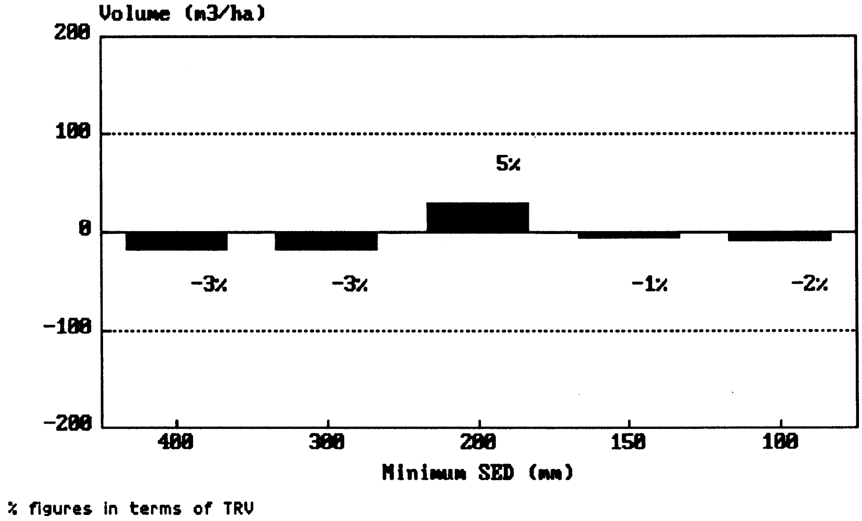
Figure 3: Volume by log grade



The main dissimilarity between LOGRAD predictions and MARVL estimates was in the volume of small branched sawlogs (S1~S4) compared with large branched sawlogs (L1~L4). LOGRAD (the dotted bars) predicted that most of the unpruned sawlog volume would fall into the **Large branch** grades, while MARVL (the empty bars) estimates that it would go into the **Small branch** ones.

The differences between the model and cruise were subdivided by log size and branch size, since both are major determinants of log quality.

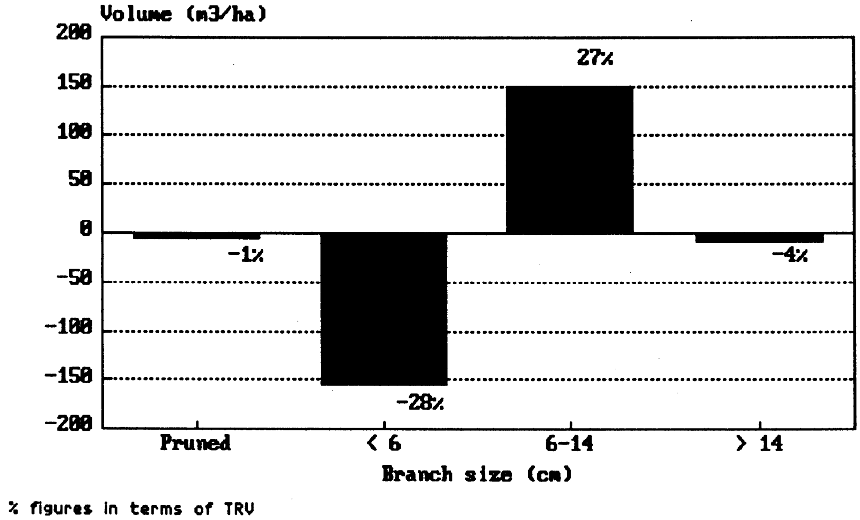
Figure 4: LOGRAD - MARVL by Log Size



Log size estimates were very similar from the model and the cruise (*Figure 4*). Log size is predicted by program PROD using tree volume and taper tables for individual 'trees' taken from the diameter distribution and height/diameter curve the program generates for the stand. Diameter distributions were predicted very well for nine of the ten treatments. The null hypothesis tested was "that there was no significant difference between the actual and predicted distributions". For all but one treatment the null hypothesis was accepted even if a 20% chance of being wrong was taken. DBH distributions and results of Kolmogorov-Smirnov tests are shown in *Appendix 5*. In addition to the general shape of the curves being similar, the predicted minimum and maximum diameters also appeared to be similar to the actual data.

Measurements of the remaining treatment, which was aerially seeded and thinned at age 7 to 200 stems/ha, showed that a high proportion of the stand was in the middle of the diameter range, whereas the FRI weibull function for Rotorua predicted a much flatter distribution. In this treatment the null hypothesis was rejected even if only a 2% chance of being wrong was demanded.

Figure 5: LOGRAD - MARVL by Branch Size



The model predicted a far greater proportion of large branched logs than the cruise estimated (*Figure 5*).

