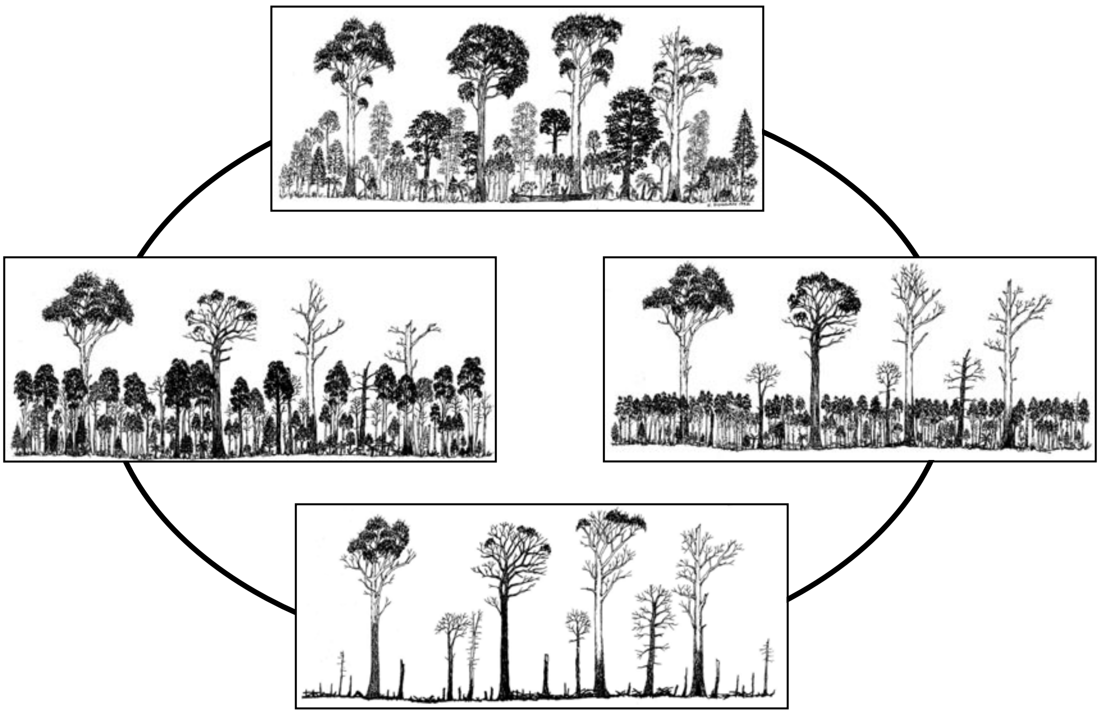
Forestry Tasmania

Native Forest Silviculture

TECHNICAL BULLETIN No. 5

2010



Silvicultural systems for native eucalypt forests

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This Bulletin is consistent with Forestry Tasmania's 2008 Sustainability Charter, which outlines its forest management strategy for the coming decade.
Amongst other things, the Charter states the following forest management aims:

"Maintain a diversity of natural habitats and mixed age forests to support biodiversity across the forest estate.
Maintain the current proportion of native forest in State forests.
Retain oldgrowth elements including large trees, stags, understoreys and logs across the forest estate.
Ensure an ongoing long-term supply of the highest quality eucalypt timber from native forests.
Manage State forests for long-term carbon storage and provide a sustainable source of products that contribute to locking up carbon and reducing emissions."

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Contents

1. Introduction

This Technical Bulletin is different to all the other bulletins in the Native Forest Silviculture Technical Bulletin Series, which are designed as guides to the management of particular forest types, for example high altitude *E. delegatensis* forests, or for particular subjects, for example regeneration surveys.

This Technical Bulletin is designed as a general reference manual for the management of native eucalypt forests in Tasmania. It briefly describes all the silvicultural systems that are prescribed for use in native eucalypt forests. It describes the natural regeneration processes, and how regeneration is established following harvesting. It also contains a range of reference information: for example, forest product classes, growth stages of the eucalypts and tables of appropriate spacing of retained trees for a given basal area.

Rainforests and blackwood forests have specific silvicultural requirements which are described in Technical Bulletins 9 and 10 respectively, and there is no further discussion of those forest types in this bulletin.

Silviculture is the science and art of managing the establishment, composition and growth of forests.

A **Silvicultural System** is a regime of operations applied to a forest to produce or enhance forest values such as wood production, water yield, wildlife habitat, soil conservation and landscape aesthetics. To develop the appropriate silvicultural system for any given coupe requires:

- a management objective
- a harvesting system
- a regeneration treatment
- monitoring and protection

It is important to note that this bulletin is written for the area of the coupe that is to be harvested. It assumes that all set-asides for biodiversity conservation or other requirements as prescribed in the Forest Practices Code (Forest Practices Board 2000) have already been taken into account.

2. Planning Silvicultural Treatments

2.1 Forest Practices Code

Harvesting and regeneration treatments for forests in Tasmania must be prescribed in Forest Practices Plans prepared under the provisions of the Forest Practices Code.

The planning for silvicultural treatments should commence well in advance of harvesting operations. Long term planning is particularly important to ensure that:

- safe burning boundaries are established,
- seed requirements can be met,
- proposed silvicultural treatments are compatible with other management objectives.

This is particularly relevant to factors such as the shape, size and dispersal of coupes. Guidelines on coupe planning are detailed in the Forest Practices Code.

The Forest Practices Plan should provide sufficient detail to ensure that successful regeneration will be achieved. Table 2.1 provides a checklist of factors that may be considered when formulating a silvicultural prescription. Obviously not all of these factors will be relevant to individual coupes - the important consideration is to identify those key factors that are critical to the success of each silvicultural operation.

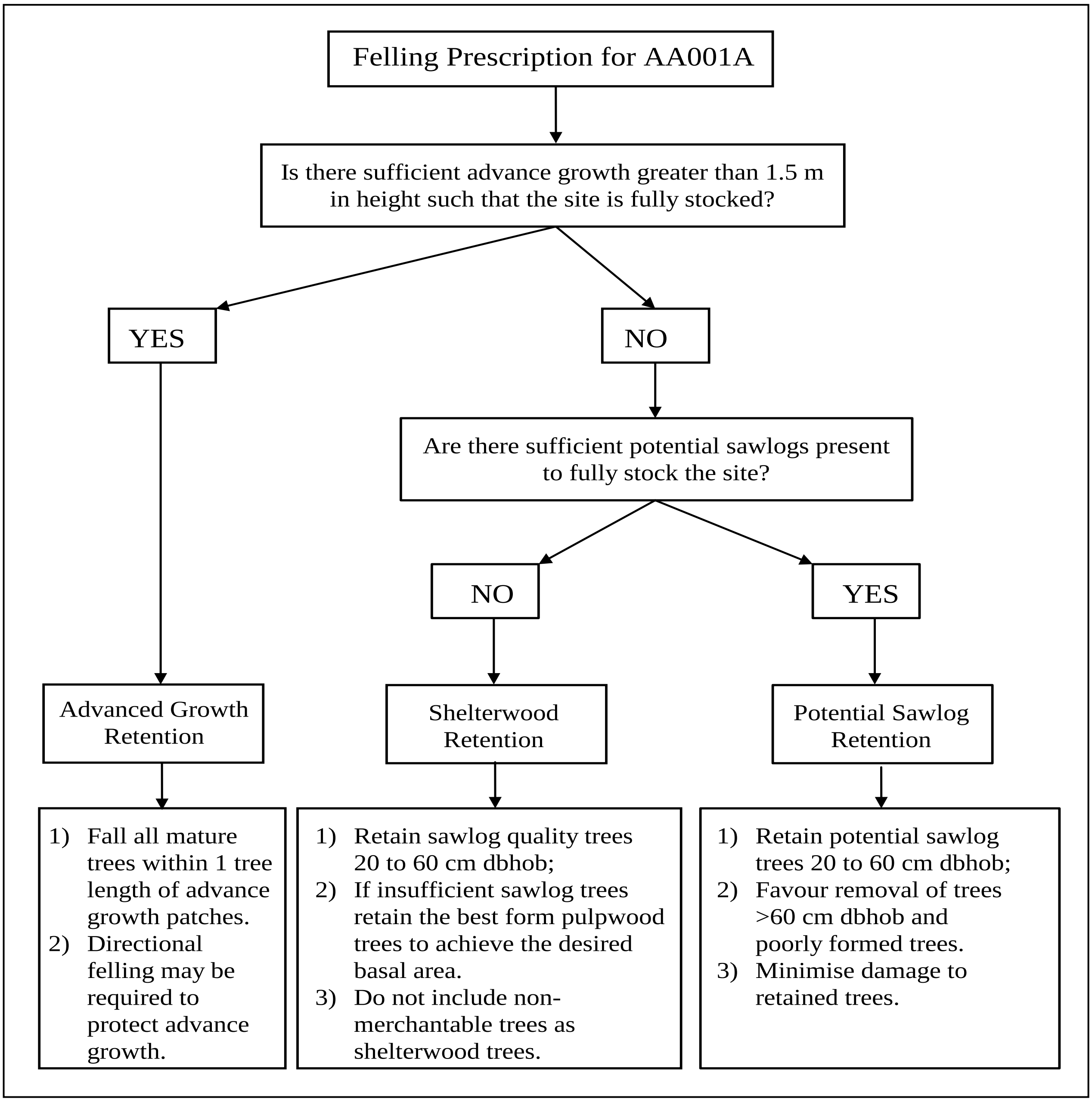
Table 2.1. Checklist for silvicultural prescriptions.

Objectives	Reforestation aims	maximise eucalypt regeneration or biodiversity
	Utilisation standards	veneer, sawlog, special species, craft, pulp sales
	Maintenance of other values	landscape, soil, water, flora, fauna, cultural etc
Forest type	Species	overstorey, understorey
	Structure	forest type, age
	Condition	health, density, fire history
Site factors	Altitude	frost, wind, exposure
	Rainfall	amount, distribution
	Soil	quality, depth, structure, erodibility
	Drainage	water, cold air
	Slope	aspect, steepness
Harvesting	Silvicultural system	clearfell, aggregated retention, group selection, seed tree, shelterwood, advance growth retention, potential sawlog retention, thinning
Seedbed	Burning	preparation, timing, intensity, coverage
	Mechanical	timing, machine type, coverage, cost
Regeneration	Retention of advance growth	size, species, stocking (% 16 m²), density (stems per ha)
	Natural regeneration	seed from retained trees, felled crowns, aggregates, edges
	Sowing	coupe area, timing, species mix, rate
Seed collection	Calculate seed needs	coupes, zones, species, germination rate, sowing rate
	Consult with Seed Store	seed stocks, availability
	Locate seed trees	zone, species, maturity, collectability, contractor info
	Supervise collection	felling, collection, labelling, transport, extraction, storage
Sowing	Confirm coupes	coupes to be sown this season
	Consult with Seed Store	seed stocks, mixing, delivery
	Prepare sowing plan	aircraft, maps, fuel, crew
	Supervise sowing	equipment, weather forecasts, pilot briefings, seed, crew, calibration, monitoring seed fall, residual seed in hopper, sow indicator plot
	Complete documentation	review ops, reports, coupe records and FOD
Crop protection	Monitor browsing levels	indicator plots, monitoring transects, mammals & insects
	Assess potential damage	severity, costs, growth losses, wildfire risk
	Control program	method, risks, training, notification, timing, cost
	Review	monitoring, growth improvement, documentation, FOD
Regeneration survey	Select stocking standard	regeneration survey type, timing, crew
	Growth standards	assessment, silvicultural system modification
	Forest Operations Database	input data, maps and information
	Review	silvicultural system, processes, safety, costs, regeneration
Remedial options	Reasons for understocking	understand losses e.g. seedbed, sowing, browsing, weather
	Treatment choice	don't do it again; more seed, seedbed or protection
	Review	options, processes, reasons, regeneration, costs

2.2 Uneven-aged forests

Variable structure within many forest stands will preclude the application of a single silvicultural system. In many cases a combination of systems will be appropriate, leading to a mosaic that contains patches of retained trees that have different age classes or structures. A mixture of systems is common in dry, uneven-aged forests whereas single systems tend to predominate in wet forests, particularly those with a dense understorey. Examples of mixed silviculture are given in Technical Bulletins No. 2 and No. 3 and in the flow chart example below. For simplicity's sake, the prescriptions that follow (Section 3) are written for uniform stands.

Figure 2.1. A flow chart for a high altitude coupe containing patches of advance growth, patches of potential sawlogs and areas lacking both. Note that in this example, three silvicultural systems will be applied within the one coupe.



2.3 General principles of partial harvesting

Safety is always the first consideration. Any identified threat posed by hazardous trees within the harvested area must be removed.

The aim of all partial harvesting is to retain the most useful growing stock in the best condition for the future.

All retained trees should have healthy well balanced crowns.

Priority for selection of retained shelterwood trees:

- Potential sawlogs (20 to 60 cm diameter at breast height over bark (dbhob))
- Mature sawlogs (60 to 80 cm dbhob – larger trees should be removed)
- Pulp trees with a healthy crown and a good seed crop
- Non-merchantable trees with a reasonable crown and a good seed crop

Priority for selection of retained seed trees:

- Potential sawlogs (20 to 60 cm dbhob)
- Pulp trees with a healthy crown and a good seed crop
- Non-merchantable trees with a reasonable crown and a good seed crop

Target levels for damage are 0%, and damage levels should not exceed 10%.

Logs greater than 12 m in length should be cross-cut prior to snigging to avoid butt damage to retained stems. Snig tracks should be as straight as reasonably possible. Rub or bump trees should be retained on primary snig tracks. These trees should be the last to be removed from each section of the coupe.

Tree heads and other logging debris should not be pushed up or left against retained trees or in patches of advance growth. Firebreaks should be prepared to the minimum practical width necessary for access as required for fire control operations and browsing control. In coupes that are not fully stocked at the completion of harvesting, receptive seedbed must be created by burning or by mechanical disturbance to expose mineral soil.

2.4 Silvicultural prescriptions for partial harvesting

A seed crop assessment should be undertaken and a satisfactory seed crop recorded (as prescribed in Technical Bulletin 1) before partial harvesting commences. Where the seed crop assessment identifies a lack of seed and scheduling dictates that harvesting must go ahead, then on-site or in-zone seed must be collected during the harvesting for later sowing unless the Seed Centre is known to hold appropriate seed in store.

