Development of operational techniques for thinning eucalypt regeneration

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Abstract

A major project undertaken as part of the Intensive Forest Management Program was the investigation of operational techniques for thinning high quality silvicultural eucalypt regrowth forest. Non-commercial (manual and chemical) and commercial (ground-based and cable) methods were evaluated for productivity, cost, residual stand damage, safety and other parameters.

The high labour component of manual thinning using chainsaws and clearing saws means this option cannot seriously be considered on an operational scale. Even the lowest cost of thinning, $1242 /ha (47.9 hrs) achieved in some trials, was too expensive. The unacceptable increase in fire risk from the felled and elevated fuels leaves this system suitable only for research purposes.

Early age spacing of overstocked stands (i.e. > 3000 stems/ha), using stem injection with chemicals as a thinning tool at age 10–15 years, has potential for operational use. Thinning these overstocked stands will allow a second thinning for a commercial return. Cost is determined by stand accessibility but should not exceed $400/ha. The work is ideally suited for contract employment where final payment is made based on work quality.

Ground-based mechanical thinning trials did not meet their commercial potential although they provided a substantial proving ground from which later trials benefited. Specialised skills had to be acquired during these operations, and assessment and post-harvest monitoring systems, newly designed at the time of the first trials, were proven during this initial work period. These systems remain to the present time as a means of evaluating the stands and the quality of thinning operations.

While these trials were not commercially viable, the results indicate that ground-based mechanical thinning could be used in some areas, providing operations are limited to dry weather periods to minimise stand damage and daily production rates are at least 70–80 m^3/day. The ability of the operation to move freely over the forest floor will allow optimum production. The initial logging operations snigged long distances to often poorly located roads, making access for thinning much more difficult. However, construction of roads solely for thinning cannot be economically justified and, ideally, ground-based thinning should be integrated with another operation nearby so additional personnel and machines can be utilised as required. Any ground-based thinning is likely to be confined to small patches of regrowth, from five to ten hectares. An operation to harvest such sites should be based on a two-machine configuration: one machine to snig the wood from stump to landing and the other used for preparation, sorting and loading. Felling is best done by manual operation using directional falling techniques.

Cable-thinning operations were established during the project and, since then, have operated continuously over a broad range of geographical situations and weather conditions. They have proved commercially viable in the trials and have now been implemented in several Forest Districts. A rolling, five-year harvesting schedule has been prepared which will allow advance planning to proceed with minimum interruption to harvesting. In terms of cost or production figures, this harvesting system must be viewed as a specialist operation requiring unique planning and supervision skills rather than be equated with other cable-clearfelling or ground-based systems.

Cable thinning has demonstrated consistent performance in meeting the silvicultural objectives *set for the operation. The ability of this technique to thin a stand evenly to varying retention rates according to tree volume classes, with extremely low damage levels to the retained trees, has not been equalled by any other operation evaluated during the project. All wood harvested from the cable-thinning and other mechanical operations has been utilised in industry for pulpwood, sawlog, piles and veneer logs.*

Introduction

While thinning of eucalypts has been attempted on a number of occasions in Tasmania over the past 50 years, many trials were never adequately documented. Most were initiated for research needs or curiosity, with little thought given to the economic viability of such operations.

With the development of new equipment, combined with research results obtained through the Young Eucalypt Program (YEP 1988) and an innovative approach by industry, the concept of thinning as a commercial reality became a realistic expectation by the time the Forests and Forest Industry Strategy was developed in 1990. Thus, thinning of eucalypt regrowth forests was an integral part of that Strategy (FFIC 1990). However, at that time, no operational techniques existed to make sawlogs more readily available on the vastly expanded scale required.

The Intensive Forest Management (IFM) thinning operations project was designed to evaluate commercial and non-commercial methods of thinning. Any system, manual or chemical, was available for appropriate evaluation. Productivity, cost effectiveness, damage to retained stems and safety in suitable eucalypt forests were to be assessed. Field trials were undertaken over the five-year life of the project, using a range of

Table 1. Location of trial sites referred to in the text.

		Grid reference*	
Coupe	Location	Easting	Northing
Manual thinning			
SO014	Southport	$^{4}978$	$^{51}985$
SO022	Southport	$^{4}965$	$^{51}947$
AR008	Arve Road	$^{4}823$	$^{52}179$
Herbicide treatment			
AR053c	Ligerwood Spur 2	$^{4}866$	$^{52}277$
Ground-based thinning with a single machine			
CL314T	Lake Highway	$^{4}784$	$^{58}489$
SM108b	Smiths Plains	$^{4}183$	$^{54}188$
Ground-based thinning with multiple machines			
RP004d (MI028**)	Florentine Road	$^{4}607$	$^{52}976$
Cable thinning (pilot)			
RP003B (JG003**)	Florentine Road	$^{4}608$	$^{52}977$
FO001A	Urb Turners Road	$^{4}589$	$^{52}945$
FO001B	Urb Turners Road	$^{4}592$	$^{52}948$
Cable thinning			
FO002A	Urb Turners Road	$^{4}589$	$^{52}954$

* Taken from the Tasmap series published by the Department of Environment and Land Management
** Previous code, no longer in use.

thinning intensities based on tree volumes, and using machine and manual options to identify the most cost-effective method of thinning eucalypt regeneration. Silvicultural regeneration established in the 1960s was used in the trials (see Table 1). The following criteria were set for each operation:

- The thinning operation must be commercially viable.
- The operation had to meet pre-set silvicultural criteria.
- Retained potential sawlogs were to have minimum damage.
- Any impact on the stand must be enviromentally acceptable.

Expressions of interest were called from industry to undertake the thinning operation. Applications were screened for suitability and areas were chosen that met the criteria for that operation. Management of field operations was often undertaken jointly by industry and Forestry Tasmania, using a consultative approach to resolve areas of conflict. Information from each operational trial was analysed and incorporated into each subsequent trial to improve work performance. Systems developed to monitor work output and quality were field oriented, which provided feedback to the operators who were able to implement operational changes quickly to improve work practices.

