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Improving the durability of low durability plantation hardwoods for use as power poles

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Improving the durability of low durability plantation hardwoods for use as power poles

Prepared for

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Executive Summary

A review of timber resources available to Australian energy distribution authorities revealed that there was an impending shortage of material that is suitable for use as power distribution poles (Francis and Norton, 2006). A program of research was implemented over a three year period to generate data on the treatment characteristics, decay and termite durability and mechanical performance of four plantation sourced species; *Eucalyptus globulus* (southern blue gum), *Eucalyptus grandis x camaldulensis, Eucalyptus dunnii* (Dunn's white gum) *and Eucalyptus nitens* (shining gum).

A pre-treatment technique called through-boring has been successfully used in the United States to increase the heartwood durability of low durability species that reject traditional preservative treatment. Through-boring involves drilling a pattern of 12 mm holes right through a pole in a zone 600 mm above and below the ground line. The pattern of holes is designed to minimize impact on pole strength and create zones of treated wood to fully protect the pole. These holes allow limited penetration of preservative into the heartwood which most often is resistant to preservative treatment.

The plantation hardwoods being evaluated are currently being used for lower value products such as pulp. The intent of the research was to up-grade the value of this material by making it usable for power distribution poles. By improving the durability of low durability plantation hardwoods, the project aimed to achieve two positive outcomes. Plantation owners may receive in the order of \$165/m^3 for sales as power poles compared to around \$30/m^3 for pulp or landscaping timber. A successful outcome of the research would also be an increase in the resource base available for use as pole material.

The first stage of the research involved optimizing the timber treatment schedule that would lead to the maximum penetration of preservative into the heartwood. Unlike sapwood, where the level and duration of vacuum has the most impact on preservative penetration, increased periods of high pressure were found to be most important. The results of this first component of the research showed that pressures needed to be maintained for up to eight hours to achieve a 'reasonable' level of preservative penetration into the heartwood.

Test material was then treated with copper, chromium arsenate (CCA) wood preservative and exposed to decay organisms in the controlled environment of a fungal cellar and in the field in three locations in Queensland. Field exposures were also installed to investigate resistance to termite attack.

After 21 months exposure in the fungal cellar, all treated specimens, are still sound. Untreated specimens however, have started to deteriorate. The *Corymbia maculata* control specimens are in almost perfect condition with a small amount of surface softening. The *Pinus elliottii* controls and *the E. grandis x camaldulensis* have suffered 'moderate' attack losing an average of three to ten percent of the cross-section. The remaining candidate species suffered between 'severe' (30 - 50% loss of cross-section) and 'very severe' (50-75% loss of cross-section) attack.

To investigate decay in the field, six replicate pole stubs of each species were through-bored and treated in a commercial timber treatment plant. Pole stubs were two meters long. The stubs were installed in Innisfail (tropical north Queensland), Dalby (western Queensland) and Redlands (south-east Queensland). No decay was found in any of the exposed material after 12 months in the field. As the exposure period is very short, this is not an unexpected result and exposures/assessments are on-going.

Six through-bored and treated replicates were also installed at the Redlands field site surrounding a prepared termite aggregation bed. No termite attack was found in any of the exposed specimens after 12 months exposure. This exposure is also on-going.

Approximately 30 six-metre pole sized lengths of each test species were preservative treated in a commercial pole-treating facility. After air drying, this material was evaluated for strength as measured by Modulus of Rupture (MOR) using a four point bending rig. The average MOR of the control *C. maculata* was 167 Mpa. The strongest candidate species was the *E. grandis x camaldulensis* with an average MOR of 95 Mpa followed by *E. nitens, E. globulus* and the *E. dunnii* which were in the order of 60 Mpa. Whilst not as strong as *C. maculata*, the *E. grandis x camaldulensis* was significantly stronger than the other candidate species. Finalization of the decay and termite durability information will determine if this species is suitable for use as power poles.

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Introduction

A review of timber resources available to Australian energy distribution authorities revealed that there is an impending shortage of material that is suitable for use as power distribution poles (Francis and Norton, 2006). Traditionally, poles in Queensland and New South Wales are high durability Durability Class (DC) 1 and 2 (AS5604.2005) species. The current in-ground durability classifications are shown in Table 1. Lower durability DC3 species have been used in Western Australia and DC3 and DC4 species may be used in Tasmania. However this low durability material is sourced from native forests as opposed to plantations.

Table 1 Natural heartwood durability classification

Durability Class	Probable in-ground life expectancy (years)
1	Greater than 25
2	15 to 25
3	5 to 15
4	0 to 5

Some of the plantation hardwood resource that might find application as power distribution poles is currently being used for lower value products such as pulp. These species are usually DC3 and DC4 timbers and the intent of the research described in this report was to up-grade the value of this material by making it usable for power distribution poles. By improving the durability of low durability plantation hardwoods, the project aims to achieve two positive outcomes. Plantation owners may receive in the order of \$165/m^3 for sales as power poles compared to around \$30/m^3 for pulp or landscaping timber. A successful outcome of the research would also be an increase in the resource base available for use as pole material.

The pre-treatment technique called through-boring (Figure 1) has been successfully used in the United States to increase the durability of low durability softwood species that reject traditional preservative treatment (Morrell et. al, 2002). Through-boring involves drilling a pattern of 12mm holes right through a pole in a zone 600 mm above and below the ground line. The pattern of holes is designed to minimize impact on pole strength and create zones of treated wood to fully protect the pole. These holes allow limited penetration of preservative into the heartwood which most often is resistant to preservative treatment.

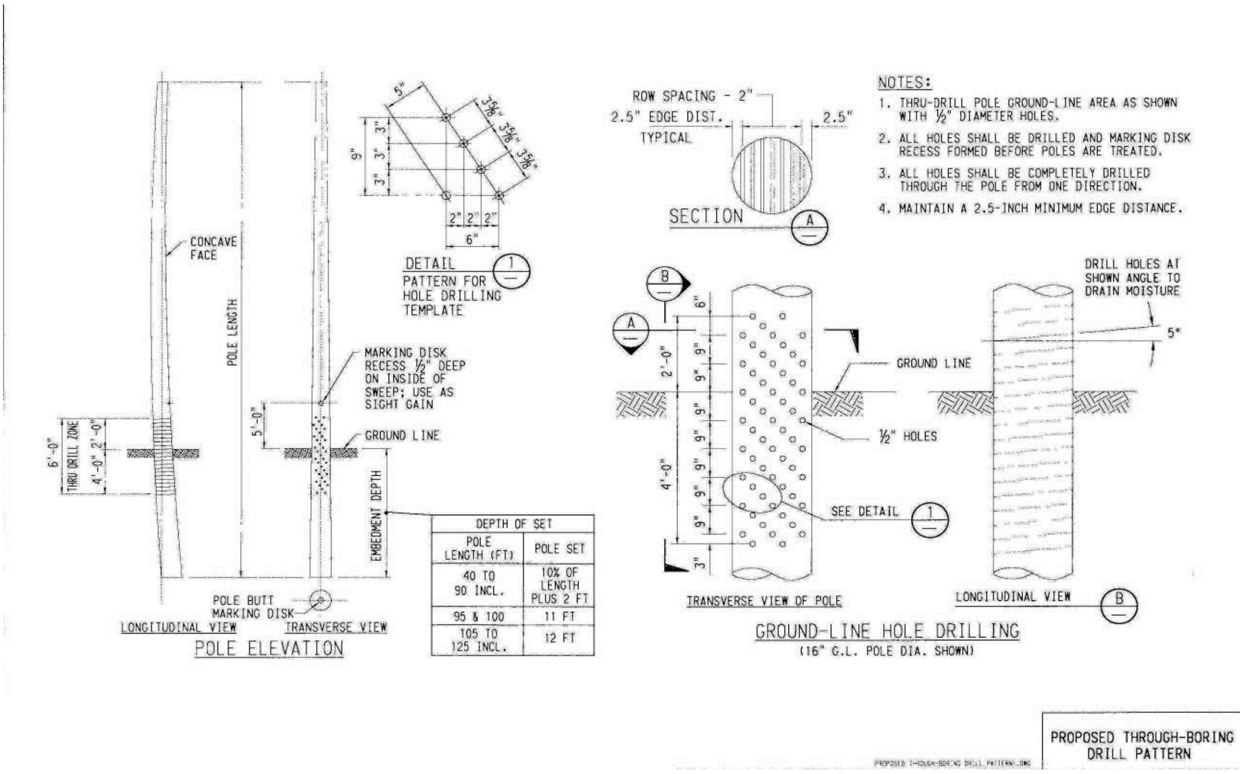

Figure 1 Through-boring drill pattern

The research discussed in this report was designed to generate data on the treatment characteristics, decay and termite durability and mechanical performance of four through-bored plantation sourced species; *E. globulus* (southern blue gum), *E. grandis x camaldulensis, E. dunnii* (Dunn's white gum) *and E. nitens* (shining gum).

A map for the project is presented in Figure 2 and a project flow or organization is presented in Figure 3.

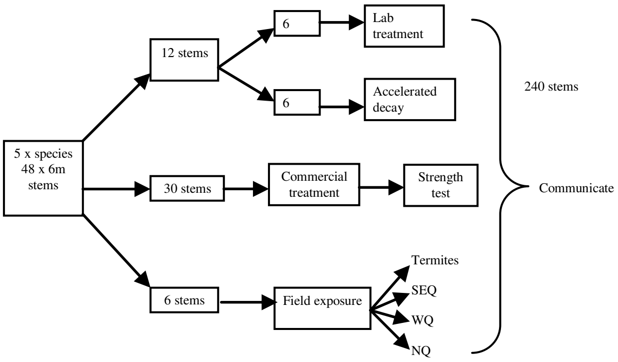

Figure 2 Project map

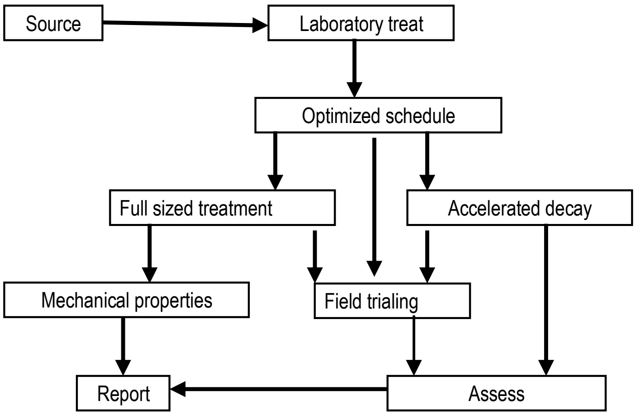

Figure 3 Project flow

Methodology

Test material preparation

Sourcing

The source of the test material is presented in Table 2. All logs were delivered to the Dale & Meyers' sawmill and treatment plant at Tiaro, just south of Maryborough in South East Queensland. Felling took place over a period of 4 months as the trees became available. After felling, logs were end plated and end sealed before shipping to Tiaro.

Table 2 Source of test material

Species	Species
E. globulus	McDonnnell Plantation, planted in 1997, located approximately 17km WSW of Dartmoor, Victoria (grid reference GDA 050700 5799200)
E. grandis x camaldulensis	Hillgrove, Planted 2000, located 37 km south of Miriam Vale Qld., between -151,60251 - 24,60251 and 151,64695 - 24,60295
E. dunnii	"GR001 Reids" located on Ellangowan Rd Ellangowan NSW. Approximate location in plantation is Map-sheet Ellangowan 95394N, Grid ref Easting 508500, Northing 6786300
E. *nitens*	Property NE046A, *E.nitens* plantation at Warrentinna NE Tasmania

Log processing

On arrival at the Dale & Meyers' sawmill, all logs were laid out on skids approximately 300 mm off the ground to air season and to facilitate further processing (Figure 4).

Figure 4 Log storage (*E. grandis x E. camaldulensis)*

Each pole was given an individual identifying number and 36 of the straightest poles were selected for mechanical testing and field exposure samples. The 36 'best form' logs were left at the Dale and Meyers' sawmill and all remaining poles were shipped to the Department of Employment and Economic Development and Innovation (DEEDI (now the Department of Agriculture, Fisheries and Forestry Queensland (DAFF-Q))) research sawmill located at Salisbury in Brisbane for treatment and durability tests.

Laboratory scale test specimens

On arrival, all logs were docked at least 500 mm from the butt end and further 1500mm billets were then removed for preparation of test specimens.

Heartwood test specimens for each of two sizes were prepared from the four test species and *C. maculata* controls. Test specimens 35 x 35 x 300 mm (Figure 5) were prepared for developing timber treatment schedules and specimens 25 x 25 x 300 mm (Figure 6) were prepared for accelerated decay tests in a fungal cellar. The final step in processing the test specimens involved thicknessing the material to the required dimension.

Figure 5 Treatment test specimens (*E. dunnii)*

Figure 6 Fungal cellar test specimens

All test specimens were tested for the presence of heartwood (AS1605.1-2006). In some cases, the small diameter of the logs led to the inclusion of up to 20% sapwood in the cross-section of the test specimens.

Laboratory treatment

Treatment cycles were developed and implemented in collaboration with Professor Jeff Morrell of Oregon State University. Professor Morrell has a great deal of experience with through-boring and preservative treatment of refractory timber species that are used for power poles in the USA.

Each test specimen was individually identified linking the number back to its original stem.

Samples were taken from each species and oven dried to establish an average moisture content prior to treatment.

Groups of test specimens from each species were then enclosed in a mesh bag (Figure 7) and treated to one of nine treatment schedules (Table 3) in a laboratory scale timber treatment plant (Figure 8). Treatment schedules were selected on the basis of those used in the treatment industry in Australia and the United States of America. The treatment plant is capable of matching the levels of vacuum and pressure applied by timber treatment plants in Australia.