Patches within a coupe which are likely to be particularly difficult to regenerate, such as exposed rocky knobs, frost hollows and the poorest quality grassy peppermint forests, should not be harvested.

Retain a forested environment during harvesting to minimise the rate of grass invasion, reduce climatic extremes and minimise browsing damage to eucalypt seedlings. Keep existing advance growth wherever possible as it is already established and is the product of many years of growth. Trees retained for seed and shelter should be of reasonable form and quality with healthy, balanced crowns and good seed crops. The species mix of the retained trees should reflect the original forest composition. Regeneration must be established before all the overstorey is removed.

Most non-merchantable trees should be removed from harvested areas. Non-merchantable trees with large spreading crowns are a priority for removal as they compete directly with the new regeneration for growing space. Overmature and/or hollow-bearing trees should be incorporated in wildlife habitat clumps wherever possible.

The use of fire to create receptive seedbed is not essential in dry forests, provided that adequate exposure of mineral soil has been obtained by logging disturbance and/or additional scarification. When fuel levels after logging are high, burning may be undertaken as a slash management option. Where valuable advance growth is present the use of high intensity or broadcast fire is undesirable, particularly on sites which may be difficult to regenerate.

Mechanical disturbance should aim to expose mineral soil by the removal of vegetation and litter layers. Care must be taken to minimise soil movement, compaction or displacement, particularly on infertile soils and sites susceptible to erosion.

Retained mature trees and older regrowth which carry good seed crops provide an ongoing source of on-site seed which assists the successful establishment of regeneration and provides a form of insurance against wildfires. If a wildfire destroys the regeneration, the retained trees can provide further seed.

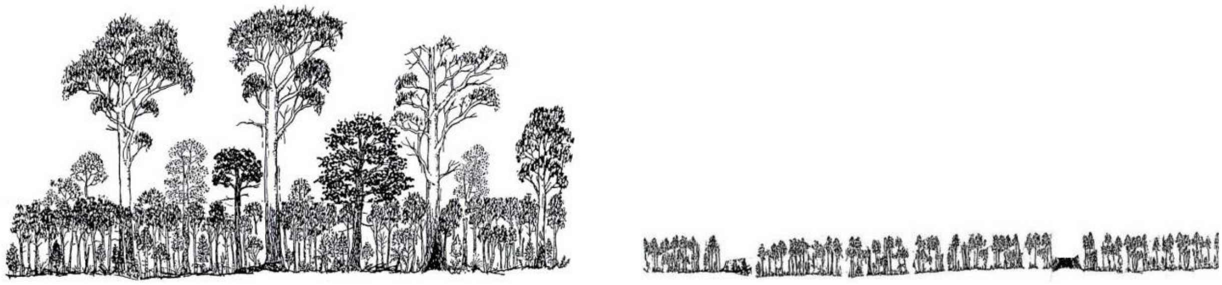
During the regeneration phase, monitoring of browsing animals, and control where required, is essential to ensure successful regeneration.

2.5 Silvicultural systems

Silvicultural systems currently applied to multiple-use forests in Tasmania are illustrated in Figure 2.2.

Guidelines for the selection of harvesting methods and regeneration treatments are provided in Figure 2.3.

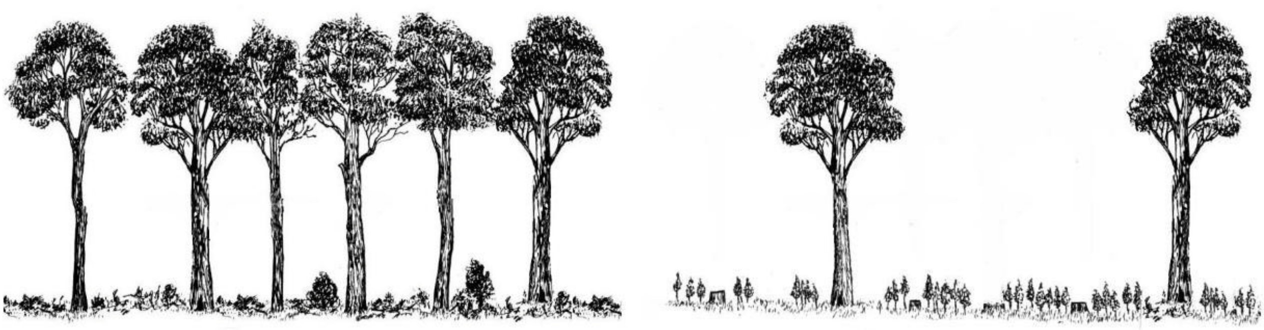
Figure 2.2. Silvicultural systems that are currently applied to native eucalypt forests in Tasmania.



Clearfelling: Applied to wet eucalypt forests that have a dense understorey, thick ground cover or litter layer, and to dry forests on steep slopes harvested by cable. All stems are felled. Receptive seedbed is prepared by high intensity burning or by mechanical disturbance. Seed is aerially sown.

Aggregated retention: Applied to wet eucalypt forest coupes where more than 25% of the coupe is oldgrowth, or to wet eucalypt forests rich in special timbers. Can also be applied if required to manage particular site values. The majority of the harvested area of the coupe is under the influence of forest that is retained for the next rotation. Receptive seedbed is prepared by moderate intensity burning. Seed is aerially sown unless the natural seedcrop is deemed to be sufficient.

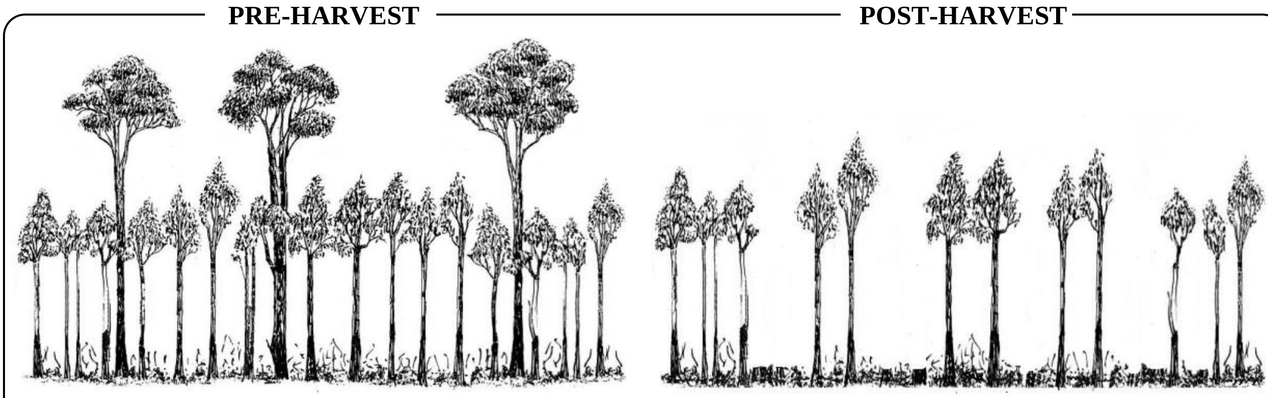
Group selection: Applied to wet eucalypt forest coupes rich in special timbers. Up to one-third of the coupe may be harvested at each cycle in openings about two tree heights wide. Receptive seedbed is prepared by moderate intensity burning. Eucalypt seed may be aerially sown. Rainforest species should regenerate adequately naturally.



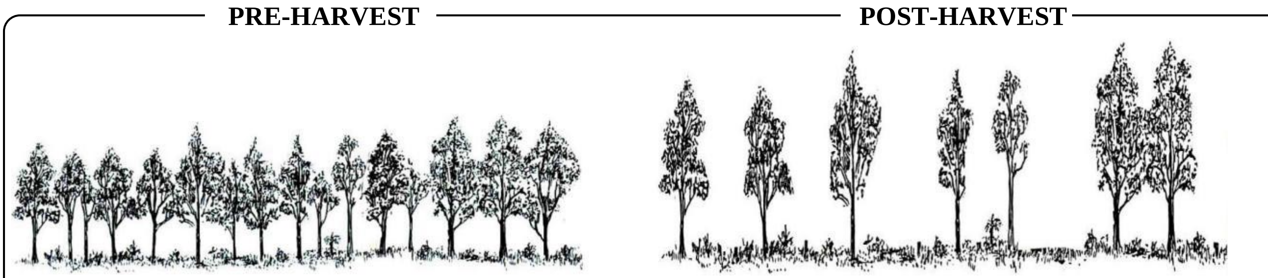
Shelterwood: Applied to high altitude open *E. delegatensis* forests which contain little advance growth. Trees with good crowns are retained at 9–14 m^2 of basal area per hectare. Seedbed is created by low intensity burns, or excavator heaping. Regeneration arises from natural seeding, sowing, and/or release of advance growth. The overstorey should be removed when the average height of the regeneration is greater than 1.5 m.

Seed tree retention: Applied to lowland dry eucalypt forests that lack advance growth or potential sawlogs. Seven to 12 healthy well-spaced trees per ha with a good seed crop are retained. Receptive seedbed is prepared by low intensity burning, or excavator heaping. Seed trees should be removed once the regeneration is established.

Advance growth retention: Applied to uneven-aged forests containing advance growth that has good potential for further growth. Mature stems are harvested. No additional regeneration is required as the stand should be maintained in a stocked condition.

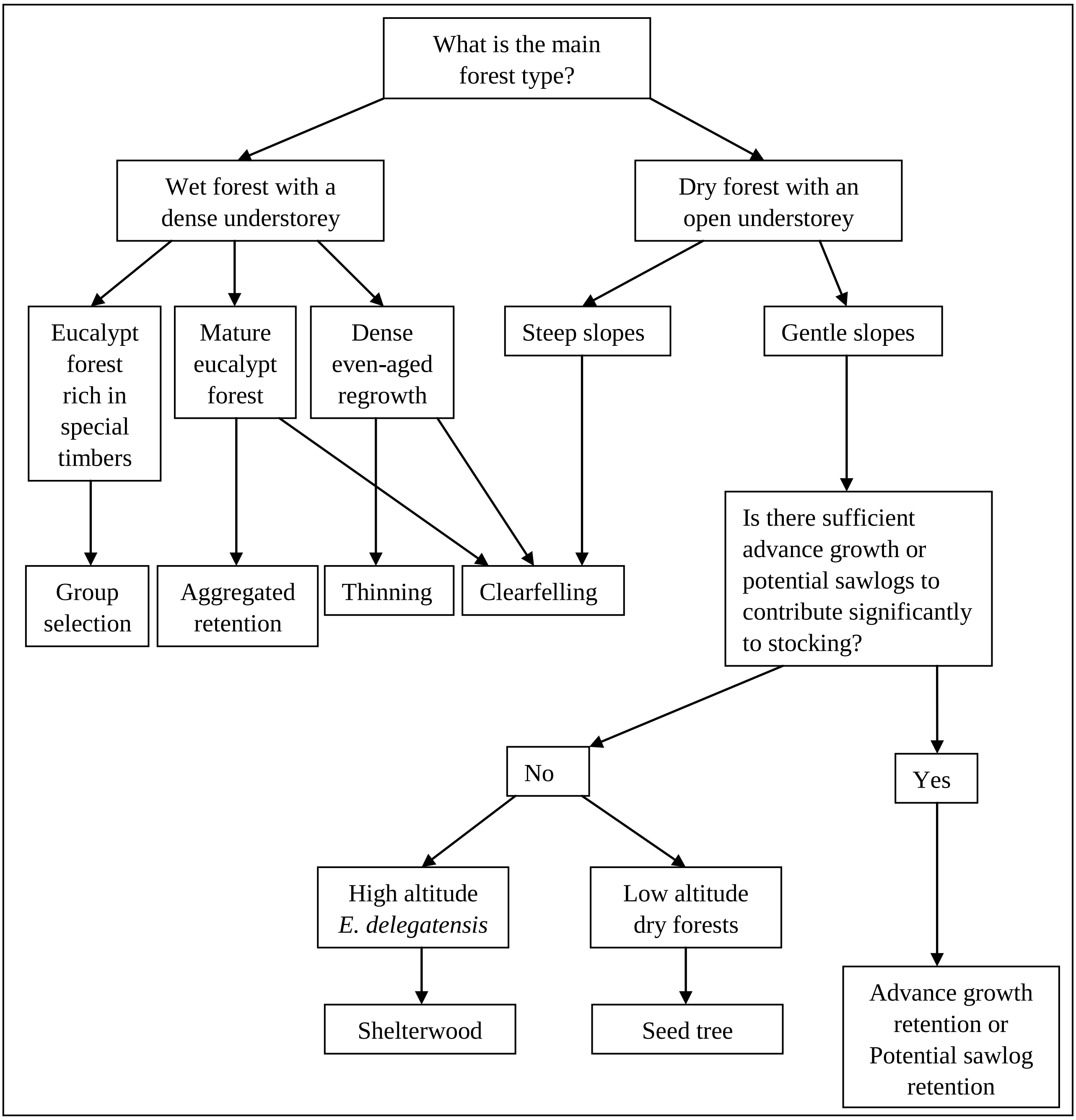


Potential sawlog retention: Applied to two-aged high quality forests comprising potential sawlogs and a mature overstorey. All mature trees should be harvested and the potential sawlogs evenly retained at 9 to 12 m^2 of basal area per hectare. Minimal additional regeneration is required for the stand to be maintained in a stocked condition.



Thinning: Applied to well stocked even-aged regrowth on sites with good growth potential. The prescription varies according to the size and stocking of the regrowth. No additional regeneration is required as the stand should be maintained in a stocked condition.

Figure 2.3. Selection of the appropriate silvicultural system and regeneration treatment for native eucalypt forests.



Note that the dominant forest type within each coupe is the key factor that determines the appropriate silvicultural system, and also that there is often more than one option for any given coupe. In most partial harvests, more than one silvicultural system will be applied within the one coupe.

3. Silvicultural Prescriptions

3.1 Clearfelling

Appropriate forest stands:

Lowland wet eucalypt forests (i.e. both mixed forests and wet sclerophyll forests) typically dominated by *E. obliqua* or *E. regnans*.

High altitude *E. delegatensis* forests on moderate to steep slopes with a rainforest or wet sclerophyll understorey.

Lowland dry eucalypt forests on steep slopes, which are to be harvested using cable machines.