A. Non-Commercial thinning

1. *Manual thinning*

Three areas were scheduled for manual thinning trials. One area (SO14) had been burnt in the 1967 wildfires, salvage logged and then sown aerially. The resulting well-stocked regrowth was burnt in another wildfire in 1988. This fire removed most of the understorey layer and made tree selection difficult because of crown damage from the fire.

A comparable site (SO022) with the understorey intact was also thinned. The understorey, up to 6 m tall, consisted of a thick, scrubby layer of tea tree (*Leptospermum lanigerum*), estimated at 20 000 stems/ha. Its density prevented the eucalypts from falling to the ground when cut and it was felled to provide safe working conditions. However, this requirement doubled the operational hours to complete the thinning.

On the third area (AR008), the use of clearing saws was examined. However, tree size was too great and the operation too slow to be considered an economic option. Clumps of thick scrub and the presence of cutting grass hindered the free swinging action necessary for clearing saws to operate correctly.

Potential sawlog trees in all trials were selected on the basis of form, vigour and spacing in that order. Trained contract crews of 3–4 people worked in strips 30 m wide, operating on a continuous work-face with small chainsaws (Stihl 011) and clearing saws. Areas exposed to unfavourable weather conditions were thinned first, leaving the more sheltered sites for later in case weather conditions deteriorated. Thinning commenced on the lower slopes and continued uphill allowing the cut stems to fall away from the work-face so that the working zone was left as clear as possible.

In all cases, the high labour effort required meant that this manual thinning option could never be considered seriously on an operational scale. Even at the cheapest thinning rate of $1242/ha (47.9 hrs/ha) with a 4% internal rate of return (IRR), the cost of the forest product at final harvest cannot be justified (Table 2).

Results from the manual thinning trial are summarised below.

- There is an increased risk to operators because of restricted working conditions.
- The high unit cost of the operation is compounded with increasing levels of understorey density.
- There is no commercial outlet for the thinnings.

Table 2. Details of the manual thinning trials.

Coupe	Thinning method	Number of retained stems	Operational damage	Pre-existing damage	Operational hrs/ha	Comment
SO014	Chain saw	299	5%	21%	47.9	Pre-existing damage from wildfire in 1988
SO022	Chain saw	277	6%	7%	90.2	20 000 stems/ha of tea tree
AR008	Clearing saw	290	5%	0	70.7	Tree size too large

- Significant quantities of coppice growth developed from the cut stumps in the stand following thinning (Photo 1).
- There are relatively low damage levels (5%), mainly from damage during felling.
- Huge quantities of slash (up to 100 m^3/ha) were produced by the thinning operations, with no possibility of understorey burning to reduce slash levels.

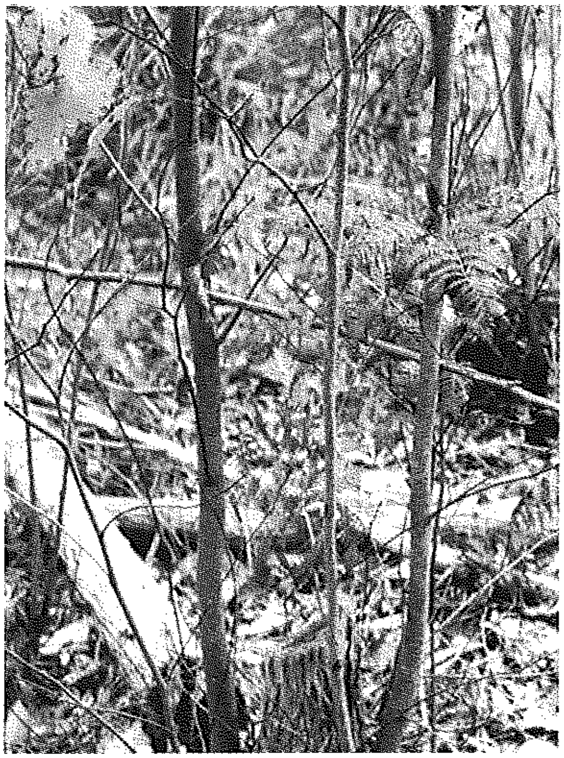


Photo 1. Coppice growth commonly develops from cut stumps following manual thinning.

2. *Chemical thinning*

In selecting stands for chemical thinning treatment, regrowth eucalypt forest was grouped into three age classes (4–10 years, 11–20 years, 21–30 years) chosen from the two photo-interpretation classes (E1, E2) with the highest site potential for eucalypt forest in Tasmania.

In the youngest age class, a major difficulty was encountered in locating densely stocked stands (> 3000 stems/ha). Most stands inspected were adequately stocked and usually growing in association with thick cutting grass. Tree form was poor, with little evidence of branch shedding.

Densely stocked stands in the 11–20-year age class were available for non-commercial thinning. In this age class, canopy closure to reduce understorey competition greatly improved access compared to younger stands. Tree selection is easier where the lower limbs have been shed and the clear bole of the final crop tree is apparent. Retention rate is recommended at 1100 stems/ha at 3 m x 3 m spacing. These stands have the potential to be commercially thinned when the average tree size reaches 0.2 m^3, possibly 20 years after the initial non-commercial thinning.

While no treatment was applied to 21–30-year-old stands, monitoring work done indicates that selected trees freed from competition show a positive growth response (R. Ellis, pers. comm.). A one-off treatment, selecting 200 stems/ha, injecting trees within a radius 20 the times diameter of the retainer would be sufficient to produce a growth response in stands of this character.

Access

Initially, a bulldozer was used to open up old logging tracks in the coupes to provide access for the operators. This strategy was only marginally successful. It resulted in damage to the stand and the initial time spent in locating the original tracks limited its effectiveness. By using these tracks, operators were committed to walking at right angles to the contours and to travelling long distances (up to five hours return) each day. Long periods without a break also resulted in a variable work output. An improved approach was developed where walking tracks were cut at 200 m intervals at right angles to the contours, with the crew working around the contour. Moving in line, a swathe 10–15 m wide was worked for a distance of 100 m and return from the initial foot track. This proved a much more satisfactory approach to the task, allowing a speedy return for maintenance and recharging of the backpack units (Photo 2).

