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Review of WURC stockpiling and sawmilling studies

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SUMMARY

The stockpiling and sawmilling research trials carried out since 1986 at the Wood Utilisation Research Centre of the Western Australian Department of Conservation and Land Management are reviewed in this report. The major species assessed were jarrah (*Eucalyptus marginata* Donn. ex Sm.) and karri (*E. diversicolor* F. Muell.). Other species assessed were marri (*E. calophylla* R. Br. ex Lindl.), and six species growing in the eastern Goldfields area: Dundas blackbutt (*E. dundasii* Maiden), York gum (*E. loxophleba* Benth.), gimlet (*E. salubris* F. Muell.), redwood (*E. transcontinentalis* Maiden), mulga (*Acacia aneura* F. Muell. ex Benth.), and northern cypress pine (*Callitris columellaris* F. Muell. sens. lat.). Western Australian-grown Tasmanian blue gum (*E. globulus* Labill. ssp. *globulus*), and rose gum (*E. grandis* W. Hill ex Maiden) were also assessed, as well as karri, red mahogany (*E. resinifera* Sm.), spotted gum (*E. maculata* Hook.) and tallowwood (*E. microcorys* F. Muell.) grown on rehabilitated bauxite minesites.

The stockpiling trials indicated that storing logs under a water spray schedule of 15 min in every 3 hours gave acceptable log quality with a 93 per cent saving in power and water. The sawmilling trials indicated the potential for processing small regrowth eucalypts into structural or appearance grade timber products, and the results confirmed the close correlation between log size and sawn recoveries.

The comparatively high incidence of defects, e.g. knots, borer damage, rot, bow and spring reduced graded recoveries in all species.

INTRODUCTION

The Department of Conservation and Land Management's (CALM) Wood Utilisation Research Centre (WURC) at Harvey was originally established in 1984 to carry out both applied and basic research to assist the Western Australian (WA) timber industry. The 1993 WURC Mission Statement reads: 'to provide scientifically sound information to improve the efficiency and timber utilisation in Western Australia'.

The major research program carried out by the WURC was the Small Eucalypt Processing Study from 1986 to 1990 to develop techniques for value-adding of small regrowth eucalypt thinnings. The program was funded by the Commonwealth through a Public Interest Project on a $1 for $2 basis. The program carried out applied research in stockpiling logs, sawmilling, timber drying and assessment of wood properties, before developing VALWOOD® (an edge- and face-glued panel) and the CALM Solar-assisted kilns, and commencing a computer model of the timber industry. The individual trials were previously reported in WURC Reports or WURC Technical Reports, as part of a Commonwealth requirement for quick dissemination of research results.

This review discusses the research trials on stockpiling and sawmilling of regrowth and plantation-grown eucalypts carried out at the WURC since 1986. The major species assessed were jarrah (*Eucalyptus marginata* Donn. ex Sm.) and karri (*E. diversicolor* F. Muell.). Other species assessed were marri (*E. calophylla* R. Br. ex Lindl.), and six species growing in the eastern Goldfields area: Dundas blackbutt (*E. dundasii* Maiden), York gum (*E. loxophleba* Benth.), gimlet (*E. salubris* F. Muell.), redwood (*E. transcontinentalis* Maiden), mulga (*Acacia aneura* F. Muell. ex Benth.), and northern cypress pine (*Callitris columellaris* F. Muell. *sens. lat.*). Western Australian-grown Tasmanian blue gum (*E. globulus* Labill. ssp. *globulus*), and rose gum (*E. grandis* W. Hill ex Maiden), were also assessed, as well as karri, red mahogany (*E. resinifera* Sm.) spotted gum (*E. maculata* Hook.) and tallowwood (*E. microcorys* F. Muell.) grown on rehabilitated bauxite minesites.

STOCKPILING

A major factor in the WA timber industry is the need for sawmillers to stockpile logs for processing during the winter months. The logging season is restricted in order to minimize the spread of dieback, caused when *Phytophthora cinnamomi* Rands fungal spores are carried in wet soil on machinery or transport. Industry experience had confirmed that dry stockpiling of logs results in unacceptable degradation, particularly end splitting and insect attack. Stockpiling under water sprays is essential to reduce end-splitting and surface checking of logs, and to reduce the incidence of insect attack, particularly by the bardi borer (*Phoracantha semipunctata*). There is evidence from the eastern States that stockpiling under water sprays can also reduce the level of growth stresses in ash-type eucalypts, which will consequently reduce the amount of bow and spring in the sawn product (Waugh 1980).

White (1990) compared the efficiencies of a high pressure spraying system, with its high volume knocker-type sprinklers, and a low pressure/low volume black polypipe 'Soaket' system. Twenty cubic metres of bark-on and debarked regrowth jarrah sawlogs, including a mixture of butt and crown logs, were assessed under each system. The components and costs of each system are given. Each log was assessed for sapstain, insect damage, surface checking and decay before sawing. The results indicated that both systems were capable of maintaining regrowth jarrah logs in good condition through the severe summer conditions. The daily consumption of water using continuous watering was 26.6 kL and 6.9 kL for high pressure and low pressure systems respectively for 20 m^3 of logs. White (1990) recommended the low pressure system where capital and water are limiting factors and where stockpiles are small.