The preservative used was a copper chrome arsenic oxide formulation with solution strength in the order of 2.5% mass/volume. As the primary purpose of treatment was to maximize preservative penetration, it was considered unnecessary to establish the concentration of preservative more accurately.

Figure 7 Mesh treatment bag

Figure 8 Laboratory scale timber treatment plant

Table 3 Treatment schedules applied to test specimens

Schedule #	Time at -98 kPa vacuum (minutes)	Time at 1500 kPa pressure (minutes)
1	60	60
2	120	60
3	60	960 (16 hrs)
4	60	120
5	60	240
6	180	60
7*	60	120
8**	60	480 (8 hrs)
9***	60	130

* Charge made up of steamed and oven dry and multi-bored test specimens

** Pre-dried 114 hrs at 50°C

*** Oven dried before treatment

Two test specimens each of *E. globulus, E. grandis x camaldulensis and E. dunnii* were double hole drilled (3 mm), two were steamed for 2.5 hours at 105°C and two were oven dried to 0% moisture content. Drilled holes were 50 mm apart and positioned so that one hole was in the middle of the stake. Stakes were to be positioned so that the second hole was 50 mm below ground line. The *E. nitens* was not processed in this way because of the late arrival of the test material. This 'extra processing' was carried out to investigate if further treatments were worth carrying out.

The weight of each test specimen was recorded before and after preservative treatment so that a net absorption figure could be obtained. Test specimens were then allowed to dry for at least 24 hours before each test specimen was cut in half longitudinally and evaluated for copper penetration using chrome azurol (AS1605- 2005).

Accelerated decay – fungal cellar and field stakes

Preparation

Heartwood test specimens were prepared from the four test species (*E. globulus, E. grandis x camaldulensis, E. dunnii and* E. *nitens)* and *C. maculata* and *P. elliottii* controls. Twelve replicate specimens 25 x 25 x 300 mm were prepared for each species and dressed to the final size (Figure 6).

Ten stakes of each species were prepared to examine each of the following parameters. Details are presented in Table 7:

- Through-bored
- Not through-bored

- Preservative treated
- Untreated
- Redlands field exposure
- Fungal cellar exposure
- Moisture content

Treatment

All stakes were individually labeled with a numbered stainless steel tag and conditioned to equilibrium moisture content before preservative treatment. (Table 4)

Table 4 Pre-treatment moisture content

Species	MC (%)
E. globulus	13.2
E. grandis x camaldulensis	10.4
E. dunnii	12.9
E. nitens	12.8

Commercially sourced pole strength copper chrome arsenate (CCA) solution (4.3% m/v total active ingredient) was used to preservative treat all test specimens. The treatment schedule applied in all cases was one hour vacuum at -90 kPa followed by slow flooding and eight hour pressure at 1400 kPa. After the treating solution was returned to the storage vessel, a ten minute vacuum of -70 kPa was applied to remove excess solution.

Twelve replicates of treated (H5 (AS1604.1: 2010)) and untreated slash pine and spotted gum were also prepared for exposure at both the Redlands field site and in the fungal cellar.

Exposure

All treated stakes were air dried for 12 weeks followed by installation at the Redlands site and the fungal cellar in September 2010 Figure 9). Stake numbers were randomized for installation.

Redlands exposure

Fungal cellar exposure

Figure 9 Stake exposure

Commercial pole and stub treatment

The 36 straightest stems were allocated for commercial treatment. Strength testing was to be carried out on 30 stems and six stems were used to prepare pole stubs destined for exposure.

A template based on penetration achieved in the laboratory treatment component of this project was prepared (Figure 10) and transferred to a 5 mm thick rubber mat (Figure 11). The mat was 1200 mm long so that the pattern in the bored pole or stub extended 600 mm above and below the nominal ground line.

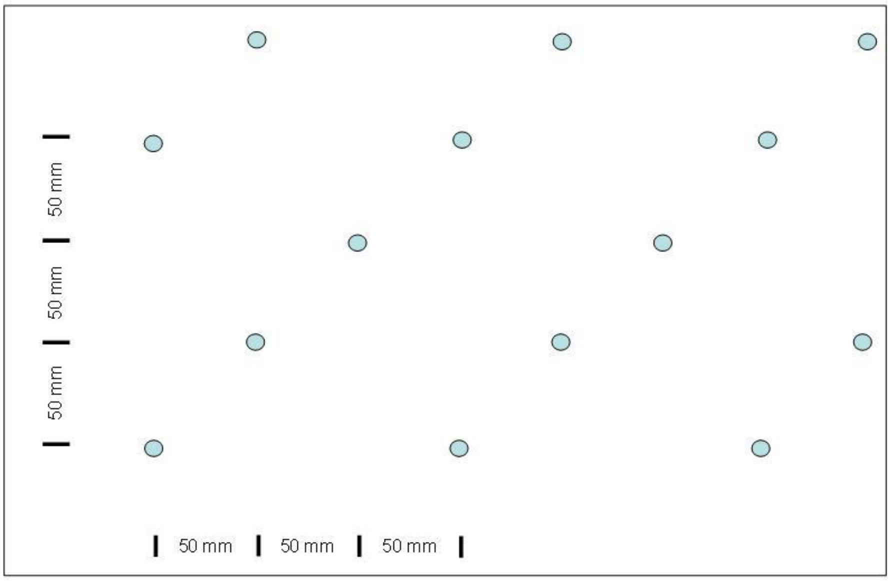

Figure 10 Adopted drilling pattern

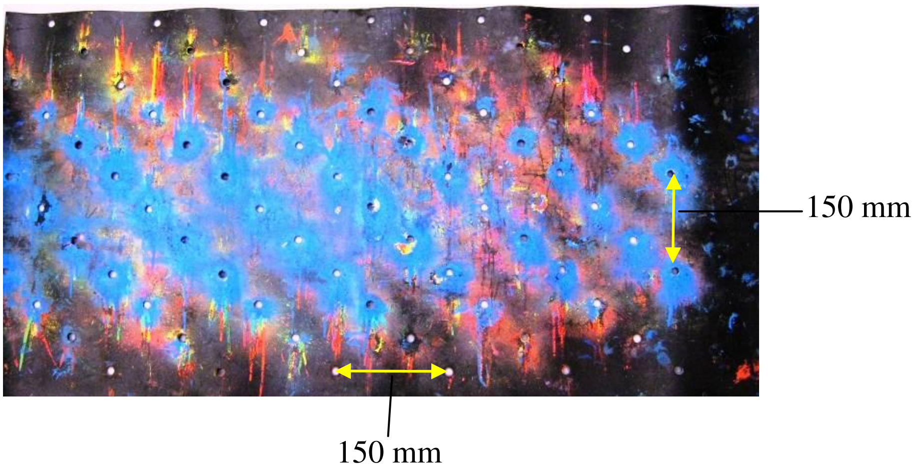

Figure 11 Through-boring template

A wad punch that makes a 12 mm hole was used to cut through the mat.

The logs that were to be through bored were laid out under cover in the Dale and Meyers (Tiaro) preparation area. The rubber template was then laid over the pole and the hole positions marked on the log with spray paint (Figure 12). The template was positioned so that it evenly straddled the expected ground line. After marking, a 12 mm auger bit was used to bore all the way through the pole (Figure 13). Once laid out on the skids, marking and boring took 10 – 12 minutes per pole. There were 30 - 35 holes per pole depending on its diameter.

Figure 12 Marking poles

Figure 13 Boring poles

A number of the *E. globulus* poles had decay fruiting bodies on the surface and these poles were carefully examined to determine the extent of any decay. The fruiting bodies appeared after pre-treatment seasoning which took place over a very hot and wet period.

Figure 14 Fruiting bodies on the surface of *E. globulus* poles before treatment

Pole stubs 1500 mm long were similarly bored except that the holes were positioned to extend from 400 mm below to 200 mm above the nominal ground line. Ground line on the pole stubs is 600 mm from the butt.

Preservative treatment

All poles and pole stubs were preservative treated in the Dale and Meyers' treatment facility. Treatment was carried out in August 2010. The treatment cycle used on all test species was one hour vacuum at -98 kPa followed by flooding and a pressure of 1400 kPa applied for 8 hours.

Spotted gum controls were treated using a vacuum of -98 kPa for one hour, and a pressure of 1400 kPa for one hour. This is the normal cycle applied to this pole species.

After treatment, poles and stubs were shipped to the Salisbury Research Facility of the Queensland Department of Employment, Economic Development and Innovation (now DAFF-Q).

Static modulus of elasticity (MOE) and modulus of rupture (MOR) determinations were started in June 2011. Once broken, six poles were selected at random and cut in half to evaluate preservative penetration. The extent of copper penetration was determined using a chrome azurol penetration test (AS1605 – 2006). The results of copper penetration tests are shown in Appendix 2**.** For each sample, one half was sprayed with chrome azurol to show copper penetration and the matching half was left unsprayed.

Termite and decay exposure - stubs

Preparation of termite aggregation trench

To facilitate the termite exposure component of this research, a site was chosen at the Redlands Research Facility (a DEEDI (DAFF-Q) facility) where the subterranean termite *Coptotermes acinaciformis* was known to be active. Previously, trees either adjacent to or near the proposed trial site were drilled and live *C. acinaciformis* soldiers were identified emerging from the drill holes. As well some untreated pine stakes in an exposure trial nearby had been damaged by termites, possibly *C. acinaciformis*. The site is secure and there is access for the heavy machinery required during the trial process viz. to dig the trench and to install the pole stubs.

To expedite sustained foraging by termites in the area where the pole stubs were to be exposed and to improve the likelihood that the pole stubs were subject to termite attack, a trench (approximately 0.5 x 1.5 x 15m) was dug (Figure 15) and filled with a mixture of hardwood and softwood timber (Figure 16).

Figure 15 Digging the trench

Figure 16 Filling the trench with softwood and hardwood

The trench was then back-filled in the expectation that termites would quickly encounter the timber and then continue to forage in the trench due to the amount of food available. The hardwood timber was included to provide an on-going food source which would break down slowly thus providing a long term food supply for the termites. This approach was adopted to ensure sustained foraging by the termites in the short and long term of the trial.

A number of 1.5 m lengths of untreated pine were inserted vertically into the trench at the time of construction. These were used to act as "dipsticks" which could be removed and inspected on a regular basis to ascertain termite activity within the trench.

The termite aggregation trench was constructed on the 18th November 2009 prior to the onset of hot and humid conditions during summer when termites are most active.

Pole stub installation

Figure 17 Pole stubs bundled for shipping

Material used to prepare the pole stubs was preservative treated in the same batches used to treat the through-bored poles. Through-boring was carried out before preservative treatment. Each stub was identified with an aluminium disc in the same way as used for standard commercial power poles (Figure 17).

After treatment, pole stubs were bundled in groups of six and shipped to South Johnstone in north Queensland, Redlands in south east Queensland (two batches of six) and Dalby which is west of Toowoomba in southern Queensland. The intent for each species was to expose six stubs to a high decay hazard in tropical north Queensland, six stubs to decay and six stubs to termites in Redlands and six stubs to decay in Dalby.

Pole stubs were installed on the 30th June at Redlands, 5th July at Dalby and 21st July 2011 at South Johnstone. The layout of the stubs is presented in Appendix 3.

The termite exposure at the Redlands site, involved the installation of feeder material connecting each stub to the prepared termite trench (Figure 18) as well as feeder material between stubs (Figure 19). All the feeder material was buried.

Figure 18 Feeder material connected to the trench

Figure 18 Feeder material connecting stubs

Immediately after installation, all stubs were capped with bitumastic paper to stop rain water trapping.

Pole stub inspection

Twelve months after installation, all pole stubs in all locations were inspected for deterioration. Pole stubs were exposed to a depth of 200 – 300 mm and bored with a 12 mm auger to a depth of approximately 200 mm. Boring started at ground line and angled down at approximately 45 degrees towards the centre of the pole.

Shavings were collected and examined in the field for the presence of decay (Figure 20).

Figure 20 Drill shavings for examination

Resistance to the drill was used to determine if decay was present. Whilst this is a classic technique used by pole inspectors it runs the risk of missing decay pockets if the auger bit only passes through solid wood.

After drilling, the holes were probed with a tool specifically designed to examine the walls of the drill hole. The tool is a stainless steel rod with a small 90^{o} hook on the end. The hook is scraped along the walls of the drill hole and the presence of any softness is noted.

The assessment (drilling and probing) was carried out on all pole stubs. After assessment and before backfilling, bore holes were filled with silicon sealant.

Strength testing

Through-bored and treated poles were shipped to the Department’s Salisbury Research Facility for strength testing.

Whilst the project plan called for 30 poles of each species to be strength tested, the actual number is shown in Appendix 8. There are two reasons why there were fewer than 30 results for the candidate species. Firstly insufficient material may have been initially supplied and secondly process problems were encountered during the testing and the results were consequently rejected..

The details of the pole breaking rig are presented schematically (Figure 21) and the loaded rig is shown (Figure 22).