4.2 Stage Two: Including Growth Model Errors

Errors in height prediction were small, random and would have had very little effect on predicted volume or quality.

Figure 6 is a greatly simplified representation of results over time. Results were considered at four stages: the beginning of the simulation, end of the EARLY growth model, midway through PPM88 and at the end of PPM88. The exact ages at which each stage of the simulation was reached varied between different regimes so the average ages were shown. The predicted and actual means were calculated from the basal areas of all plots. The number at the top of each bar shows the proportion by which the basal area prediction for the plot which was most highly overpredicted differed from the actual basal area of that plot. Likewise for the most underpredicted plot, which is the figure at the bottom of each bar. The length of the bar above the actual mean was calculated by multiplying the mean actual basal area by the figure at the top of the bar. Likewise for the length of the lower bar. The figure to the right of each bar was calculated from the mean of the differences between actual and predicted basal area of each plot, expressed as a percentage of the mean actual basal area of all plots.

On average, basal area was predicted very well. Mean error was within one percent. The highly summarized method of expressing the results in *figure 6* could have concealed trends over time within prediction errors, but none were found in more detailed examination against treatment (*appendix 7*) and time, despite the fact that the simulation period often spanned more than 20 years.

Overall, basal area prediction error was negligible and if growth model errors had no compounding effect on log quality predictions, then LOGRAD results would not have changed when modelling errors were included. In fact the two sets of predictions were not identical, as shown in *figure 7*.

Figure 6: Growth Modelling Errors EARLY and PPM88

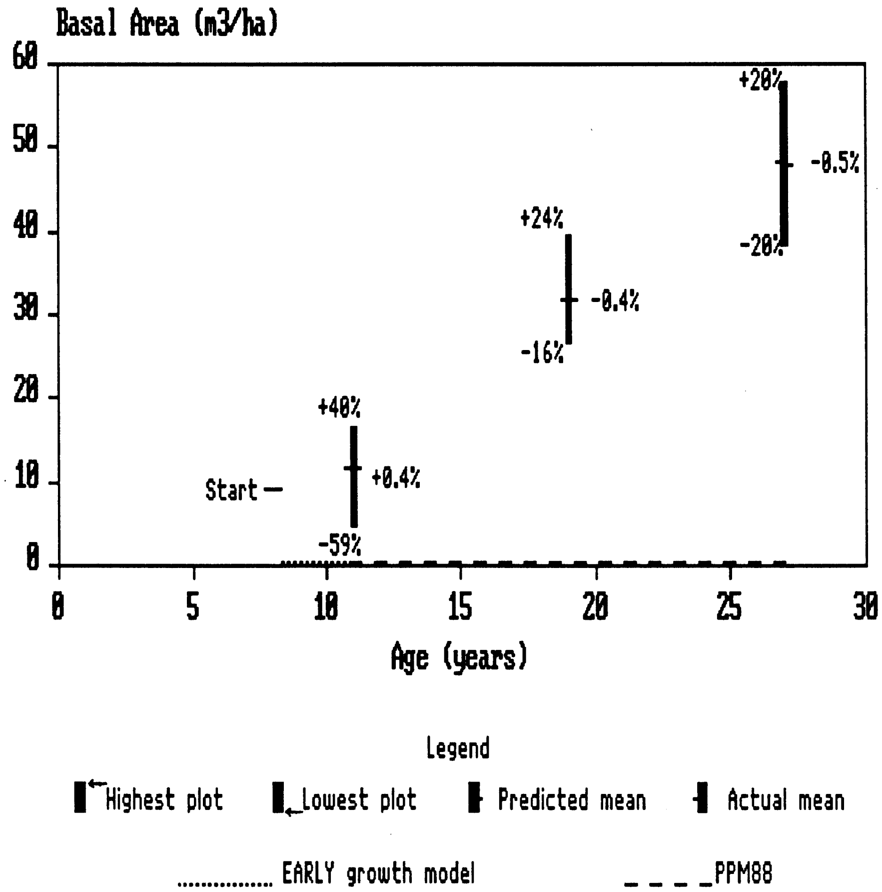
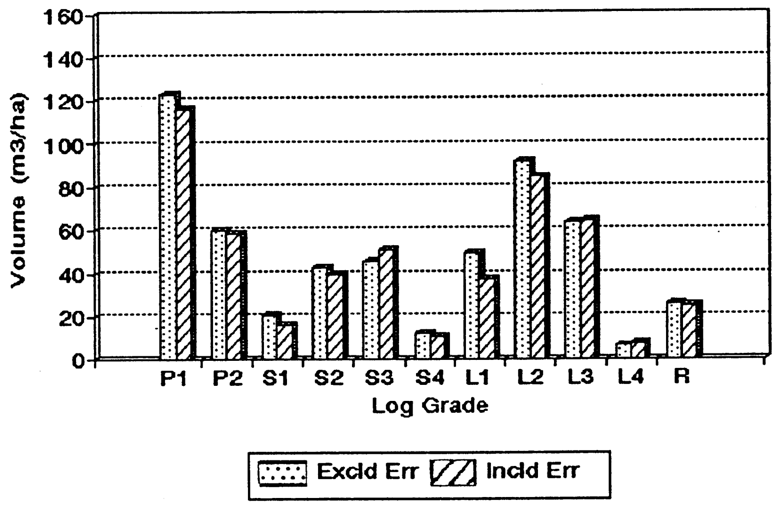