Although Brennan (1988) reported a stockpiling trial of WA sheoak (*Allocasuarina fraseriana* (Miq.) L. Johnson), the major trial on regrowth eucalypts was that by Brennan *et al.* (1990) on stockpiling regrowth jarrah and karri using the high pressure watering system. The trial was conducted in two parts: the first part, using jarrah logs, compared the effects of water spray schedules ranging from continuous (during daylight hours) to 1 h on : 3 h off, by assessing log degradation and borer infestation in the stockpiling, and the amount of bow and spring in flitches, wings and sawn boards after sawmilling. The results indicated that the most extreme watering schedule assessed (1 h on : 3 h off) did not adversely affect the quality of logs or sawn timber.

The results of the first part were the basis for the second part of the study, in which regrowth karri logs were included with the regrowth jarrah. More radical watering schedules were used, although karri is known to be more susceptible to splitting than is jarrah. The results indicated that a 15 min on :165 min off schedule (i.e. 15 min in each 3 h) gave satisfactory results, and this would result in a 92 per cent savings in water and electricity compared with continuous water spraying. The technical details of the high pressure system are given by Brennan *et al.* (1990). Logs that were dry stockpiled developed major splitting, which made many of them unsuitable for milling, and those milled produced very low recoveries.

SAWMILLING

Jarrah

The first major trial was an assessment of the effects of sawmilling and stockpiling of 50-year-old regrowth jarrah (White 1989b). By measuring bow and spring in flitches and boards, White compared the sawn graded recoveries from logs, either freshly sawn or stockpiled under water sprays before milling (and sawn using one of three different sawmilling patterns), in reducing the effects of growth stresses in these regrowth logs. The sawmilling patterns assessed were based on those described by Waugh (1980) and Machin (1981) and are shown in Figure 1. Data were collected for four log length classes and five log diameter classes. The results indicated that, in both freshly sawn and stockpiled treatments, log length had no effect on sawn graded recoveries, but as expected, increasing log

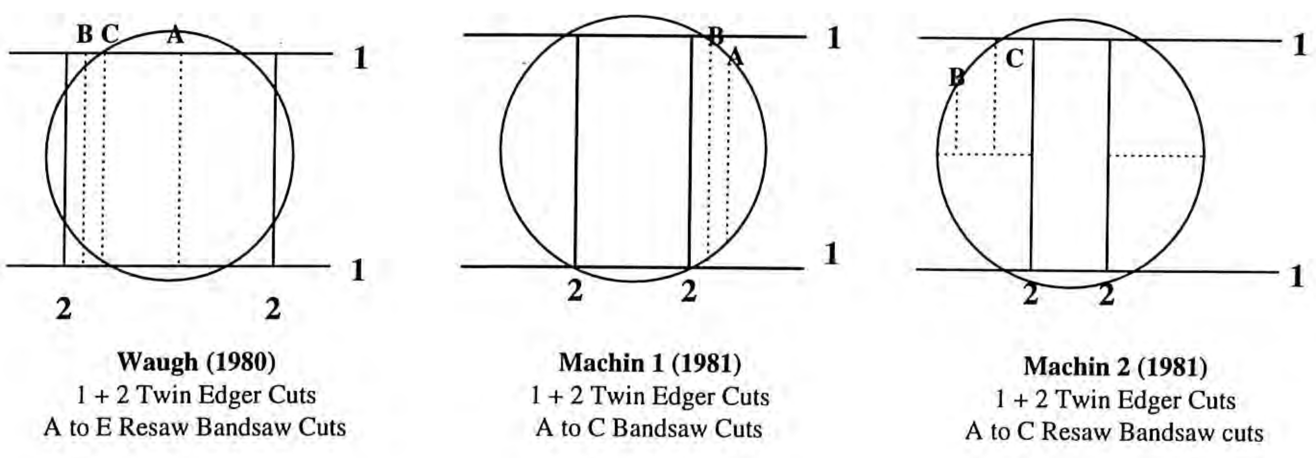

Figure 1. Sawing patterns tested in jarrah sawmill trial.

diameter resulted in increasing recoveries. The recoveries from each sawing pattern were similar, ranging from 20.2 per cent to 22.2 per cent. Log diameter differences in each treatment would explain the small variation. The three different sawing patterns resulted in similar levels of bow and spring in flitches, but bow in boards was slightly larger in the stockpiled material. All were within Australian Standard AS 2082-1979 specifications (Standards Association of Australia 1979).

Brennan and Ward (1990) summarized studies on the green sawn recoveries of 28 mm thick regrowth jarrah boards milled from the following areas in the northern jarrah forest :

Banksiadale Road, Dwellingup District;
Inglehope Plots, Dwellingup District;
Kent Block, Harvey District;
Ross Block, Harvey District.

The Inglehope Plots logs were either fresh-sawn or stockpiled for three to four months before milling, and the standard log specification for small regrowth eucalypt logs used in the study is given in Appendix 1 of the present review.

The sawing pattern based on Waugh (1980) was followed, using a twin-edged saw with overhead beam feed for initial breakdown, and a vertical bandsaw for resawing. The appearance grade timber produced was graded to WURC Grading Rules (Appendix 2), which are similar to the specifications of the 'Industry Standard for Seasoned, Sawn and Skip-dressed WA Hardwoods', subsequently published (FIF (WA) 1992). The latter is now the standard reference.