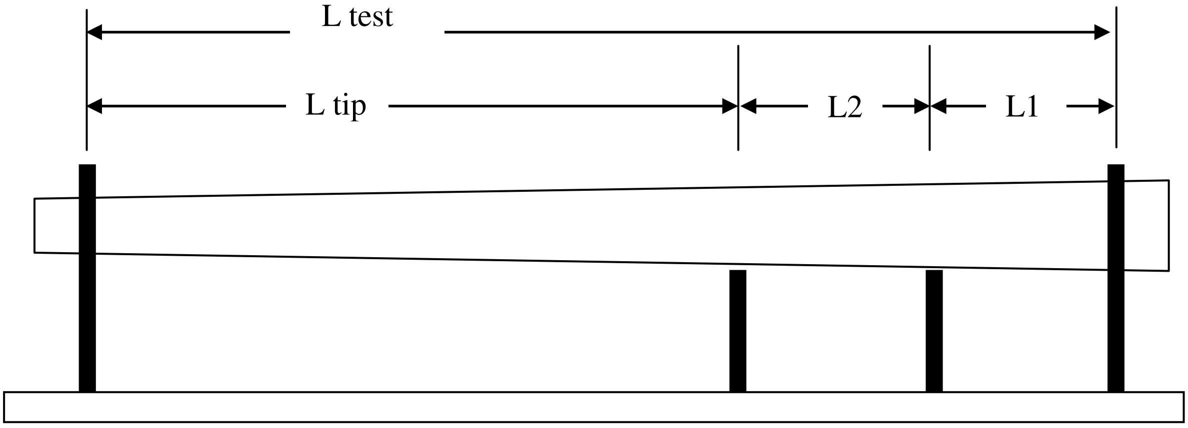

Figure 191 Schematic of pole rig set-up

For each pole:

- L test = 5500 mm
- L tip = 2780 mm
- L1 = 1200 mm
- L2 = 1500 mm

Figure 22 Test material in the rig

After placement in the rig, both end yokes were packed to stop movement once stress was applied (Figure 23).

Tip yoke and pole mid point circumference, circumference at the 100 T ram, circumference at the 200 T ram and butt yoke circumference were then recorded for the pole.

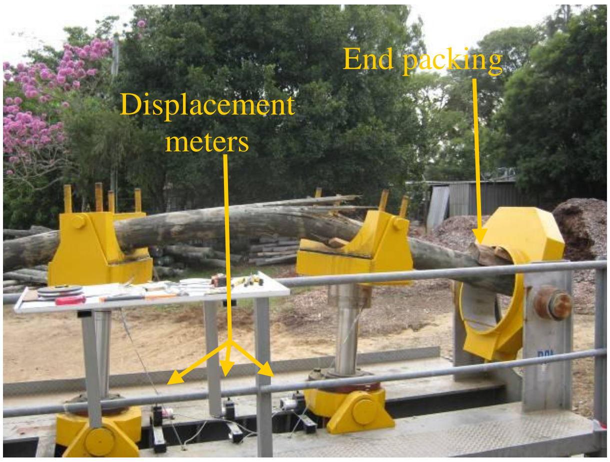

Figure 23 Displacement meters, broken log and end packing

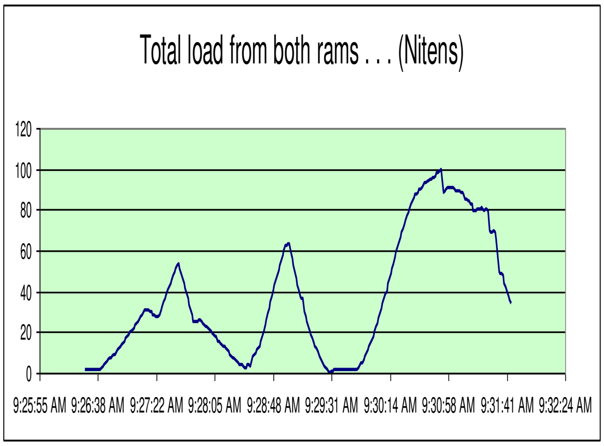

Figure 24 Load profile for *E. nitens*

The lines/leads of the displacement meters were then attached beside the 100 tonne and the 200 tonne ram as well as mid-way between the two rams (Figure 23).

Both rams were then evenly loaded twice to ‘bed in’ the pole in the yokes and the pole was then loaded to failure. Care was taken to evenly load both rams. An example of the loading profile for *E. nitens* is presented in Figure 24.

Immediately after breaking each pole, discs were cut as close to the break point as possible for moisture content determination. Some of the moisture content samples fell apart during drying in which case moisture content is not reported (Appendix 4 Moisture content data). The modulus of rupture (MOR) was calculated for each pole.

Communication

The structure, intent and progress of the project were communicated to a number of organizations with an interest in the project outcomes. These included:

- A total of five presentations to the electricity supply industry; Ergon Energy (a project collaborator), Energex and Country Energy.
- Staff of the DEEDI (now DAFF-Q);
- Dale and Meyers; a project participant,
- A webinar to Forest & Wood Products Australia, Elders Forestry and Forest Enterprises Australia.
- The Wood Preservation 2012 Conference in Melbourne

A presentation has also been organized for delivery to the 2012 Australian Forest Growers Conference at Gympie in October 2012.

A copy of the latest Power Point presentation is provided in Appendix 6.

Results

Test material quality

All test species showed a level of physical deterioration during drying. *E. dunnii* had a very thick sapwood band and split and checked extensively (Figure 5and Figure 25) as drying progressed.

Figure 25 *E. dunnii* 1m butt end off-cuts

Figure 26 Distortion in *E. grandis x camaldulensis*

The *E. grandis x camaldulensis, E. globulus* and *E. nitens* all distorted and/or showed evidence of collapse (Figure 26, Figure 27 & Figure 28).

Figure 27 Collapse & distortion in *E. globulus*

Figure 28 Collapse & distortion in *E. nitens*

It was important not to discount these species at this early stage because of the physical deterioration observed in small test specimens subjected to extreme conditions. The mechanical performance and durability of the final through-bored and treated pole should be considered when determining whether or not the species is suitable for use as poles.

Internal decay in the *E. globulus* logs was uncovered when the test specimens were being prepared (Figure 29). Not all logs contained internal decay and it was not possible to determine its presence whilst in the log form. The decay appears to have entered from a branch stub and improved silvicultural management in the plantation may address this problem.

Figure 29 Internal decay in *E. globulus*

Laboratory treatment

The moisture content immediately before treatment of test specimens was determined using an electronic moisture meter. The results are summarized in Table 5.

Table 5 Average moisture content of test specimens dried at 50°C

Species	Average MC (%)
E. globulus	25 (10.0)*
E. dunnii	32(11.2)
E. grandis x camaldulensis	36(9.3)
E. nitens	30(6.5)

* Values in parenthesis are standard deviations

Liquid absorption

Twelve samples were taken randomly from the stock of prepared test specimens and dried in an oven at 103°C. Average moisture content values were then determined and used to calculate the oven dry mass of the test specimens selected for preservative treatment. Using the calculated oven dry mass and the mass after treatment, the net absorption was determined as a percentage of the calculated oven dried mass. To determine the impact of vacuum and pressure on the percent net absorption for the four candidate species, the percent net absorption was plotted for increasing time at vacuum (-98 kPa) (Figure 30) and increasing time at Pressure (1400 kPa) (Figure 31). In the case of the vacuum figures for material dried at 50°C, there were four charges run at -98 kPa for 60 minutes. For this 60 minute vacuum value, the data in Figure presents the average percent net absorption. Similarly, for Figure , the value for 60 minutes at 1400 kPa is the average of three sets of percent net absorption. Data on samples containing sapwood were omitted from net absorption calculations.

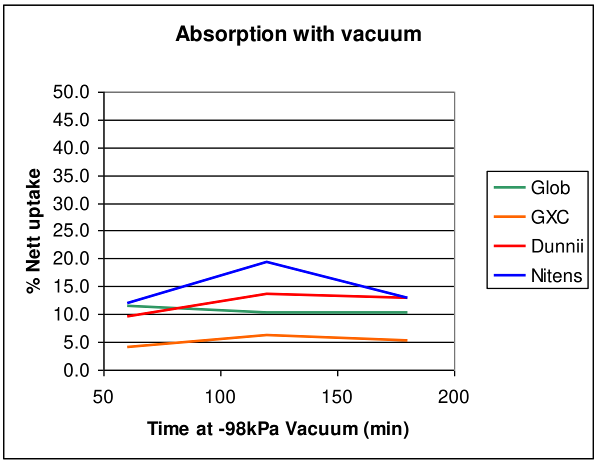

Figure 30 Percent net absorption with time at -90 kPa vacuum

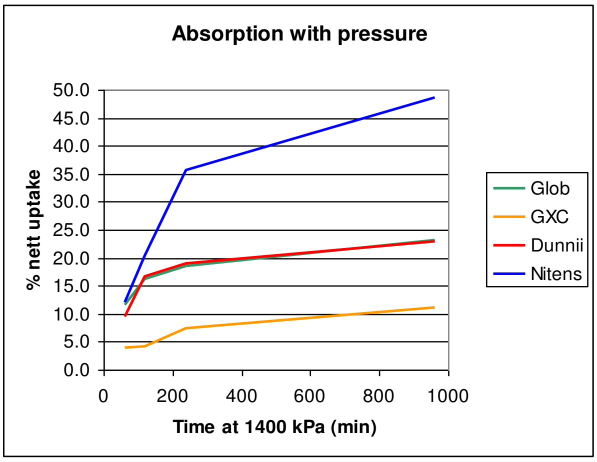

Figure 31 Percent net absorption with time at 1400 kPa

Preservative penetration

Preservative penetration in all test specimens was established by testing for the presence of copper (AS1605 – 2006). An indicator dye was applied to a freshly sawn surface of the treated timber and if copper is present in the wood the dye turns blue (see samples pictured in Appendix 2).

Accelerated decay – fungal cellar and field stakes

Various methods have been used to determine the rate and extent of deterioration caused by biological activity (Clausen 2003). The simplest, most cost effective and most commonly used technique involves probing with a pointed implement and allocating a score describing the extent of attack ((AWPA) 2008). The major problem with this 'pick' technique however, is that score allocation is subjective and the method does not detect early stages of decay (Goodell 2003; Nicholas 2003).

After six, 12, 17 and 21 months exposure, all stakes were removed and assessed for deterioration according to the scale presented in Table 6.

Table 6 Rating scale used to assess exposure stakes

Rating	Condition	Description
10	Sound	No sign or evidence of decay, wood softening or discolouration
9.5	Trace-suspect	Some areas of discolouration and/or softening associated with superficial microorganism attack
9	Slight attack	Decay & wood softening – up to 3% of cross section affected
8	Moderate attack	3-10% of cross section affected
7	Moderate/ severe attack	10 – 30% of cross section
6	Severe attack	30 – 50% of cross section
4	Very severe attack	50 – 75% of cross section
0	Failure	Failure – broken or penetrated by probe

All the assessment results are presented in Appendix 1. The average pick scores over 12 replicates are presented in Table 7.

Table 7 Average pick result for stakes exposed in the fungal cellar and at Redlands

Species	Exposure	Treatment	Drilled	6 months	12 months	17 months	T21 months
E. dunnii	FC*	Treated	Yes	10.0 (0.00)***	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
	FC	Treated	No	9.9 (0.19)	9.9 (0.29)	10.0 (0.14)	9.9 (0.29)
	FC	Un-treated	No	8.9 (0.29)	8.9 (0.51)	6.9 (2.27)	5.8 (3.49)
	RL**	Treated	Yes	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)	10.0 (0.14)
E. globulus	FC	Treated	Yes	10.0 (0.14)	10.0 (0.14)	10.0 (0.00)	9.9 (0.29)
	FC	Treated	No	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
	FC	Un-treated	No	8.9 (0.29)	8.3 (0.78)	6.2 (2.98)	5.1 (3.78)
	RL	Treated	Yes	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
E. grandis x camaldulensis	FC	Treated	Yes	10.0 (0.00)	10.0 (0.00)	10.0 (0.14)	9.9 (0.29)
	FC	Treated	No	10.0 (0.00)	10.0 (0.14)	10.0 (0.00)	10.0 (0.00)
	FC	Un-treated	No	9.0 (0.00)	8.8 (0.58)	8.1 (0.79)	8.0 (0.74)
	RL	Treated	Yes	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)	9.8 (0.40)
E. nitens	FC	Treated	Yes	10.0 (0.14)	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
	FC	Treated	No	10.0 (0.14)	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
	FC	Un-treated	No	8.9 (0.29)	8.5 (0.67)	6.8 (2.29)	5.9 (2.94)
	RL	Treated	Yes	10.0 (0.00)	9.9 (0.29)	10.0 (0.00)	9.7 (0.90)
P. elliottii	FC	Treated	No	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)	10.0 (0.00)
	FC	Un-treated	No	9.7 (0.45)	9.6 (0.47)	8.4 (0.67)	7.8 (2.52)
	RL	Treated	No	9.9 (0.29)	10.0 (0.00)	10.0 (0.14)	10.0 (0.14)
	RL	Un-treated	No	9.8 (0.40)	9.1 (1.28)	5.8 (4.41)	3.6 (4.58)
C. maculata	FC	Un-treated	No	9.5 (0.14)	9.7 (0.33)	9.4 (0.29)	9.4 (0.31)
	RL	Un-treated	No	9.7 (0.33)	9.5 (0.33)	9.3 (0.25)	9.3 (0.26)

* FC = fungal cellar exposure

** RL = Redlands exposure facility

*** Value in parenthesis is standard deviation

Strength testing

The heartwood moisture content (MC) of all poles is summarized in Table 8. All data is presented in Appendix 4.

