# Variation in Rotary Veneer Recovery from Australian Plantation *Eucalyptus globulus* and *Eucalyptus nitens*

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The processing of Australian plantation-grown *Eucalyptus globulus* and *E. nitens* into rotary veneer was shown to produce acceptable recoveries. Three plantation sites for each species were sampled. Silvicultural treatments (thinning and pruning) and growing environments varied between sites. Graded veneer recoveries were dominated by D-grade veneer across all six sites. Variation between the *E. nitens* sites was evident, with recoveries differing between sites reflecting silvicultural treatments. However, only minimal variation in recovery was shown between the *E. globulus* sites. The presence of similar levels of defects across all *E. globulus* sites indicates that the intensive silvicultural management at one site studied was not effective in the production of clear wood, and may possibly have adversely affected grade recovery. Veneer value analysis demonstrated only minimal differences between *E. globulus* sites. More variation was observed in the *E. nitens* value analysis; however, intensive silvicultural management implemented did not necessarily result in higher veneer value.

*Keywords: Eucalyptus; Veneer; Hardwood; Plantation; Processing; Grade quality; Recovery; Silviculture; Pruning; Thinning*

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## INTRODUCTION

The establishment of commercial hardwood plantation forests in Australia has seen rapid expansion in recent decades. Gavran (2013) reported that over two million hectares of plantation forestry now exists in Australia, of which about one million are hardwood species. While the industry's softwood sector in Australia has become well-established with reliance on a plantation resource, the hardwood sector remains largely dependent on native forests for log supply, especially for value-added products, including sawn timber and engineered wood products. With increasing limitations preventing access to some native forest areas, as well as the increasing availability of maturing hardwood plantations, interest exists from the processing sector as to the quality and suitability of plantation wood for value-added products. In addition, plantation growers are continuously seeking the processing streams and end uses that can provide the highest return from their plantations.

Of the one million-hectare hardwood estate, *Eucalyptus globulus* and *E. nitens* dominate (55% and 24%, respectively), with over three quarters of the plantation estate growing these two species (Gavran 2013). Small areas of some plantations have been established and managed with a high-value product focus. Wood *et al.* (2009) reported approximately 26,000 hectares of plantations principally located in Tasmania, which are predominantly *E. nitens* plantations that have been thinned, pruned, and managed for higher-value end-uses. The majority of the estate, however, has been managed for pulpwood markets and is dominated by trees selected primarily by pulpwood properties, and which are therefore mostly unthinned and unpruned. The result is a plantation estate that contains forest and wood qualities that are most likely not optimal for higher-value products. Understanding the quality and variability of the new resource is critical for the wood processing sector's ability to adapt and plan for the future.

Despite the original plantation establishment and management intent, less than favourable market conditions for Australian hardwood pulpwood have prompted the exploration of alternative higher-value markets. As reported by McGavin *et al.* (2014a), the processing of Australian-grown hardwood plantations into veneer using relatively new spindleless veneer lathe technology has the potential to produce veneer recoveries that are more favourable when compared with solid wood processing techniques.

While the veneer recoveries reported by McGavin *et al.* (2014a) were high, the grade recoveries were dominated by D-grade veneers when graded to Australian and New Zealand Standard AS/NZS 2269.0:2012 (Standards Australia 2012). The low recovery of higher-grade veneers (C-grade and better) was identified by McGavin *et al.* (2014a, b) as a challenge for commercial panel production with insufficient proportions of face veneer qualities to allow a standard commercial mix of structural panel products to be manufactured when using only a resource of this quality.

Defects such as bark and decay, encased knots, gum pockets, veneer splits, veneer roughness, and veneer compression were reported by McGavin *et al.* (2014b) as the main contributing defects that cause high proportions of *E. globulus* and *E. nitens* veneer to be restricted to D-grade, the lowest grade described within AS/NZS 2269.0:2012 (Standards Australia 2012).

The analyses reported by McGavin *et al.* (2014a, b) were performed on semi-commercial batches and reported at the species level to provide an overview of the performance of plantation estate eucalypt species. The two species examined in these studies have been previously shown to be genetically stable in different environments (Callister *et al.* 2011; Blackburn *et al.* 2014). Strong race stability and inter-site additive genetic correlations for additive effects in the traits examined were also high, indicating a lack of genotype x environmental interaction at the family level. The overall findings suggest that any significant variation in growth (and therefore associated veneer grade quality traits such as splitting and compression) can mainly be attributed to the stand's silvicultural management and the growing environment in that rotation period.

The objective of this study was to analyse the variation in veneer recoveries, including the defect assessment of veneer produced from a range of mid-rotation *E. globulus* and *E. nitens* plantations. The selected plantations under study represent a range of site qualities and management regimes (*e.g.*, thinning and pruning). The resulting analysis will contribute to the understanding of the quality and variability of the current *E. globulus* and *E. nitens* plantation resources, as well as offer guidance on future plantation management strategies.

## EXPERIMENTAL

### Plantation Sampling

Plantation trees were sourced from a total of six different sites (three sites for each species), representing a range of site qualities and management regimes (Table 1). The *E. globulus* plantations were located at Deans Marsh, Orford, and Mumbannar in Victoria, while the *E. nitens* plantations were located at Strathblane, Geeveston, and Florentine in Tasmania. Selected trees were representative of diameter at breast height over bark (DBHOB) and form of the surrounding plantation trees most likely to be suitable for veneer or solid wood processing (Table 2). From each selected tree, two 2-m logs were removed from between 0.5 m to 2.5 m and 3.7 m to 5.7 m. Each log was docked to 1.3 m immediately before peeling. The merchandising and docking strategy adopted aimed to simulate the common commercial practice of minimising the time between final billet docking and veneer processing. This is achieved in the industry by maintaining long log lengths after harvesting and only merchandising into billets immediately before processing. The 2 m log sections provided sufficient additional length which was sacrificed to allow the 1.3 m billets to be docked immediately before processing. This removed any degrade from the ends that resulted from the delay between harvesting and veneer processing.