The dimensions and green sawn recoveries from the logs from the different areas are given in Table 1.

The combined data showed that sawn graded recovery was not affected by log length, but increased significantly with increasing log diameter. Apart from the constraints of milling small diameter logs, brittle heart was the major factor reducing recovery, followed by knots, rot, kino, wane and insect damage.

Brennan and Pitcher (1992) also assessed green sawn recoveries from regrowth jarrah grown under different stand densities in the Inglehope Plots, Dwellingup District. The nominal stand basal areas under bark of five different treatments ranged from 7.0 to 22.0 $m^2 ha^{-1}$, but only the lowest three basal area treatments (7.0, 11.0 and 15.4 $m^2 ha^{-1}$) were used for this study. Before thinning again the actual basal areas were 12.8, 17.7 and 21.8 $m^2 ha^{-1}$ respectively. Both sawlogs and poles were extracted. The sawlog specification is given in Appendix 1.

The logs were broken down by two passes through a twin-edged saw with overhead beam feed to produce a centre baulk, and the baulk and wings were resawn on a vertical bandsaw or circular saw. Logs were either sawn fresh or milled after stockpiling under water sprays for three months. Log degradation was assessed, and bow and spring of flitches and boards measured to compare the two treatments, using combined data from the three stand basal areas.

Stockpiled logs had less end splitting than logs sawn fresh, which were stored in a dry stockpile until actually milled. The results indicated that in thinning the same basal area from different stands, the lowest stand basal area (thinned from 12.8 to 4.8 $m^2 ha^{-1}$) produced twice the number and 2.5 times the volume of sawlogs produced from the medium stand basal area (thinned from 21.8 to 15.8 $m^2 ha^{-1}$). The effects of log diameter class and log length were assessed for the combined data, and while the green sawn recovery increased with increasing log diameter, there was a trend to decreasing recoveries with increasing log length (which could be attributed to variations in stem straightness). The sawn recoveries from the fresh-sawn and stockpiled logs were 24.7 and 20.4 per cent respectively, but the mean s.e.d.u.b. (small end diameter under bark) figures were 22.6 and 20.2 cm, which would explain most of the variation. The graded recoveries for the combined material, using the WURC Grading Rules (Appendix 2), were as follows: Clear (12.1 per cent), Feature (32.2 per cent), Processing (16.6 per cent), Merchantable (37.7 per cent), and Reject (1.5 per cent). The major defects in Feature grade material were

TABLE 1
Mean small end diameter (s.e.d.u.b.), log length and green sawn recovery percentage of timber milled from four different log sources.

LOG SOURCE	S.E.D.U.B. (cm) MEAN	S.D.	LOG LENGTH (m) MEAN	S.D.	RECOVERY (%) MEAN	S.D.
Banksiadale Road	21.2	4.3	3.6	1.2	21.6	8.3
Inglehope Plots						
(fresh-sawn)	22.8	5.4	3.4	1.1	25.6	10.2
(stockpiled)	20.4	3.4	3.6	1.1	21.4	8.7
Kent Block	19.3	3.9	3.3	0.8	21.2	8.4
Ross Block	20.9	3.6	5.0	1.0	26.4	8.2
Mean	20.9	5.3	3.8	1.2	23.2	9.2

epicormics, in Processing grade skip, knots and epicormics, and in Merchantable grade surface checks, knot holes, knots, gum veins and skip.

A study of sawn recoveries of regrowth jarrah, which actually included some karri logs, assessed two grades of regrowth jarrah logs and a single grade of regrowth karri logs that were substantially smaller than the mature logs currently supplied to industry (White and Siemon 1992). Four log size classes were assessed, with combinations of 15-19.9 cm or 20-30 cm s.e.d.u.b. and 2.4 m or 3.6 m length. The log specifications were: (1) Regrowth 1st Grade logs had minimum 50 per cent millable wood at the worst end, with maximum sweep of 30 mm in any 2 m length in one direction only. (2) Regrowth 2nd Grade logs had minimum 30 per cent millable wood at the worst end, with similar sweep provision. In both grades minimum acceptable log length was 1.2 m, and minimum s.e.d.u.b. was 150 mm. The sawing strategies used were designed to produce structural timber, boards, or a combination of both products. Any defects that required docking to upgrade the boards were assessed.

Analysis of the data indicated significant differences in sawn graded recovery between species and grade ($p < .001$) which was the result of 2nd Grade jarrah logs producing lower grade timber. As expected, log size class and the species *x* size class interaction were significantly different at the same probability level. The mean log diameter and graded recoveries in each log size class are given in Table 2.

The mean s.e.d.u.b. figures for 1st Grade jarrah logs indicate some bias in sampling with three treatments around 20 cm in the 15-19.9 cm s.e.d. class (Table 2). However, the average 5 cm difference between the two log diameter classes provides adequate variation. The ungraded sawn recoveries were closely associated with log size classes, and long slender logs (3.6 m, 15-19.9 cm) gave lowest recoveries. The 1st Grade logs in the largest diameter class (20-30 cm) produced a mean 35.8 per cent ungraded recovery, similar to that reported from industry milling of mature logs. The mean graded recovery over the three treatments in this diameter class was 23.8 per cent (Table 2).