Table 8 Moisture content at the time of breaking

Species	Number of samples	Mean MC (%)	Standard deviation	Significant difference ** (F pr.<0.001)
C. maculata	32	29.5	3.17	a
E. dunnii	24	49.7	15.03	b
E grandis X camaldulensis	26	49.6	8.39	b
E. nitens	27	54.8	13.28	b
E. globulus	23	63.9	11.74	c

** Species with the same letter are not significantly different

The *C. maculata* was significantly drier than the test species of which *E. globulus* was significantly higher in moisture content. There was no significant difference (ANOVA, $p<0.001$) in the moisture contents of *E. dunnii, E. grandis* x *camaldulensis and E. nitens.*

The coefficient of variation (CV) is a normalized measure of the dispersion of a probability distribution and shows the extent of variability in relation to the mean of a population. The CV is defined as the ratio between the standard deviation and the mean and may be expressed as a percentage. The CV of the average MC (Appendix 4) for *C. maculata* (11%) is the lower than the CV for the candidate species which range from 17% for *E. grandis X camaldulensis* to 30% for *E. dunnii.*

The detailed MOR results are presented in Appendix 5 Strength test data.

Discussion

Laboratory stake treatment

The reason for the apparent decreasing percent net absorption with increasing time at -98 kPa is unclear. Given that the level of replication of samples treated was low (n=6), further work should be carried out in future projects to establish the variability in the results obtained and the apparent trend observed.

Tamblyn, quoted in Hillis and Brown (1984), reported that *Eucalyptus* species responded to treatment with preservative oils by the application of pressures up to 7,000 kPa. Kohli and Kumar

(1989) achieved 0.6 mm lateral penetration and 3 mm end grain penetration of a 50:50 creosote and fuel oil mixture in a *Eucalyptus* hybrid after using a treatment pressure of 3,500 kPa. One vacuum pressure impregnation plant at Smithton in Tasmania operates at 3,000 kPa (Jensen pers. comm. 2010). All other plants in Australia are rated to operate at 1,200 kPa hydrostatic pressure. It is unlikely that water borne preservative treatment vessels designed to achieve the pressures quoted by Hillis and Brown (1984) and Kohli and Kumar (1989) can be economically justified.

The information presented in Figure 31 indicates that time at pressure had a larger impact on the percent net absorption than time at vacuum. Timber treatment schedules on refractory species in the USA involve much longer times at pressure than is generally the case in Australia. (Prof. Jeff Morrel, Oregon State University, personal communication). In Australia, it is usual to manipulate time at vacuum to achieve full sapwood penetration of eucalypt sapwood. Pressure periods are usually applied until the sapwood stops absorbing preservative fluid. In the timber treatment industry, the point when the sapwood stops absorbing fluid is called “refusal”. However this practice applies to the penetration of permeable sapwood. When attempting to penetrate impermeable heartwood, it may be necessary to rethink the use of a refusal point and apply pressure for set periods of time.

In Figure 31 *E. nitens* appears to be more responsive to increased pressure times than the other three candidate species. This may be because the *E. nitens* was dried in an oven at 50^{o}C before preservative treatment. As the *E. nitens* arrived in mid February the timber was very wet and test specimens were placed in an oven to reduce the pre-treatment moisture content. Moisture content at time of treatment has a major impact on preservative absorption into sapwood and the indications are that there are similar effects in the treatment of heartwood for this species.

Drying heartwood to levels in the order of 35% will require either drying in commercial timber kilns or long periods of air seasoning. This matter will need further research and technology associated with drying poles is outside the scope of this project.

Preservative penetration

In Figure 32 to Figure 40 , some of the test specimens show intense blue colouration down one side of the test specimen. This is particularly evident for *E. dunnii*. This pattern of copper treatment is because of the presence of fully penetrated sapwood. Obtaining test specimens that were heartwood only was difficult because of the small diameter of the available logs and because of the thick sapwood bands that were present.

Figure 32 Copper penetration after schedule #1

Figure 33 Copper penetration after schedule #2

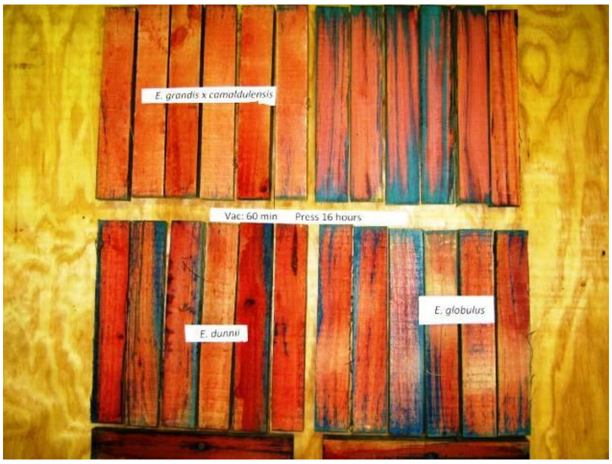

Figure 34 Copper penetration after schedule #3

Figure 35 Copper penetration after schedule #4

Figure 36 Copper penetration after schedule #5

Figure 37 Copper penetration after schedule #6

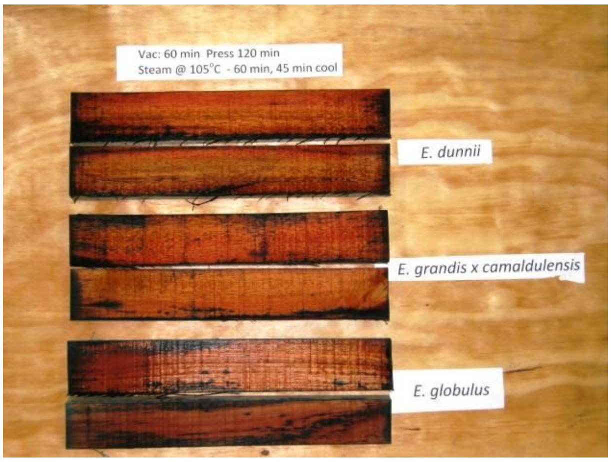

Figure 38 Copper penetration after schedule #7

Figure 39 Copper penetration after schedule #8

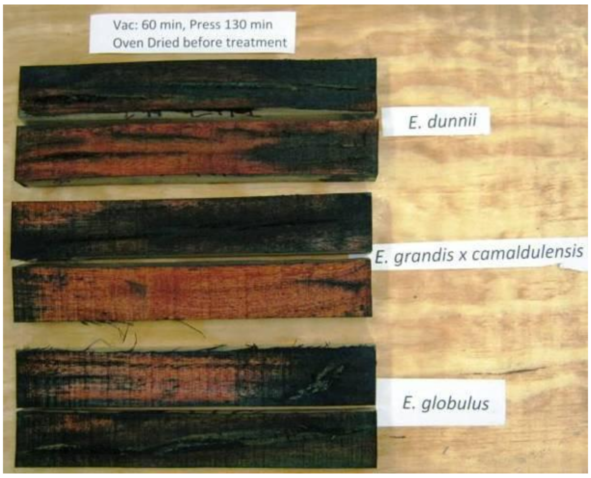

Figure 40 Copper penetration after schedule #9

E. grandis x camaldulensis

Figure 32 to Figure 40 indicate that test specimens of this species were the least penetrated for all treatment cycles carried out. The best penetration was achieved on test specimens that were oven dried at 50°C followed by 60 minutes vacuum and 480 minutes pressure (Schedule #8, Figure 39). The impact of pre-treatment drying is further indicated for the two samples that were dried to 0% moisture content (Schedule #9, Figure 40). One of these samples was almost completely penetrated and the other showed more penetration than occurred for non-dried test specimens. Steaming or double drilling the test specimens did not improve preservative penetration compared to vacuum pressure processes.

E. dunnii

The treatment cycles with longer pressure periods improved preservative penetration. As for the *E. grandis* x *camaldulensis*, drying the timber improved preservative penetration. In Figure 39, for the photograph of test specimens subjected to drying at 50°C and eight hours pressure, the test specimen on the far left was all heartwood and almost completely penetrated.

E. globulus

For this species, the longer pressure periods improved preservative penetration although the charge with three hours vacuum and one hour pressure also gave promising results. The results from oven dried *E. globulus* samples mirrored those from *E. grandis* x *camaldulensis* and *E. dunnii.* Steaming improved preservative penetration in this species and double drilling also showed promising results. The specimens dried at 50°C and subjected to eight hours pressure also showed improved preservative penetration.

E. nitens

The *E. nitens* test specimens experienced the most preservative penetration as a result of the schedules tested. The longer pressure periods were the most effective. Treating the test specimens at lower moisture content also had a positive effect on preservative penetration

Accelerated decay – fungal cellar and field stakes

The original timing for this part of the project involved exposure for 18 months with future assessments being supported by chemical suppliers. However due to the late installation of pole stubs, the stake exposures could be continued to 21 months for the preparation of this report. Assessments are to continue into the future.

Over the 21 months of exposure, none of the treated test species, drilled or undrilled were assessed as having a score of less than 9.5 or ‘Trace-suspect’ deterioration. This result was the same for both the fungal cellar and the Redlands exposures.

However, with the exception of spotted gum heartwood, untreated material in the fungal cellar, has started to deteriorate (Figure 41)

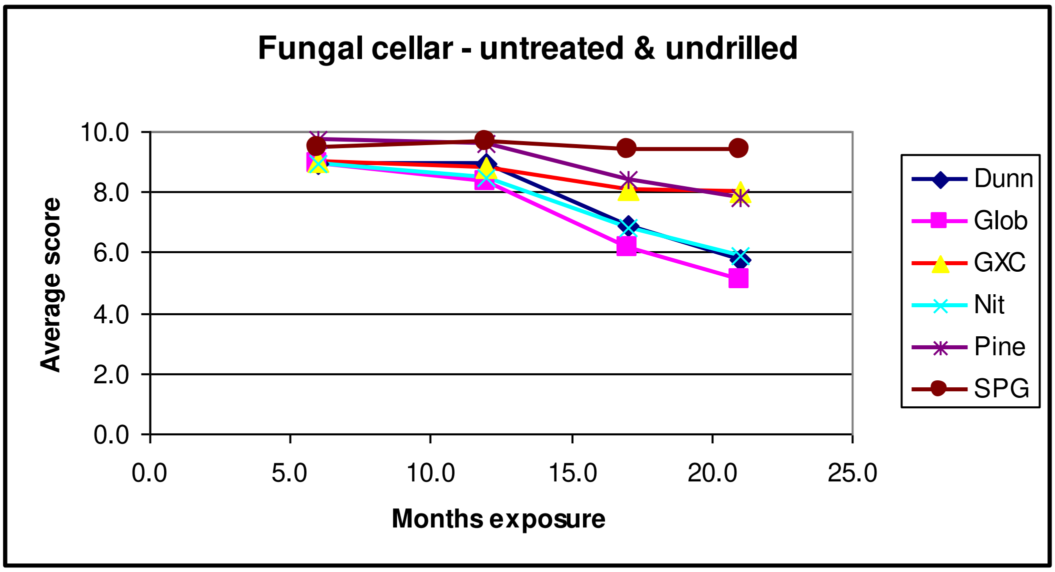

Figure 41 Average stake scores in the fungal cellar

Untreated *E. globulus, E. nitens* and *.E dunnii* heartwood is deteriorating faster than the heartwood of *E. grandis x E. camaldulensis* and *P. elliottii*. The untreated heartwood of *E. globulus* is deteriorating the fastest of all the test species.

Over the 21 months of exposure, none of the treated test species, drilled or undrilled were assessed as having a score of less than 9.5 or 'Trace-suspect' deterioration. This result was the same for both the fungal cellar and the Redlands exposures.

Three untreated *E. dunnii,* four *E. globulus* and two *E. nitens* stakes failed completely (score = 0) in the fungal cellar after 21 months exposure. None of the *E. grandis x E. camaldulensis* stakes failed over the same period. Two of the *E. grandis x E. camaldulensis* stakes were scored nine (slight attack), nine stakes were scored eight (moderate attack) and one stake scored six (severe attack).

One *P. elliottii* stake in the fungal cellar failed (score = 0) compared to seven failed stakes of the same species exposed at the Redlands site. All the untreated *P. elliottii* stakes exposed in the fungal cellar were heavily saturated, wicking water from the soil bed (Figure 42). None of the adjacent treated stakes exhibited the same level of water absorption (Figure 43). The wicking behaviour of untreated *P. elliottii* warrants further investigation.

Deterioration in the untreated material indicates that the there is an appropriate level of decay hazard. The fact that none of the treated material in either the fungal cellar or at the Redlands field exposure site is decaying is a positive sign for the treatment, however longer exposure is needed before a definite conclusion can be drawn.

Figure 42 Saturated untreated *P. elliottii stake*

Figure 43 Saturated stake between adjacent dry stakes

Commercial treatment

Ground staff at Dale and Meyers expressed concern about the time needed to mark and bore the holes. Professor Morrell advised that pole producers in the US have tried unsuccessfully to automate/mechanize the hole marking and drilling process. The task is menial requiring little skill or decision making.

The decay fruiting bodies occurring on the surface of some of the *E. globulus* logs is a concern. Sourcing the logs took place over six months depending on the availability of staff and access. The candidate species were not felled at the same time and some of the logs (species) sat untreated in the Dale and Meyers' yard for many weeks. Over the same period, south east Queensland experienced periods of extremely wet weather. Also, as advised in the methodology and results sections, a number of the poles had internal decay (see Figures 14 and 29).

The photos of copper penetration into *E. globulus* (Appendix 2) show areas of discoloration that could have been decay. There areas were heavily penetrated by preservative.

Copper penetration tests showed that the *E. nitens* was the 'best' penetrated of the candidate species followed by *E. globulus*. The heartwood penetration in *E. dunnii* was random and the *E. grandis* x *camaldulensis* showed almost no copper penetration into the heartwood.

The penetration photographs for *E. nitens* indicate that all the penetration was longitudinal with virtually no radial penetration. Photographs of the other three species indicate that for some of the through-bored holes, liquid penetrated the hole but the copper appears to have filtered out. The liquid stain can be seen on the un-spot-tested half of the sample.