**Table 1.** Plantation Management History

| Species | Plantation Location | Planting Year | Establishment at Stocking (Stems per Hectare)* | Age at Thinning (Years)* | Age at Pruning (Years)** |
|---|---|---|---|---|---|
| *Eucalyptus globulus* | Deans Marsh, Victoria (38°39′S, 143°92′E) | 1997 | 1000 | 4 and 10<br>(250 and 190) | 4 and 6<br>(4.5 and 6.5) |
| *Eucalyptus globulus* | Orford, Victoria (38°21′S, 142°07′E) | 2000 | 1190 | No thinning | No pruning |
| *Eucalyptus globulus* | Mumbannar, Victoria (37°96′S, 141°22′E) | 2000 | 1000 | No thinning | No pruning |
| *Eucalyptus nitens* | Strathblane, Tasmania (43°38′S, 146°94′E) | 1993 | 1250 | 11<br>(314) | 3 to 4 and 5<br>(2.5 and 4.5) |
| *Eucalyptus nitens* | Geeveston, Tasmania (43°15′S, 146°84′E) | 1991 | 1333 | 10<br>(192) | 4 to 6<br>(up to 6.4) |
| *Eucalyptus nitens* | Florentine, Tasmania (42°66′S, 146°47′E) | 1993 | 1250 | No thinning | No pruning |

* Retained stocking (stems per hectare) presented in parentheses
** Pruned height (metres) presented in parentheses

**Table 2.** Plantation Trial Material

| Species | Plantation Location | Age (Years) | Number of Trees | Average DBHOB of Plantation Trees * (cm) | Average DBHOB of Selected Trees * (cm) | Thinned and Pruned |
|---|---|---|---|---|---|---|
| *Eucalyptus globulus* | Deans Marsh, Victoria | 16 | 20 | 37.0<br>(4.9) | 33.8<br>(2.6) | Yes |
| *Eucalyptus globulus* | Orford, Victoria | 13 | 20 | 22.2<br>(5.7) | 29.5<br>(3.2) | No |
| *Eucalyptus globulus* | Mumbannar, Victoria | 13 | 20 | 21.0<br>(9.8) | 28.5<br>(2.9) | No |
| *Eucalyptus nitens* | Strathblane, Tasmania | 20 | 20 | 31.3<br>(6.0) | 30.0<br>(3.4) | Yes |
| *Eucalyptus nitens* | Geeveston, Tasmania | 22 | 10 | 43.1<br>(10.7) | 42.0<br>(9.8) | Yes |
| *Eucalyptus nitens* | Florentine, Tasmania | 20 | 11 | 26.9<br>(11.1) | 33.8<br>(2.6) | No |

* Standard deviation presented in parentheses

## Billet Assessment

The following parameters were measured on each billet prior to processing:

- Large end diameter under bark, *LEDUB* (m)—measured from the circumference with a diameter tape;
- Small end diameter under bark, *SEDUB* (m)—measured from the circumference with a diameter tape; and
- Sweep, *S* (m)—measured as the maximum deviation from a straight edge that bridges the ends of the 1.3-m billets.

From the measured data, billet volumes were derived following the methodology adopted by McGavin *et al.* (2014a).

## Billet Processing

Processing was undertaken using an OMECO spindleless veneer lathe, model TR4 (OMECO, Curitiba, Estado de Paraná, Brazil). The lathe is capable of processing billets with a maximum length of 1350 mm and a maximum log diameter of 400 mm. The minimum peeler core size was 45 mm. Twelve *E. nitens* billets from the Geeveston site, which were too large (> 400-mm diameter) to directly process on the spindleless lathe were rounded and/or partially peeled using a conventional spindled lathe before the peeling was completed on the spindleless lathe. For the study, the lathe settings and log conditioning were fixed, and the nominal dried veneer thickness was 2.5 mm.

The resulting veneer ribbon was sequentially clipped to target 1400-mm maximum width sheets. This target sheet size was chosen to provide 1200-mm dried and trimmed veneer sheets as per standard industry practise. Veneer widths as narrow as 300 mm were included, while veneer sheets narrower than 300 mm were discarded. Veneer sheets were labelled with a unique identifier. Clipped veneer was seasoned using a conventional jet box veneer drying system using standard commercial practises (temperatures ranged from 160 to 190 °C during drying), with a target moisture content of 5%. Veneers were then stabilised to 10% moisture content in storage.

A more detailed description of the methodology regarding billet preparations and processing is described by McGavin *et al.* (2014a).

## Visual Grading

Veneer quality was assessed by visual grading in accordance with Australian and New Zealand standard AS/NZS 2269.0:2012 (Standards Australia 2012). This standard is widely adopted across the Australian veneer industry and follows the same principles as other international visual grading classification systems. The standard separates structural veneer into four veneer surface qualities and a reject grade according to the severity and concentration of imperfections and defects.

To facilitate comparisons between species and sites, only resource-related defects have been included in this analysis. Defects that could be directly attributed to the veneering process, such as splitting caused by veneer handling, have been excluded from the analysis so as to not disadvantage any particular species or site that may benefit from a further refined process. For each veneer, the visual grade was recorded for each type of defect present within the veneer. This allowed the analysis of the impact of each type of defect in terms of its contribution to the assigned grade of each veneer. The defects that caused the lowest visual grade were identified as grade-limiting defects, and the resulting assigned grade was recorded for each veneer. The grading process was undertaken by a minimum of two experienced graders to minimise variation with defect definition and measurement, as well as to ensure consistent assessment.

## Recovery

Four recovery calculations following the same methodology as detailed by McGavin *et al.* (2014a) were made to determine green veneer recovery, gross veneer recovery, net veneer recovery, and graded veneer recovery.

Green veneer recovery was calculated using average green veneer thickness; green veneer width (perpendicular to grain) as measured prior to clipping and excluded any major defects (*i.e.*, wane or undersize thickness) that were present at the beginning or end of the veneer ribbon; veneer length (same as billet length); and billet volume.

Gross veneer recovery was calculated using average dry veneer thickness; veneer width (perpendicular to grain) of dried veneer that met the grade requirements of A-grade, B-grade, C-grade, and D-grade in accordance with AS/NZS 2269.0:2012; veneer length (same as billet length); and billet volume.

Net veneer recovery was calculated as the gross veneer recovery minus a trimming factor. Graded veneer recovery was the net grade recovery separated into individual grades (A-grade, B-grade, C-grade, and D-grade) expressed as a proportion of net recovered volume. Veneers that did not meet these grade requirements were labelled reject grade (F-grade).