The timber was graded into structural or appearance grades, as discussed below.

The mean graded recoveries in the smallest size class (2.4 m, 15-19.9 cm s.e.d.) showed major differences between 1st Grade jarrah and the other two log sources. As expected, the 2nd Grade jarrah logs produced low recoveries, but log quality was obviously a problem in 1st Grade karri logs with defects that could not be predicted by inspection of log ends.

The major defects docked from structural timber to comply with Structural Grade 3 of AS2082-1979 (Standards Association of Australia 1979) or from boards to comply with Appearance Grades 1 and 2 of AS 2796-1985 (Standards Association of Australia 1985), in decreasing order of occurrence, were as follows :

1st Grade jarrah	wane, knots, end splits
2nd Grade jarrah	rot, gum veins, knots
1st Grade karri	knots, insect attack

A detailed description of defect occurrence is given in White and Siemon (1992).

TABLE 2

Mean graded recovery from different sawing strategies for graded regrowth logs in different length and diameter classes.

Sawing Strategy	Log length (m)	s.e.d. Class (cm)	1ST GRADE JARRAH Mean s.e.d.u.b. (cm)	1ST GRADE JARRAH Mean graded recovery (%)	2ND GRADE JARRAH Mean s.e.d.u.b. (cm)	2ND GRADE JARRAH Mean graded recovery (%)	1ST GRADE KARRI Mean s.e.d.u.b. (cm)	1ST GRADE KARRI Mean graded recovery (%)
S	2.4	15-19.9	20.0	25.1	18.7	0.0	17.4	1.5
B	"	"	19.7	28.4	17.7	4.5	17.8	16.2
B & S	"	"	19.7	24.6	18.7	8.9	18.6	5.6
S	2.4	20-30	25.4	30.4	26.0	6.5	25.4	23.2
B	"	"	25.5	35.7	26.6	10.7	27.5	51.9
B & S	"	"	23.0	27.2	23.0	12.6	26.1	29.3
S	3.6	15-19.9	20.0	14.3	18.4	0.0	18.1	13.4
B	"	"	19.9	13.9	18.8	0.6	18.2	10.8
B & S	"	"	18.3	10.1	19.1	1.6	18.8	13.7
S	3.6	20-30	25.6	26.7	25.4	5.5	26.3	24.0
B	"	"	24.8	22.1	24.5	2.1	27.5	14.6
B & S	"	"	26.9	22.5	26.5	5.1	27.0	26.1

S = structural timber
B = boards

Karri

White (1989c) reported the results of a regrowth karri sawmilling trial after two years stockpiling logs under water sprays. While stockpiling under water sprays is essential, as explained previously, the trial was designed to assess whether long term stockpiling produced any adverse effects on log quality. The logs were sawn on a twin-edged saw with overhead beam feed for initial breakdown and a circular resaw, using a sawing pattern based on Machin (1981). Logs exceeding 40 cm s.e.d.u.b. were broken down on an old sizing carriage. The green structural grade products were graded to AS 2082-1979 (Standards Association of Australia 1979), and appearance products to TAS-G4 (1985) (FPA (WA) 1985) and AS 2796-1985 (Standards Association of Australia 1985) after drying in a progressive tunnel kiln, and dressing. The green timber was stored under water spray and regraded after three months to assess possible reduction in growth stresses and therefore reduced bow and spring.

The mean log size was 32 cm s.e.d.u.b. The recoveries are given in Table 3.

Kino and brownwood associated with rot were the major factors for downgrading structural grades, but in the small volume of appearance grade material milled, insect damage was the major factor. Bow was considerably reduced in the green structural timber after three months storage under water sprays.

The major karri sawmilling study assessed structural and appearance grade timber milled from six different sites in the Southern Forest Region, representing a range of age classes (49-70 years) and dominance classes (dominant to suppressed stems) (Brennan *et al.* 1991). Basic details of the plots, which represent the range of site productivity in older regrowth stands, are given in Table 4.

The logs were sawn into structural timber (40 or 50 mm thick), and appearance grade boards (30 mm thick) that were air-dried for nine months before final drying to 8 per cent moisture content in a kiln. Structural timber was graded to AS 2082-1979 (Standards Association of Australia 1979); appearance grade timber was graded using WURC Grading Rules (Appendix 2).

Brennan *et al.* (1991) gave detailed results on log size distribution, and structural and appearance grade recoveries for each plot, showing the effect of site quality and dominance class.

The mean recoveries of timber milled from these regrowth karri logs are compared using site quality, log position and dominance class (Table 5). The overall relationship between log diameter class and green-sawn recoveries is shown in Figure 2.

The occurrence of defects in timber from each site type was assessed by Brennan *et al.* (1991). The major variation was in the incidence of borer damage, where the percentage of pieces of timber affected ranged from 34 per cent in Plot 4 to 87 per cent in Plot 2. While there was some rot associated with this borer damage, the overall occurrence of rot and brownwood varied in each plot. Incidence of knots, gum veins, sapwood, etc. was uniform.

The combined regrowth jarrah and karri study by White and Siemon (1992) was reported previously.

Twelve-year-old karri logs grown on a rehabilitated bauxite minesite were one of four species assessed by milling 18 mm thick appearance grade boards suitable for panel production (Brennan 1992). Although logs were comparatively large (mean s.e.d.u.b. and 21.9 cm), the dried dressed recovery of 10.8 per cent was low because of defects attributed mainly to borer damage.