Termite and decay exposure - stubs

At this early stage, none of the poles have showed evidence of either decay or termite damage. This is not an unexpected result after only 12 months exposure and further assessments are necessary to establish the durability of the treated material.

Strength testing

Morris and Winandy (2002) observed that wood will decay above 30% moisture content (MC) and will not decay below 20%. The authors called the range between 20% and 30% MC a 'grey area' and carried out experimentation to measure the limiting thresholds for decay to take place. The four candidate species had moisture content greater than 30% and thus rely on the natural durability of the heartwood to prevent decay. The *E. globulus* had the highest average moisture content (63.9%) and decay was found in this species during initial processing (Figure 29).

Figure 44 Splinter break

Whilst the conditions were conducive for decay to occur, it is not known if there was decay present inside the logs at the time of breaking. In all 153 logs that were broken, breaks were splinter like (Figure 44) with none of the characteristic carrot fracture that occurs in decayed timber. None of the poles broke completely in two and so it was not possible to identify any decay at the point of break.

The photos in Appendix 2 indicate stained zones of heartwood in all candidate species. When probed, these resisted penetration and did not exhibit decay characteristics.

An analysis of variance (ANOVA) was carried out on the logarithmic transform of the mean MOR for each species excluding outlier results.

The results of the ANOVA on the mean MOR are presented in Table 9. The analysis was carried out on a logarithmic transform of the data as the transformation improved the shape of the distribution. Values with the same letter are not significantly different ($P<0.001$) using a Fishers protected LSD test.

Table 9 Analysis of Variance results

Species	MOR (Mpa)	Ln MOR (ex)				
S	167.9	a	🟥			
X	94.8	b		🟩		
N	66.4	c			🟦	
G	62.4	d				🟧
D	58.4	d				🟧

* S = *C. maculata,* X = *E. grandis* x *camaldulensis,* N = *E. nitens,* G = *E. globulus* and D = *E. dunnii.*

The data in Table 9 shows that *C. maculata* is significantly stronger as measured by MOR, than the candidate species. *E. dunnii wa*s the weakest. Of all the candidate species, the *E. grandis* x *camaldulensis* is the strongest being approximately twice the strength of the *E. dunnii*.

Conclusions and recommendations

Work at the laboratory scale indicated that time at pressure has a greater influence than time at vacuum on the absorption of liquid into the candidate species. Currently, timber treatment specifications in Australia focus on sapwood penetration with a limited envelope of penetration specified for heartwood. If in the future the intent is to upgrade heartwood durability, the approach to vacuum pressure processes will have to be reviewed. More work is required to investigate the absorption of preservative (liquid) into the heartwood.

The decay in (Figure 29) and on (Figure 14) the *E. globulus* is a concern. To address this, management practices both in the plantation and the saw mill would need to be implemented. Associated with this issue, is the need to dry the heartwood to a level that is optimum for liquid penetration. Further work should be carried out on the relationship between heartwood moisture content and net absorption. In the worst case, kiln drying of heartwood may be needed to avoid pre-treatment decay and to achieve adequate penetration of preservative.

With regard to durability, field and fungal cellar trials currently in place will need more time before a definite outcome can be achieved. Untreated stakes are already showing signs of deterioration, however treated material in both the fungal cellar and the field is still sound.

The durability performance is the most important characteristic that needs to be established. If the treated material resists decay and termite attack, then the strength results can be used to design appropriate pole sizes for a particular job. Past experience indicates that at least five years exposure is required before durability performance information becomes meaningful.

The saturation behaviour of untreated slash pine in the fungal cellar (Figure 42) is interesting and warrants further investigation, although this feature is unlikely to have an impact on the outcomes of the research reported in this document.

The MOR data developed in this work provides design data for engineers to make the necessary calculations for in-line performance.

Of the four candidate species, the untreated (natural) durability of *E. grandis* x *camaldulensis* is the highest (Figure 41). This species also has significantly higher average strength than the other three candidate timbers (Table 9). Unfortunately, this species was also the least penetrated by CCA wood preservative. Long term exposure will reveal if the limited penetration associated with the higher natural durability is enough to provide an adequate service life.

Ongoing inspections with the support of Osmose, Lonza (Arch) and Timtech are planned up to five years exposure.

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Appendices

Appendix 1 Assessment results after 6, 12, 17 and 21 months

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
D39-4	Fungal cellar TTD	No	10 2121	10	10	10	10
D41-5	Fungal cellar TTD	No	10 2122	10	10	10	10
D43-1	Fungal cellar TTD	No	10 2123	9.5	10	10	10
D43-3	Fungal cellar TTD	No	10 2124	10	10	10	10
D43-4	Fungal cellar TTD	No	10 2125	10	10	10	10
D47-7	Fungal cellar TTD	No	10 2126	10	10	10	10
D48-1	Fungal cellar TTD	No	10 2127	10	9	10	10
D48-11	Fungal cellar TTD	No	10 2131	10	10	10	10
D48-15	Fungal cellar TTD	No	10 2132	10	10	10	10
D48-3	Fungal cellar TTD	No	10 2128	10	10	10	10
D48-5	Fungal cellar TTD	No	10 2129	10	10	10	10
D48-6	Fungal cellar TTD	No	10 2130	9.5	10	9.5	9
D39-1	Fungal cellar TTD	Yes	10 2097	10	10	10	10
D39-10	Fungal cellar TTD	Yes	10 2098	10	10	10	10
D41-10	Fungal cellar TTD	Yes	10 2100	10	10	10	10
D41-7	Fungal cellar TTD	Yes	10 2099	10	10	10	10
D42-2	Fungal cellar TTD	Yes	10 2101	10	10	10	10
D42-7	Fungal cellar TTD	Yes	10 2102	10	10	10	10
D47-13	Fungal cellar TTD	Yes	10 2106	10	10	10	10
D47-14	Fungal cellar TTD	Yes	10 2107	10	10	10	10
D47-3	Fungal cellar TTD	Yes	10 2105	10	10	10	10
D48-16	Fungal cellar TTD	Yes	10 2104	10	10	10	10
D48-4	Fungal cellar TTD	Yes	10 2108	10	10	10	10
D48-9	Fungal cellar TTD	Yes	10 2103	10	10	10	10
G38-6	Fungal cellar TTD	No	10 2025	10	10	10	10
G38-7	Fungal cellar TTD	No	10 2026	10	10	10	10
G39-4	Fungal cellar TTD	No	10 2027	10	10	10	10
G39-5	Fungal cellar TTD	No	10 2028	10	10	10	10
G41-5	Fungal cellar TTD	No	10 2029	10	10	10	10
G44-10	Fungal cellar TTD	No	10 2031	10	10	10	10
G44-5	Fungal cellar TTD	No	10 2030	10	10	10	10
G45-1	Fungal cellar TTD	No	10 2032	10	10	10	10
G47-1	Fungal cellar TTD	No	10 2033	10	10	10	10
G47-8	Fungal cellar TTD	No	10 2034	10	10	10	10
G48-11	Fungal cellar TTD	No	10 2036	10	10	10	10
G48-3	Fungal cellar TTD	No	10 2035	10	10	10	10

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
G37-4	Fungal cellar TTD	Yes	10 2001	10	10	10	10
G38-2	Fungal cellar TTD	Yes	10 2002	10	10	10	10
G40-7	Fungal cellar TTD	Yes	10 2003	10	10	10	10
G41-2	Fungal cellar TTD	Yes	10 2004	10	10	10	9
G42-1	Fungal cellar TTD	Yes	10 2005	10	10	10	10
G43-4	Fungal cellar TTD	Yes	10 2006	10	10	10	10
G44-9	Fungal cellar TTD	Yes	10 2007	10	10	10	10
G45-6	Fungal cellar TTD	Yes	10 2008	10	10	10	10
G47-15	Fungal cellar TTD	Yes	10 2011	10	10	10	10
G47-2	Fungal cellar TTD	Yes	10 2010	9.5	9.5	10	10
G48-17	Fungal cellar TTD	Yes	10 2012	10	10	10	10
G48-6	Fungal cellar TTD	Yes	10 2009	10	10	10	10
X37-16	Fungal cellar TTD	No	10 2171	10	9.5	10	10
X37-7	Fungal cellar TTD	No	10 2169	10	10	10	10
X37-9	Fungal cellar TTD	No	10 2170	10	10	10	10
X38-3	Fungal cellar TTD	No	10 2172	10	10	10	10
X38-4	Fungal cellar TTD	No	10 2173	10	10	10	10
X38-5	Fungal cellar TTD	No	10 2174	10	10	10	10
X38-8	Fungal cellar TTD	No	10 2175	10	10	10	10
X39-16	Fungal cellar TTD	No	10 2178	10	10	10	10
X39-19	Fungal cellar TTD	No	10 2179	10	10	10	10
X39-5	Fungal cellar TTD	No	10 2176	10	10	10	10
X39-9	Fungal cellar TTD	No	10 2177	10	10	10	10
X41-11	Fungal cellar TTD	No	10 2180	10	10	10	10
X37-12	Fungal cellar TTD	Yes	10 2145	10	10	10	10
X37-17	Fungal cellar TTD	Yes	10 2146	10	10	10	10
X38-2	Fungal cellar TTD	Yes	10 2147	10	10	10	9
X39-10	Fungal cellar TTD	Yes	10 2149	10	10	9.5	10
X39-11	Fungal cellar TTD	Yes	10 2150	10	10	10	10
X39-21	Fungal cellar TTD	Yes	10 2151	10	10	10	10
X39-6	Fungal cellar TTD	Yes	10 2148	10	10	10	10
X40-3	Fungal cellar TTD	Yes	10 2152	10	10	10	10
X40-6	Fungal cellar TTD	Yes	10 2153	10	10	10	10
X40-8	Fungal cellar TTD	Yes	10 2154	10	10	10	10
X41-10	Fungal cellar TTD	Yes	10 2156	10	10	10	10
X41-9	Fungal cellar TTD	Yes	10 2155	10	10	10	10

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
N37-12	Fungal cellar TTD	No	10 2076	10	10	10	10
N37-23	Fungal cellar TTD	No	10 2077	10	10	10	10
N37-5	Fungal cellar TTD	No	10 2073	10	10	10	10
N37-6	Fungal cellar TTD	No	10 2074	10	10	10	10
N37-7	Fungal cellar TTD	No	10 2075	10	10	10	10
N38-1	Fungal cellar TTD	No	10 2078	10	10	10	10
N39-24	Fungal cellar TTD	No	10 2079	9.5	10	10	10
N39-41	Fungal cellar TTD	No	10 2080	10	10	10	10
N39-44	Fungal cellar TTD	No	10 2081	10	10	10	10
N40-16	Fungal cellar TTD	No	10 2083	10	10	10	10
N40-35	Fungal cellar TTD	No	10 2084	10	10	10	10
N40-5	Fungal cellar TTD	No	10 2082	10	10	10	10
N37-1	Fungal cellar TTD	Yes	10 2049	10	10	10	10
N37-16	Fungal cellar TTD	Yes	10 2052	10	10	10	10
N37-3	Fungal cellar TTD	Yes	10 2050	10	10	10	10
N37-9	Fungal cellar TTD	Yes	10 2051	10	10	10	10
N38-5	Fungal cellar TTD	Yes	10 2053	10	10	10	10
N38-9	Fungal cellar TTD	Yes	10 2054	10	10	10	10
N39-2	Fungal cellar TTD	Yes	10 2055	10	10	10	10
N39-6	Fungal cellar TTD	Yes	10 2056	9.5	10	10	10
N40-2	Fungal cellar TTD	Yes	10 2057	10	10	10	10
N40-3	Fungal cellar TTD	Yes	10 2058	10	10	10	10
N41-07	Fungal cellar TTD	Yes	10 2059	10	10	10	10
N41-9	Fungal cellar TTD	Yes	10 2060	10	10	10	10
P1	Fungal Cellar TTD	No	10 2277	10	10	10	10
P2	Fungal Cellar TTD	No	10 2278	10	10	10	10
P3	Fungal Cellar TTD	No	10 2279	10	10	10	10
P4	Fungal Cellar TTD	No	10 2280	10	10	10	10
P5	Fungal Cellar TTD	No	10 2281	10	10	10	10
P6	Fungal Cellar TTD	No	10 2282	10	10	10	10
P7	Fungal Cellar TTD	No	10 2283	10	10	10	10
P8	Fungal Cellar TTD	No	10 2284	10	10	10	10
P9	Fungal Cellar TTD	No	10 2285	10	10	10	10
P10	Fungal Cellar TTD	No	10 2286	10	10	10	10
P11	Fungal Cellar TTD	No	10 2287	10	10	10	10
P12	Fungal Cellar TTD	No	10 2288	10	10	10	10