Photo 2. An operator in special protective clothing worn during the chemical thinning trials.

Herbicide treatment

Chemical thinning was undertaken using the herbicide Glyphosate 360, injected into trees with the 'Sirax' tool. This equipment allows one-handed delivery using a modified hammer connected to a manually pressurised backpack. The propellant driving the system is air. The herbicide was injected into the sapwood at a rate of 1 ml/10 cm diameter of the tree, through a system of pneumatic components.

Monitoring plots were established at the rate of one per hectare, or a 1% sample. Both injected and non-injected trees were recorded to show forest structure as well as to provide a measure of the quality of the work undertaken.

Results

Comparison of recent results of the day-labour work output (Figure 1) to the work targets set at the initial trials indicates that work targets are now within an acceptable range set for the access difficulty of the coupe (AR053c). Productive work is 63% of the time per hectare and falls within the target range of 60–65% set for this activity. A total 16.9 hrs/ha was achieved for the operation at a cost of $270/ha.

Providing costs are kept at less than $400/ha with an IRR of 5%, growth increment will provide a positive return at final harvest. If a non-commercial treatment cost can be contained within these limits, followed by a second thinning with commercial potential, the final sawlog crop harvest at age 65 will far exceed the sawlog component of an unthinned stand of the same age.

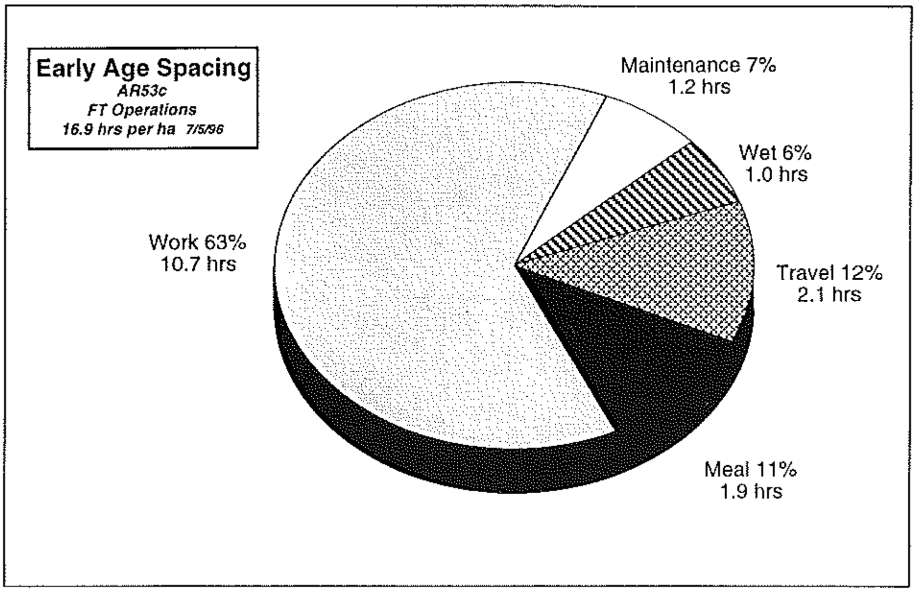


Figure 1. Diagram showing the time dissection per hectare achieved in the chemical thinning operation.

A summary of results from the chemical thinning trial is given below.

- There is a relatively moderate investment ($400/ha) for a significant increase in sawlog production.
- Work can be done by contract workers and the results easily monitored.
- Work can be easily integrated with other forest operations.
- The operation can be integrated with commercial thinning where zones of small diameter trees cannot be thinned commercially.

Recommendations for non-commercial thinning (manual and chemical)

- Manual thinning with chainsaws or clearing saws for commercial thinning cannot be economically justified.
- Chemical thinning of overstocked stands (> 3000 stems/ha) in the age class 11–20 years has the potential to significantly increase the sawlog output and should be considered as a legitimate means of stand treatment.
- Chemical thinning should ideally be undertaken by a contract workforce.
- Long-term monitoring plots need to be established to monitor and measure growth response.

B. Commercial thinning

1. Ground-based thinning (single machine)

The machine chosen for this trial was an excavator fitted with a hydraulically operated shear blade mounted on 'Crab Grab' jaws (Photo 3). The excavator was able to pull the tree from the ground using the reach of the boom as a lever, assisted by pulling hooks attached to the side of the jaws. The root ball was severed by the hydraulic shear blade attached to the jaws. The payload was assembled and chained to the excavator boom which ferried the logs to the landing for barking, sorting and loading.

The push/pull system of felling gave directional control, the attached root system slowing the falling momentum of the tree. The root ball, after being severed, was stacked to one side. This unique harvesting action left the forest floor partially cleared and allowed easier machine access although care was necessary with the excavator to ensure that it did not fall into the stump holes and damage the retainers. Trees to 45 cm diameter could be treated by this means. Larger diameter trees and oldgrowth trees were felled manually. While dry conditions prevailed, timber was stockpiled in the bush, with the trucks driving to the stockpiles on dirt roads. This allowed a shorter snig distance and provided more productive time for the excavator to harvest.

Results and discussion

Damage to crop trees was 12%. Most damage was caused to the butt section during the snigging process. The stand density varied between 130 and 150 stems/ha, of which 78% had sawlog potential. These results were well within the range of prescriptions set for the operations before harvesting, and produced a generally even-spaced stocking of retainers. The visual results were pleasing, producing a low-impact operation. Many of the understorey species were left undisturbed.

During the life of the trial, production never managed to reach commercial viability. On average, a production rate of 4.2 t/hr was achieved whereas a rate of 5.6 t/hr is needed for the operation to be commercially viable.

The main factors that affected the cost of production were the time taken for operators to achieve operational efficiency, the requirement to bark all timber, the low snigging speed of the excavator (100 m snig distance was considered the maximum economical drag) and the employment, for safety reasons, of a full-time tree faller, even though his productive time was less than 50%.

The stand treated in CL314T (RP518 plot) has been monitored over a long period. Measurement of trees before thinning had shown no appreciable increment over 15 years of monitoring. However, two years after thinning, trees have begun to show a positive response. On-going measurements will determine how long this response continues.