## Relative Veneer Value

Accurate commercial veneer values for the species included in the study are difficult to determine; however, to provide an indication of the economic impact that the different species and plantation sites had on veneer value, relative values for each grade were provided by the Engineered Wood Products Association of Australasia (2014). This suggests that C-grade veneer attracts a value 1.2 times higher than D-grade, B-grade attracts a value 1.7 times than D-grade, and A-grade attracts a value three times higher than D-grade. Reject grade is considered of no value. This analysis focuses on the ratios of veneer grades recovered and discounts for the variation in veneer volume recovered.

## RESULTS AND DISCUSSION

### Visual Grading

A total of 202 billets (16.4 m$^3$) from six different hardwood plantations were processed using a spindleless lathe, which produced 3,097 m$^2$ of rotary veneer. Table 3 provides details of the billet characteristics for each site.

**Table 3.** Billet Characteristics of the Six Hardwood Plantation Sites

| Plantation Location | Species | Thinned and Pruned | Average Billet Small-end Diameter under Bark (cm) | Average Billet Volume (m$^3$) | Total Volume Processed (m$^3$) | Average Sweep (mm) |
|---|---|---|---|---|---|---|
| Deans Marsh | *Eucalyptus globulus* | Yes | 28.4<br>(3.2) | 0.088<br>(0.019) | 3.517 | 12<br>(5.0) |
| Orford | *Eucalyptus globulus* | No | 24.8<br>(2.7) | 0.067<br>(0.015) | 2.661 | 10<br>(5.4) |
| Mumbannar | *Eucalyptus globulus* | No | 23.8<br>(2.7) | 0.062<br>(0.015) | 2.482 | 11<br>(5.3) |
| Strathblane | *Eucalyptus nitens* | Yes | 24.6<br>(3.1) | 0.067<br>(0.017) | 2.663 | 8<br>(4.8) |
| Geeveston | *Eucalyptus nitens* | Yes | 36.6<br>(9.2) | 0.152<br>(0.074) | 3.039 | 6<br>(3.2) |
| Florentine | *Eucalyptus nitens* | No | 29.6<br>(2.5) | 0.094<br>(0.017) | 2.075 | 8<br>(3.9) |
| Standard deviation presented in parentheses. | | | | | | |

The measured veneer recoveries are displayed in Table 4.

**Table 4.** Veneer Recoveries

| Plantation Location | Species | Thinned and Pruned | Green Recovery (%) | Gross Recovery (%) | Gross Recovery Percentage of Green Recovery (%) | Net Recovery (%) |
|---|---|---|---|---|---|---|
| Deans Marsh | *Eucalyptus globulus* | Yes | 77 | 56 | 73 | 49 |
| Orford | *Eucalyptus globulus* | No | 77 | 58 | 77 | 51 |
| Mumbannar | *Eucalyptus globulus* | No | 77 | 59 | 77 | 52 |
| Strathblane | *Eucalyptus nitens* | Yes | 76 | 64 | 84 | 56 |
| Geeveston | *Eucalyptus nitens* | Yes | 74 | 61 | 82 | 54 |
| Florentine | *Eucalyptus nitens* | No | 76 | 61 | 79 | 54 |

All sites achieved similar green veneer recoveries of between 74% and 77%. The *E. globulus* sites achieved gross recoveries of between 56% and 59%, with Deans Marsh achieving the lowest gross recovery value (56%), despite receiving the most intensive silvicultural management. The *E. nitens* sites achieved higher gross recoveries of between 61% and 64%, with the Strathblane site achieving the highest gross recovery (64%). Geeveston and Florentine both achieved gross recoveries of 61%. The net recoveries are proportional to the gross recovery values.

The recoveries measured in this study are high compared to most previous studies in Australia when rotary peeling eucalypt species. For example, Thomas *et al.* (2009) reported green off-lathe recoveries for plantation *E. dunnii* (aged between 12 and 34 years-old) ranging from 35% to 45%. Blakemore *et al.* (2010) reported similar recovery values for a small-scale *E. nitens* (21-year-old) veneering trial. The difference in recoveries between the previous studies and this study is probably attributed to the application of traditional technologies (spindled lathe), which produce larger diameter peeler cores and failed peeling due to spindle grip problems (*e.g.*, core splitting). Different veneer grading methods also help explain the variation.

Luo *et al.* (2013) reported an average green veneer recovery (defined similarly to gross veneer recovery in this study) of 44% (ranging from 28% to 51%) for 11 different five-year-old eucalypt clones in China. While adopting spindleless lathe technology, similar to this study, the comparatively low green veneer recovery observed is likely attributable to a lower average small-end diameter of the billets (112 mm). The recoveries are comparable to those reported by McGavin *et al.* (2014a) using similar processing technologies and methodologies to this study, for the assessment of six Australian hardwood plantation species.

There was no relationship between billet SEDUB and veneer recovery because of the compounding influences of billet geometry (*i.e.*, sweep, taper, ovality, and surface irregularities) and billet end splitting, as well as billet core defects, which influence the residual peeler core diameter (McGavin *et al.* 2014a).

Table 5 provides details of the grade recovery (recovered veneer for each grade as a proportion of total veneer surface area) for each site.

**Table 5.** Graded Veneer Recovery (Recovered Veneer for Each Grade as a Proportion of Total Veneer Surface Area)

| Plantation Location | Species | Thinned and Pruned | A-grade Recovery (%*) | B-grade Recovery (%*) | C-grade Recovery (%*) | D-grade Recovery (%*) | Reject Recovery (%*) |
|---|---|---|---|---|---|---|---|
| Deans Marsh | *Eucalyptus globulus* | Yes | 0.0 | 1.3 | 3.4 | 80.7 | 14.6 |
| Orford | *Eucalyptus globulus* | No | 0.0 | 1.1 | 2.3 | 86.5 | 10.1 |
| Mumbannar | *Eucalyptus globulus* | No | 0.0 | 0.9 | 2.0 | 87.1 | 10.0 |
| Strathblane | *Eucalyptus nitens* | Yes | 1.1 | 22.9 | 20.8 | 52.4 | 2.8 |
| Geeveston | *Eucalyptus nitens* | Yes | 0.1 | 7.4 | 17.1 | 64.9 | 10.5 |
| Florentine | *Eucalyptus nitens* | No | 0.0 | 0.5 | 4.6 | 93.1 | 1.8 |

* Recovered grade veneer as a proportion of veneer surface area

Despite the Deans Marsh site having intensive silvicultural management, implemented to increase proportions of higher-quality end-products, there was minimal difference in the spread of veneer grades. The D-grade recovery was less for the Deans Marsh site compared with the two unthinned and unpruned *E. globulus* sites at Orford and Mumbannar; however, the recovery of reject grade was higher, resulting in minimal improvement being observed in higher-grade qualities (C-grade and better). This explains the lower gross recovery observed for Deans Marsh in comparison with the other two sites (Table 4), which had comparable graded veneer recoveries. The spread of grade recoveries are consistent with other similar studies, such as Peng *et al.* (2014), who reported over 80% of eucalypt hybrid veneers being categorised as D-grade (although based on a slightly different grading standard), and less than 3% of veneers meeting the grade requirements of C-grade or better (with the balance being reject grade).