TABLE 3

Green sawn structural and appearance grade recoveries from milling regrowth karri logs.

Structural Grade	Recovery (%) (based on log volume)
1	10.5
2	31
3	11.1
4	1.3
Reject	4.2
Appearance Grade	
Furniture	0.02
Standard	0.33
Utility	0.03
Commons	0.54

TABLE 4

Stand description of regrowth karri trees from six sites in the Southern Forest Region.

Plot No.	Location	Stand Age (years)	Site	Basal Area (m^2ha^{-1})	Stocking (stems ha^{-1})
1	Murtin Block	70	Very low	30.4	304
2	Sutton	58	Low	39.0	288
3	Channybearup	55	Med	30.3	460
4	Channybearup	49	Med	43.7	631
5	Court	53	High	23.8	364
6	Yanmah	51	Med	36.8	519

TABLE 5

Mean recoveries of timber by site quality, log position and dominance class.

Site Quality	Recovery (%)	Log Position	Recovery (%)	Dominance Class	Recovery (%)
High	36.6	Butt	30.7	Dominant/ co-dominant	32.8
	(11.9)[a]		(12.8)		(11.4)
Medium	27.4	Mid	28.8	Sub-dominant/ suppressed	19.6
	(13.7)		(10.6)		(12.4)
Low	20.4	Crown	16.4		
	(13.1)		(12.5)		

[a]S.D. is given in parentheses below the mean value.

Marri

While marri is a major species in the forests of south-west WA, its use for sawn timber has been restricted because of extensive occurrence of kino veins. It has been used for structural purposes, weatherboards and case material, but has potential for furniture manufacturing when the timber is comparatively free of kino veins.

White (1989a) described a sawmilling trial of regrowth marri from Pimelia Plantation in Pemberton District, which produced structural and some appearance grade products. The logs had been stockpiled under water spray, and milling was done using a twin-edged saw and two-operator resaw bench. The green recovery was 35.1 per cent, which reduced after docking to remove large knots and kino veins.

The timber was dipped in borax solution to prevent the powder post borer (*Lyctus* spp.) attacking the sapwood, and then block-stacked. The small quantity of appearance grade material produced was kiln-dried, dressed, and graded to AS 2796-1985 (Standards Association of Australia 1985), and the green structural material was graded to AS 2082-1979 (Standards Association of Australia 1979). The final recovery was 23.0 per cent structural grade and 3.0 per cent appearance grade, a total of 26 per cent.

Goldfields species

Assessment of response to sawmilling was part of an overall study of the utilization potential of six species growing in the eastern Goldfields of WA, *viz*. Dundas blackbutt, York gum, gimlet, redwood, mulga and northern cypress pine (Brennan and Newby 1992).

Logs were sawn on a 'Forester 150' horizontal bandsaw, mainly into 14 mm thick boards, with some flitch material cut for demonstration purposes. There were problems with milling because of the high wood density of the species (except for the cypress pine). Feed speeds through the saws had to be reduced, and saw life before sharpening was required was reduced. Drying rates were about one-third of those achievable for jarrah and karri boards of the same thickness, because of the high density of the eucalypt and mulga timbers.

Tasmanian blue gum

Tasmanian blue gum is the major species grown specifically for pulp and paper production in south-west plantations, but it has the potential to be a major source of sawlogs for structural and appearance grade timber.

Thomson and Hanks (1990) milled forty-one 24-year-old Tasmanian blue gum logs from Willow Springs Arboretum in Nannup District, to produce either 40 or 50 mm thick structural timber or 30 mm thick appearance grade boards. A twin-edged saw with overhead beam feed was used for initial breakdown, and a vertical bandsaw for resawing. Sweep was the most common defect found in the logs, but large branches and angular swellings were also found. End splitting caused losses in recovery, even when freshly docked during preparation before milling.

The operators considered Tasmanian blue gum more difficult to mill than regrowth jarrah and karri, and a slower feed speed was required through the saws. Sixty-four per cent of the sawn recovery met the requirements of Structural Grade 3 (SG3) or better (Standards Association of Australia 1979), and 39 per cent of this was Structural Grade 1. Docking of merchantable material to remove defects near the ends of the pieces would increase recoveries of SG3 or better to 79 per cent.

The major defect in the structural timber was excessive bow (which indicated high levels of growth stresses),