The site on the Lake Highway used for the trial is atypical. The terrain is relatively flat with very few ground obstacles and the average tree size was greater than the normal thinning stand of 25–30-year-old regrowth (> 1.0 m^3). A subsequent short-term trial at Smiths Plains where all the above difficulty factors were encountered highlighted the limitations of the operation for broadscale use.

Results from the trial are summarised below.

- Operations are feasible in dry weather only.
- The machines are limited to slopes less than 25%.
- The amount and position of ground debris from previous logging operations are important.
- The operation has a low production rate.

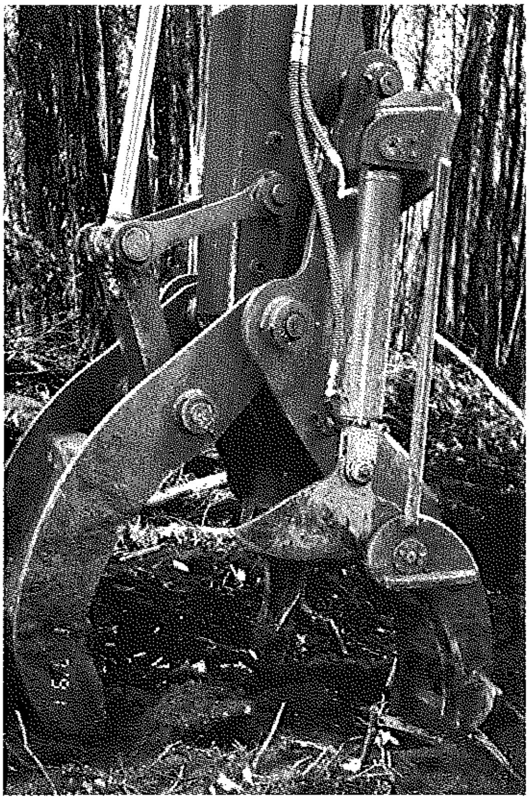


Photo 3. Crab Grab jaws of the excavator, with the hydraulically operated Padgett Shear Sense, used for the first time in thinning operations.

- The operation can achieve low damage levels to the crop trees on an operator selection basis.
- Variation in stand structure makes tree selection difficult for the operator.

2. *Ground-based thinning (multiple machines)*

This thinning system followed the single-machine thinning operation, incorporating lessons learned in minimising crop-tree damage while still maintaining an economic production level. The logging machinery available included a tracked feller buncher (Photo 4), an excavator fitted with a Waratah felling and processing head (Photo 5), an excavator fitted with a Padgett Shear Sense attachment (Photo 3), and a grapple skidder.

Felling was done mechanically using an hydraulically operated chainsaw mounted on a Bell feller buncher. The felled pieces were placed in bundles for the grapple skidder to take to the processing site.

Results and discussion

Previous trials had shown that debarking the harvested wood was the limiting factor in maintaining production. It was hoped that the Waratah processing head would overcome this limitation. Initially, debarking was undertaken at centralised points in the coupe. However, debarking 20 m tree lengths in a confined space increased damage to the retainers by up to 25%. Additional snigging problems were caused from trying to transport many small broken pieces from the 'at stump' processing site to the landing. Large downers (e.g. Photo 6) confined the harvesting equipment to existing snig tracks and often had the effect of creating clumps and gaps, the clumps being unthinned areas and the gaps resulting from 'repair' salvage

Photo 4. The Bell tracked feller buncher used for felling during ground-based thinning operations.

of damaged trees while trying to manoeuvre tree-length timber in a confined space.

While there was a range of equipment available, there was only one machine capable of mechanically felling. This caused congestion in the bush and did not always allow the remainder of the equipment to operate under safe conditions. In an effort to disperse the felling and provide safe working conditions, some pieces of equipment were not used to their full potential.

The system producing the best results involved full length snigging to the processing head located at the landing, using a combination of close and distance snigging. The trees were not easy to debark, with many stems requiring three passes through the debarking head for complete bark removal. Small stems (< 17 cm diameter) were often broken by the

Photo 5. An excavator fitted with a Waratah felling and processing head was used to speed the debarking process and increase production in the ground-based thinning operation.

Photo 6. Large downers remaining on the forest floor from previous logging operations are common in regrowth forests and can cause access difficulties for workers and machinery during thinning operations.

debarking process, causing sorting and loading problems.

The requirement for debarked wood deliveries to the processing plant occupied the processing head almost full-time, requiring the use of additional machines to prepare and ferry wood to the landing. In addition, poor weather, downers, slope and rocky outcrops all contributed to reduced productivity. The planned daily production rate of 80 m^3 could not be maintained, with the actual rate being closer to half this volume. As a result, the operation did not approach commercial viability.

Results from the trial are summarised below.

- Slope and rock affect the trafficability.
- The size and position of the downers affect thinning potential. Where residual volumes exceed 150 t/ha and downers greater than 60 cm DBH are present, difficulties will be experienced.
- Use of existing snig tracks often provides the only access and the tracks can be very difficult to rehabilitate. Often they are lower than the surrounding landform.
- Operations should be limited to dry weather only.
- Average tree size needs to be greater than 0.2 m^3.

3. Cable thinning

Cable thinning has been practised widely in both hardwood and softwood plantations so the basic engineering requirements and principles were well understood before the silvicultural thinning trials commenced.

Pilot trial.—A twelve-week pilot trial was initiated on coupes RP003B, FO001B and FO001A, and it soon became apparent that the limiting factors for ground-based thinning (discussed earlier in this paper) offered no impediment to the cable-thinning system.

Photo 7. A cable-thinned forest. Recovered wood is pulled laterally from the forest into the outrow and then hauled along it to the road edge. Drop-cutting of downers in the outrow lowers ground obstacles, making payload recovery easier.

The ability of this method to recover wood from steep slopes over ground obstacles, with minimum damage to the retained trees, was a feature of the operation.