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
D39-5	Fungal cellar UT	No	10 2193	9	10	8	8
D39-7	Fungal cellar UT	No	10 2194	8	8	8	8
D41-1	Fungal cellar UT	No	10 2195	9	9	7	7
D41-2	Fungal cellar UT	No	10 2196	9	9	0*	0
D41-3	Fungal cellar UT	No	10 2197	9	8	7	0
D41-4	Fungal cellar UT	No	10 2198	9	9	8	8
D41-6	Fungal cellar UT	No	10 2199	9	9	8	7
D42-5	Fungal cellar UT	No	10 2200	9	9	7	7
D43-6	Fungal cellar UT	No	10 2201	9	9	8	8
D43-8	Fungal cellar UT	No	10 2202	9	9	8	8
D48-12	Fungal cellar UT	No	10 2203	9	9	6	0
D48-14	Fungal cellar UT	No	10 2204	9	9	8	8
G38-5	Fungal cellar UT	No	10 2229	9	7	0	0
G40-1	Fungal cellar UT	No	10 2230	9	9	8	7
G40-3	Fungal cellar UT	No	10 2231	9	8	8	8
G40-4	Fungal cellar UT	No	10 2232	9	9	8	8
G40-5	Fungal cellar UT	No	10 2233	9	9	8	8
G41-3	Fungal cellar UT	No	10 2234	9	9	8	8
G43-2	Fungal cellar UT	No	10 2235	9	7	0	0
G43-9	Fungal cellar UT	No	10 2236	8	8	7	7
G45-10	Fungal cellar UT	No	10 2238	9	9	7	7
G45-9	Fungal cellar UT	No	10 2237	9	8	6	0
G48-21	Fungal cellar UT	No	10 2240	9	9	8	8
G48-4	Fungal cellar UT	No	10 2239	9	8	6	0
X37-10	Fungal cellar UT	No	10 2205	9	9	8	8
X37-14	Fungal cellar UT	No	10 2206	9	9	9	8
X38-16	Fungal cellar UT	No	10 2207	9	9	8	8
X39-1	Fungal cellar UT	No	10 2208	9	9	9	9
X39-20	Fungal cellar UT	No	10 2212	9	9	8	8
X39-21	Fungal cellar UT	No	10 2213	9	7	6	6
X39-3	Fungal cellar UT	No	10 2209	9	9	8	8
X39-4	Fungal cellar UT	No	10 2210	9	9	8	8
X39-8	Fungal cellar UT	No	10 2211	9	9	8	8
X40-14	Fungal cellar UT	No	10 2214	9	9	8	8
X40-18	Fungal cellar UT	No	10 2215	9	9	9	9
X40-20	Fungal cellar UT	No	10 2216	9	9	8	8

* shaded cells indicate specimens that have failed (score = 0)

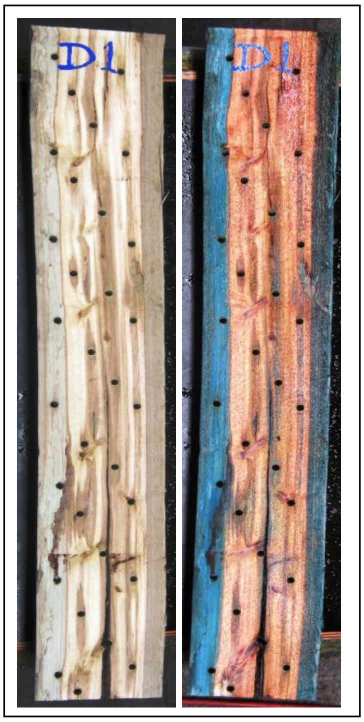
Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
N37-22	Fungal cellar UT	No	10 2217	9	9	7	6
N37-25	Fungal cellar UT	No	10 2218	9	7	0	0
N37-26	Fungal cellar UT	No	10 2219	8	8	7	0
N38-15	Fungal cellar UT	No	10 2220	9	9	7	6
N39-14	Fungal cellar UT	No	10 2221	9	9	9	9
N39-23	Fungal cellar UT	No	10 2222	9	8	6	6
N39-35	Fungal cellar UT	No	10 2223	9	9	8	8
N39-48	Fungal cellar UT	No	10 2224	9	9	8	8
N40-29	Fungal cellar UT	No	10 2226	9	8	8	8
N40-33	Fungal cellar UT	No	10 2227	9	8	7	7
N40-34	Fungal cellar UT	No	10 2228	9	9	8	6
N40-9	Fungal cellar UT	No	10 2225	9	9	7	7
P13	Fungal Cellar UT	No	10 2289	9	9	8	8
P14	Fungal Cellar UT	No	10 2290	9	9.5	9	9
P15	Fungal Cellar UT	No	10 2291	9.5	9.5	8	8
P16	Fungal Cellar UT	No	10 2292	10	10	9	9
P17	Fungal Cellar UT	No	10 2293	10	10	9	9
P18	Fungal Cellar UT	No	10 2294	10	9	8	8
P19	Fungal Cellar UT	No	10 2295	10	10	9	9
P20	Fungal Cellar UT	No	10 2296	9	9	8	8
P21	Fungal Cellar UT	No	10 2297	10	9	9	9
P22	Fungal Cellar UT	No	10 2298	10	10	7	0
P23	Fungal Cellar UT	No	10 2299	10	10	9	9
P24	Fungal Cellar UT	No	10 2300	10	10	8	8
SG-37-4	Fungal cellar UT	No	10 2241	9.5	10	9.5	9.5
SG-38-1	Fungal cellar UT	No	10 2242	9.5	10	9	9
SG-39-4	Fungal cellar UT	No	10 2243	9.5	9.5	9.5	9.5
SG-40-3	Fungal cellar UT	No	10 2244	9.5	9.5	9.5	9
SG-41-2	Fungal cellar UT	No	10 2245	9.5	9.5	9	9
SG-42-3	Fungal cellar UT	No	10 2246	9.5	10	9.5	9.5
SG-43-4	Fungal cellar UT	No	10 2247	9.5	9.5	9.5	9.5
SG-44-5	Fungal cellar UT	No	10 2248	9	9	9	9
SG-45-3	Fungal cellar UT	No	10 2249	9.5	9.5	10	10
SG-46-1	Fungal cellar UT	No	10 2250	9.5	10	9.5	9.5
SG-47-4	Fungal cellar UT	No	10 2251	9.5	10	9.5	9.5
SG-48-7	Fungal cellar UT	No	10 2252	9.5	9.5	9.5	9.5

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
D39-11	Redlands TTD	Yes	10 2112	10	10	10	10
D39-2	Redlands TTD	Yes	10 2109	10	10	10	10
D39-3	Redlands TTD	Yes	10 2110	10	10	10	10
D39-9	Redlands TTD	Yes	10 2111	10	10	10	10
D41-11	Redlands TTD	Yes	10 2114	10	10	10	10
D41-8	Redlands TTD	Yes	10 2113	10	10	10	10
D42-3	Redlands TTD	Yes	10 2115	10	10	10	10
D42-4	Redlands TTD	Yes	10 2116	10	10	10	10
D47-15	Redlands TTD	Yes	10 2119	10	10	10	10
D47-16	Redlands TTD	Yes	10 2120	10	10	10	10
D47-4	Redlands TTD	Yes	10 2117	10	10	10	9.5
D47-5	Redlands TTD	Yes	10 2118	10	10	10	10
G38-1	Redlands TTD	Yes	10 2013	10	10	10	10
G38-3	Redlands TTD	Yes	10 2014	10	10	10	10
G42-6	Redlands TTD	Yes	10 2015	10	10	10	10
G46-1	Redlands TTD	Yes	10 2016	10	10	10	10
G46-10	Redlands TTD	Yes	10 2019	10	10	10	10
G46-2	Redlands TTD	Yes	10 2017	10	10	10	10
G46-4	Redlands TTD	Yes	10 2018	10	10	10	10
G47-12	Redlands TTD	Yes	10 2021	10	10	10	10
G47-4	Redlands TTD	Yes	10 2020	10	10	10	10
G48-15	Redlands TTD	Yes	10 2022	10	10	10	10
G48-16	Redlands TTD	Yes	10 2023	10	10	10	10
G48-18	Redlands TTD	Yes	10 2024	10	10	10	10
X37-13	Redlands TTD	Yes	10 2157	10	10	10	10
X37-15	Redlands TTD	Yes	10 2158	10	10	10	9.5
X37-20	Redlands TTD	Yes	10 2159	10	10	10	10
X38-1	Redlands TTD	Yes	10 2160	10	10	10	10
X39-14	Redlands TTD	Yes	10 2161	10	10	10	10
X39-15	Redlands TTD	Yes	10 2162	10	10	10	10
X40-1	Redlands TTD	Yes	10 2163	10	10	10	10
X40-21	Redlands TTD	Yes	10 2166	10	10	10	10
X40-5	Redlands TTD	Yes	10 2164	10	10	10	9
X40-9	Redlands TTD	Yes	10 2165	10	10	10	10
X41-23	Redlands TTD	Yes	10 2168	10	10	10	9
X41-8	Redlands TTD	Yes	10 2167	10	10	10	10

Treatment Label	Exposure	Drilled?	Tag #	T6 pick result	T12 pick result	T17 pick result	T21 pick result
N37-20	Redlands TTD	Yes	10 2061	10	10	10	10
N37-32	Redlands TTD	Yes	10 2062	10	10	10	10
N39-10	Redlands TTD	Yes	10 2064	10	10	10	10
N39-11	Redlands TTD	Yes	10 2065	10	10	10	10
N39-12	Redlands TTD	Yes	10 2066	10	10	10	10
N39-7	Redlands TTD	Yes	10 2063	10	10	10	10
N40-12	Redlands TTD	Yes	10 2068	10	9	10	7
N40-24	Redlands TTD	Yes	10 2069	10	10	10	10
N40-6	Redlands TTD	Yes	10 2067		10		
N41-10	Redlands TTD	Yes	10 2070	10	10	10	10
N41-11	Redlands TTD	Yes	10 2071	10	10	10	10
N41-12	Redlands TTD	Yes	10 2072	10	10	10	10
P25	Redlands TTD	No	10 2301	10	10	10	10
P26	Redlands TTD	No	10 2302	10	10	10	10
P27	Redlands TTD	No	10 2303	10	10	10	10
P28	Redlands TTD	No	10 2304	10	10	10	10
P29	Redlands TTD	No	10 2305	10	10	10	10
P30	Redlands TTD	No	10 2306	10	10	10	10
P31	Redlands TTD	No	10 2307	10	10	10	10
P32	Redlands TTD	No	10 2308	10	10	10	10
P33	Redlands TTD	No	10 2309	10	10	10	10
P34	Redlands TTD	No	10 2310	10	10	10	10
P35	Redlands TTD	No	10 2311	10	10	10	10
P36	Redlands TTD	No	10 2312	9	10	9.5	9.5
P37	Redlands UT	No	10 2313	10	9.5	7	7
P38	Redlands UT	No	10 2314	10	10	10	10
P39	Redlands UT	No	10 2315	9.5	9	0	0
P40	Redlands UT	No	10 2316	9	9	0	0
P41	Redlands UT	No	10 2317	10	10	8	0
P42	Redlands UT	No	10 2318	10	10	10	10
P43	Redlands UT	No	10 2319	10	9.5	9	7
P44	Redlands UT	No	10 2320	10	10	10	9.5
P45	Redlands UT	No	10 2321	10	7	0	0
P46	Redlands UT	No	10 2322	9	6	0	0
P47	Redlands UT	No	10 2323	9.5	9.5	8	0
P48	Redlands UT	No	10 2324	10	9.5	8	0
SG-37-9	Redlands UT	No	10 2253	9	9	9	9
SG-38-3	Redlands UT	No	10 2254	10	10	9.5	9.5
SG-39-6	Redlands UT	No	10 2255	10	9.5	9.5	9.5
SG-40-4	Redlands UT	No	10 2256	9.5	9.5	9	9
SG-41-8	Redlands UT	No	10 2257	9.5	10	9.5	9.5
SG-42-9	Redlands UT	No	10 2258	9.5	9	9.5	9
SG-43-8	Redlands UT	No	10 2259	9.5	9.5	9.5	9.5
SG-44-6	Redlands UT	No	10 2260	10	9.5	9	9
SG-45-2	Redlands UT	No	10 2261	9.5	9.5	9.5	9
SG-46-4	Redlands UT	No	10 2262	10	9.5	9.5	9.5
SG-47-6	Redlands UT	No	10 2263	9.5	10	9.5	9.5
SG-48-4	Redlands UT	No	10 2264	10	9.5	9	9

Appendix 2 Copper penetration

Copper penetration into *E. dunnii*



Copper penetration into *E. grandis x camaldulensis*

Appendix 3 Stub layout

South Johnstone

Railway line

North

GN1	XN3
XN2	DN5
DN2	GN3
XN4	XN1
GN6	NN5
DN1	XN6
GN4	NN6
DN3	GN2
DN4	XN5
NN3	NNA
GN5	DN6
NN4	NN3

South

Figure 45 Stub layout at South Johnstone

Redlands termite layout

North		
DRT5	Termite trench	
NRT1		
GRT2		XRT3
XRT4		NRT3
DRT2		DRT3
GRT6		GRT5
NRT2		XRT6
XRT1		NRT4
DRT1		DRT4
NRT5		GRT4
XRT5		XRT2
GRT3		NRT6
		DRT6
Stub GRT1 was installed in the decay site		

Figure 46 Stub layout Redlands - termites

Redlands decay site

NR3	DR4		
XR4	GR4	N	GRT1
NR6	XR6	NR1	DR2
XR1	XR2	GR6	NR4
GR1		XR3	GR3
DR6	XR5	NR2	NR5
		GR2	
GR5	DR5	DR3	DR1

Figure 20 Stub layout Redlands - decay

Dalby decay site

N

XD2	XD1	ND5	ND6	GD4	XD3
DD3	GD2	GD6	DD1	ND4	GD3
XD4	DD6	DD2	ND2	XD6	GD5
DD4	ND1	GD1	DD5	XD5	ND3

Figure 48 Stub layout Dalby - decay

Appendix 4 Moisture content data

E. dunnii	
Tag #	% MC
56	74.0
70	48.9
72	72.7
53	62.0
63	43.9
69	42.8
68	43.7
77	47.3
51	30.4
59	36.0
57	46.6
58	80.0
67	36.2
50	53.8
86	40.8
79	41.9
60	78.8
64	43.0
78	41.5
52	46.1
62	35.6
75	72.0
54	41.0
49	34.6
Av	49.7
SD	15.03
CV	30