Figure 7: Effect of Growth Model Errors on LOGRAD Predictions



5 DISCUSSION

5.1 Stage One: Excluding Growth Model Errors

LOG SIZE

Predicted diameter distributions were good and estimates of log size from the model and cruise were quite close, which indicates that the predicted height/diameter curves and the method of "cross-cutting" were reasonable.

BRANCH SIZE

Branch predictions from the model differed markedly from cruise estimates. LOGRAD predicted that the majority of unpruned sawlogs would fall into the large branched category while MARVL suggested that most would meet the small branch specification.

In all treatments the model was operating within the range of data that went into its construction. The cruise had been carried out by experienced operators and spot checked by TFL staff. Obviously both systems cannot be right about branch size, but as cruising of quality features was subjective it could not be determined which, if either, was correct.

LOGRAD predicted an average branch index for the unpruned sawlogs of 5.50 for the plots in this study. MARVL does not provide a direct estimate of branch size, but the proportion of 'L' to 'S' grade material suggests a branch index of around 4.05. (*Appendix 6*).

Actual branch measurements by the Management of Improved Breeds Co-operative, were available from 23 trees from 2 plots in one of the experiments included in this study. This very limited sample (which related to only 1 of the 10 treatments) indicated a branch index of 5.06. Though this was closer to the LOGRAD prediction than was implied from the MARVL results, it was not considered conclusive and the issue could only be resolved by branch measurements in the same plots that were cruised.

SWEEP

Sweep is another important factor determining log quality. Like branch size it was classified subjectively in the cruising.

The maximum sweep allowed for sawlogs during the cruise was D/2 on a 3.7m log length. LOGRAD uses stand average sweep rather than working with individual trees, so there was no way of directly equating the two systems. From a visual assesment the 'Medium' sweep option in LOGRAD was judged to be the most appropriate (7.5mm/m for a 5.5m butt log and 4.5mm/m for logs 2,3,4). LOGRAD predicted that 'pulp' (R, S4, L4 combined) accounted for an average of 8% of the Total Recoverable Volume. Had the 'High' level been used (10.0mm/m and 5.5mm/m) the result would have been 11% 'pulp'. Sweep did not have a great effect on the estimate of pulp in terms of Total Recoverable Volume, with the the high versus low estimates resulting in a difference of only 13m³/ha.

The MARVL estimate of 'pulp' being 10% of Total Recoverable Volume was between the results of the 'Medium' and 'High' options of the model. This supported the selection of the medium sweep level for LOGRAD predictions in this study. Ideally however, the decision on which sweep level to use for the simulations should have been based on stand measurements.

LOG CUTTING STRATEGY

MARVL estimates of volume by log grade were very sensitive to what log specifications were set. For example **with a cutting strategy designed to maximise export log out-turn (ie. where long straight lengths were required) instead of the one that approximated FRI log grades, the proportion of pulp was 25%.** (*Table 6*).

Table 6: Effect of cross-cutting strategy on out-turn estimated by MARVL

FRI Log Grades Strategy		Export Log Grades Strategy	
Pruned	34%	Pruned	32%
Unpruned Sawlogs	56%	Export	12%
		Domestic Sawlogs	31%
Pulp (R,S4,L4)	10%	Pulp (R,S4,L4)	25%

As LOGRAD stood at the time of this study, it was not suitable for evaluating export log cutting patterns and results would be misleading if it were used for this purpose. Kimberly & Whiteside (1990) have reworked the data that LOGRAD was based on, so that predictions will be able to be made for log lengths other than 5.5m. PC STAND-PAK, which is scheduled to be released this year, will allow the user to define their own log grades. Estimates for export log cutting patterns appear to be reliable (Ian Whiteside pers. com.) with pulp comprising up to one third of TRV in some stands.