The cable system in the pilot trial used a gravity or shotgun system where the carriage returned to the stump by gravity. Power for the payload recovery was provided by a 55-tonne Prentice loader. The two-drum winch system had the capacity for uphill yarding only so a suitable site was chosen to cater for this requirement.

The level of damage to the retained stems was 10% while soil disturbance was less than 1%; by comparison, an adjacent area of the same coupe that had been thinned with conventional equipment averaged 33% soil disturbance, with crop tree damage levels of 25%.

While silvicultural and environmental expectations were met, timber production was low, averaging 34 m^3/day for the life of the trial. The requirement to deliver wood without bark to the processing plant meant that the excavator spent 60% of its time debarking. Many of the smaller diameter logs were broken during this process, requiring the use of a cradle to bundle the small pieces for dispatch. This caused delays and loading difficulties, and safety risks were a concern at both the dispatch and receiving depot when handling these small logs. Barking, sorting and stacking caused delays in clearing the timber from under the skyline as it was yarded. The line recovery speed of the yarder was very slow when compared with purpose-built machines.

Despite the low production levels, the overall results from the pilot trial were so encouraging that a purpose-built cable harvesting machine was purchased with funding from the Forests and Forest Industry Council. This machine (a Christy yarder) was delivered on site in March 1994.

Cable-thinning trial

A diagrammatic view of a cable thinning operation is shown in Figure 2 and a typical processing layout is shown in Figure 4. Details of the yarder are shown in Figure 3 and on page 98.

The ground contour and access of the areas chosen for the trial (FO002A) allowed uphill yarding. The carriage returned to the stump by gravity and was radio controlled, with a chokerman being able to brake the carriage by activating a toggle-action clamp. The main line was mechanically fed from the carriage to a point in the bays where the chokers had been pre-set on the logs. Once

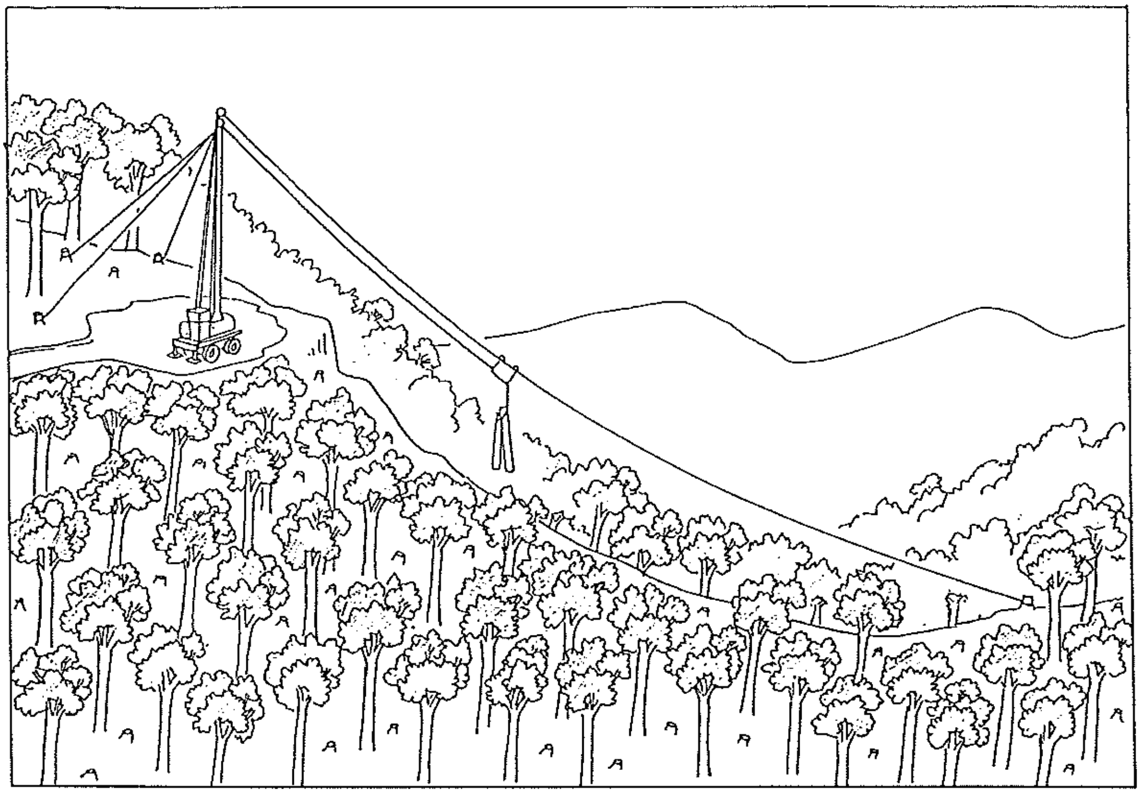
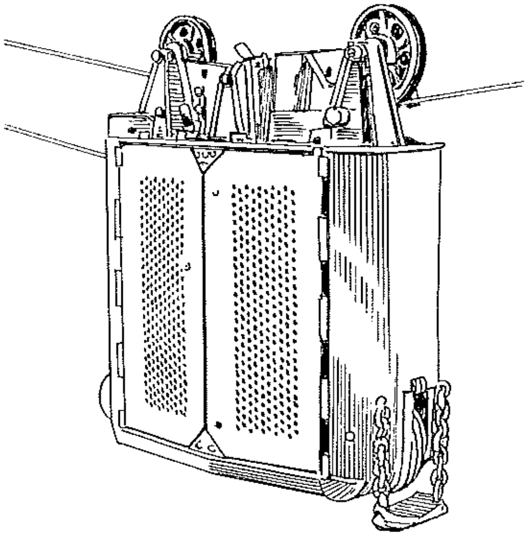


Figure 2. A diagrammatic view of the cable-thinning operation.