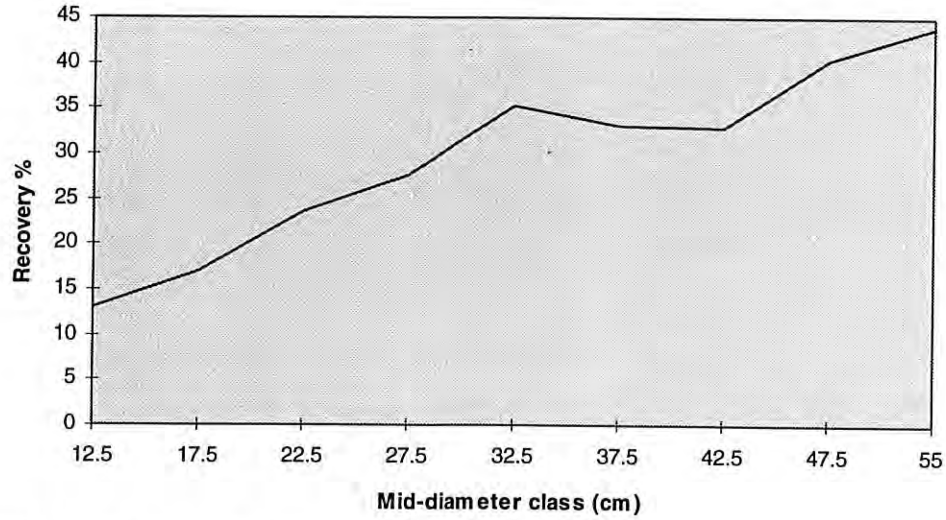

Figure 2. Effect of log diameter class on sawn recovery of karri.

followed by knots, kino veins, borer holes, spring and shakes. In the appearance grade timber, grading was carried out using the principle of 'phantom docking' (i.e. the position for docking is marked and lengths of different grades estimated, without the actual docking being done). Only 20.1 per cent of the 1.2 m^3 milled made Clear or Feature Grades, with 10.5 per cent Processing, 68.7 per cent Merchantable, and 0.7 per cent Reject material. The incidence of kino veins was the major reason for the low recovery of Clear or Feature grades, averaging more than one per board. Knots were the major defect on 32.2 per cent of the boards, followed by surface checking, cup, and skip. In general, the results indicated that appearance grade timber for furniture or joinery use would be a small percentage of the sawn timber, but structural timber recoveries were satisfactory.

Brennan *et al.* (1992) carried out a sawmilling study of very young Tasmanian blue gum, using 8-year-old trees from a former pastured site and 10-year-old trees from a former bush site. The initial breakdown was done using a 'Forestor 150' horizontal bandsaw, and boards were resawn to 18 mm thickness using a vertical bandsaw. Details of the drying schedules used are given, as well as basic data on shrinkage and density of this young plantation-grown material (Brennan *et al.* 1992).

The green sawn recovery of 18 mm thick boards was 52.7 per cent, with ex-pasture and ex-bush material producing 55.2 per cent and 49.9 per cent respectively. Dried dressed recovery of 10 mm thick boards (allowing for shrinkage and dressing) was 28.3 per cent based on log volume.

The data are broken down further into log s.e.d.u.b. class and log length class. The shrinkage in width of the mainly backsawn boards was 9.5 per cent, and in thickness 6.9 per cent. The mean basic density was 470 kg m^{-3}. The boards were subsequently used for VALWOOD® panel manufacture, but that aspect is outside the scope of this report.

Rose gum

The rose gum logs used in Hanks' (1990) sawmilling trial were first thinnings from a 1964 planting in the Willow Springs Arboretum in Nannup District. Two sawing methods were assessed : (1) 'Forestor 150' horizontal bandsaw for initial breakdown of logs, and resawing on a vertical bandsaw; (2) twin-edged saw for initial breakdown, and resawing on a vertical bandsaw. Boards were milled to 30 mm thickness, and then initially air-dried to below fibre saturation point and kiln-dried to final moisture content at temperatures increasing from 30° C to 80° C for over 2 h, then 80° C for 6 h.

The logs milled using the 'Forestor 150' for initial breakdown had green sawn recovery of 39.4 per cent, compared with the twin-edged saw breakdown and recovery of 32.1 per cent. With the former, logs were slightly larger, the saw has a smaller kerf (i.e. width of cut) and taper sawing can be done, which produces better recovery.

The dried dressed recoveries were 24.5 per cent and 20.0 per cent respectively. However, only 22.4 per cent of the boards produced were Clear or Feature grade, with 23.3 per cent Processing, 52.0 per cent Merchantable, and 2.3 per cent Reject. The major defects were knots in 50.3 per cent of boards, kino in 24.0 per cent, and borer damage in 20.2 per cent. Many boards were downgraded from Clear to Feature because of epicormics.

Red mahogany

The logs milled in this trial by Raper (1990) came from 23-year-old trees grown on a rehabilitated bauxite minesite in Turner Block, Dwellingup District. The mean s.e.d.u.b was only 190 mm (S.D. 2.4 mm), and mean length 2.7 m (S.D. 0.8 m). Two passes through a twin-edged saw with overhead beam feed produced a central baulk which was resawn on a vertical bandsaw to produce 115 x 34 mm pieces. Defects were docked, and a phantom grading done at the docker. After two weeks curing at high humidity, the timber was air-dried to below fibre saturation point, and then kiln-dried at 90°C to final moisture content. The boards were then pre-dressed to 100 x 25 mm and graded to Structural Grade 3 of AS 2082-1979 (Standards Association of Australia 1979).

The results confirmed the overall low quality of the logs, with a high incidence of defects. Some logs were actually rejected. The occurrence of decayed wood around branch stubs was of particular concern, and wandering heart was a problem. Grading at the docker before drying indicated the following defects: knots - 97.4 per cent of boards affected; sapwood - 94.9 per cent; borer damage - 76.9 per cent; gum pockets - 76.9 per cent; and rot - 28.2 per cent, i.e. combination of defects occurred in most boards. The WURC Grading Rules (Appendix 2) were used in the phantom docking exercise. There was no Clear grade material, 5.3 per cent Furniture grade, 16.1 per cent Processing, 68.5 per cent Merchantable, and 10.1 per cent Reject. Large knots, gum pockets, borer damage and rot were the major defects, resulting in the high percentage of Merchantable grade. The SG3 recovery after drying and dressing was only 12 per cent of log volume.