5.2 Stage Two: Including Growth Model Errors

The growth models predicted basal area very well (to within one percent) despite simulations that spanned more than 20 years and which included regimes with very heavy early thinnings (from up to 5000 stems/ha down to as low as 200 stems/ha).

Although mean growth model error was negligible, the deviations in individual plot predictions from actual development had meant that growth model errors had affected mean log grade predictions (see *figure 7*).

The compounding effect that growth model errors had on quality predictions was expected to be larger in situations where growth prediction errors were large.

6 CONCLUSIONS

1. Growth predictions from EARLY/PPM88 were good and there was no evidence of bias.
2. Diameter distribution predictions were not significantly different from actual distributions for 9 of the 10 treatments.
3. There was little difference in volume by log size between MARVL and LOGRAD.
4. LOGRAD and MARVL gave similar figures for total recoverable, pruned, unpruned sawlog and pulp volumes, but differed significantly over quality of the unpruned sawlog volume. MARVL estimated that the majority would meet the *small* branched specification whereas LOGRAD predicted that it would fall into the *large* branched category. It is not possible that both systems were correct, but because branch size was determined subjectively during cruising (however carefully), no definitive statement could be made about this aspect of the model's performance.
5. The product breakdown estimated by MARVL changed dramatically when different cross-cutting strategies were used. The proportion of pulp went from 10% to 25% of recoverable volume with a change from a strategy with 5.5m logs on FRI grades, to one based on 12m export logs (pruned logs were cut to variable lengths in both cases).
6. For the cutting strategy used in LOGRAD, this study found no evidence to suggest that the model was overly optimistic in its predictions of log quality, nor does it appear to overpredict the amount of pulp.
7. In order to validate the model, branch and sweep measurements would have to be collected in addition to the information available from a cruise, therefore a study involving tree felling or at least climbing would be required.
8. Where growth models are used to estimate the parameters that a log grading model uses to make its predictions, the reliability of log quality predictions is limited by the performance of the growth models. Overall, the EARLY and PPM88 models predicted growth very well for these stands, but growth modelling errors for individual plots did have a compounding effect on log quality predictions. Though small in this case the effect could be significant where growth model errors are larger.

7 ACKNOWLEDGEMENTS

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9 APPENDICIES

9.1 Data Set

ID	PSP number	Cmpt no. Kaingaroa	Estab. year	Seed source	Site Index	Final Stocking	Final Thin age
1	589/2/9/0	917	1966	Climb & Select	30.5	250	9
2	589/2/11/0				30.4	250	9
3	589/2/12/0				30.1	250	9
4	589/2/13/0				30.2	250	9
5	589/2/15/0				28.6	250	9
6	589/2/20/0				30.3	250	9
7	680/0/10	1119	1960	Regeneration	30.0	200	13
8	680/0/11				28.7	200	13
9	680/0/13				29.2	200	9
10	680/0/14				28.7	200	9
11	680/0/15				29.0	200	9
12	680/0/16				29.3	200	9
13	680/0/27				29.6	200	13
14	680/0/28				30.6	200	13
15	680/0/33				30.1	200	12
16	680/0/34				28.4	200	12
17	680/0/35				29.5	200	12
18	680/0/36				30.1	200	12
19	681/0/2/0	48	1961	Regeneration	31.6	200	8
20	681/0/4/0				28.4	200	8
21	681/0/6/0				29.7	300	12
22	681/0/7/0				30.2	300	12
23	681/0/8/0				30.3	300	12
24	681/0/18/0				30.3	200	12
25	681/0/19/0				30.6	200	12
26	681/0/45/0				33.4	300	8
27	681/0/46/0				33.6	300	8
28	681/0/47/0				34.5	300	8
29	681/0/48/0				33.2	300	8
30	681/0/49/0				33.2	200	8
31	681/0/52/0				33.6	200	8

35	695/1/5/0	84	1964	Aerial Seeding	29.4	200	7
36	695/1/9/0				29.4	200	7
37	695/1/16/0				29.4	200	7
38	695/1/19/0				30.2	200	7
39	695/2/4/0				30.8	300	7
40	695/2/12/0				30.8	300	7
41	695/2/15/0				31.8	300	7
42	695/2/23/0				30.9	300	7
43	695/3/1/0				29.5	400	7
44	695/3/11/0				31.3	400	7
45	695/3/14/0				30.4	400	7
46	695/3/24/0				33.0	400	7

9.2 Further Information on Simulations

STANDPAK inputs that were kept constant:

Early Growth Model		
Monthly growth	3	No adjustment
BA model	2	Medium basal area growth
Schedule on	1	Age
Site index		was calculated from latest height
Initial stocking		PSP
Lift defined by	1	Pruned height
Growth Models		
Later Model	22	PPM88
Height model	34	PPM88
Stand vol tab	29	KGM3
PROD		
Volm eqn	182	New crop
Weibull	1	Rotorua
Taper	182	New crop
Breakage	1	C.N.Is.
LOGMIX		
Sweep	3	Medium
Resin pockets	2	Low
Internode index	3	C.N.Is. Pumice
Density	2	Medium

9.3 Quality Codes used in Cruise

MARVL cruising codes

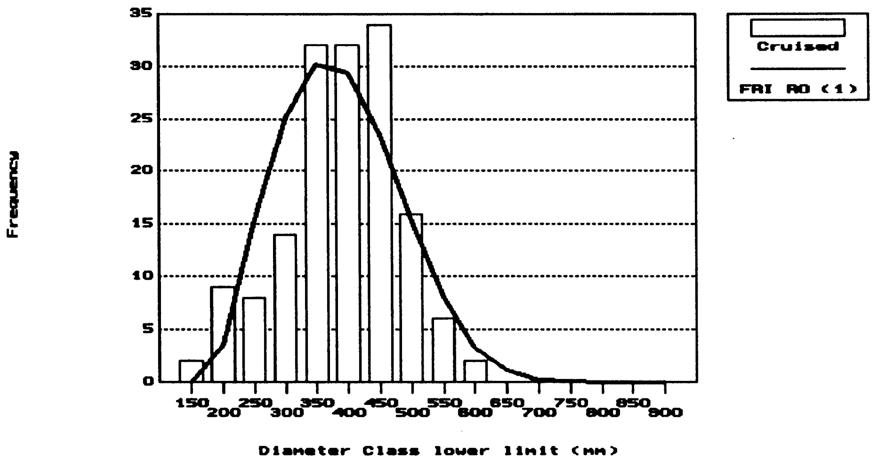
W	Unmerchantable wood
A	Pruned, sweep < D/4
B	Pruned, sweep D/4 to D/2
C	Pruned, sweep > D/2
D	Branch size 6-14cm, sweep D/4 to D/2
E	Branch size 6-14cm, sweep > D/2
G	Branch size > 14cm, sweep < D/4
H	Branch size > 14cm, sweep D/4 to D/2
J	Branch size > 14cm, sweep > D/2
K	Branch size < 6cm, sweep < D/4
L	Branch size < 6cm, sweep D/4 to D/2
M	Branch size < 6cm, sweep > D/2
N	Branch size 6-14cm, sweep < D/4
Q	Branch size < 6cm, sweep < D/2, wobble
Y	Sweep D/4 to D/2 between sections of <D
Z	Damaged live wood
P	Swelling at whorls (nodal swelling)
V	Sound dead

9.4 Method used in Correcting Growth Model Predictions

In the first stage, where growth model errors were to be excluded, the simulations were halted and basal area, stocking and height corrected using measurements from the PSP system. This had to be done at age 20 as well as at the end of the rotation, as not only were the final values used by LOGRAD, but the basal area at age 20 was too. Another driving variable of the branch size model was stand height at last thinning, so this was also corrected. The Early growth model does not allow for such corrections to be made at any time other than at the end of its simulation period. To get around this, the starting height was adjusted by trial and error until the desired MTH was obtained at the time of final thinning.

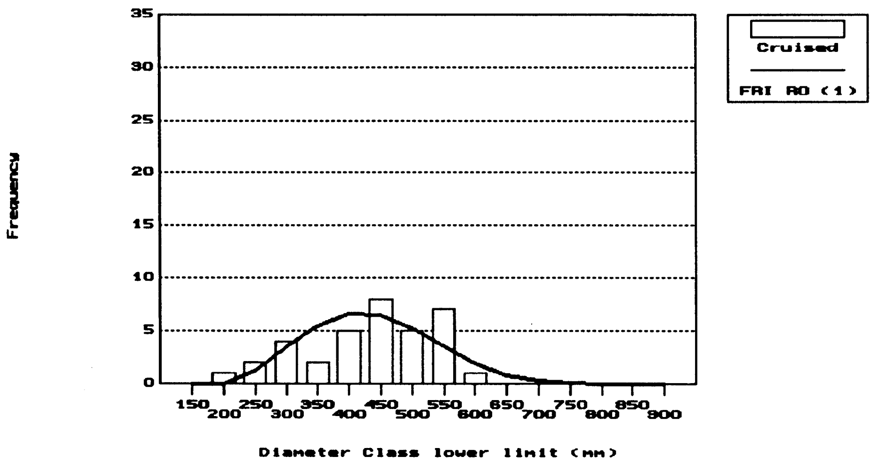
9.5 Diameter Distributions

400 stems/ha Thinned age 7 Clearfelled age 25.8 (treatment 3)