EAGLE CARRIAGE
Specifications:
All functions radio controlled 10 hp diesel motor 5 tonne payload capacity Slack puller speed up to 100 m/min

CHRISTY YARDER
Specifications:
Telescopic tower to 14.5 m Three working drums Mainline drum capacity - 350 m Mainline drum speed - 350 m/min All terrain flexibility

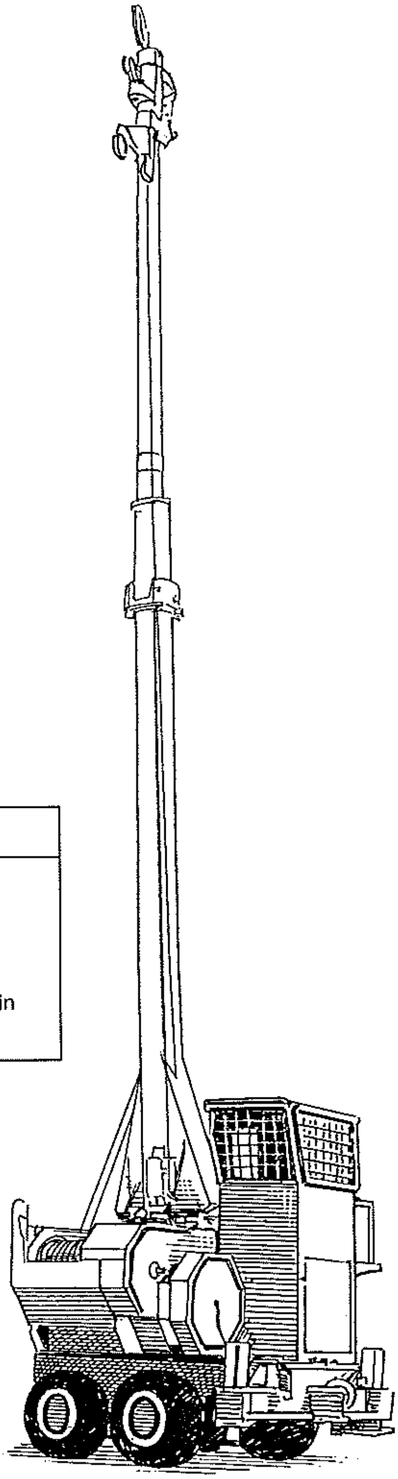


Figure 3. The eagle carriage and Christy yarder used in the cable-thinning trial. (Specifications and details of their operation are given on p. 98.)

Equipment and Functions

Christy Yarder

The Christy yarder is a small (9000 kg) compact yarding unit. While not self mobile, the tyre-mounted suspension allows the rig to be manoeuvred into position through a towing hitch using a five-tonne truck as a power source.

The 14.5 m telescopic spar is hydraulically raised and lowered. It is stabilised by four guys that are tensioned through a 12-volt power winch driver. Safety pins are inserted through the spar when the correct height is selected prior to final tensioning of the guy wires. The weight of the machine is supported by a large diameter metal foot located directly under the spar. This relieves any excessive load being placed on the yarder's trailer suspension when in operating mode.

The yarder operates a three-drum slack skyline system. The three drums allow for planned down hill and flat land in haul, unlike the Prentice loader which could only operate a shotgun or gravity system of payload recovery. Power is supplied through a turbo-powered 140 hp Cummins diesel engine which powers the winch drums. The air operated brakes (shoe type) provide positive drum control.

The yarder operator controls the speed and payload recovery process once the load and carriage are turned into the outrow.

Eagle Carriage

The 600 kg carriage is of T-1 quality steel construction. (US specifications = 3 times the tensile strength of mild steel). The carriage encloses a modified 10 hp diesel motor that can be inclined at an angle of 83^0 and continue to operate normally. It provides power to feed slack line to the chokerman while power for payload recovery is supplied by the yarder.

Using a gravity yarding system, the momentum of the returning carriage is slowed by the yarder operator. The toggle action skyline clamp is activated by a radio signal from the chokerman who positions the carriage along the skyline for best payload recovery. Slowing the carriage before final clamping prolongs the life of the aluminium jaws of the clamp.

Feeding slackline, payload recovery and skyline clamp activation are all radio controlled functions activated by the chokerman.

Maximum payload capacity is rated at 5 t; however, operational working loads for thinning should not exceed 2.5 t.

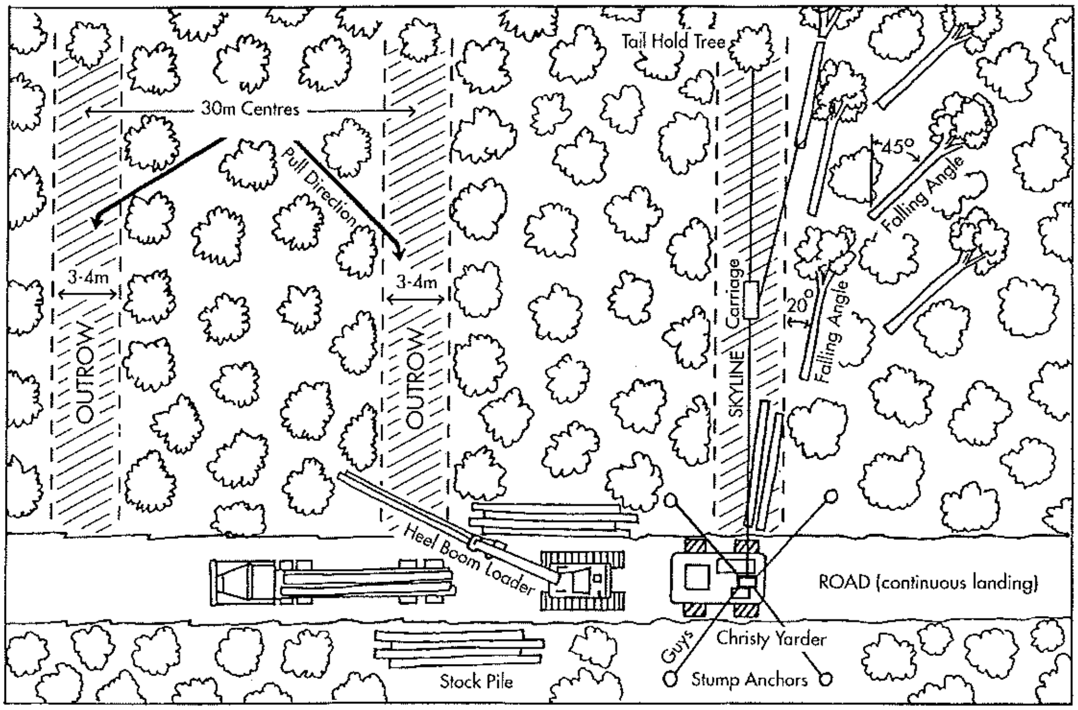


Figure 4. A typical processing layout for cable thinning.

the chokers were secured, the logs were pulled laterally into the outrow and then up the outrow to the yarder. Two sets of three chokers were in use, one being pre-set for the next payload while the other was in use ferrying the payload to the landing. Loads were partially suspended, which allowed the payload to easily clear ground obstacles and minimised soil disturbance.