E. globulus	
Tag #	% MC
136	58.7
149	57.1
126	30.9
134	76.2
124	78.9
152	63.8
132	70.0
183	54.7
125	73.4
133	82.8
130	68.9
122	66.4
138	54.6
128	77.9
135	66.7
137	70.4
140	59.2
127	68.7
139	48.6
131	63.3
129	68.8
171	61.0
107	48.0
Av	63.9
SD	11.74
CV	18

E. nitens	
Tag #	% MC
96	32.1
101	36.2
119	49.2
103	49.7
100	48.1
102	51.3
108	58.3
121	45.6
104	85.1
114	69.3
105	58.5
86	42.2
99	55.0
175	54.5
109	42.2
106	81.3
112	51.7
111	72.8
97	48.4
113	66.1
167	39.6
166	51.9
118	71.1
117	59.6
115	56.3
173	39.6
110	64.3
Av	54.8
SD	13.28
CV	24

E. grandis x camaldulensis	
Tag #	% MC
159	38.0
153	49.6
162	50.0
172	54.3
160	43.1
150	36.6
180	38.2
157	35.5
178	51.7
163	56.1
158	50.4
165	56.0
168	53.3
176	53.7
181	48.9
182	57.3
155	44.0
174	50.7
161	46.6
154	44.6
179	49.3
164	59.0
177	37.8
170	50.2
148	66.7
156	66.9
Av	49.6
SD	8.39
CV	17

C. maculata	
Tag #	% MC
169	28.0
91	26.0
40	32.0
93	25.6
36	30.3
32	26.4
82	29.3
38	30.3
42	33.8
47	29.1
84	35.1
81	29.3
33	26.1
95	34.0
34	28.0
46	29.6
39	31.4
31	27.6
29	28.7
41	30.6
43	27.5
48	29.6
85	30.6
87	30.9
90	23.2
35	27.1
89	27.4
37	32.1
83	27.9
80	29.5
94	39.4
92	27.0
Av	29.5
SD	3.17
CV	11

Appendix 5 Strength test data

E. dunnii	
ID	MOR (Mpa)
D1	67
D2	61
D3	40
D4	60
D5	83
D9	44
D12	63
D13	49
D14	39
D15	36
D16	65
D18	89
D19	56
D20	74
D21	47
D22	48
D23	48
D24	64
D25	43
D26	66
D27	38
D28	92
D31	75
D32	72
D33	53
D34	61
D35	58
D36	43

E globulus	
ID	MOR (Mpa)
G2	36
G7	49
G8	35
G9	134
G10	85
G11	59
G12	54
G13	52
G14	61
G15	42
G16	61
G17	53
G20	77
G21	76
G22	47
G24	79
G25	56
G26	59
G27	55
G28	61
G30	72
G31	48
G32	67
G33	68
G34	73
G35	68

E. nitens	
ID	MOR (Mpa)
N1	69
N2	71
N4	81
N5	60
N6	51
N7	83
N8	101
N9	62
N10	61
N13	84
N14	51
N15	79
N17	51
N19	58
N20	66
N20A	45
N21	60
N22	63
N23	61
N24	66
N26	54
N27	81
N28	60
N29	78
N31	62
N34	54
N35	70
N36	48

E. grandis X camaldulensis	
ID	MOR (Mpa)
X1	115
X2	104
X3	78
X4	27
X5	63
X6	102
X7	67
X8	92
X9	68
X10	90
X11	122
X12	80
X13	92
X14	125
X15	85
X16	47
X17	90
X18	82
X19	98
X20	91
X21	94
X22	76
X23	100
X24	79
X25	78
X26	87
X34	207

C. maculata	
ID	MOR (Mpa)
S1	184
S2	148
S3	132
S4	156
S5	165
S6	135
S7	127
S8	134
S9	161
S10	234
S11	181
S12	183
S13	196
S14	224
S15	144
S16	159
S169	189
S17	104
S17A	163
S18	155
S19	145
S21	153
S22	160
S23	127
S24	131
S25	149
S26	183
S27	204
S28	169
S29	177
S30	202
S31	203
S32	193
S35	202
S36	180
S37	188

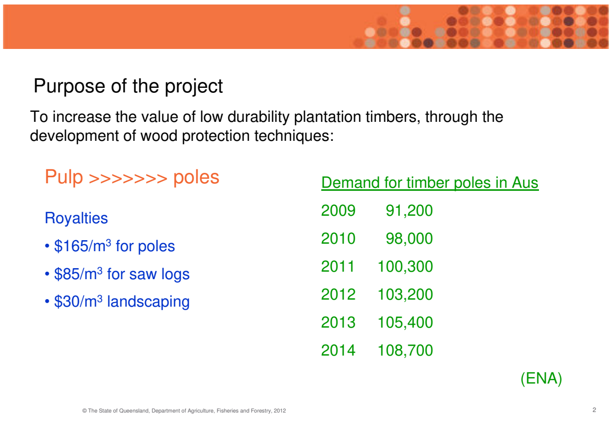
Appendix 6 Communication presentation

Department of **Agriculture, Fisheries and Forestry**

Improving the durability of low-durability Australian hardwoods for use as poles

Thru-boring project

Queensland Government



Purpose of the project

To increase the value of low durability plantation timbers, through the development of wood protection techniques:

Pulp >>>>>>> poles

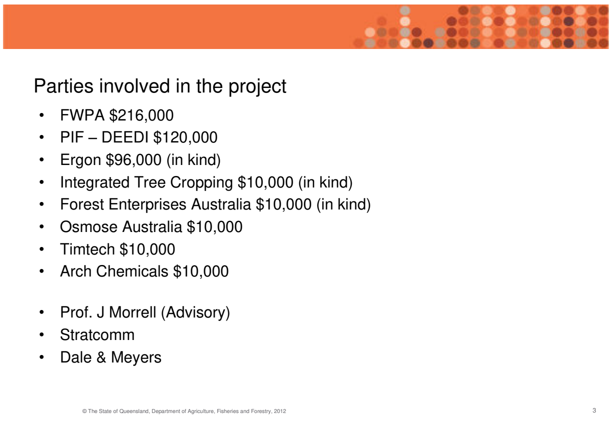
Royalties

- $165/m^3 for poles
- $85/m^3 for saw logs
- $30/m^3 landscaping

Demand for timber poles in Aus

2009	91,200
2010	98,000
2011	100,300
2012	103,200
2013	105,400
2014	108,700

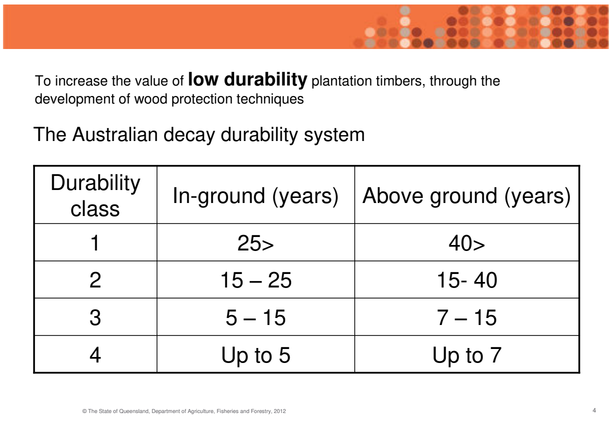
(ENA)



Parties involved in the project

- FWPA $216,000
- PIF – DEEDI $120,000
- Ergon $96,000 (in kind)
- Integrated Tree Cropping $10,000 (in kind)
- Forest Enterprises Australia $10,000 (in kind)
- Osmose Australia $10,000
- Timtech $10,000
- Arch Chemicals $10,000

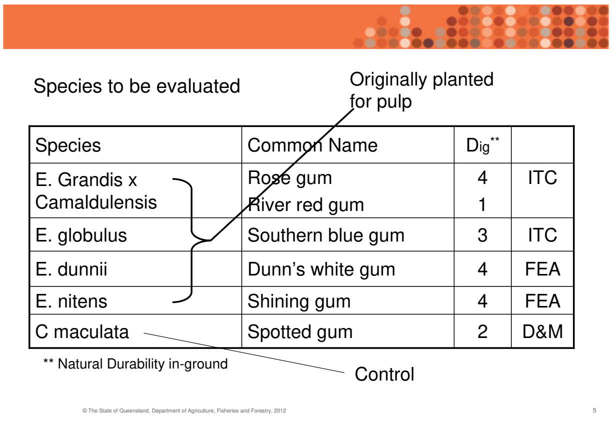
- Prof. J Morrell (Advisory)
- Stratcomm
- Dale & Meyers



To increase the value of **low durability** plantation timbers, through the development of wood protection techniques

The Australian decay durability system

Durability class	In-ground (years)	Above ground (years)
1	25>	40>
2	15 – 25	15- 40
3	5 – 15	7 – 15
4	Up to 5	Up to 7



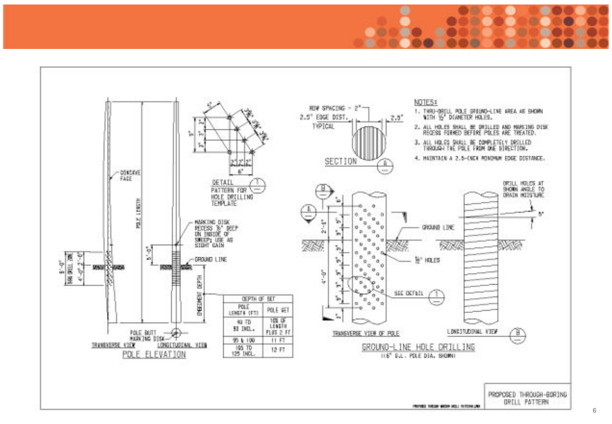
Species to be evaluated

Originally planted for pulp

Species	Common Name	Dig**	
E. Grandis x Camaldulensis	Rose gum River red gum	4 1	ITC
E. globulus	Southern blue gum	3	ITC
E. dunnii	Dunn's white gum	4	FEA
E. nitens	Shining gum	4	FEA
C maculata	Spotted gum	2	D&M

** Natural Durability in-ground

Control



NOTES:

1. THRU-DRILL POLE GROUND-LINE AREA AS SHOWN WITH ½" DIAMETER HOLES.
2. ALL HOLES SHALL BE DRILLED AND MARKING DISK RECESS FORMED BEFORE POLES ARE TREATED.
3. ALL HOLES SHALL BE COMPLETELY DRILLED THROUGH THE POLE FROM ONE DIRECTION.
4. MAINTAIN A 2.5-INCH MINIMUM EDGE DISTANCE.

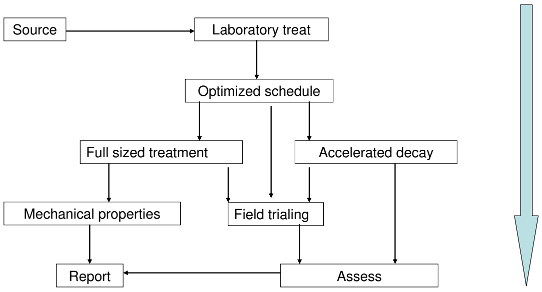
DEPTH OF SET	
POLE LENGTH (FT)	POLE SET
40 TO 90 INCL.	10% OF LENGTH PLUS 2 FT
95 & 100	11 FT
105 TO 125 INCL.	12 FT

PROPOSED THROUGH-BORING DRILL PATTERN

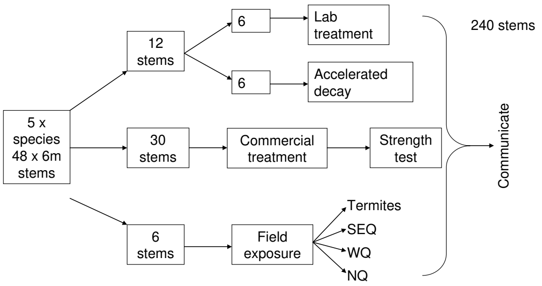
Phases

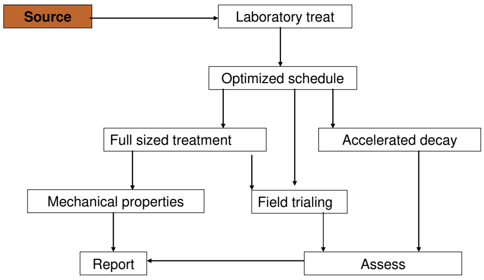
- Setting up the project
- Laboratory treatment
- Accelerated decay
- Mechanical properties
- Field testing
- Communication

Broad organization


Source
Laboratory treat
Optimized schedule
Full sized treatment
Accelerated decay
Mechanical properties
Field trialing
Report
Assess

Project Map


5 x species 48 x 6m stems
12 stems
6
Lab treatment
6
Accelerated decay
30 stems
Commercial treatment
Strength test
6 stems
Field exposure
Termites
SEQ
WQ
NQ
240 stems
Communicate


Source
Laboratory treat
Optimized schedule
Full sized treatment
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Field trialing
Report
Assess

Dunnii logs

Very hot AND very wet conditions

GxC logs

Dunnii logs

Splitting & checking

Large sapwood band – good to treat

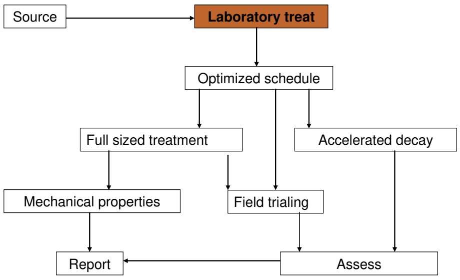
Globulus logs

Really bad debarking damage – will need to be addressed if the species is to be used as poles