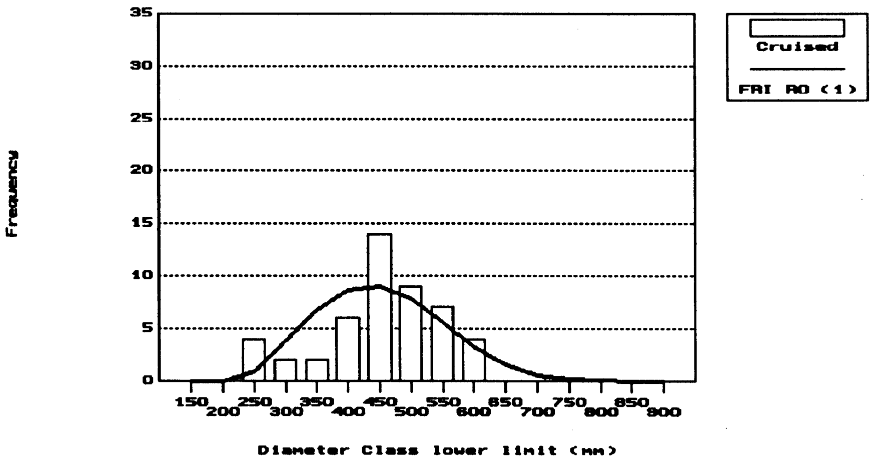
Not Significant for p < 0.2

300 stems/ha Thinned age 12 Clearfelled age 28.8 (treatment 6)



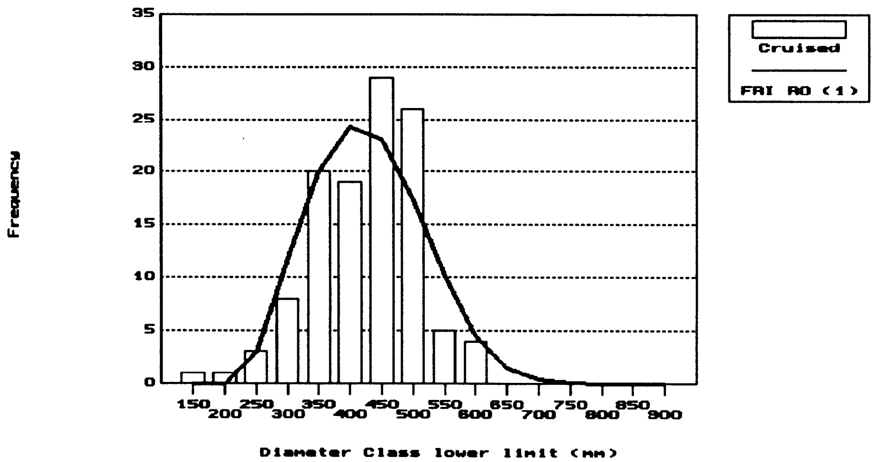
Not Significant for p < 0.2

300 stems/ha Thinned age 8 Clearfelled age 28.8 (treatment 5)



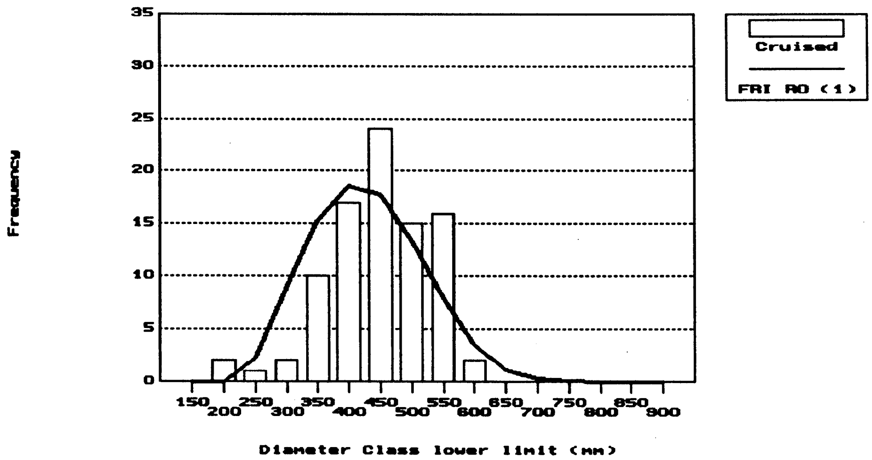
Not Significant for p < 0.2

300 stems/ha Thinned age 7 Clearfelled age 25.8 (treatment 10)