A greater variation was shown in grade recoveries between the three *E. nitens* sites. The Florentine site, which was not thinned or pruned, was almost totally dominated by D-grade veneer (93.1%), and as expected, the thinned and pruned Strathblane and Geeveston sites achieved an improved spread of recoveries across higher-grade qualities when compared with the Florentine site. Of the three *E. nitens* sites, the Strathblane site performed best, with superior recovery of higher grades (C-grade and better). For example, the Strathblane site achieved three times more B-grade veneer than the Geeveston site, despite the latter being thinned and pruned and having the largest diameter billets. The Geeveston site yielded a higher reject recovery (10.5%), which was three to five times higher than the other two *E. nitens* sites (1.8% and 2.8%, respectively).

The Engineered Wood Products Association of Australasia (2013) suggests that the rotary veneer industry requires approximately 30% to 40% of their graded veneer production to be at least C-grade or better to enable saleable product manufacture. The Strathblane site was the only site to achieve this benchmark, with 45% of veneer meeting the grade requirements of C-grade or better.

Table 6 illustrates the five highest-ranked defects (in order of severity) that prevented veneers from attaining grades higher than D-grade for each site.

All six sites were impacted by similar defects. Bark pockets or decay, mostly surrounding knots, was the highest-ranked grade-limiting defect in five of the six sites, and it ranked second in the remaining site. While highly ranked, the impact was more severe for *E. globulus*. The presence of these defects in the peeled veneer supports the findings of previous research studies, which have shown that these species may not heal well after pruning or self-pruning, with the section of stem-wood laid down post-prining being prone to decay entry and slow occlusion (Wardlaw and Neilson 1999; Pinkard 2002; Pinkard *et al.* 2004; Deflorio *et al.* 2007).

Encased knots also featured heavily across all sites, although they had less impact in the thinned and pruned *E. nitens* sites (Strathblane and Geeveston). Despite the Deans Marsh *E. globulus* site also being thinned and pruned, there was little benefit gained when compared with results from the unthinned and unpruned *E. globulus* sites. Instead of the veneer of the pruned billets being knot-free (at least from the pruned diameter plus an allowance for branch occlusion), the tree seems to have not been effective in producing knot- (and knot-related defects-) free wood; rather, the branch stubs produced a deficient occlusion pattern (along with a high proportion of gum pockets) as the tree grew.

**Table 6.** Top Five Ranked Defects Preventing Veneers from Attaining Assigned Grades Higher than D-grade

| Plantation Location | Species | Thinned and Pruned | Rank | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 |
| Deans Marsh | *Eucalyptus globulus* | Yes | Bark or decay (85%) | Gum pockets (64%) | Encased knots (48%) | Roughness (41%) | Compression (35%) |
| Orford | *Eucalyptus globulus* | No | Bark or decay (82%) | Gum pockets (68%) | Encased knots (62%) | Roughness (31%) | Compression (26%) |
| Mumbannar | *Eucalyptus globulus* | No | Bark or decay (93%) | Encased knots (75%) | Gum pockets (52%) | Roughness (33%) | Compression (25%) |
| Strathblane | *Eucalyptus nitens* | Yes | Bark or decay (36%) | Encased knots (24%) | Roughness (8%) | Splits (5%) | Gum pockets (4%) |
| Geeveston | *Eucalyptus nitens* | Yes | Bark or decay (43%) | Encased knots (35%) | Splits (30%) | Roughness (12%) | Defect combination (9%) |
| Florentine | *Eucalyptus nitens* | No | Encased knots (86%) | Bark or decay (46%) | Splits (22%) | Roughness (17%) | Gum pockets (9%) |

Note: The proportion of veneer impacted by each defect is provided in parentheses.

Gum pockets ranked highly for the *E. globulus* sites. As suggested by McGavin *et al.* (2014b), the size of this defect was often small and concentrated, and while it would influence the appearance of the veneer, it would be expected to have a negligible effect on mechanical properties or on the panel manufacturing process. The characteristics of this defect in the veneer are such that it may be unnecessarily severe to downgrade such quantities of veneer to D-grade, especially when compared with other appearance-affecting defects, which are permissible in higher grades. A market acceptance analysis and review of the permissible limits outlined in the grading standards for this defect could be beneficial.

Veneer surface roughness ranked either third or fourth for preventing veneer from all sites from attaining a grade higher than D-grade. Veneer surface roughness is mostly present in areas of veneer where there is grain deviation present, such as around knots and knot holes. This was supported by the fact that surface roughness has more impact on *E. globulus* veneers, which also reported a higher severity of encased knots when compared with *E. nitens*. McGavin *et al.* (2014b) reported a significant ($p<0.001$) and positive, although relatively weak correlation between sound or encased knot rank and veneer surface roughness rank.

Splits ranked third for the Geeveston and Florentine *E. nitens* sites. While splits ranked fourth for Strathblane, splits only prevented 5% of veneers from attaining a grade higher than D-grade for this site. Splits fell outside the top five ranked defects (Table 6) for *E. globulus* sites; however, splits were responsible for between 10% and 15% of veneers' inability to attain a grade higher than D-grade.

Compression in the *E. globulus* veneer (ranked fifth) resulted in 25% to 35% of veneer being restricted to D-grade. This defect was much more obvious when the veneer was dried, with many veneers being “rippled” and uneven. The presence of this defect can be attributed to the differential transverse shrinkage induced by the frequent presence of veins or casts of tension wood within this species (Washusen and Ilic 2001), and it has been shown to cause product recovery losses in sawn timber (Washusen 2011). Compression had less impact on the grade recovery of *E. nitens* veneer.