Harvesting method: All stems are harvested, including non-merchantable trees (culls). Scrub felling or pushing is often used to improve the fuel preparation prior to the regeneration burn.

Regeneration treatment:

Site preparation: High intensity burn to reduce fuels and create receptive seedbed.

Source of regeneration: Aerial sowing. Seed should be sown onto the receptive seedbed as soon as possible after the regeneration burn. Further details on sowing are contained in Technical Bulletin No. 1.

Monitoring and protection: Indicator plots must be established to monitor germination and problems due to frost, drought, insects and browsing damage, as prescribed in Technical Bulletin No. 12.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin No. 12.

Regeneration survey: A seedling regeneration survey should be carried out in late summer/early autumn in the year following the regeneration burn, as prescribed in Technical Bulletin No. 6.

Further details: See Technical Bulletin No. 2, *Eucalyptus delegatensis* forests, No. 3, Lowland dry eucalypt forests and No. 8, Lowland wet eucalypt forests.

3.2 Aggregated retention

Appropriate forest types:

Wet eucalypt forest coupes where greater than 25% of the coupe by area is oldgrowth.

Wet eucalypt forests rich in special timbers.

Can also be applied if required to manage particular site values.

Harvesting method: Aggregated retention is currently recommended for use only in ground based operations. Coupes must be designed such that the majority of the harvested area of the coupe is under the influence of forest that is planned to be retained unharvested for at least the next rotation. This is usually achieved by retaining edge or island aggregates, that are located where possible in areas of ecological value. Aggregates are maintained as undisturbed as possible during the harvesting, whilst the remaining area of the coupe is harvested.

Regeneration treatment:

Site Preparation: Moderate intensity burn to reduce fuels and create receptive seedbed. The aim of the burn should be to achieve the best seedbed possible, whilst also minimising the impact of the regeneration burn on the aggregates. Firebreaks should be prepared to the minimum practical width required for access if required for fire control operations and browsing control.

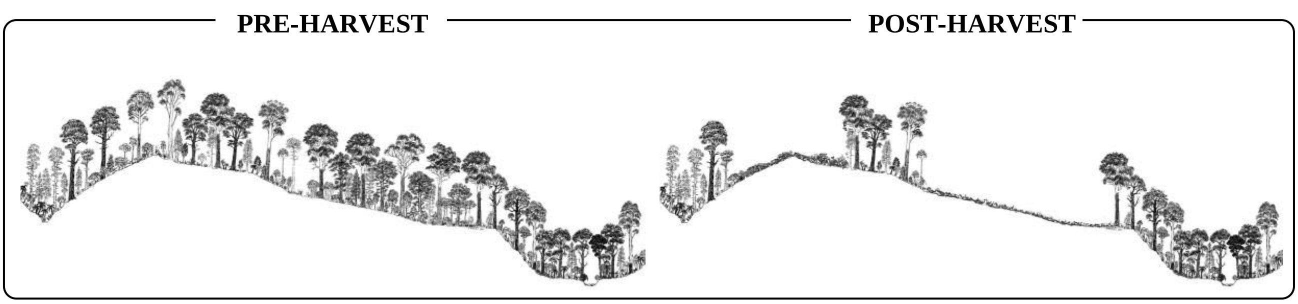
Source of Regeneration: Seed should be sown onto the receptive seedbed as soon as possible after it is created. Further details on seed and sowing are contained in Technical Bulletin No. 1. Seedcrops around the harvested area of the coupe should be assessed prior to the regeneration burn. Where the seedcrop is adequate, natural seedfall may be sufficient to regenerate the coupe.

Monitoring and protection: Indicator plots must be established to monitor germination and problems due to frost, drought, insects and browsing damage, as prescribed in Technical Bulletin No. 12.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin No. 12.

Regeneration survey: A seedling regeneration survey should be carried out in late summer/early autumn in the year following the regeneration burn, as prescribed in Technical Bulletin No. 6.

Further details: See the Variable Retention Manual for advice on planning and harvesting aggregated retention coupes. For guidance on maximising biodiversity outcomes see Baker *et al.* (2009).



3.3 Group selection

Appropriate forest types: Wet eucalypt forests rich in special timbers.

Harvesting method: The broad aim is to harvest about 30% of the coupe at each of three stages, such that by the end of the rotation up to (but probably less than) 90% of the coupe may have been harvested, with at least 10% of the coupe retained for maintenance of late successional species and structures. Planned rotations will be longer than is usual for coupes containing only eucalypts.

- Emphasis should be on harvesting mature trees.
- >70% of forest canopy to be retained after each harvest.
- Potential crop trees should be retained undamaged.
- Harvested fairways approximately 80 m or about two tree lengths wide.
- Leatherwood rich patches should be retained undamaged.
- Individual sound and safe eucalypts may be retained within the fairways, where practicable and at the contractor's discretion, at an approximate spacing of one to two tree lengths to improve aesthetics, seed source, habitat and longer rotation eucalypt sawlog.

Regeneration treatment:

Site Preparation: Moderate intensity burn to reduce fuels and create receptive seedbed. The aim of the burn should be to achieve the best seedbed possible, whilst also minimising the impact of the regeneration burn on the surrounding forest. Firebreaks should be prepared to the minimum practical width required for access if required for mop-up operations and browsing control.

Source of Regeneration: Seedcrops around the harvested area of the coupe should be assessed prior to the regeneration burn. Where the seedcrop is adequate, natural seedfall may be sufficient to regenerate the coupe. Where the seedcrop is inadequate, eucalypt seed should be sown onto the receptive seedbed as soon as possible after it is created. Further details on seed and sowing are contained in Technical Bulletin No. 1. The rainforest species should regenerate adequately from natural seedfall and ground-stored seed.

Monitoring and protection: Indicator plots must be established to monitor germination and problems due to frost, drought, insects and browsing damage, as prescribed in Technical Bulletin No. 12.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin No. 12.

Regeneration survey: A seedling regeneration survey should be carried out in late summer/early autumn three years after the regeneration treatment, as prescribed in Technical Bulletin No. 6.

3.4 Thinning

Appropriate forest types: Dense even-aged regrowth on sites with good growth potential.

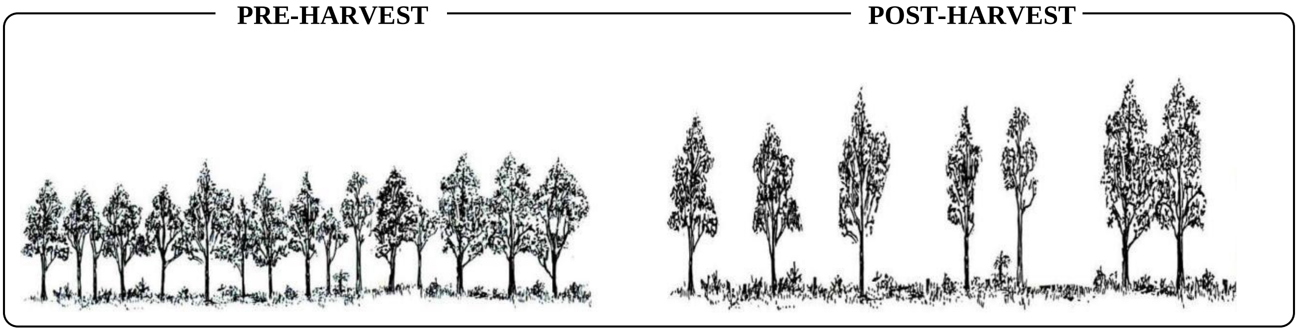
Harvesting method: Thinning is conducted 'from below', where the smaller trees are removed and about one-half the original basal area is retained after thinning. Methods and prescriptions vary according to site factors and the age and quality of the regrowth.

Pre-commercial thinning (PCT) is generally undertaken at age 10 to 25 years using stem injection of herbicide. Areas selected for PCT should have a stand basal area of at least 20 m²/ha and at least 1000 stems per hectare larger than 10 cm dbh. After PCT the stand should comprise at least 500 crop trees per hectare with a basal area of at least 12 m²/ha. The intention is to maximise the early growth of the best stems (the crop trees) and increase the viability of a subsequent commercial thinning.

Commercial thinning (CT) is generally undertaken at age 25 to 45 years. Coupes selected for CT should have a stand basal area of at least 32 m²/ha and at least 500 stems per hectare larger than 17 cm dbh. After thinning the density is reduced to between 150 to 250 stems per hectare, depending on the initial structure of the stand, and the retained basal area should be at least 16 m²/ha. Retained trees must be well-formed, vigorous trees with good growth potential.

Regeneration treatment:
Generally, no additional regeneration is required as the stand should be maintained in a stocked condition. Minimising damage to retained stems is critical. Stocking and any damage to retained trees should be monitored throughout the thinning operation.

Further details: See Technical Bulletin No. 13, Thinning regrowth eucalypts.



3.5 Shelterwood retention

Appropriate forest stands: *E. delegatensis* forests with open understoreys that lack sufficient advance growth greater than 1.5 m in height. An adequate seedcrop should be present in the retained trees. If the seedcrop is inadequate it is acceptable to sow; however it is preferable when possible to reschedule harvesting until an adequate seedcrop is available.

Harvesting method: All trees are harvested other than those required to provide the shelterwood. Retained trees should have good crowns and be evenly distributed at a rate corresponding to 9 - 12 m^2/ha basal area on coupes where the rainfall is below 1000 mm. On coupes with higher rainfall the retained basal area can be up to 14 m^2/ha. The proportion of species present on the site prior to harvesting should be reflected in the retained trees.

Regeneration treatment:

Site preparation: Receptive seedbed must be created by low intensity broadcast burning, top disposal burning, excavator heaping, harvesting disturbance or additional mechanical disturbance. On grassy sites, deliberate additional mechanical disturbance may be required to create sufficient seedbed.

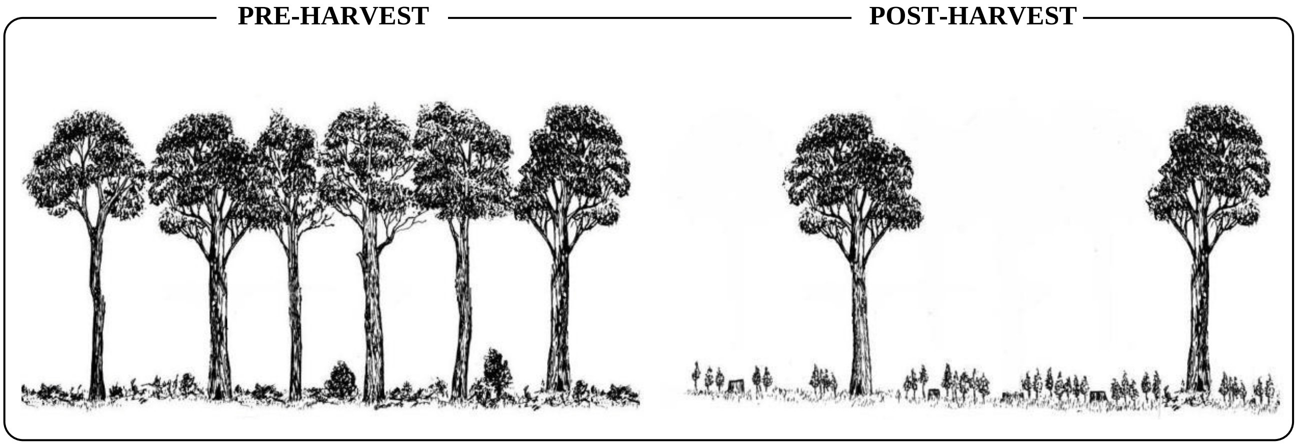
Source of regeneration: From seed shed during and after harvesting and from the release of advance growth (where present). If the seed supply is inadequate the coupe must be sown. If rapid grass invasion of the coupe is expected, supplementary sowing onto receptive seedbed should be undertaken.

Monitoring and protection: Indicator plots must be established to monitor germination and problems due to inadequate seedfall, lack of receptive seedbed or browsing damage, as prescribed in Technical Bulletin 12. As the plots are a measure of the success of the seedfall on the coupe, they should not be artificially sown.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin 12.

Regeneration survey: A seedling regeneration survey must be carried out about two years after the regeneration treatment, as prescribed in Technical Bulletin No. 6. A multi-aged survey is the appropriate method where shelterwood retention occurs as a mosaic within patches treated by the advance growth or potential sawlog retention methods.

Further details: See Technical Bulletin No. 2. *Eucalyptus delegatensis* forests.



3.6 Shelterwood removal

Appropriate forest stands: Two-aged forests comprising the mature stems retained in a previous shelterwood retention harvest and now stocked with advance growth.

Harvesting method: The retained shelterwood should be removed in a second harvest, when the coupe is stocked with regeneration > 1.5 m in height.

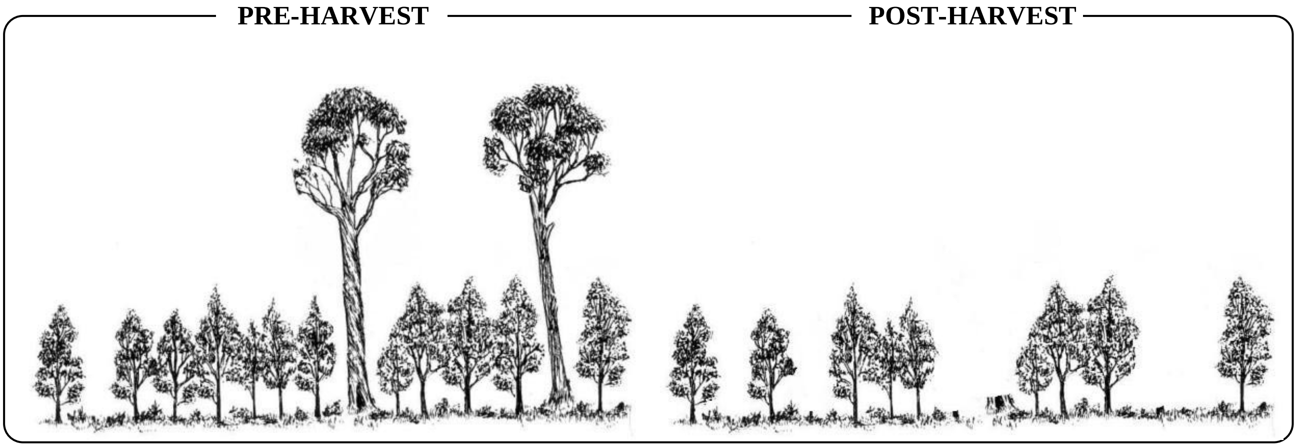
The shelterwood should be removed as soon as possible after the regeneration is established, and before the retained trees suppress the regeneration, generally between 5 to 15 years after harvesting.