Processing

Processing

Processing



Source

Laboratory treat

Optimized schedule

Full sized treatment

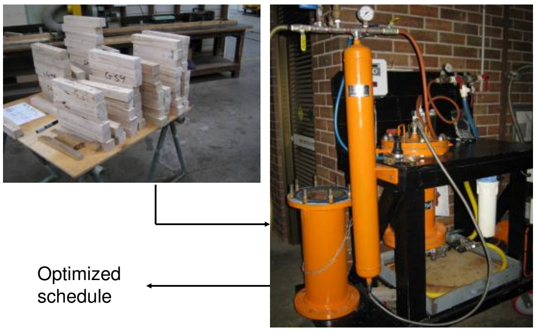
Accelerated decay

Mechanical properties

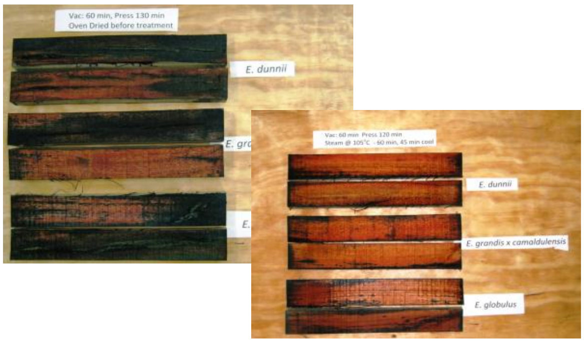
Field trialing

Report

Assess

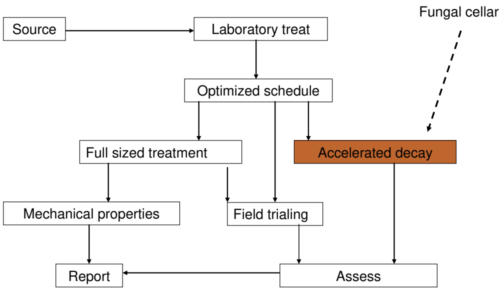


Optimized schedule



Vac: 60 min, Press 130 min
Oven Dried before treatment

Vac: 60 min Press 120 min
Steam @ 105°C - 60 min, 45 min cool



Source

Laboratory treat

Fungal cellar

Optimized schedule

Full sized treatment

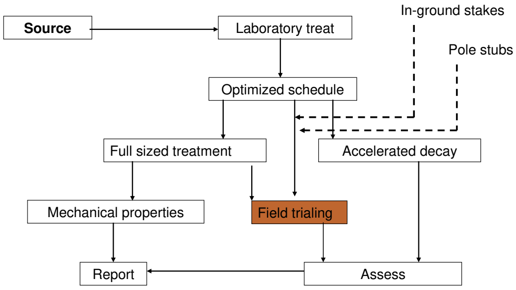
Accelerated decay

Mechanical properties

Field trialing

Report

Assess



Source

Laboratory treat

In-ground stakes

Pole stubs

Optimized schedule

Full sized treatment

Accelerated decay

Mechanical properties

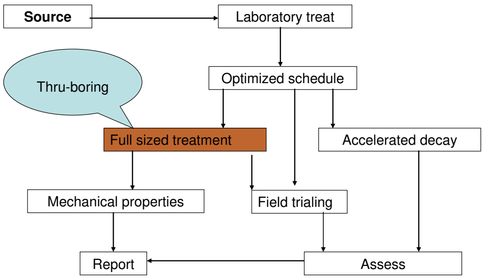
Field trialing

Report

Assess

Field stake exposure @ Redlands in S.E. Qld

Termite exposure



Source

Laboratory treat

Thru-boring

Optimized schedule

Full sized treatment

Accelerated decay

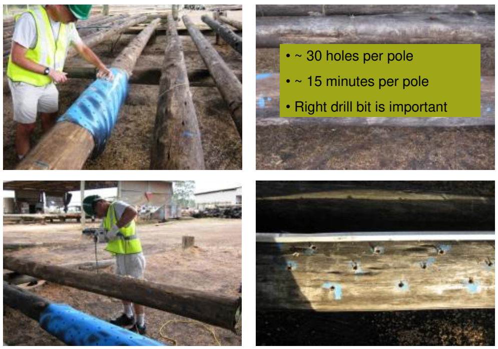
Mechanical properties

Field trialing

Report

Assess

Thru-boring

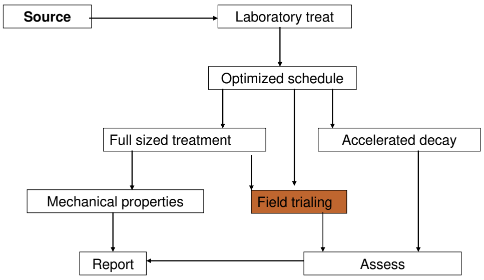


- ~ 30 holes per pole
- ~ 15 minutes per pole
- Right drill bit is important

Preservative treatment

8 hour pressure
compared to 2 hours for
current poles

Preparation of pole stubs



Source

Laboratory treat

Optimized schedule

Full sized treatment

Accelerated decay

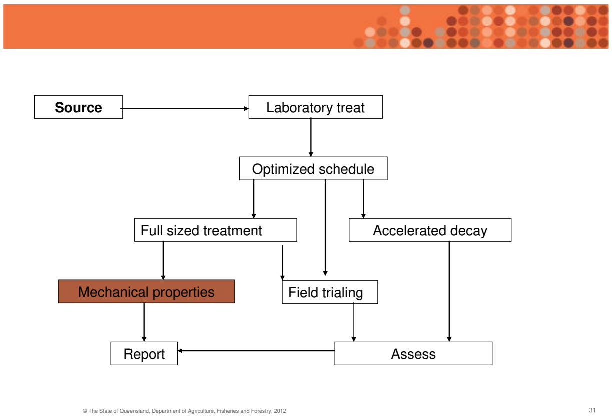
Mechanical properties

Field trialing

Report

Assess

Pole stubs



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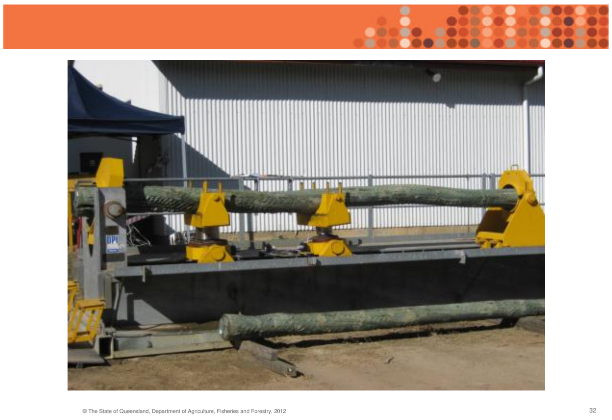
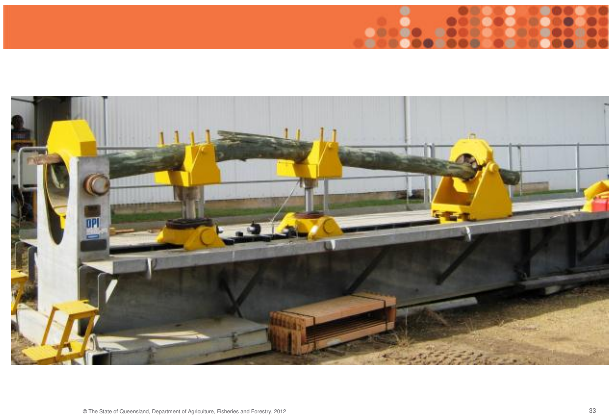
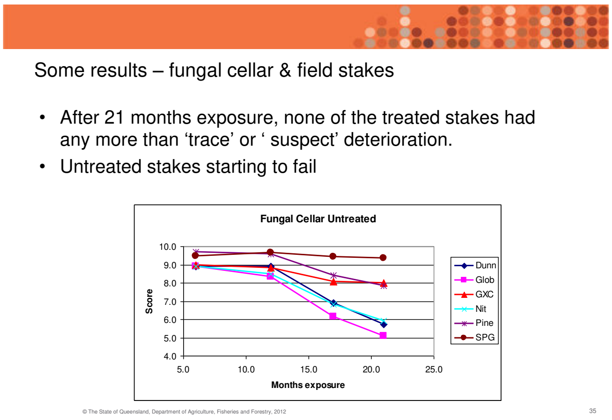


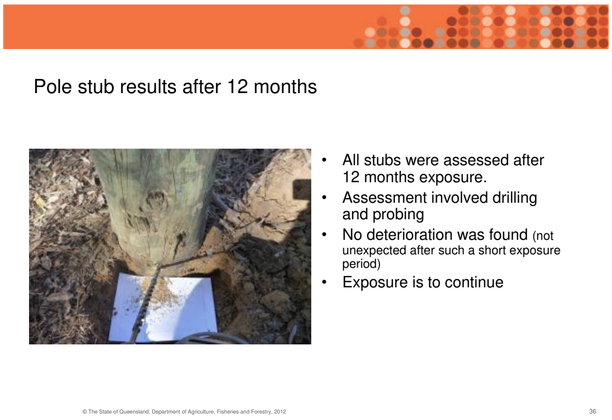




Some results – fungal cellar & field stakes

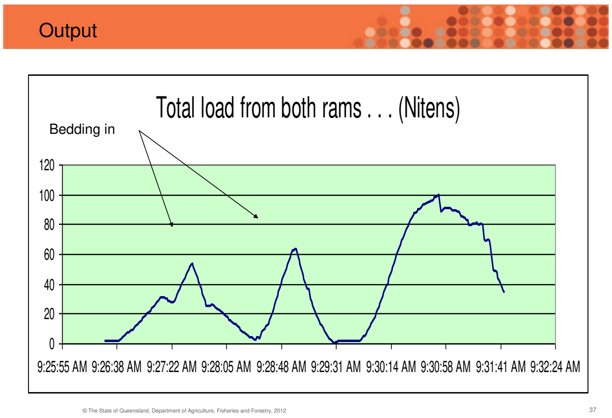
- After 21 months exposure, none of the treated stakes had any more than ‘trace’ or ‘ suspect’ deterioration.
- Untreated stakes starting to fail

Fungal Cellar Untreated



Pole stub results after 12 months

- All stubs were assessed after 12 months exposure.
- Assessment involved drilling and probing
- No deterioration was found (not unexpected after such a short exposure period)
- Exposure is to continue

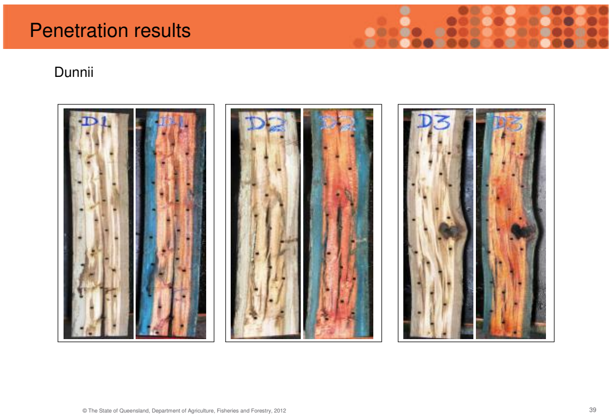


Output

Total load from both rams . . . (Nitens)

Results of strength tests (interim)

	MOR failure (Mpa)		MOR 100T (Mpa)		MOE (Mpa)	
Species	Mean	Sig diff	Mean	Sig diff	Mean	Sig diff
Spg	201.6	a	197.9	a	58099	a
GxC	75.4	b	90.3	b	34172	b
Nitens	54.8	bc	66.4	c	29767	bc
Glob	43.2	c	62.1	c	24495	bc
Dunnii	36.0	c	58.4	c	20097	c

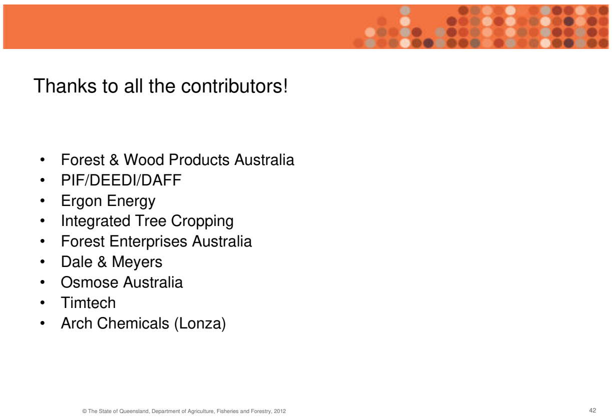


Penetration results

Dunnii

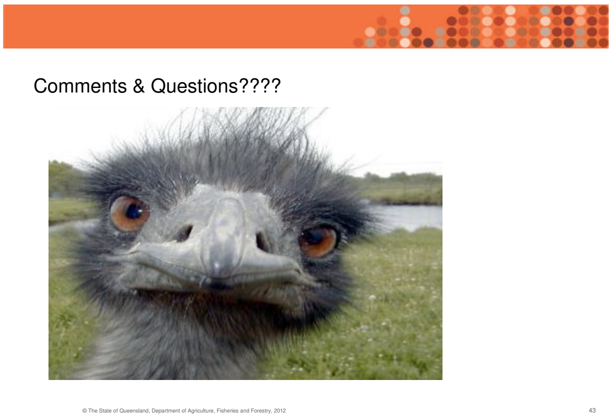
Penetration results

Globulus



Thanks to all the contributors!

- Forest & Wood Products Australia
- PIF/DEEDI/DAFF
- Ergon Energy
- Integrated Tree Cropping
- Forest Enterprises Australia
- Dale & Meyers
- Osmose Australia
- Timtech
- Arch Chemicals (Lonza)



Comments & Questions????

---End of Report---