Parallel outrows (rows of trees removed in the thinning operation) were usually produced during thinning. However, where appropriate, a fan pattern of outrows was used. The ability of the operation to vary the configuration permitted the yarding process to operate more efficiently.

The access road was used as a continuous landing for all processing and loading, with stockpiling being done on the road verges. The running surface of the road remained in good repair, having been surfaced with heavy metal when the area was initially harvested. Low-profile grousers on the track gear of the excavator and sensible machine movement while loading the trucks also assisted in maintenance of road surfaces.

Results and discussion

The two major problems affecting production in the pilot trial were overcome by the time the main cable-thinning trial commenced. Pulpwood could be delivered with its bark on, the logs being debarked at the processing plant. This left the excavator available to keep the decking area free of accumulating pulpwood. The excavator stacked and sorted systematically, and there were no 'shorts' to clog the limited stockpiling area on the road edge. The heel boom excavator designed for the job allowed end-on loading over the back bolsters of the jinker whereas previously, logs had to be loaded from the side, requiring the construction of laybys.

The second problem involved the speed of the yarder. The line speed of the Christy yarder is 360 m/min, which is five times greater than that of the Prentice loader used in the pilot trial. This faster speed reduced the cycle time and boosted production.

The trial indicated that commercial thinning of eucalypt regrowth to pre-set retention rates was possible. The outcome was a thinned stand containing a very high proportion of potential sawlogs and with minimal harvesting damage.

Cable thinning has operated continuously since its introduction early in 1994. During this period, all the silvicultural requirements for the operation have been achieved. Damage to the retainers has not exceeded 10% and has often been half this value. Soil disturbance has consistently been less than 1%. This situation assists growth responses because the root system remains undamaged and lessens the chance of pathogens attacking the tree.

At the end of the first 17 months, 110 ha had been thinned, producing 19 000 m^3 of thinnings. On a daily basis, this averaged 64 m^3/day. Initial planning rates were based on a production level of 75 m^3/day. Recently, members of the work crew re-organised their work mode, shifting the centre of responsibility from the yarder to the stump. This has improved productivity, with the initial daily output target of 75 m^3 being consistently met and often exceeded.

Improvements in the development of electronic chokers have now made these items much more reliable and robust. A complete set suitable for the current machinery arrangement has been delivered. The benefits are improved production and improved safety for personnel in the decking area.

Reviewing the production levels, major areas that affect cost and production are:

- Felling;
- Weather conditions; and
- Method of yarding.

Felling.—Felling production is directly related to tree size (volume). Areas harvested to date have had an average tree size greater than 0.5 m^3. As the older stands are thinned, the average tree size is likely to decrease to around 0.3–0.4 m^3 and this will impose limits on daily felled production. With experience, a competent faller can fell about 100 trees per day. It was quite normal to fell a significant number of trees that were less than minimum size or to fell trees that had died through natural mortality.

Weather factors.—Daily work sheets have been kept since the trial began and the loss of production from the effects of adverse weather is well documented. During the twelve months from the end of June 1994 to the end of June 1995, work output was reduced on 41 days, either totally or partially (Table 3). Given a workforce of six people,

Photo 8. In early trials with cable thinning, injury to the tail-hold tree was caused by rope-burn from the steel cable used for the skyline. This problem has now been eliminated using broad-band strapping.

Table 3. The loss of production from the effects of adverse weather across a 12-month period.

	Snow	Fire	Wind	Felling	Other	Total
Expanded hours (i.e. x 6 people)	702	90	567	552	180	2091
Number of work days affected	13	3	10	10	5	41

this equates to a full work year for one person, or an additional $2.50/m^3 cost of production. Planning operations with a winter bias in low-altitude sheltered sites are a necessity to minimise non-productive time.

Methods of yarding.—Uphill yarding is the most productive work mode, allowing the carriage to return by gravity. The three-drum winch system on the yarder permits downhill and flat-terrain yarding. However, a sustained production period of six weeks on flat terrain showed a wood production loss of 30% on a daily basis. This was due to the additional time required to rig the haul-back line during which time the yarder was inoperative.

The above trends only became apparent over an extended period of trial operation. These concerns, now recognised, can be managed to minimise impact on production. Planning a thinning zone at low elevation on the Tasman Peninsula minimised the impact of non-productive time.

(a) Operational considerations

The viability of the cable-thinning operation depends on the ability of the faller to prepare timber in excess of the yarding capacity of the hauler. The average size of the trees felled was 0.55 m^3, requiring a tree to be felled every four minutes to produce sufficient timber to maintain a daily production of 64 m^3. This rate does not include the felling of non-commercial trees required for safety reasons. It soon became apparent during the trial that two fallers were necessary to maintain a commercial production rate.

The minimisation of non-productive time is important in maintaining production and is the joint responsibility of all crew members. Planning, co-operation and anticipating tasks will assist in minimising lost time.

The operation is sensitive to windy conditions and snow periods. The seasonal strategic planning of operational moves to other locations to minimise time lost due to unfavourable climatic conditions is important in maintaining wood production. As the thinned area is, by prescription, adequately stocked after thinning, no further afforestation work is needed. Therefore, moving the machinery at short notice will not impact on the site productivity.