McGavin *et al.* (2014b) reported a grade scenario based on the improvement of veneer grade made possible with the implementation of effective pruning. For *E. globulus*, the simulated improvement included changes in veneer grade recovery percentage of −9% for D-grade, +11% for C-grade, and +5% for B-grade (difference between measured and simulated). A-grade remained unchanged at 0%. The simulated benefits of pruning were not supported within this study for *E. globulus*, with a negligible difference in grade recovery between the pruned and thinned site and the two unpruned and unthinned sites. The presence of defects, including bark pockets and decay, which were mostly associated with knots, encased knots, surface roughness, and gum pockets in similar proportions across all sites, suggest that at the Deans Marsh site the pruning had not been effective in allowing clear wood to be produced. This may be due to suboptimal pruning techniques, timing and procedures, and/or may be a physiological characteristic of this species (Wardlaw and Neilson 1999; Pinkard 2002; Pinkard *et al.* 2004; O’Hara 2007; Deflorio *et al.* 2007). An additional influence may be the below average rainfall (665 mm in 2004, 709 mm in 2005, and 474 mm in 2006 recorded at the site compared with a 852 mm long-term average) the Deans Marsh site received for the three years following the last pruning. This almost certainly impacted the rate and processing of branch stub occlusion.

The same grade scenario reported by McGavin *et al.* (2014b) simulating effective pruning for *E. nitens* produced a change in grade recovery percentage of −33% for D-grade, +16% for C-grade, and +19% for B-grade grade (difference between measured and simulated). This is close to what was observed in the present study, with D-grade recoveries for both the thinned and pruned sites having between 28% and 41% less than the unthinned and unpruned site, while C-grade recoveries for the thinned and pruned sites were between 13% and 16% higher than the unthinned and unpruned Florentine site. The thinned and pruned Strathblane site had the most favourable result and was comparable to the grade simulation, with 22.5% higher grade recovery for B-grade veneers when compared with the Florentine site. The thinned and pruned Geeveston site produced 7% higher B-grade than the Florentine site. The gains simulated by McGavin *et al.* (2014b) and measured in this study are greater than the grade quality difference reported by Blakemore *et al.* (2010) for a small study that included five pruned and five unpruned *E. nitens* trees. In this study, the changes in percentage recoveries with pruned billets compared with unpruned billets were as follows: A-grade +5.7%; B-grade +3.1%; C-grade +3.8%; D-grade +0.5%; and reject grade −13.1%. It should be noted, however, that the veneer quality from the unpruned trees was already much higher than presented in Table 5, with over 50% of the resulting veneer achieving C-grade or better. Moreover, the trees sampled by Blakemore *et al.* (2010) were bigger (mean diameter of 50.6 cm) than in this study, and the peeling and grading methods were different, making any comparison between the studies speculative.

Across all sites, the major cause for veneer being labelled reject grade was a combination of multiple defects that individually were within permissible limits of higher grades, but when combined in close proximity (*i.e.*, defect combination), prevent veneers from attaining higher grades. For the *E. globulus* sites, the high incidence of a range of defects, including bark and decay, encased knots, gum pockets, *etc.* contributed to reject recoveries of between 10.0% and 14.6%. For *E. nitens*, the Strathblane and Florentine sites had low reject recoveries (1.8% to 2.8%); however, the heavily thinned and pruned Geeveston site had 10.5% reject recovery. The defect that contributed to this variation was the high occurrence of splits in Geeveston veneers. The Geeveston billets were also observed to have severe splitting prior to peeling, which obviously carried through to the veneer. The presence of these splits is an indicator of high levels of growth stresses, most likely exacerbated by the relatively late and heavy thinning. This may have caused severe destabilisation among the remaining trees and consequently induced high levels of growth stresses. The release of these stresses has been shown to result in severe billet end splitting (Kubler 1988).

Figures 1 through 6 illustrate the distribution of assigned grades for individual grade-limiting defects for each species. In this type of diagram, each bubble represents the percentage of a given grade for a given defect. The grey scaling and diameter of the bubble are both proportional to the percentage of the total veneer surface area for each individual defect. In addition, similarly for each defect, the assigned grade is determined for each veneer from the defect(s) causing the lowest individual grade.