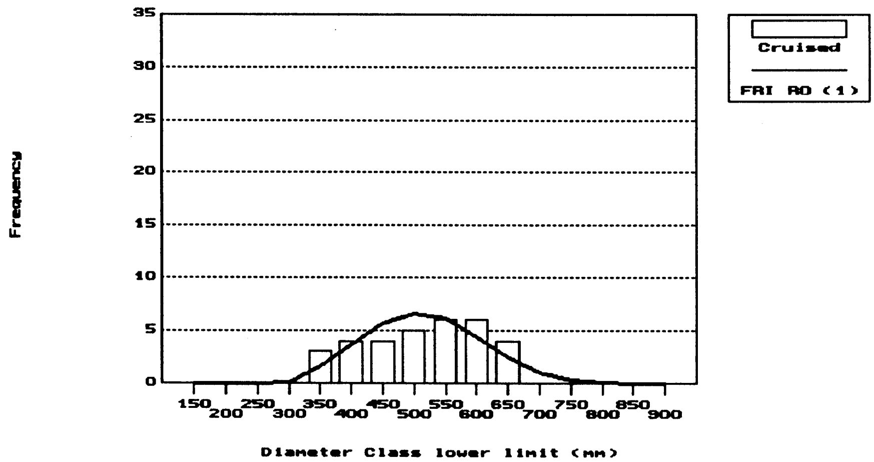
Not Significant for p < 0.2

250 stems/ha Thinned age 9 Clearfelled age 23.8 (treatment 1)



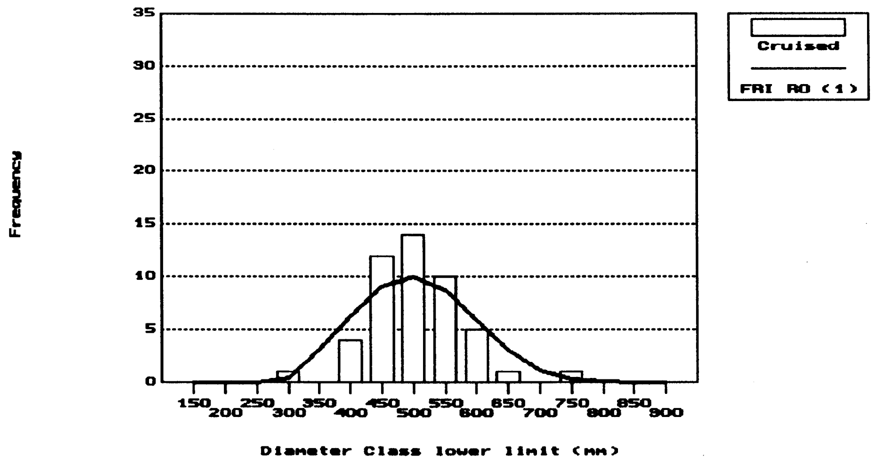
Not Significant for p < 0.2

200 stems/ha Thinned age 13 Clearfelled age 29.8 (treatment 2)



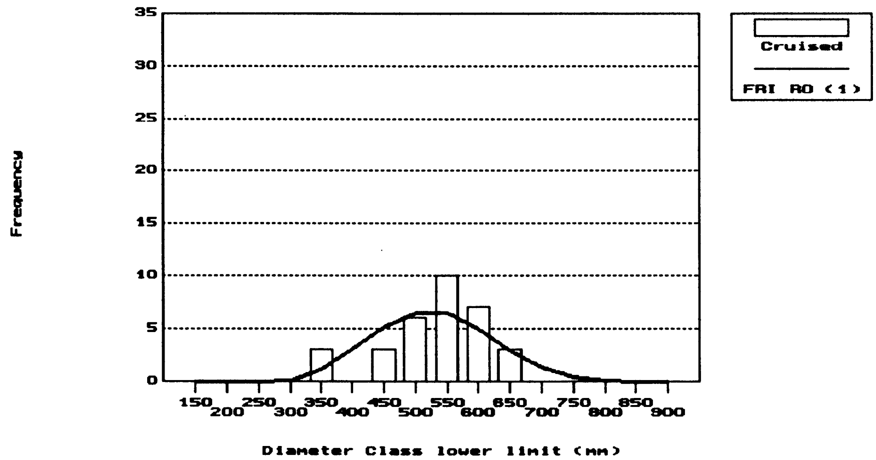
Not Significant for p < 0.2

200 stems/ha Thinned age 12 Clearfelled age 29.5 (treatment 7)