Regeneration treatment:

Shelterwood removal is only undertaken when the stand is stocked with advance growth. No additional regeneration should be required. However, minimisation of damage to the advance growth is essential to leave the stand in a healthy and well stocked condition following harvesting.

Regeneration survey: Either a sapling regeneration survey must be completed prior to the shelterwood removal harvest, or a seedling survey completed within two years after the harvest, as prescribed in Technical Bulletin No. 6.

Further details: See Technical Bulletin No. 2. *Eucalyptus delegatensis* forests.



3.7 Seed tree retention

Appropriate forest stands: Lowland dry eucalypt forests that lack sufficient advance growth or potential sawlogs suitable for retention. An adequate seedcrop should be present in the retained trees. If the seed crop is inadequate it is acceptable to sow; however it is preferable when possible to reschedule harvesting until an adequate seed crop is available.

Harvesting method: All trees are harvested other than seven to twelve well-spaced trees per hectare. Seed trees should be of good form and quality with healthy, balanced crowns and adequate seed crops. The proportion of species present on the site prior to harvesting should be reflected in the retained trees. Any advance growth should be retained undisturbed.

A higher retention rate should be used in grassy forests and sites prone to windthrow, e.g. granite soils on ridges in north-east Tasmania.

Regeneration treatment:

Site preparation: Receptive seedbed must be created by low intensity broadcast burning, top disposal burning, excavator heaping, harvesting disturbance or additional mechanical disturbance.

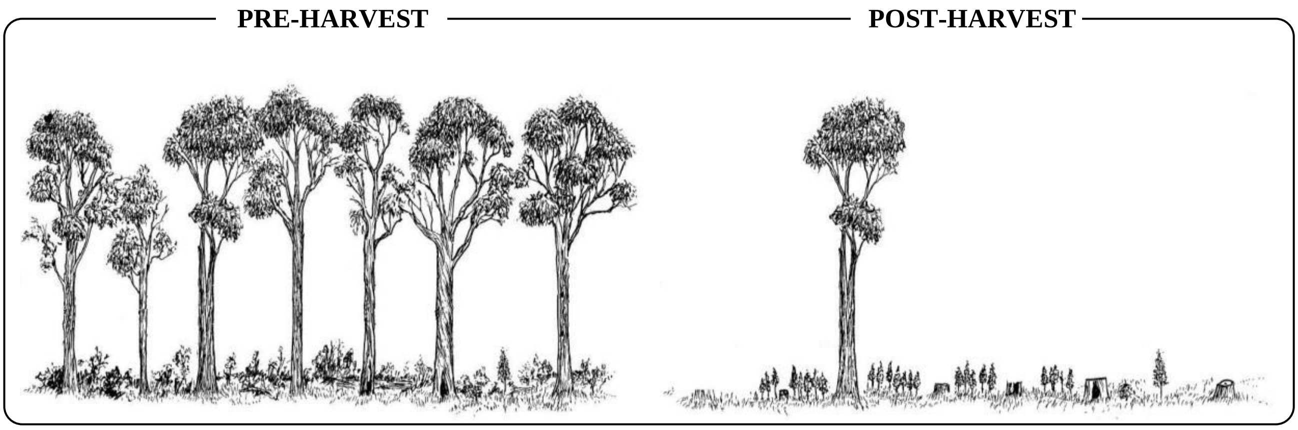
Source of regeneration: New seedlings may arise from seed shed from felled crowns (if the slash is retained unburnt), from the retained seed trees and from the release of advance growth (where present). If no seed is present the site must be sown.

Monitoring and protection: Indicator plots must be established, as soon as site preparation is completed, to monitor germination and problems due to inadequate seedfall, lack of receptive seedbed or browsing damage, as prescribed in Technical Bulletin No. 12. An unsown plot will quantify the success of the natural seedfall and germination. The plots can be larger than standard, up to 4 m by 4 m, because they rely on natural seedfall which may be lighter than an aerial sowing, but will occur over an extended period. Another fenced enclosure should be artificially sown to monitor the germination following a known sowing event.

Browsing damage: Browsing transects should be established and monitored, and control of browsing undertaken if required, as prescribed in Technical Bulletin 12.

Regeneration survey: A seedling survey must be carried out about two years after the regeneration treatment, as prescribed in Technical Bulletin No. 6. A multi-aged survey is the appropriate method where seed tree retention occurs as a mosaic within patches treated by the advance growth or potential sawlog retention methods.

Further details: See Technical Bulletin No. 3, Lowland dry eucalypt forests.



3.8 Seed tree removal

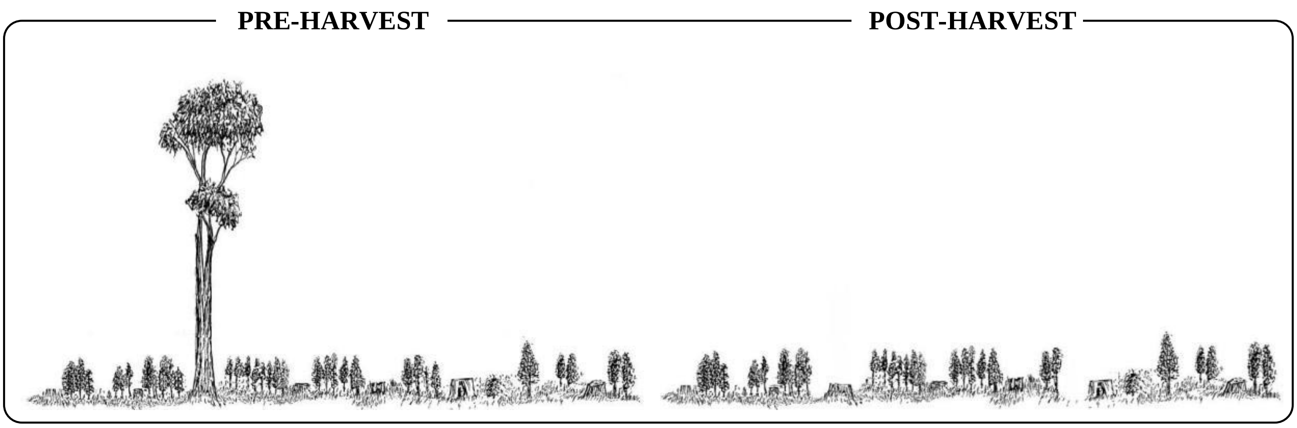
Appropriate forest stands: Lowland dry eucalypt forests that have previously been harvested to a seed tree retention prescription.

Harvesting method: The retained seed trees may be removed when the coupe is stocked with regeneration taller than the competing understorey. This may require 3 to 7 years, depending on site quality. The seed trees may be retained if required for other objectives such as for aesthetics or to provide habitat.

Regeneration treatment:

Seed tree removal is only undertaken when the stand is stocked with advance growth. No additional regeneration should be required.

Further details: See Technical Bulletin No. 3, Lowland dry eucalypt forests.



3.9 Advance growth retention

Appropriate forest types: Uneven-aged forests containing advance growth that has good potential for further growth. The cohorts of advance growth are often of different ages as they arise from different disturbances such as low intensity fires or previous harvesting events.

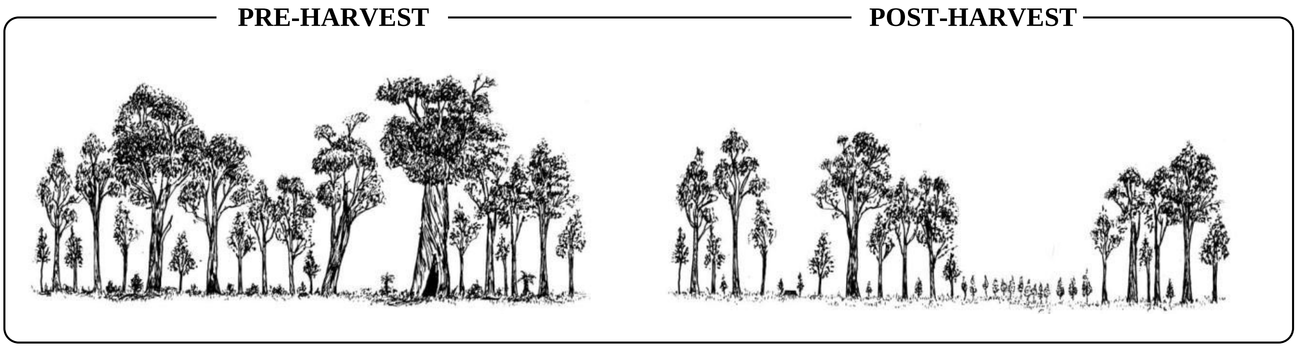
Harvesting method: Most mature and over-mature stems should be harvested. Regardless of the understorey type (grassy, sedgey, heathy or shrubby), the advance growth should be clearly taller than the competing understorey before the overstorey trees are removed.

Regeneration treatment:

Advance growth retention is only undertaken when the stand is stocked with advance growth. No additional regeneration should be required.

Regeneration survey: A multi-aged survey must be carried out within one year of the regeneration treatment, as prescribed in Technical Bulletin No. 6.

Further details: See Technical Bulletin No. 2. *Eucalyptus delegatensis* forests and No. 3, Lowland dry eucalypt forests.



3.10 Potential sawlog retention

Appropriate forest types: Two-aged high quality forests comprising potential sawlogs (20 to 60 cm dbh) and a mature overstorey.

Harvesting method: All mature trees should be harvested and the potential sawlogs evenly retained at 9 to 12 m² of basal area per hectare.

Regeneration treatment:

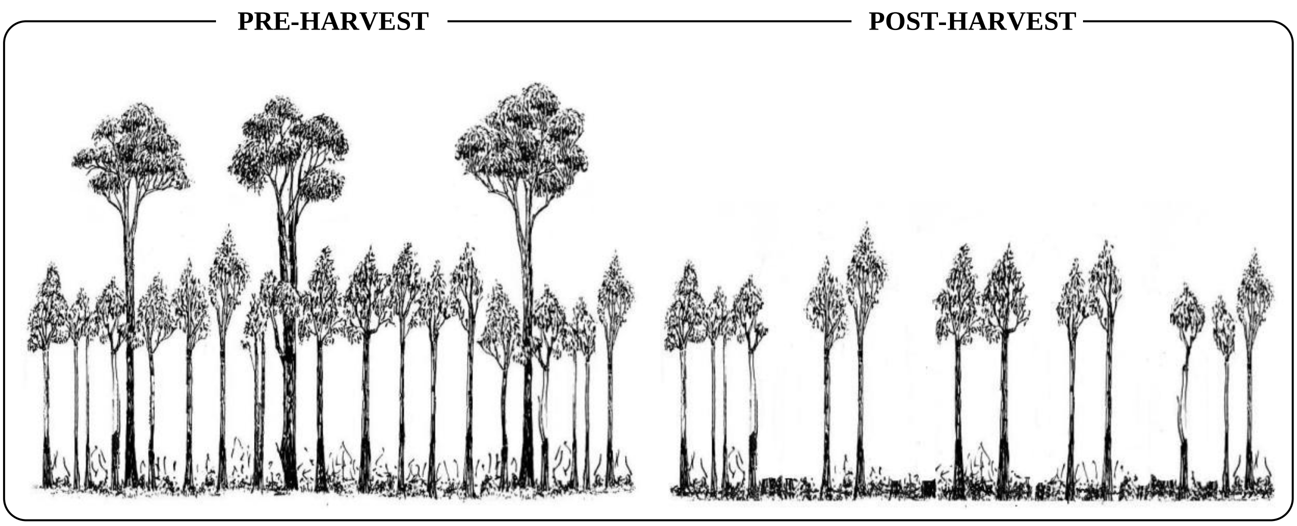
Potential sawlog retention is only undertaken when the stand is adequately stocked. No additional regeneration should be required.

Regeneration survey: A multi-aged survey must be carried out within one year of the regeneration treatment, as prescribed in Technical Bulletin No. 6. If the operation is monitored using Progressive Harvesting Assessment, and is known to be fully stocked at the completion of harvesting, a regeneration survey is not required.

Further details: See Technical Bulletins No. 2. *Eucalyptus delegatensis* forests and No. 3, Lowland dry eucalypt forests.

Potential sawlog retention spacings

See spacing and basal area tables in Section 12.