Twelve-year-old red mahogany logs grown on a rehabilitated minesite were milled into 18 mm thick boards, together with karri, spotted gum and tallowwood (Brennan 1992). The red mahogany boards were not kiln dried because the high incidence of defect, largely attributable to borer damage, prevented them satisfying the requirements for appearance grade products.

Spotted gum

The 13.5 per cent dried dressed recovery (based on log volume) of spotted gum timber from 12-year-old trees grown on a rehabilitated minesite was mainly attributable to the small log size (mean s.e.d.u.b. of 14.4 mm). There were few problems with defects in the timber (Brennan 1992).

Tallowwood

This material was 19-year-old timber, also milled from logs from a rehabilitated minesite. It was supplied to the WURC as 25 mm thick boards, which were dressed green to 18 mm before drying. Recovery data based on log volume were not available, but there were no particular problems with defects (Brennan 1992).

GENERAL DISCUSSION

The series of stockpiling and sawmilling trials carried out at the WURC since 1986 has provided useful information on the potential of small regrowth eucalypts for processing into either structural or appearance grade timber products. The effects of silvicultural treatment on jarrah log production were discussed by Brennan and Pitcher (1992), and the effects of site quality and dominance class on karri log production by Brennan *et al.* (1991).

General experience has confirmed the importance of minimizing the time between felling trees and either stockpiling or processing the logs. Stockpiling under water sprays is essential during the summer months to prevent end splitting, minimize insect attack, and possibly to reduce growth stresses. White (1990) found both high pressure and low pressure spray systems were effective. The former was more expensive but had advantages where water availability was not a problem. The supplementary research by Brennan *et al.* (1990) found that a watering schedule of 15 min on in each 3 h did not adversely affect log quality. Extended storage under water sprays was shown by White (1989c) to have no adverse effects on karri logs, just an economic disadvantage.

Sawmilling small regrowth eucalypt logs has one major disadvantage, *viz.* the occurrences of growth stresses, and *Eucalyptus* is the most susceptible of all genera (Kubler 1987). The problem decreases with increasing stem diameter, but the major effect in small logs is decreased sawn recoveries and increased bow and spring in the sawn timber. The production of backsawn boards (with growth rings parallel to the width) is recommended because bow can be reduced in drying, but the spring in quarter sawn boards cannot.

The trials confirmed that sawn recovery is closely related to log diameter, but the economies of milling logs smaller than 20 cm s.e.d.u.b. would be very doubtful because of low recoveries. The productivity rates were not assessed in any of the studies, but would obviously be substantially reduced using a small-log resource. Log length generally had no effect on sawn recoveries provided that stem straightness was acceptable; the exceptions were the Brennan and Pitcher (1992) trial where sawn recoveries decreased in long slender logs, and the White and Siemon (1992) trial where the 2.4 m, 15-19.9 cm class logs had higher recoveries than the 3.6 m, 15-19.9 cm class.

The milling equipment used for processing small regrowth logs has a significant effect on sawn recoveries, with 7-8 mm kerf of twin-edged circular saws compared with 3 mm kerf of bandsaws. The twin-edged saw has the advantage of reducing the effect of growth stresses by producing a stable central flitch, although the wings are bowed. The alternative method of using a linebar carriage and taper sawing to process regrowth eucalypt logs has been used for ash-type eucalypts. Accuracy of sawing has a major effect on the subsequent graded dried dressed recoveries, because undersized boards can twist between the stickers (i.e. strip sticks) during drying and cause problems when dressing the timber. The results of the WURC trials consequently provide a conservative guide to the ungraded sawn recoveries from regrowth and plantation-grown eucalypt logs.

Apart from the smaller log dimensions, the other major factor encountered in the sawmilling trials was the high incidence of defects, *viz.* knots, borer damage, rot, bow and spring were the major defects encountered. Consequently, there were major differences between the ungraded and graded recoveries in different species. The 2nd Grade jarrah and 1st Grade karri milling study reported by White and Siemon (1992) and the red mahogany study (Raper 1990) provided good examples.

Regrowth jarrah generally provides satisfactory sawn timber, although it is susceptible to borer (mainly bardi) and fungal attack. Branch size, and hence knot size, tend to be less significant. The karri logs assessed had a higher incidence of borer larvae attack, either the bullseye borer (*Tryphocaria* sp.) or cossid moth (*Xyleutes* sp.), as well as brownwood, which has been confirmed as incipient rot. Growth stress levels are comparatively high, and bow and spring reduce the graded recoveries.

Marri, like most bloodwoods, is susceptible to kino formation as a result of wounding, whether by insects, fire or mechanical damage. The kino veins produced are the major reason for the species' limited use as timber, as well as regular occurrence of damage by bardi or bullseye borers. The size of the resource means that it is essential to find an economic use, and it would be a definite advantage when value-added timber conforming to FIF (WA)(1992) specifications can be milled.