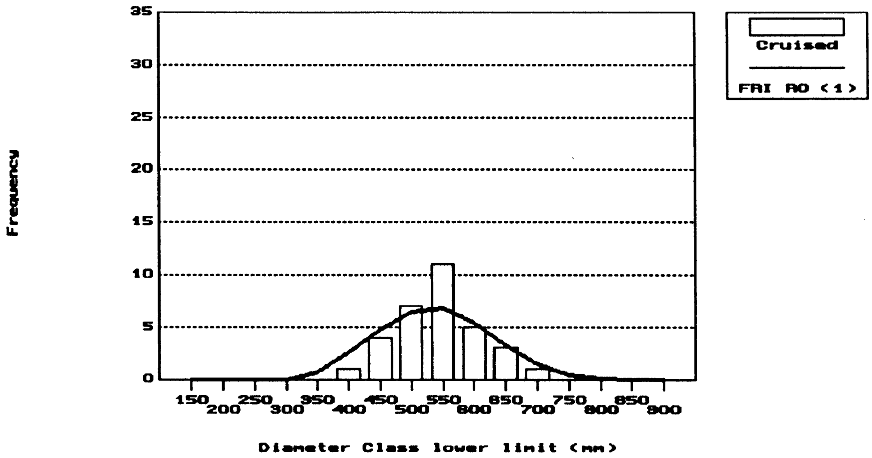
Not Significant for p < 0.2

200 stems/ha Thinned age 9 Clearfelled age 29.8 (treatment 8)



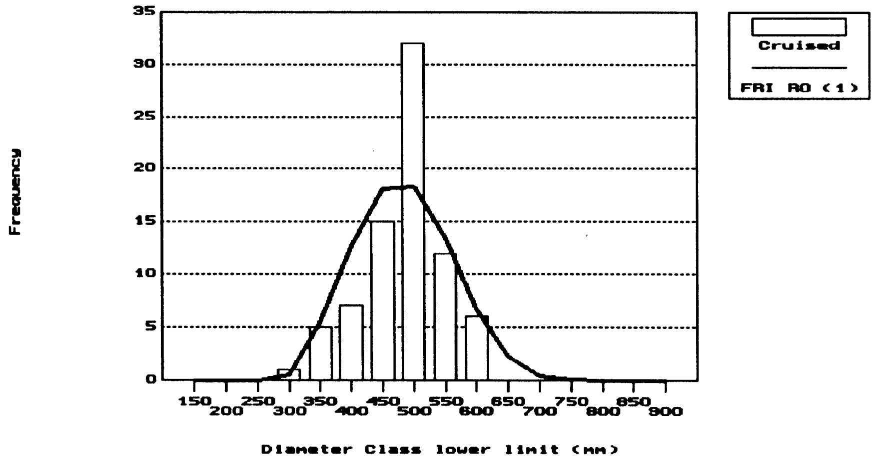
Not Significant for p < 0.2

200 stems/ha Thinned age 8 Clearfelled age 28.8 (treatment 9)



Not Significant for p < 0.2

200 stems/ha Thinned age 7 Clearfelled age 25.8 (treatment 4)



Significant at p >= 0.02

9.6 Method for Implying BIx from Proportion of Large Branched Logs

Based on discussion with Mark Kimberly.

MARVL only gives the volume of various grades, but the mean BIX for a plot can be infered from the proportion of unpruned logs that fall into S and L grades (can assume that almost no R is due to branches >14cm so this is all taken out by size before branching has to be considered).
Chris Inglis had found that branch size followed a normal distribution, with a standard deviation of 0.182 * BIx.
L and S grade logs are separated at a 6cm max branch size. From the branch size model:
BIX = 0.6426 * Largest Branch + 1.036
So a 6cm max branch size equates to a BIX of 4.89

For example:
If there was a volume of 100m3/ha of unpruned logs (TRV-R-P) and 70m^3 were in S grade, then the proportion of S to L grade is 0.70. So 70% of the volume has a BIX of less than 4.89

Want to find the Mean BIX for the plot.
As more than 1/2 of the volume is in S grade, the mean must be below 4.89
50% of the volume will be below the mean and 20% will be between the mean and 4.89 (the other 30% is L grade).
To find the 'distance' from the mean to the 4.89 cutoff we can use the cumulative normal frequency distribution: Look up the Z value that corresponds to an area under the standard normal curve of 0.20. The Z value in this case is 0.525 so:

$$Z = \frac{4.89 - mean}{stddev}$$

$$0.525 = \frac{4.89 - mean}{mean \times 0.182}$$

$$4.89 - mean = 0.525 \times mean \times 0.182$$

$$mean \times (1 + 0.525 \times 0.182) = 4.89$$

$$mean = \frac{4.89}{1 + 0.525 \times 0.182}$$

$$mean = 4.46$$

ie. A 70% proportion of logs in the small branched grade, implies that the mean branch index would be around 4.5