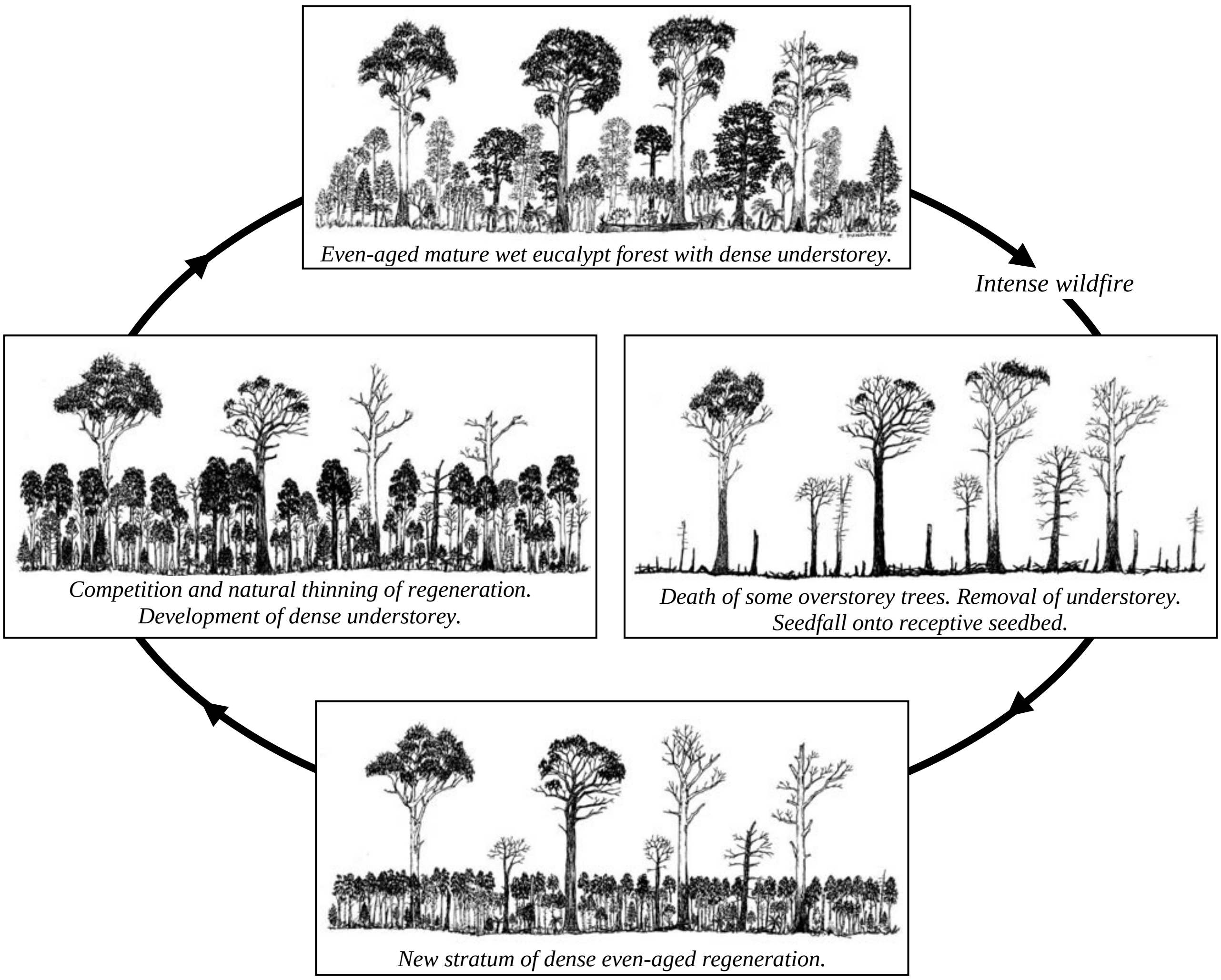
4. Natural Regeneration in Eucalypts

Eucalypt forests require disturbance to create suitable conditions for regeneration. Regeneration pathways in both wet and dry eucalypt forests are strongly related to fire frequency.

4.1 Natural regeneration in wet eucalypt forests

In wet eucalypt forests which have a dense understorey, wildfires are infrequent since weather conditions are rarely severe enough to dry out fuels sufficiently to sustain a fire. When wildfires do occur, the combination of high fuel loads and severe fire weather leads to often very intense fires. The fire removes most of the understorey vegetation, and may kill some or rarely all the mature eucalypts (Figure 4.1). (See Technical Bulletin No. 8 for further information about lowland wet eucalypt forests).

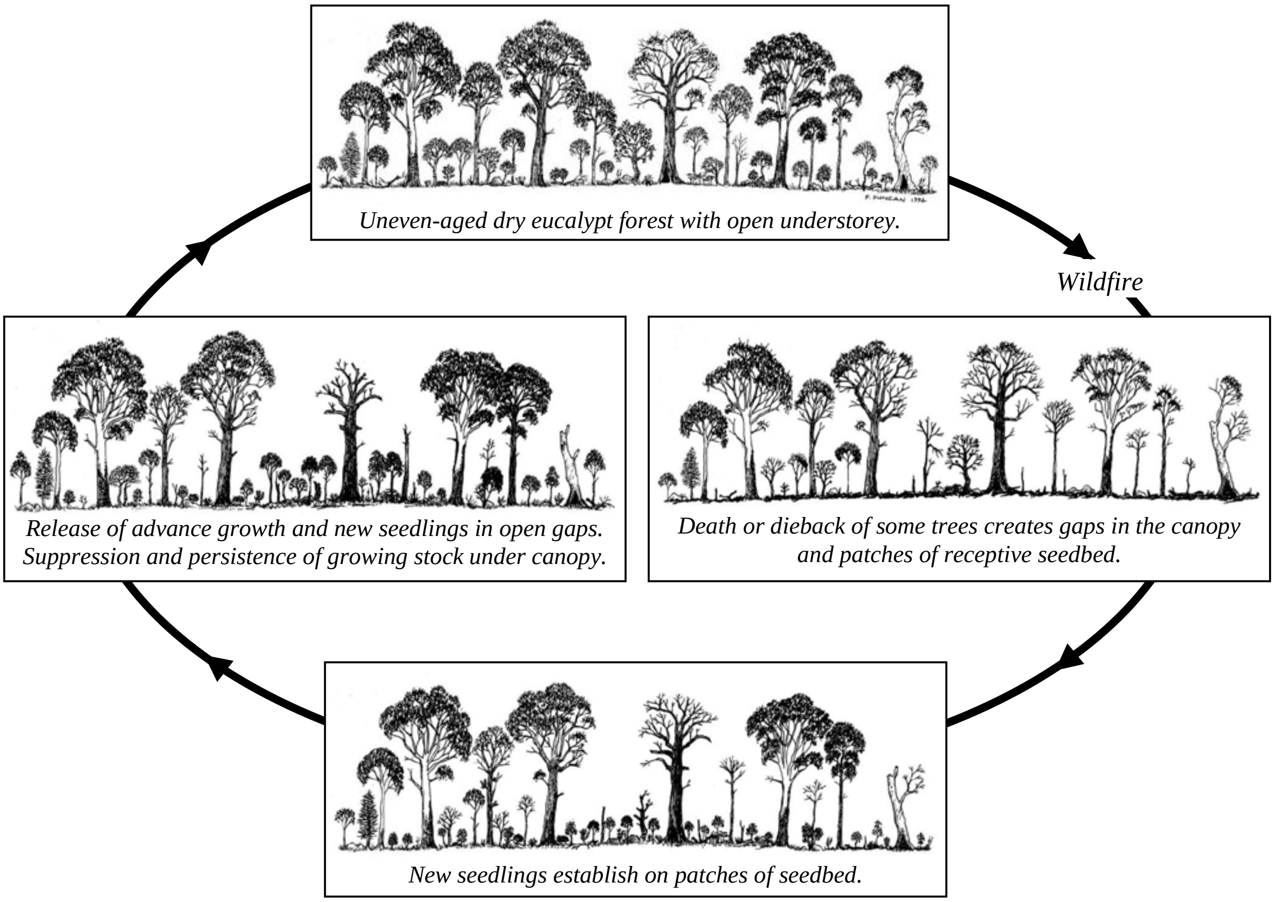
Figure 4.1. Natural regeneration pathway: Wet eucalypt forest; major, infrequent disturbance.



4.2 Natural regeneration in dry eucalypt forests

In dry eucalypt forests, which have a more open understorey, wildfires tend to be more frequent and will burn under relatively mild weather conditions. Fires are often patchy with variable intensity depending upon the accumulation of fuel and the prevailing weather conditions. Regeneration can also establish in open areas without fire. Consequently the forest structure is often a mosaic with cohorts of different age classes reflecting the previous fire history (Figure 4.2). (See Technical Bulletin No. 3 for further information about dry eucalypt forests, and Technical Bulletin No. 2 for further information about *E. delegatensis* forests).

Figure 4.2. Natural regeneration pathway: Dry eucalypt forest; moderate, frequent disturbance.



5. Regeneration After Harvesting

The establishment of a healthy crop of regeneration after harvesting requires a number of processes to be initiated. There are three important factors; seed, seedbed and protection, as shown below (Figure 5.1).

Figure 5.1. The processes involved in the establishment of a healthy crop of regeneration after harvesting.

Nurture existing or establish new seedlings

Following timber harvesting, there are two main sources of regeneration:
- the release of advance growth, or
- new seedlings from natural seedfall or sowing.

Advance growth
The release of advance growth requires:
- removal of part or all of the mature component of the stand to reduce competition for light, moisture and nutrients,
- minimisation of damage to the retained advance growth by harvesting and fire.

New seedling regeneration
The establishment of new seedlings requires:
- receptive seedbed,
- adequate seed, and
- a suitable environment for establishment and growth.

Seedbed

Receptive seedbed is:
- exposed mineral soil, and
- favourable soil factors.

In managed forests, exposed mineral soil can be created by one or a number of the following:
- planned burning of logging slash and litter to simulate natural processes,
- logging disturbance,
- scarification (cultivation) using machinery.

Favourable soil factors are:
- friable (not compacted) soil,
- reduced grass competition.

Seed

Seed comes from:
- natural seedfall from retained trees (both in and around the harvest area) and the crowns of felled trees
- artificial sowing.

Protection

A suitable environment for establishment and growth requires:
- sufficient moisture, nutrients and light,
- protection from damage by animals, climatic extremes and fire.

5.1 Nurture existing or establish new seedlings

Following timber harvesting, there are two main sources of regeneration:
- the release of advance growth, or
- new seedlings from natural seedfall or sowing.

Advance growth

The release of advance growth requires:
- removal of part or all of the mature component of the stand to reduce competition for light moisture and nutrients,
- minimisation of damage to the retained advance growth by harvesting and fire.

Advance growth may arise from either seedling or vegetative origin (Jacobs 1955).

Seedling origin of advance growth

Plants may occur as established seedlings, saplings or poles that may be suppressed by the overstorey canopy. The persistence of seedling advance growth is possible due to the presence of lignotubers.

The lignotuber is a woody swelling at the base of the stem which contains food reserves and a mass of dormant buds. It can form in a seedling within weeks after germination. With increasing age and size lignotubers become partially buried below ground level where they are well protected from fire. Lignotubers retain a high capacity to produce new shoots to replace any stems damaged by fire, drought, browsing or other causes. Although they may persist for long periods in a suppressed state, they are capable of rapid growth following release. Most Tasmanian eucalypts produce lignotubers with the exception of *E. regnans*, *E. delegatensis* and *E. sieberi*. In *E. delegatensis* the seedlings are tolerant of shade and competition for moisture and suppressed seedlings may survive for 30-40 years by growing only very slowly (2-3 cm per year) (R. Ellis pers. comm.).

Photo 5.1. Eucalypt lignotuber. The woody swelling at the base of this seedling contains dormant buds, which enables the plant to produce new shoots following the loss of the original shoot as a result of fire, drought, browsing or harvesting damage.

Vegetative origin of advance growth

Regeneration from existing trees may occur through the production of coppice shoots after stems have been killed by fire or cut down during harvesting operations. These shoots may arise from buds within lignotubers or from epicormic buds. Epicormic buds arise from the original leaf axils along the young stem. As the stem expands these buds grow outwards, forming a strand of radial tissue which maintains dormant buds within the inner bark region of the stem and major branches. The formation of shoots from these buds is inhibited by hormones produced by the existing crown. The loss of crown due to fire or felling removes this inhibition and allows the development of epicormic shoots.

Minimisation of damage
Damage to retained growing stock must be minimised during logging or site preparation operations. Seedlings up to about one metre in height will generally recover from moderate physical damage, although in well stocked regeneration about 20% of the seedlings may be destroyed. Damage to older growing stock may result in serious defect. Stem breakage of young trees often leads to stem distortion and multi-stemming due to epicormic growth. Cambial damage of the stem or branches may result from bruising or dislodgement of bark which allows the entry of decay organisms.

Recent research has shown that even minor cambium damage may result in decay. The spread of decay from the wound may be held in check by natural barriers produced within the tree. However, these barriers appear to break down after about 15 years, allowing the rapid spread of decay throughout the stem (White and Kile 1991, Wardlaw 1996).

Photo 5.2. Butt scrape on a stringybark. Any damage that separates the bark and the cambium will lead to formation of a decay column within the tree.

New seedling regeneration
The establishment of new seedlings requires:
- receptive seedbed,
- adequate seed, and
- a suitable environment for establishment and growth.

5.2 Seedbed

Receptive seedbed is:
- exposed mineral soil, and
- favourable soil factors.

In nature, receptive seedbed is created by wildfire which removes the vegetation and litter layers and enhances early growth through the 'ashbed effect' (Pryor 1960), which appears stronger in wet forests than in dry forests (Lockett and Candy 1984, Neyland *et al.* 2009a).

In managed forests, exposed mineral soil seedbed can be created by one or a number of the following:
- planned burning of logging slash and litter to simulate natural processes,
- logging disturbance,
- scarification (cultivation) using machinery.

The range of different seedbed types produced in most operations is shown in Figure 5.2.

High intensity slash burns are prescribed for clearfelled forests with a dense understorey in order to ensure the removal of slash and organic layers, to expose maximum seedbed and to utilise the 'ashbed effect' (Pryor 1960). Much of the understorey will generally be felled or pushed down in the course of logging, although a separate operation, such as cull felling, scrub felling or machine clearing may be necessary to complete the process. Burns of high intensity cannot be conducted in areas where the retention of growing stock is required. For further information about high intensity burns see Forestry Tasmania (2005a).

Photo 5.3. A high intensity burn and the characteristic smoke column that develops. Note the way the strong in-draft created by the column draws the edges of the fire towards the centre of the burn.

Moderate intensity slash burns or ‘slow’ burns are prescribed for wet eucalypt forests coupes harvested to an aggregated retention (ARN) prescription. ‘Slow’ burning is prescribed in coupes with heavy fuels but where there are also retained aggregates of standing forest, where it is important to keep fire damage to the aggregates to a minimum, whilst still preparing adequate seedbed. For further information about burns in ARN coupes see the VR Manual or Chuter (2007).

Low intensity slash burns are prescribed for dry, open understorey forests where slash and litter levels are low, but where fire can be applied to reduce the slash fuels and to prepare receptive seedbed additional to that created by the harvesting disturbance. The fires can be lit under mild to warm weather conditions but the low fuel loads reduce the fire intensity. For further information about low intensity burns see Forestry Tasmania (2005b).

Top disposal and heap burns are prescribed for partially logged forests where burning is restricted to slash heaps resulting from logging or from mechanical heaping operations. The objective of top disposal burning is to restrict fire to discrete heaps for the purposes of creating a seedbed and to reduce the accumulation of fuels. Slash heaps should be burnt under mild conditions which minimise the risk of damage to sensitive growing stock or other values (such as vegetation retained for conservation or soil protection values). Top disposal and heap burns can be lit under the mildest conditions. For further information about low intensity burns see Forestry Tasmania (2005b).