(b) Costs

A significant feature of cable thinning is the high labour cost compared with other forest harvesting operations. Employee numbers reflect the specialised nature of cable thinning and the high degree of complementary skills required to make the operation financially sustainable. Wood production and, hence, cost are particularly sensitive to lost or non-productive time. Based on current production performance, if current lost time can be reduced by one hour per day, this will produce an additional 10 m^3 of wood and assist in reducing costs. A summary of typical daily costs is shown in Table 4.

To make thinning commercially viable, changes to the standard method of pricing wood must be accepted by the forest grower, sawmilling industry, and pulpwood companies. Thinning requires a highly skilled and competent workforce and, because of the harvesting prescriptions, productivity is lower than in a comparative clearfell operation.

Table 4. Summary of cable-thinning costs on a daily basis (30-year-old regrowth).

Work dissection	% costs
Wages	60
Overheads	10
Capital	20
Fuel and oil	3
Repairs and maintenance	7

Commercial thinning should be considered by the forest grower as a revenue neutral operation. Wood is harvested that would otherwise be lost through natural attrition. Forestry Tasmania has struck a reduced road maintenance charge, where the road construction cost has been amortised against the initial crop. Some rates may vary where there is a need to construct roads, or upgrade those constructed before the *Forest Practices Code* was adopted, in order to gain access to thinnable stands.

Thinning of regrowth is designed to maintain industry viability and the sawmilling industry should be prepared for additional financial input to offset the cost of thinning. The pulpwood companies should accept that thinning is a high cost operation but provides additional wood of high quality at a consistent rate of production.

Results from cable-thinning trial are summarised below.

- The system has the ability to harvest and achieve pre-set prescriptions for stand retention.
- Machinery used has the ability to overcome terrain variation and residual logging debris from previous operations.
- The operation has a low impact on the soil profile (i.e. < 1% soil disturbance).
- The operation demonstrated its commercial potential.
- There is a low visual impact resulting from cable thinning.

C. Current approach to planning and conducting commercial thinning operations in Tasmania

Resource identification

Colour aerial photography is forest typed (1:25 000 scale) and digitised to produce a GIS map. This system can be used to produce a boundary area statement of the regrowth by height class and stem density. Such zones are colour coded by five-year age classes and form the basis for assessment layout.

Assessing the resource

Inventory plots are established to assess the suitability of stands of native forest regeneration for thinning operations (REGASS plots; e.g. see Davis and Stone 1997). Recommended sampling intensity is 1% for operational requirements (i.e. 200 m between strips and 100 m between plots).

Using the assessment data, each plot (0.02 ha) is assigned an inventory unit code which identifies the retention rate and thinning priority. Each assessment plot is colour coded, a majority of one colour class being necessary to determine the retention rate for the harvest area. This aggregation procedure identifies a retention rate of crop trees of 250, 175 or 130 stems/ha, with a tree spacing of 6.5, 7.5 and 8.5 m respectively (see Forestry Tasmania, in press).

The following minimum criteria have been established for determining the suitability of a resource for commercial thinning operations:

- Minimum area of 5 ha.
- Site potential for forest types E1 and E2.
- PI types examined: ER2 and ER3 height class, and a, b, c, d, f density class.
- Site index greater than 34.
- Stand stocking greater than 400 stems/ha of which 250 stems/ha have sawlog potential.
- Average tree volume greater than 0.2 m^3.

- Assessed thinned eucalypt volume greater than 70 m^3/ha.
- Minimum tree size measured at 10 cm DBH, with the minimum potential sawlog being 3 m. For calculation of stand volumes, 17 cm DBH was set as the default value.

In evaluating areas for suitability, the most common factors affecting the available thinning area were:

- Insufficient volume (i.e. < 70 m^3/ha) to commercially thin.
- Areas adequately stocked.
- Areas understocked.
- Average tree size less than 0.2 m^3.
- Areas overstocked, but too small to commercially thin.
- Poor road access and the presence of stags that restrict thinning options.

Operational monitoring

Unlike most harvesting systems, thinning operations have defined preharvest prescriptions which are closely monitored during harvesting. The levels of operational damage, together with the number and quality of retained trees, provide the most cost-effective means of measuring the success of the completed operation.

Wound severity is not recorded. The important element is the position and cause of the injury so preventative measures can be implemented. However, some damage causes can be obscure, and careful observation and interpretation are necessary to correctly identify them. Such occasions occur when poor directional felling positions the tree in such a way that the recovery process results in stem damage. Thus, wounding may be attributed to the recovery process rather than felling. In all cases, the emphasis is on a consultative approach to operational improvement.

Monitoring procedures have been in place for five years and have proven reliable and robust. The system, with some minor modification, is used to monitor operational performance in specialty timber and selective logging operations on a statewide basis.

Integrated stand management

Further options for ground-based thinning on an extensive scale on existing resources are limited. Historically, most of the resources from the 1960s were snigged long distances (up to 1000 m) and serviced by road systems that were designed for downhill pulling. These characteristics significantly limit access for a commercial thinning operation.

Integrated stand management should be considered for those sites destined for future thinning. Thus, coupes that have a high site quality and gentle slopes should be identified as potentially thinnable before the initial harvest, and road access planned accordingly. Key landing sites, because of their location, should be taken out of the wood production zone and included as part of the road construction programme. Gravelled, drained and maintained as part of the roading system, these sites would be used as ongoing landing sites for the life of the coupe.

Coupes with future thinning as a management objective will require additional site preparation, with the logging debris arranged in the direction that provides the best option for future harvesting. This would improve the chances of using small equipment to economically thin the forests of the future. However, there would be some additional costs for roading and site preparation at the time of the initial harvest.

Integrated stand management falls midway between current clearfell, burn and sow prescriptions, and plantation site preparation. The main features are:

1. Clearfell all trees.
2. Align logging debris and residues in the direction which provides the best options for future harvest.

3. Plan road systems to allow for roading access suitable for thinning. This can be planned with a combination of ground-based and cable-thinning options.
4. For ground-based thinning, landing sites are to be integrated with the roading network for future use.
5. Increase sowing rates.

Systems developed over this trial period (1990–96) have been incorporated into commercial field operations. The current target for all styles of operations is 750 ha in 1997/98 and 1000 ha for the following year.

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