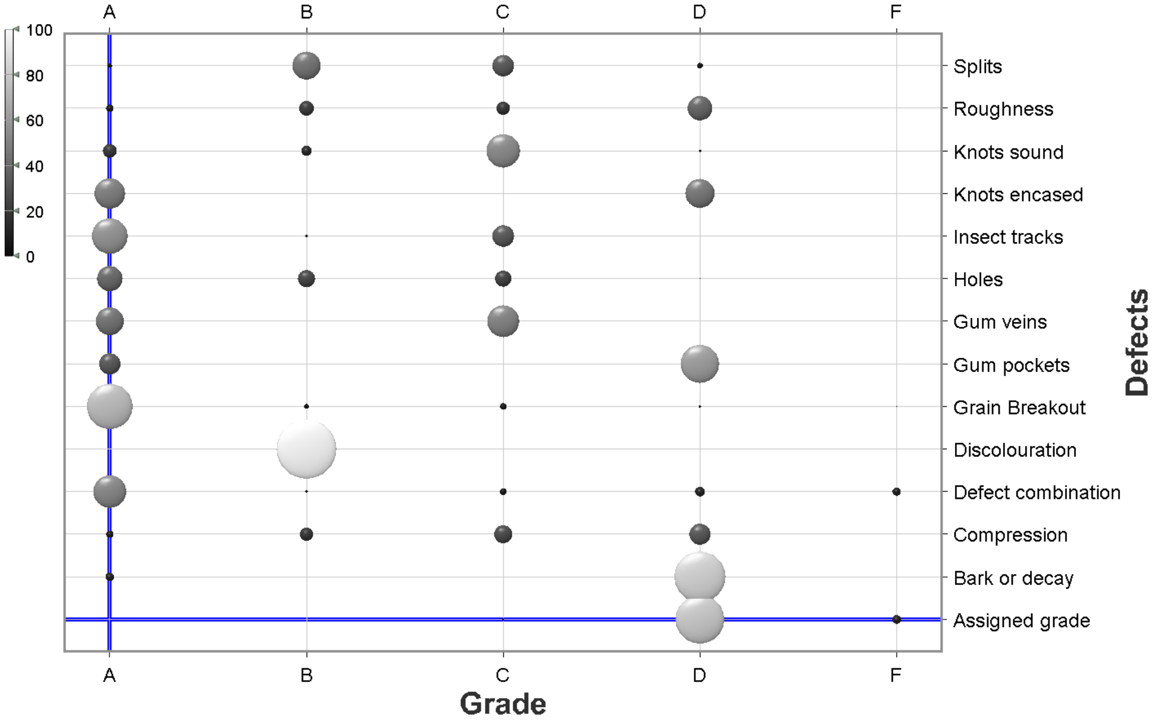

**Fig. 1.** Distribution of Deans Marsh *Eucalyptus globulus* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

From these figures, the distribution of grade-limiting defects within C-grade and higher-grade veneer show some dissimilarities. For *E. globulus*, the most noticeable variation involves the Deans Marsh site, where insect tracks and gum veins have more impact on the reduction of veneer grade compared with the other two *E. globulus* sites at Orford and Mumbannar. This demonstrates the negative impact of pruning followed immediately by drought.

For *E. nitens*, the presence of holes impacted the Florentine site at a much lower grade compared with Strathblane and Geeveston. This is a consequence of dead branch persistence in logs from this unpruned and unthinned site.