Burning is usually undertaken in autumn on mild sunny days a few days after rain. Successful burning removes the majority of fuel while the soil is relatively dry (to maximise the ‘ashbed effect’), and prepares receptive seedbed for subsequent autumn sowing. In partially logged forests, burning can stimulate seedfall, thus synchronising the preparation of seedbed and natural seeding.

The implementation of all burns, and of high intensity burns in particular, requires careful planning to avoid the risk of either a poor quality burn (and unsuccessful regeneration) or an escape.

The success of a planned regeneration burn is judged by the proportions of well-burnt, lightly burnt and unburnt seedbed in the coupe following the burn. To assist such assessments, the different seedbed types observed following harvesting and burning are shown in Figure 5.2.

Figure 5.2. The different seedbed types observed following regeneration burning.

Unburnt and undisturbed

Burnt-to-litter and disturbed

Unburnt and disturbed

Burnt to mineral soil

Unburnt compacted

Burnt to mineral soil

Burnt-to-litter and undisturbed

Ashbed

Logging disturbance
The movement of logging machinery during snigging operations results in disturbance to the vegetation and litter layers and the exposure of mineral soil. Logging disturbance can create suitable conditions for the establishment and growth of seedlings on soils that are dry and friable. However, logging disturbance should normally be complemented by top disposal burning in order to reduce fire hazard and create additional seedbed.

Logging disturbance alone can provide adequate seedbed in partially logged open forests, particularly if the contractor is willing to deliberately extend machinery movements in order to expose more soil area. However, on many sites, logging disturbance may have an adverse effect on soils. The Forest Practices Code (Forest Practices Board 2000) and Forest Soil Conservation Manual (Brown and Laffan 1993) provide details for minimising damage to soils on susceptible sites.

Mechanical scarification

Photo 5.4. Scarification involves the clearing of vegetation and litter layers and light cultivation of the soil surface.

Scarification is generally carried out using specially designed tynes mounted on excavators. Care must be taken to avoid damage to soils particularly on steep or erodible sites (Brown and Laffan 1993). Further information on the use of scarification as a site preparation technique is contained in Technical Bulletin No. 7

Favourable soil factors are:

- friable (not compacted) soil,
- reduced grass competition.

Friable soil
The following two paragraphs are extracted from Florence (1996).

'A disturbed seedbed will normally provide better conditions for germination of eucalypt seed and subsequent emergence of seedlings than will an undisturbed soil surface. To begin with, the disturbed seedbed may protect seed from predators where the seed becomes covered by soil (Stoneman and Dell 1994). The disturbed soil may have greater capacity for water infiltration and aeration than the undisturbed soil, and permit greater contact between seed and wet soil particles (Kozlowski and Gunn 1972). This may be an important factor affecting germination of eucalypt seed (Bachelard 1985; Gibson and Bachelard 1987).

Small-scale variation in the physical soil condition – at a scale of tens of centimetres – markedly affected the germination of *E. delegatensis* seed and the establishment of seedlings (Battaglia and Reid 1993). Microsites affording protection (depressions and shaded sites) probably resulted in increased humidity, causing a marked increase in the number of germinants and rate of germination. Some covering with soil may also be important; for example, germination of *E. regnans* seeds was improved when covered with 6 mm of crumbly soil, but emergence was restricted where the soil cover was greater than this, or where the soil was compacted (Cremer 1965). Much of the seed that is buried in soil during logging is lost as a source of regeneration'.

Grass competition
Grass competition can significantly reduce the final stocking of eucalypt seedlings and impede growth rates, particularly in dry peppermint forests and high altitude *E. delegatensis* forests where there is a significant component of grass present pre-harvesting.

Experience with logging and regeneration trials in such forests (Keenan and Candy 1983; McCormick 1988) indicates that the grass sward present pre-harvesting may quickly increase in cover following the removal of the overstorey. Grass does not readily re-invade where there has been a high intensity burn and ash bed is produced. However, areas of low intensity burn and ground disturbance are quickly invaded by grass. Eucalypt germination and establishment is good on these sites, but survival is sometimes poor and growth rates are slower than those achieved on ashbed. Grass prevents regeneration establishment by physical occupation of the seedbed and by competition for soil, water and nutrients (Ellis 1985a; Ellis *et al.* 1985).

On such sites it is essential that a partial canopy of mature eucalypts be maintained at all times. Seed tree (in peppermint forests) and shelterwood (in *E. delegatensis* forests) systems are appropriate.

Photo 5.5. An E. delegatensis *seedling in growth check following clearfelling and subsequent regeneration failure at a high altitude site. Grass invasion, intense frosts and heavy browsing have all contributed to the regeneration failure.*

5.3 Seed

Seedfall comes from:
- natural seedfall from retained trees (both in and around the harvest area) and the crowns of felled trees
- artificial sowing

Natural seedfall
Eucalypt seed is generally produced annually and is progressively shed from the crown over a two to three year period. Once shed, the seed does not remain viable in the litter layers or soil for longer than 12-18 months (Cremer *et al.* 1978). Heavier than average years of seed production may occur every five to seven years. However in most years the crowns will contain a sequence of flower buds, immature capsules and mature capsules which ensure a continuing source of seed. The seeding cycle commences with the initial formation of flowering buds. Flowering normally occurs about two years after initial bud formation. Mature capsules generally develop about one year after flowering. Seedfall is triggered by the drying out and opening of the capsule valves as a result of the formation of an abscission layer at the base of the stalk of the capsule. In *E. regnans*, the capsules release most of their seed in the autumn of the year after the capsules mature (i.e. approximately two years after flowering). Diminishing quantities may be shed over several more years. Heavy seed shed occurs as a result of crown scorch or death of branches following fire or drought. For further details on seed and sowing see Technical Bulletin No. 1.

Seedling establishment includes the processes of seed germination and early growth.

Germination occurs over a broad range of conditions. General requirements are for warm, moist conditions. The optimum temperature range for the germination of most Tasmanian eucalypts is between 15 to 25°C (see for example Battaglia 1997). Eucalypt seed does not require high light intensities for germination and conditions suitable for germination occur commonly in both the undisturbed and disturbed forest; germinants are often observed on moist mossy logs and undisturbed litter. However, even under conditions favourable for germination, only a minority of seeds survive to germinate. Large losses of seed occur due to predation by insects, especially ants (see Stoneman 1994 for a review).
There is no evidence that eucalypt seed germination is stimulated by fire or smoke although this requirements has been demonstrated in a range of understorey species (Dixon *et al.* 1995). A number of high altitude Tasmanian eucalypts exhibit some degree of seed dormancy i.e. a proportion of seeds in a seedlot will germinate very slowly or not at all unless they have been stratified (exposed to cold, moist conditions for more than about four weeks). On cold sites, dormancy ensures that germination of some seed will be delayed until spring, when conditions for seedling establishment may be more suitable than they are during other seasons.

Eucalypt seed is very small and contains no endosperm or reserves to sustain early growth (Boland *et al.* 1980). Newly germinated eucalypt seedlings therefore require immediate access to sufficient moisture, nutrients and light so that photosynthesis and growth may proceed. Therefore, whilst germination may proceed amongst dense plants and litter, subsequent growth cannot. Removal of vegetation and litter barriers is essential for the establishment of eucalypt seedlings.

Successful establishment of seedlings occurs when the plant's root system has developed to the extent that it is able to maintain an adequate supply of moisture and nutrients for continued growth. Further survival and growth depends upon the plant's ability to withstand damaging agencies such as frost, browsing, adverse soil factors and fire.

Artificial sowing
Aerial sowing is the preferred technique where there are large areas of suitable seedbed. Current aerial seeding equipment allows sowing mixes and rates to be easily varied. Helicopters can sow individual patches down to about 0.25 ha in area. Aerial sowing is the preferred technique for the majority of operations as it is flexible, efficient and effective.

Hand sowing is necessary where broadcast sowing would waste seed, such as:
- small and remote patches, or selective re-sowing of areas with patchy seedbed,
- occasions when lack of aircraft or unsuitable weather prevent aerial sowing.

For further detail on sowing see Technical Bulletin No. 1, Eucalypt seed and sowing.

Eucalypt populations differ genetically (Potts *et al.* 2004; Wilkinson 2008). Consequently, current sowing guidelines are designed to ensure that seed collected locally from at least a minimum number of trees of all the species present on a site pre-harvest is re-sown on the site post-harvest, in order to ensure that there is genetic diversity in the sown seed.

5.4 Seedling protection and early growth

A ***suitable environment*** for establishment and growth requires:
- sufficient moisture, nutrients and light,
- protection from damage by animals, climatic extremes and fire.

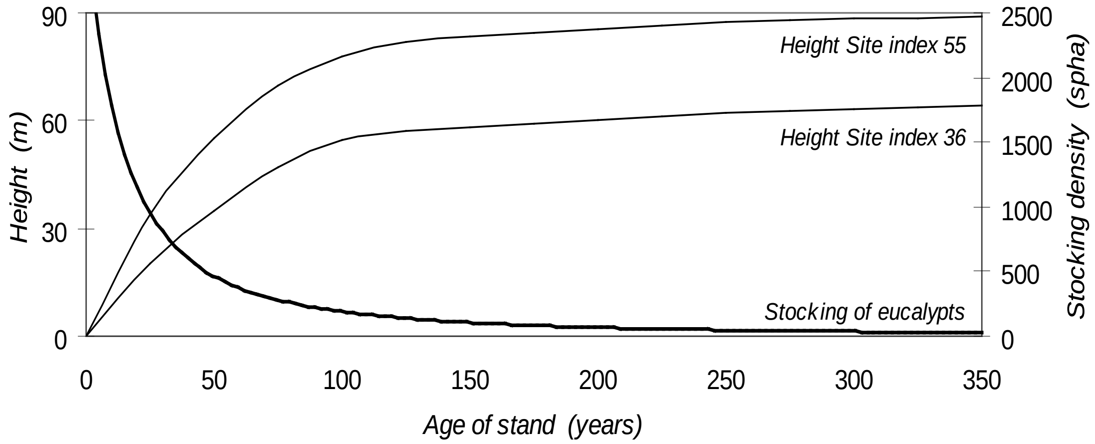
Moisture, nutrients and light
High light conditions (at least 20-30% of full sunlight) are essential for growth of shade intolerant species such as the eucalypts. An undisturbed eucalypt overstorey normally allows about 30-40% of sunlight to penetrate, however the dense understorey of wet forests reduces the final light intensity at ground level to 4-8% (Ashton and Willis 1982; Alcorn 2002). Removal of at least part of the eucalypt canopy and much of the understorey is therefore essential to allow sufficient light to reach the forest floor to allow seedlings to establish and grow.

Protection
Damage from browsing by native mammals is the predominant cause of understocking and growth losses in newly regenerated areas. Local knowledge of browsing pressures, combined with regular inspections is essential if early losses are to be avoided. Seedlings browsed at the cotyledonary stage do not recover and the loss may not be detected except by careful and regular inspection of the indicator plots. Continued growth losses due to browsing can be monitored along transects in regeneration areas. For further detail on monitoring and protecting eucalypt seedlings see Technical Bulletin No. 12, Monitoring and protecting eucalypt regeneration.

6. Stocking and Growth

The stocking of seedlings following natural regeneration is highly variable but can be as high as 2.5 million seedlings per hectare (Ashton 1976). Silvicultural sowings normally produce stocking levels of 2000 to 12 000 seedlings per hectare. Early competition is intense in well stocked stands, particularly during the first ten years when the root systems of eucalypts compete directly with other species such as *Pomaderris* (Ashton 1976). On highly productive sites the initial height growth of species such as *E. regnans* is very rapid. *Eucalyptus regnans* may reach about half its final height by age 25 to 35 years (Jackson 1968; Ashton 1976). Stocking levels fall rapidly to about 400 to 500 stems per hectare by age 40 years (Figure 6.1). The maximum height of about 90 m is approached by about age 120 years. Beyond this age there is little increase in height, but diameter growth and therefore volume production continues, up to the age of about 300 years (Jackson 1968, Ashton 1976). During the overmature stage (300 years+) the crown suffers increasing dieback and the total height reduces as the crown is progressively replaced by epicormic branches from the upper portion of the living stem.

Figure 6.1. Stocking and height growth of ash group eucalypts over time. (from Gilbert 1959 and Jackson 1968).

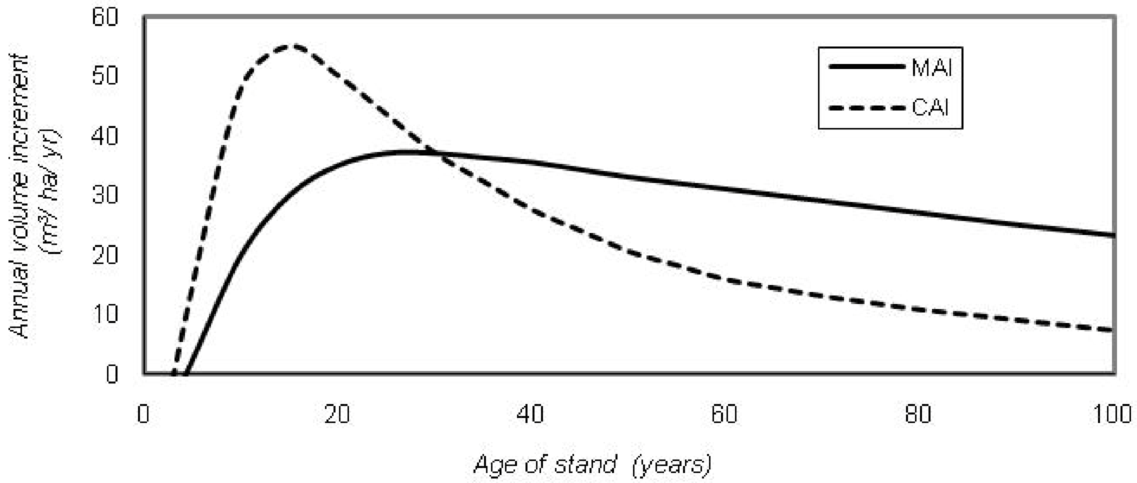


Site index (SI) is used as a relative measure of the productivity of a site. For native eucalypt forests it is defined as the mean dominant height (MDH) of a stand at age 50 years. Mean dominant height (m) is the mean of the heights of the dominant tree on each 1/30th of a hectare (Forestry Commission 1964). Mean dominant height is used to determine site index because it is relatively insensitive to stocking (Adrian Goodwin pers comm).