The sawmilling studies of Tasmanian blue gum (Thomson and Hanks 1990; Brennan *et al.* 1992) provided useful data on a rapidly expanding resource. Although the major planned use of the species is pulp and paper production, there is definite potential for structural and appearance grades. Although Thomson and Hanks (1990) produced low recoveries of appearance grade timber, there is a need for light coloured timber for furniture and flooring. Brennan *et al.* (1992) milled thin boards, which included reasonable proportions of face grade timber. The fast growth rates of the species could justify pruning of potential sawlogs to produce value-added products.

The rose gum sawmilling study (Hanks 1990) produced satisfactory results, but the red mahogany study (Raper 1990) indicated that wood quality was a major problem with trees grown on a rehabilitated minesite, owing to borer damage and rot associated with large knots.

Spotted gum and tallowwood grown on similar sites have potential for the production of appearance-grade timber.

Overall, the trials produced useful data on the sawn recoveries of structural and appearance grade timber milled from small regrowth logs of several eucalypt species. They also indicated the need for an integrated approach to carry out basic research on susceptibility to borer and fungal attack, and applied research on the interaction between borer, rot, silvicultural treatment and wood quality. A karri research strategy has been prepared and an integrated research project initiated.

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APPENDIX 1

Specification for regrowth sawlogs.

1. Small end diameter under bark (s.e.d.u.b.)

   Minimum 150 mm
   Maximum 350 mm

2. Large end diameter under bark (l.e.d.u.b.)

   Minimum 175 mm
   Maximum 400 mm

3. Length

   Any of the following, aiming for long lengths:

   2.4, 3.6, 4.8, or 6.0 m

4. Quality

   Straightness - maximum 30 mm sweep in any 2.1 m length.
   Log ends at least 50 per cent solid wood.
   Both log ends cut square.
   No deformities such as dry sides, bumps or protrusions.

Note : Logs may be docked to shorter length if sweep is excessive or short lengths are required.

APPENDIX 2

WURC Specification for grading regrowth eucalypt timber (1990).

These grade rules are intended for use with regrowth eucalypts, particularly jarrah. However, material from mature trees may also be graded to these rules.

The rules are intended for use in the sorting of dry, pre-dressed boards into one of four grades. The sizes are based on the optimum metric size, taking account of increased shrinkage, section and length requirements of the appearance grade markets, as well as the capacity of the log resource to provide these sizes.

The grades are:

CLEAR GRADE
FEATURE GRADE
PROCESSING GRADE
MERCHANTABLE GRADE.

These grades will apply to sections dressed to 2 mm over the finished size of 10, 30, 40, 60, 80, 100, 150, or 180 mm.

Lengths will range from 0.6 m, in increments of 0.3 m, to a maximum of 3.6 m. Timber must be seasoned to 10 per cent moisture content or below.

Each piece will be free of :

- Compression failures and other fractures including brittle heart and shake
- Decay and included bark
- End splits.

CLEAR GRADE

Clear grade, as the name implies, will be clear of all imperfections excepting sapwood, which may occur on the back faces and up to three-quarters of the width of each edge. Sapwood within these limits will be accepted for the full length of the piece.

FEATURE GRADE

Will carry features to the following limits.

- **Sapwood** - No limit on one face or two edges; other face must be clear of sapwood.
- **Branch occlusions** or **Birds eye** : Sound, intergrown with seasoning splits up to 1 mm wide confined within the area of the feature.
- **Surface checks :** Length of individual checks not exceeding 200 mm. Width less than 1 mm. Only one check in any 50 mm width board face.
- **Knots :** Intergrown and sound not exceeding half the width of the face or 50 mm (measured at right angles to arrises). Separated in length by twice the width of the face.
- **Knot occlusions or holes :** Free from bark and decay. Associated voids not to exceed more than 25 mm^2, frequency as for knots.
- **Tight gum veins :** As for surface checks.
- **Pin holes :** Clean edge less than 1 mm diameter. Not more than 10 holes in 10 000 mm^2.
- **Grub holes :** Clean edge up to 100 mm^2. Can occur on one face or one edge. Not more than one per linear metre.
- **Bow and spring :** Maximum of 2 mm in any length up to 1.8 m.
- **Skip and machine marks :** Less than 1 mm deep on either face of edge.

PROCESSING GRADE

Acceptable features.

- **Sapwood :** Unlimited.
- **Birds eye :** Unlimited.
- **Surface checks :** Up to 300 mm long and 1 mm wide. One check in any 50 mm width of face. Can occur on both faces.
- **Knots :** Intergrown from bark and decay. May contain fractures or voids up to 200 mm^2. Frequency unlimited.
- **Knot occlusions or holes :** Free from bark and decay, not exceeding 200 mm^2.
- **Gum veins :** 3 mm in width, maximum of 500 mm in length intergrown.
- **Gum pockets or streaks :** As for knots and holes.
- **Bow and spring :** 5 mm in any length up to 1.8 m.
- **Skip or machine damage :** On one face only, not to exceed 2 mm. On two faces not to exceed 1 mm.
- **Pine holes :** Up to 2 mm in diameter, not more than 20 in any 10 000 mm^2.
- **Grub holes :** Clean edge up to 100 mm^2.

MERCHANTABLE GRADE

May contain features in excess of the above grades but must maintain structural integrity.