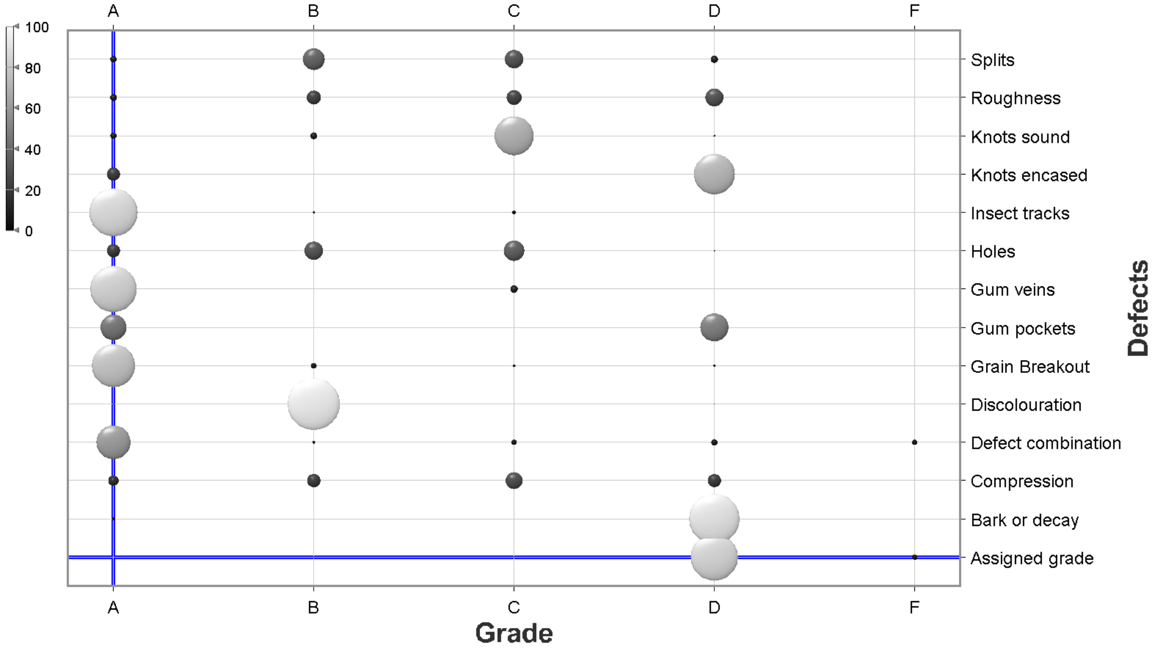

**Fig. 2.** Distribution of Orford *Eucalyptus globulus* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

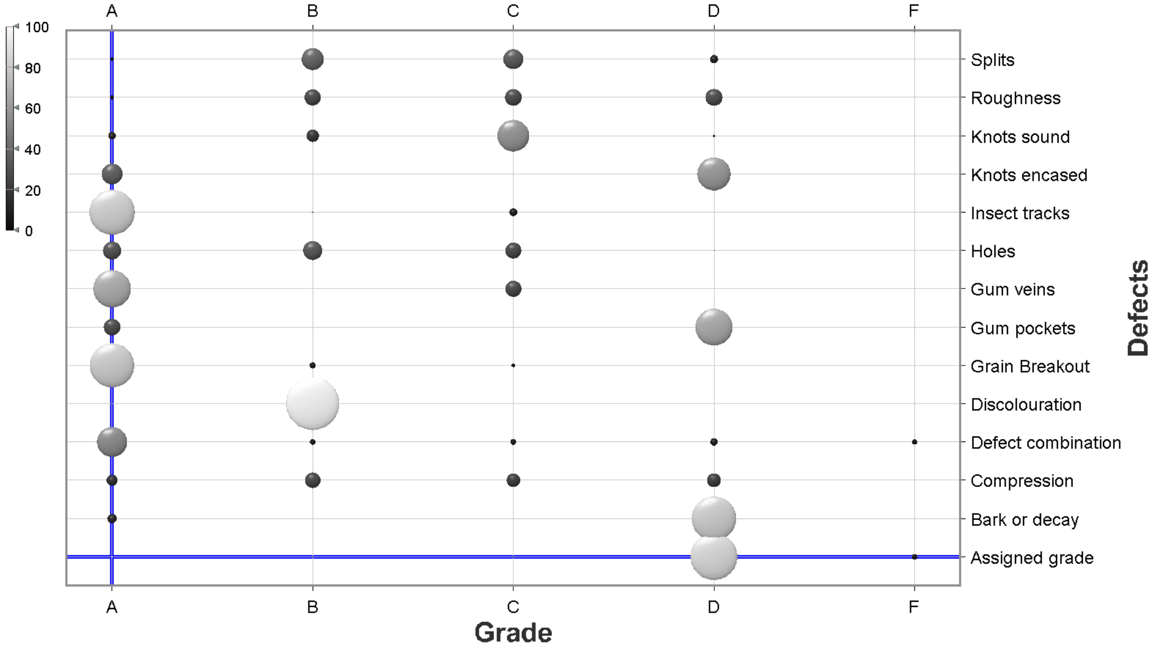

**Fig. 3.** Distribution of Mumbannar *Eucalyptus globulus* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

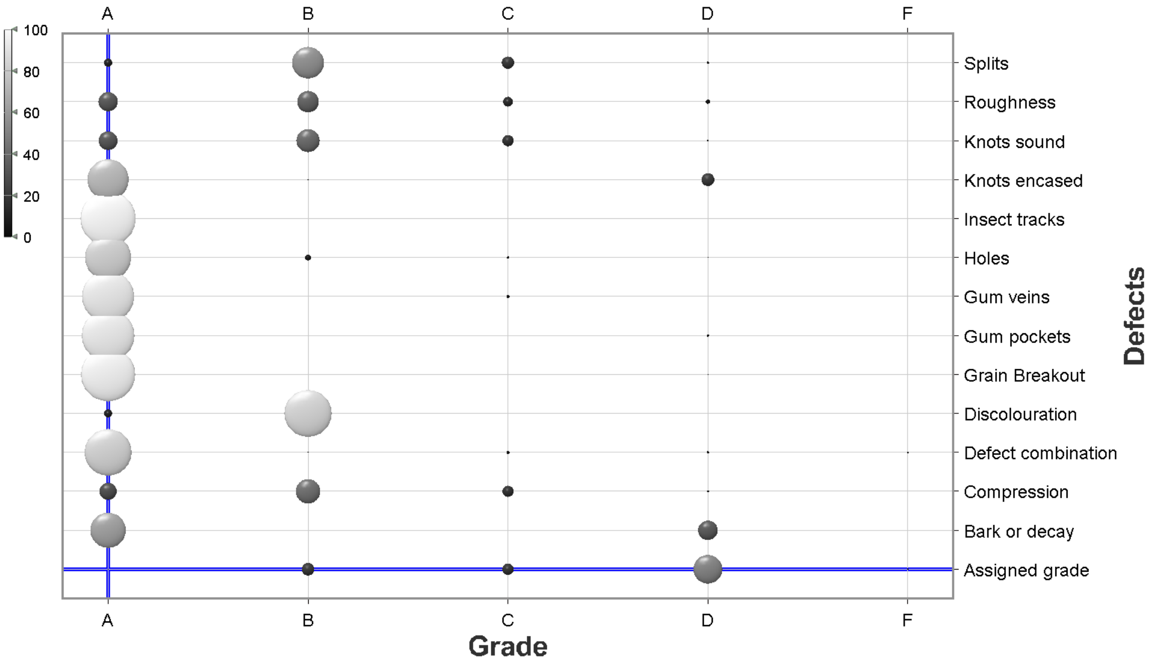

**Fig. 4.** Distribution of Strathblane *Eucalyptus nitens* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

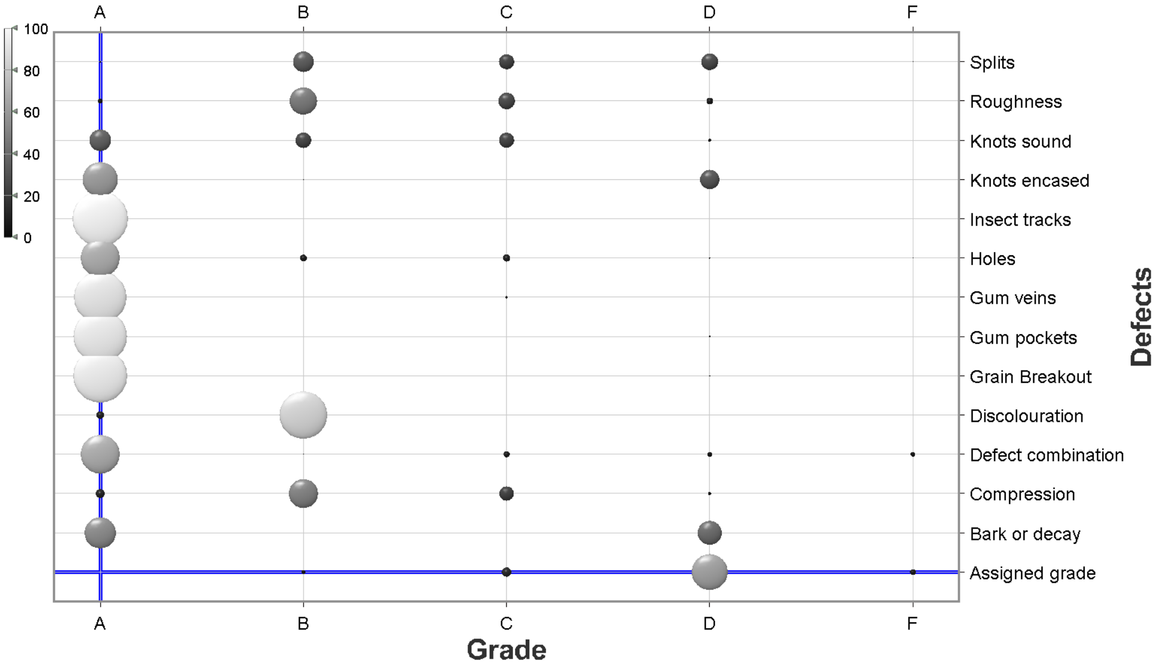

**Fig. 5.** Distribution of Geeveston *Eucalyptus nitens* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

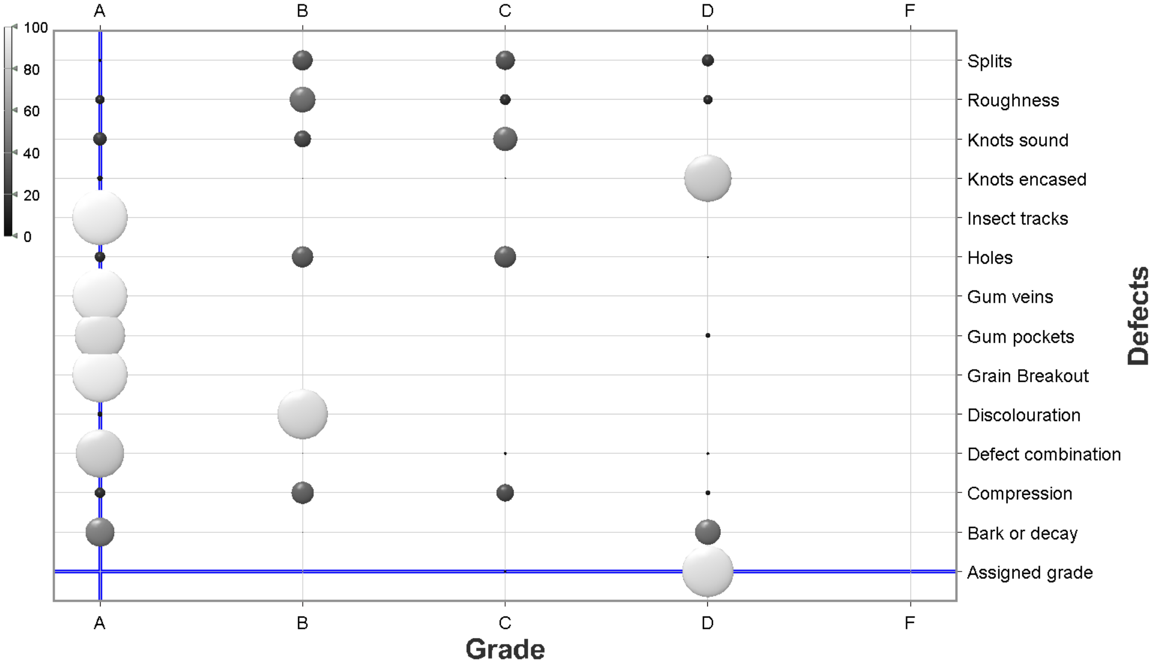

**Fig. 6.** Distribution of Florentine *Eucalyptus nitens* visually-assigned veneer grades for a range of resource-related defects. Like the grey scale, the size of the bubble is proportional to the recovered value.

## Economic Impact

Table 7 displays the relative veneer value as a proportion of the maximum possible value for each site. The analysis acknowledges that the maximum value can only be achieved if the A-grade recovery is 100%.

**Table 7.** Relative Veneer Value as a Proportion of Maximum Possible Value*

| Plantation Location | Species | Thinned and Pruned | Proportion of Maximum Possible Value (%) |
|---|---|---|---|
| Deans Marsh | *Eucalyptus globulus* | Yes | 29.0 |
| Orford | *Eucalyptus globulus* | No | 30.4 |
| Mumbannar | *Eucalyptus globulus* | No | 30.3 |
| Strathblane | *Eucalyptus nitens* | Yes | 39.9 |
| Geeveston | *Eucalyptus nitens* | Yes | 32.8 |
| Florentine | *Eucalyptus nitens* | No | 33.2 |

*A-grade recovery of 100% is used as a benchmark for the maximum percentage value.

There was minimal variation between the *E. globulus* sites. Deans Marsh veneers, which received the most intensive silvicultural treatment out of the *E. globulus* sites, demonstrated no benefit in terms of veneer grade quality and achieved a slightly lower relative value. The lower value in comparison with the other *E. globulus* sites is a direct result of the higher proportion of reject grade, which attained no value in the analysis.

More variation existed within the *E. nitens* analysis in line with the grade recovery variation. Strathblane proved to be superior, achieving 40% of the maximum possible value. This was greatly assisted by the higher proportion of B-grade by comparison, which attracts a value 1.7 times the value of D-grade. In relative veneer value, the Strathblane site had a 22% gain over Geeveston, which attained a similar relative veneer value to the Florentine site. While Geeveston achieved much higher proportions of C-grade and better veneers in comparison with the Florentine site, it was not enough to offset the impact of the high proportion of reject grade by comparison, which attained no value in the analysis.

## CONCLUSIONS

1. This study demonstrated that plantation *E. globulus* and *E. nitens* can produce acceptable marketable product recoveries of rotary veneer; however, the graded veneer recovery was dominated by D-grade veneer across most sites. The low recovery of higher-grade veneers (C-grade and better), which are more in demand for face veneers, will make the commercial production of a standard mix of saleable structural panel products challenging if relying on this resource alone.