In Tasmania, forest height and canopy density information is derived from aerial photographs and recorded on forest photo-interpretation (PI) maps (as a GIS coverage) (see section 11 for further details). These maps may also record other details such as age and origin of the stand and the height class of the previous forest. The PI types are summarised in Table 11.1. It should be noted that PI type does not equate to site index since no allowance is made for the age of the forest when PI type is determined.

Annual volume production increases rapidly for the first twenty years of the life of a stand (Figure 6.2). Once the site is fully occupied, total volume increment slows due to the increasing senescence and mortality of suppressed trees. During this period, increment on the dominant trees in the stand is maintained even though total stand increment may slowly decline.

Figure 6.2. Change with age in mean annual increment (MAI) and current annual increment (CAI) for a moderately productive stand of *E. obliqua* (from West and Mattay 1993).



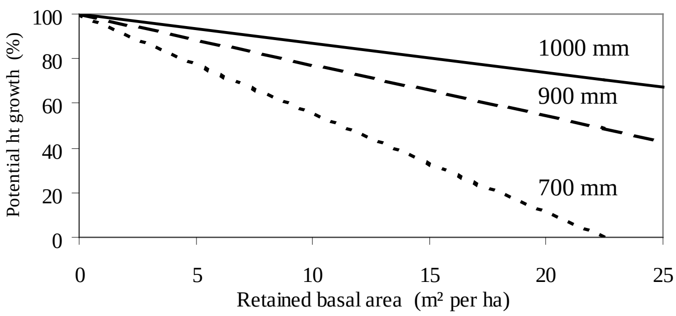
7. Effect of Retained Trees on the Growth of Regeneration – Shelterwoods, Frosts and Grass Competition

Shelterwood and seed tree systems prescribe retention of mature trees on site, both as a seed source and as shelter. It is clear from past regeneration failures that, particularly on frost-prone or grassy sites, retention of a partial canopy is essential until such time as the regeneration is well established, i.e. the regeneration is at least 1.5 m tall, and no longer subject to killing frosts at ground level. The need to retain a partial canopy of mature trees needs to be balanced against the suppressive effect that those retained trees have on the growth rates of the regeneration.

Environmental amelioration: Frost damage is considered a major factor in high altitude growth check (Webb *et al.* 1983; Bowman 1984; Nunez and Bowman 1986). The retention of some degree of canopy, either by the deliberate use of shelterwoods or by small group selection, reduces the intensity and incidence of radiative frost, relative to large clearfells. The forest canopy reduces frosting by reradiating heat at night and by reducing longwave radiation loss from the ground. In a shelterwood stand with approximately 50% canopy cover, Nunez and Sander (1981) found a 1.4°C sheltering effect by the shelterwood and, in the absence of cold air drainage, this effect would be higher. The full importance of this degree of sheltering is impossible to determine. However, small changes in environmental conditions at the environmental extremes of a plant's distribution can be critical to survival and growth. Whilst minimum temperatures in winter may be critically low in both shelterwood areas and clearfell areas, it is the ability of shelterwoods to protect young germinants from unseasonal frosts of mild intensity that is more important. Some estimate of the relative importance of frost can be gained from the close correlation of forest-grassland boundaries and small differences in relief which promote or inhibit cold air drainage.

Regeneration growth retardation: Retained trees continue to utilise the site, often at the expense of young regeneration. The suppression of regrowth by retained trees has been demonstrated for a number of eucalypt species (see Kellas 1987). Retained overstoreys at levels in excess of 12 m²/ha basal area have a pronounced suppressive effect on the growth of regeneration. Bowman and Kirkpatrick (1986) concluded that the principal cause of the growth difference shown above is competition for moisture by mature trees (Figure 7.1). They found that on a test site at Waddamana soil moisture levels were below that necessary for growth for 12 weeks of summer in a shelterwood treatment (50% basal area retention) compared with 4 weeks in a matched clearfell treatment. On sites where summer rainfall is higher it is likely that the suppressive effect of shelterwoods may be of lesser magnitude. Nevertheless, experience in other forest types (Dunlap and Helms 1983; Wellington 1984; Flint and Childs 1987) supports the general principle of soil moisture competition from retained trees being important in the suppression of regeneration. In a trial across four different sites ranging from high to low rainfall areas, Battaglia and Wilson (1990) showed that regeneration height increment at the wettest site was least affected by retained basal area, and conversely that at the driest site regeneration height increment was most affected. The relationship between the site rainfall and the rate of reduction in height increment was found to be very strong, further supporting the hypothesis that moisture is the limiting factor to growth in many instances.

Figure 7.1. The effect of retained basal area on the height growth of seedlings on high elevation sites, for various rainfalls.



Severe suppression of regeneration can be expected where the basal area of retained trees exceeds 12 m^2 per hectare on dry sites (<1000 mm per year) or 16 m^2 per hectare on wet sites (> 1000 mm per year) (Battaglia and Wilson 1990). On dry sites, the zone of suppression may occur to a distance of up to six times the crown radius of the retained tree (Incoll 1979). Rotheram (1983) estimated that in Karri forests each 5% crown cover of retained trees would reduce the growth of regeneration by 10%.

Grass competition: Grass re-invasion onto disturbed seedbed can be a major impediment to eucalypt establishment. Disturbance, or low intensity fire, which does not destroy rhizomes and root stocks may actively encourage the expansion of vegetative growth of grass. Grass prevents regeneration by physical occupation of the seedbed and by competition for soil, water and nutrients (Ellis *et al.* 1985, Webb *et al.* 1983). By restricting the flow of heat from the ground to the atmosphere (by behaving like a blanket) seedlings on grassy seedbed may be subjected to frosts of higher intensity than seedlings on bare mineral soil (Ellis *et al.* 1985, Webb *et al.* 1983).

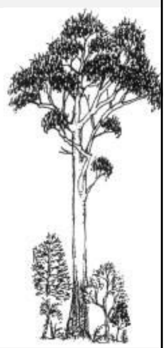
Retention of trees and regeneration stocking

Retained trees contribute to increased stocking by reducing grass invasion of exposed seedbed, by providing shelter from climatic extremes and by providing seed. Trials in *E .delegatensis* forests have demonstrated higher stockings and seedling numbers in shelterwood areas than in clearfell areas, with regeneration recruitment occurring continuously over the first few seasons whilst seedbed receptivity remains (Battaglia and Wilson 1990). Increased recruitment was observed up to retained basal areas of 12 m^2/ha, but at higher levels of retained basal areas (16 m^2/ha) mortality of regeneration increased during the summer dry period (Battaglia and Wilson 1990). Thus the level of retained basal area in a shelterwood operation is quite critical – below 12 m^2/ha and seedling recruitment is reduced, above 16 m^2/ha summer mortality and suppression through competition for moisture is increased. As competition for moisture will increase further as the regeneration increases in size, removal of the shelterwood as soon as practicable after the regeneration is sufficiently established is critical to good growth.

8. Growth Stages of the Eucalypts

The six common growth stages described by Jacobs (1955) are often viewed for management purposes as falling into one of three broader classes: regrowth, mature and overmature.

Figure 8.1. The growth stages of the Tasmanian ash group eucalypts.

growth stage	*height (m)*	*approx. age (years)*	*description*	
Regrowth				
Seedling	< 3	< 4	Fast growing eucalypts produce a seedling with a single stem. Lignotuberous seedlings may initially have a multi-stemmed form with no erect main stem.	
Sapling	3–15	4–15	Conical crowns with the dominants above the general canopy. Branches are often senescent on the lower stem and a clear bole is beginning to form.	
Pole	15–35	15–110	Strongly developed main stem with small conical crowns occupying about one-third of the stem height. Crowns of adjoining trees do not overlap. Larger branches may become more persistent.	
Mature				
Mature	30–100	110–300	Development of large trunks and large primary branches in an open flat-topped crown.	
Overmature				
Overmature	20–90	300–400	Trunks are very large and often buttressed. Most trees have dying and broken tops and the crown may consist entirely of epicormic branches.	
Senescent	20–70	400–500	Trunks are very large, often fire damaged and contain significant levels of decay. Trees have dead tops and small epicormic crowns.	

9. Forest Product Classes

For up-to-date and more detailed specifications always refer to the Log Specification Handbook.

The quality of timber contained in trees varies tremendously, depending on age, branching attributes, size, shape, internal colour and level of decay. The highest quality logs are used for sliced veneer. The poorest grade may be suitable only for fuelwood. The grading system used to classify logs is summarised below.

Veneer
Ash group preferred, with pale and even colour, minimum length 2.9 m, spiral < 1:35, no sweep.

	quality
VQ1	First grade > 50 cm small end diameter under bark
VQ2	Second grade > 60 cm small end diameter under bark, at least 50% of the log to be VQ1

VQ = veneer quality

Sawlogs
Minimum small end diameter is 30 cm.

	type	*defect*	*length*	*spiral*	*sweep*
Cat 1	OG	< ¼	> 3.6 m	< 1:8	< 1:7
Cat 3	RG	< ¼	> 3.6 m	< 1:8	< 1:7
Cat 2	OG	< ½	> 2.4 m	< 1:8	< 1:7
Cat 8	OG or RG	< ¾	> 2.4 m	< 1:6	na

Pulpwood
Minimum 2.4 m long, free of charcoal and bark, logs cut square, branches trimmed flush, logs able to pass through a 2 m long x 89 cm diameter pipe.

	diameter under bark
RG	> 10 cm
OG	> 15 cm

Peelers
Suitable logs range between 15 and 100 cm small end diameter (SED). No rot is allowed in 15 to 30 cm SED logs. Over 30 cm SED 5 cm centre defect is allowable. Sound scars, bumps, knots, sweep (up to SED divided by 3), out of round and minor cracks are all acceptable.

Eucalypt utility peeler logs shall not contain lengths that would otherwise meet the specifications for veneer log, Category 1, 2, 3 or 8 sawlogs or premium grade peelers.

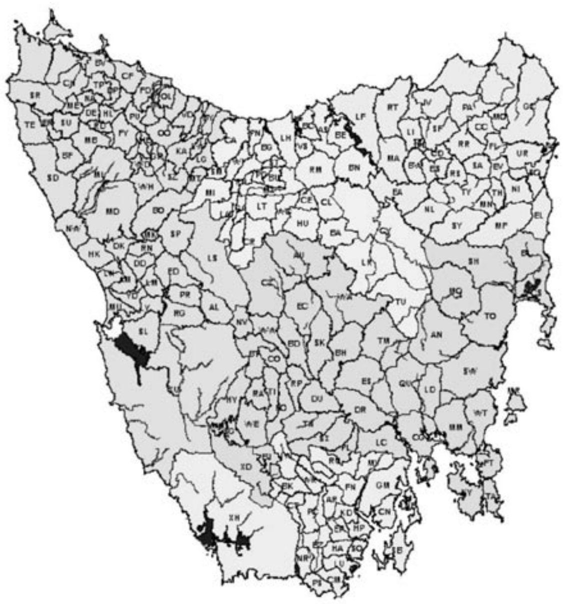
10. Spatial Planning Framework - Coupes

Foresters need a consistent way to name each piece of forest. However, forests do not grow in discrete permanent units; they change continuously across the landscape and over time, sometimes gradually, sometimes abruptly. Equally diverse are the different scientific and managerial perspectives that could guide the subdivision. No single naming/addressing system is adequate for all purposes. Three inter-related frameworks are used by Forestry Tasmania:

10.1 Administrative addressing units

These comprise a three-tiered framework that subdivide the whole of State forest into discrete units, each defined by recognisable boundary features, and permanently identified by unique names and numbers. Their purpose is administrative only, providing a common long-term basis for reference to specific areas. They provide a label for each locality, irrespective of forest(s) that currently occupy it.

Figure 10.1. Forest Districts and blocks in Tasmania.

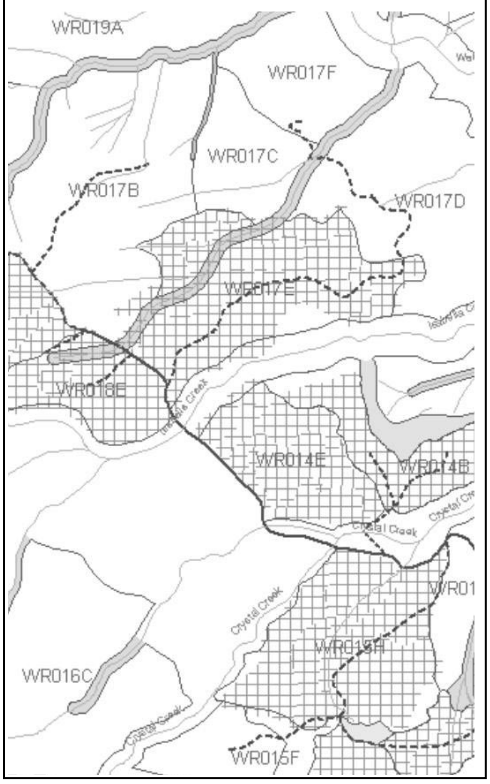


Districts are major regions that are each administered by a single business management group. Each District comprises several dozen Blocks.

Blocks are between 3,500 and 100,000 hectares in size (averaging 30,000 ha), and are typically bounded by major rivers, roads, or ridge-lines. Each Block has a unique name, abbreviated to a two-letter code, (e.g. "Warra" = WR). (see the table on page 39.)

Compartments are smaller areas of between 100 and 500 hectares in size, and typically bounded by roads, drainage-lines, and other visible topographic features. Each Compartment is identified by a three-digit number, unique within its Block, (e.g. WR017).

Figure 10.2. Compartment structure.