2. Variation between the *E. nitens* sites was evident, with gross, net, and grade recoveries being different between sites that were thinned and pruned and the site that wasn't. The best-performing site (Strathblane) achieved a recovery of C-grade and better veneers by 45%. This exceeds the minimum grade quality proportions nominated by the Engineered Wood Products Association of Australasia (30% to 40%) necessary for the commercial production of structural panel products.
3. Variation in recoveries was less evident between the thinned and pruned *E. globulus* site, as well as between the unthinned and unpruned sites. The presence of defects, including bark pockets and decay, which were mostly associated with knots, encased knots, surface roughness, and gum pockets in similar levels across all sites suggests that while pruning and thinning were conducted within the Deans Marsh site, the pruning had not been effective in allowing clear wood to be produced. This may be because of suboptimal pruning techniques, timing and procedures, physiological characteristics of this species, or drought stress resulting from the below average rainfall for the three years following the last pruning.
4. The difference in grade recovery between the thinned and pruned *E. nitens* sites and the unthinned and unpruned site was in line with the grade simulation reported by McGavin *et al.* (2014b), which describes the improvement of veneer grade by implementing effective pruning. The simulated benefits of pruning were not supported within this study for *E. globulus*, with negligible difference in grade recovery between the pruned and thinned site and the two unpruned and unthinned sites. These results indicate that the grade scenario methodology to simulate the potential grade improvement with effective pruning as proposed by McGavin *et al.* (2014b) could be a valuable tool for use in the economic modelling of silvicultural treatments, at least for *E. nitens*.
5. The veneer value analyses demonstrated minimal difference between the *E. globulus* sites, which is in line with the grade recovery. The higher proportion of reject grade veneers produced by the Deans Marsh site contributed to the slightly lower value in comparison with the other sites, despite this site receiving intensive silvicultural treatments. More variation existed within the *E. nitens* analysis. The Strathblane site proved to be superior, achieving 40% of the maximum possible value. This was

greatly assisted by the higher proportion of B-grade by comparison, which attracts a value 1.7 times the value of D-grade. Like the Strathblane site, Geeveston was also thinned and pruned; however, this site attained a similar relative veneer value to the Florentine site, which received no treatment. While Geeveston achieved much higher proportions of C-grade and better veneers in comparison with the Florentine site, it was not enough to offset the impact of the high proportion of reject grade by comparison, which attained no value in the analysis.

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