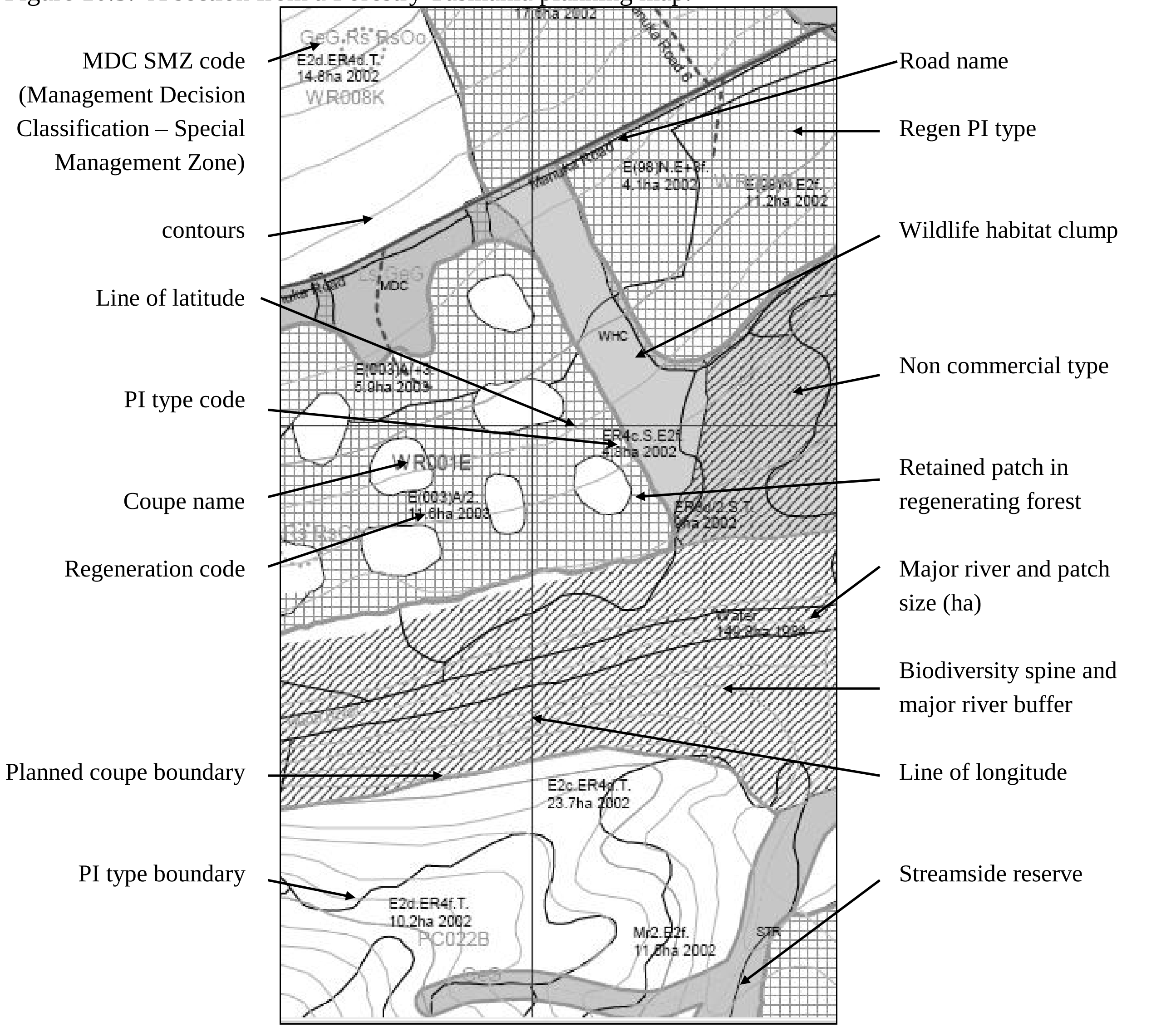
10.2 Operational management units

These describe smaller areas of forest (generally less than 100 hectares) for the purpose of operational treatment. They are temporary and changeable in nature, referring to the area/forest that will be (or was) harvested/planted/pruned/etc as one unit. However, the name of the treatment unit is often used loosely to refer to the resultant stand throughout its subsequent life.

Coupes are operational treatment units. The term is particularly used to refer to a harvest/re-establishment area. For naming purposes, an upper-case letter is added to the number of the nearest (or most significant) Compartment, (e.g. WR017B).

Sections are treatment sub-units or parts of Coupes, that are required for temporary operational purposes (e.g. to differentiate between areas with separate contractors, timing, prescriptions, etc). For naming purposes, a single-digit number is added after the Coupe code (e.g. WR017B2).

Figure 10.3. A section from a Forestry Tasmania planning map.



10.3 Forest Operations Database (FOD) identifiers

These define forest stands (Assets) and the treatments (Operations) that are applied to them for the purpose of consistent reference in FTs asset management system, FOD. For clarity, each has a unique numerical ID, a boundary, and start/end dates, so that they are unambiguously labelled and defined in space and time. However, the looser concepts of Coupe and Section are often used to provide convenient names for the areas affected.

FOD Assets are areas of forest that are each intended to be managed as a single stand (i.e. more or less consistent in age/species/condition/regime/etc). They are usually defined for the life of that stand/rotation, and are generally referred to by the Coupe name of the operation(s) that established them (e.g. WR017B). However, their authoritative identifier is a 5-6 digit number, the Asset ID.

FOD Operations are individual management activities or treatment events that occur within a forest. Major Operations that involve whole stands/Assets (e.g. burning, planting, harvesting) are usually strongly associated with Coupe names (e.g. WR017B), but this labelling is less exact and less useful for minor Operations that affect only part of a stand/Asset (e.g. fertilising, seed collection). Accordingly, their unique identifier is a 6 digit number, the Operation ID.

10.4 Forestry Tasmania block codes. names, Districts and areas.

Code	Block Name	District	Area (ha)
AL	ALMA	MU	25,546
AM	AMBER	MU	15,671
AN	ANDOVER	DE	82,880
AR	ARVE	HU	15,589
AS	ASBESTOS	ME	28,366
AU	AUGUSTA	DE	71,068
BG	BADGER HILLS	ME	17,553
BF	BALFOUR	MU	25,402
BB	BARNBACK	HU	11,908
BW	BARROW	BA	18,692
BE	BEACONSFIELD	ME	19,067
BS	BEN NEVIS	BA	17,428
BU	BEULAH	ME	9,966
BI	BICHENO	DE	45,005
BZ	BISDEE	HU	24,877
BV	BLACK RIVER	MU	19,901
BA	BLACKWOOD CK	ME	28,551
BK	BLAKES	HU	18,867
BH	BLUE HILL	DE	50,345
BY	BLYTHE	MU	13,964
BJ	BOWES	DE	14,661
BD	BRADYS	DE	36,536
BC	BRANCHS CK	ME	15,213
BN	BRIDGENORTH	ME	39,694
BO	BULGOBAC	MU	49,408
BT	BUTLERS GORGE	DE	31,430
CG	CAMBRIDGE	DE	51,106
CD	CAMDEN	BA	9,777
CC	CASCADE	BA	17,948
CA	CASTRA	ME	38,303
CM	CATAMARAN	HU	16,024
CN	CHANNEL	HU	18,832
CE	CHESHUNT	ME	10,630
CH	CHRISTMAS HILLS	MU	28,323
CZ	CLARENCE	DE	81,900
CL	CLUAN	ME	24,772
CR	CLUMNER	ME	38,210
CS	COLES BAY	DE	44,715
CO	COUNSEL	DE	15,576
CT	CRACROFT	HU	16,557
CF	CRAYFISH	MU	21,663
CY	CRESSY	ME	150,882
DE	DEMPSTERS	MU	10,157
DN	DENISON	HU	6,333
DL	DIAL	MU	13,578
DP	DIP	MU	9,539
DR	DROMEDARY	DE	46,872
DD	DUNDAS	MU	15,996

Code	Block Name	District	Area (ha)
DK	DUNKLEY	MU	15,674
DU	DUNROBIN	DE	31,097
EC	ECHO	DE	43,232
ES	ELDERSLIE	DE	63,162
ED	ELDON	MU	32,039
EL	ELEPHANT	BA	28,409
EM	EMU	MU	7,939
EP	ESPERANCE	HU	13,946
EA	EVANDALE	BA	47,831
EV	EVERCREECH	BA	10,787
FO	FLORENTINE	DE	26,671
FD	FLOWERDALE	MU	22,186
FY	FOLLY	MU	23,816
FL	FOREST LODGE	BA	13,981
FT	FORESTIER	DE	18,892
FR	FRANKLAND	MU	11,039
FN	FRANKLIN	HU	19,998
GA	GADDS	ME	7,606
GL	GLADSTONE	BA	66,941
GR	GORGE	MU	11,236
GC	GOULDS COUNTRY	BA	100,983
GM	GREY MOUNTAIN	HU	48,672
HA	HASTINGS	HU	12,598
HK	HEEMSKIRK	MU	23,913
HE	HELLYER	MU	5,902
HL	HOLDER	MU	9,546
HY	HOLLEY	DE	34,658
HP	HOPETOUN	HU	11,921
HU	HUNTSMAN	ME	30,538
IR	INGLIS	MU	18,068
JV	JETSONVILLE	BA	39,020
KA	KARA	MU	21,188
KE	KENTISH	ME	11,618
KD	KERMANDIE	HU	11,327
KY	KOONYA	DE	32,397
LC	LACHLAN	DE	38,211
LM	LAKE MARGARET	MU	15,687
LR	LAKE RIVER	ME	70,075
LS	LAKE ST.CLAIR	MU	125,644
LF	LEFROY	BA	68,014
LE	LENNA	BA	196,333
LD	LEVENDALE	DE	32,568
LI	LISLE	BA	17,211
LN	LITTLE HENTY	MU	16,288
LT	LOATTA	ME	24,594
LH	LONG HILL	ME	33,496
LG	LOONGANA	MU	16,026
LA	LORINNA	ME	23,962

Code	Block Name	District	Area (ha)
LW	LOWANA	MU	6,810
LU	LUNE	HU	15,025
LY	LYNCHFORD	MU	18,196
MZ	MAGGS	ME	12,012
MU	MANUKA	MU	15,311
MR	MARIA	DE	10,228
ME	MERYANNA	MU	9,524
MX	MAGOG	ME	29,637
MN	MANGANA	BA	11,343
MI	MOINA	ME	29,770
MO	MOORINA	BA	12,215
MV	MOUNTAIN RIVER	HU	22,665
MA	MT ARTHUR	BA	37,300
MB	MT BERTHA	MU	29,547
MK	MT BLACK	MU	5,297
ML	MT CLEVELAND	MU	71,038
MC	MT CONNECTION	DE	68,300
MF	MT FOSTER	BA	56,461
MD	MT MEREDITH	MU	83,461
MM	MT MORRISON	DE	52,214
MT	MT TOR	MU	10,734
NA	NABAGEENA	MU	9,392
NV	NAVARRE	DE	16,926
NR	NEW RIVER	HU	15,080
NW	NEWDEGATE	MU	25,925
NH	NEWHAVEN	MU	9,175
NI	NICHOLAS	BA	23,572
NL	NILE	BA	42,843
NB	NORTH BRUNY	HU	10,512
OL	OLDINA	MU	9,517
OO	OONAH	MU	23,712
PN	PALOONA	ME	13,592
PD	PARADISE	ME	6,223
PW	PARRAWE	MU	8,571
PA	PAYANNA	BA	31,477
PG	PEGARAH	MU	109,654
PC	PICTON	HU	28,133
PS	PINDERS	HU	12,484
PL	PLENTY	DE	15,199
PR	PRINCESS	MU	20,020
PU	PRUANA	MU	12,206
QU	QUOIN	DE	53,772
RG	RAGLAN	MU	31,908
RD	RAPID	MU	7,212
RA	RASSELAS	DE	17,795
RE	REDPA	MU	62,399
RM	REEDY MARSH	ME	37,653
RP	REPULSE	DE	19,401
RT	RETREAT	BA	49,076
RN	RING	MU	15,954
RR	RINGAROOMA	BA	28,382

Code	Block Name	District	Area (ha)
RS	ROSES TIER	BA	15,922
RH	ROUND HILL	ME	6,474
RU	RUSSELL	HU	25,850
SA	SADDLEBACK	BA	17,069
SR	SALMON RIVER	MU	39,322
SD	SANDY CAPE	MU	69,643
SC	SCAMANDER	BA	26,886
SI	SIDELING	BA	3,504
SM	SMITHS PLAINS	ME	7,583
SH	SNOW HILL	DE	89,618
SP	SOPHIA	MU	34,385
SL	SORELL	MU	34,832
SB	SOUTH BRUNY	HU	24,933
SO	SOUTHPORT	HU	8,939
SF	SPRINGFIELD	BA	31,901
ST	STOODLEY	ME	6,100
SY	STORY	BA	44,515
SG	STRATHGORDON	DE	15,418
SK	STRICKLAND	DE	39,971
SX	STYX	DE	37,952
SU	SUMAC	MU	18,090
SZ	SURREY HILLS	MU	22,129
SW	SWANPORT	DE	93,532
TM	TABLE MOUNTAIN	DE	60,392
TA	TARANNA	DE	14,780
TE	TEMMA	MU	31,393
TI	TIGER	DE	21,275
TP	TIPUNAH	MU	14,895
TG	TOGARI	MU	39,296
TW	TOMAHAWK	BA	47,019
TO	TOOMS	DE	75,872
TH	TOWER HILL	BA	12,354
TU	TUNBRIDGE	ME	64,067
TN	TYENNA	DE	41,462
TY	TYNE	BA	33,047
UW	UPPER WELD	HU	24,453
UR	URANA	BA	28,127
VD	V.D.L.	MU	17,541
VS	VIRGINSTOW	ME	10,828
WA	WADDAMANA	DE	95,147
WD	WANDLE	MU	11,135
WH	WARATAH	MU	23,142
WR	WARRA	HU	12,146
WE	WEDGE	DE	36,706
WW	WENTWORTH	DE	25,086
WC	WESTERN CREEK	ME	18,480
WT	WIELANGTA	DE	37,731
WI	WILMOT	ME	14,183
YD	YOLANDE	MU	15,233
YL	YOLLA	MU	13,204

11. Forest-type Mapping by Photo-Interpretation

From the earliest days of the Tasmanian Forestry Department in the 1920s, detailed forest mapping was seen as an important priority, motivated by three principal objectives:

- The Forestry Act 1920 required the 'classification of the forest lands of the State…for the purpose of determining which…are suitable to be permanently dedicated as State forests or…as timber reserves'.
- The application of the principle of sustained yield to regulate the hitherto uncontrolled timber industry required a comprehensive, reliable and ongoing inventory of the forest resource.
- Forest roading, harvest planning and operational management required the ready availability of topographic and forest-type maps.

The first attempts to document the nature and extent of the forests were by exploratory sketch mapping. From the 1920s, systematic parallel stripline surveys were undertaken. Aerial photography was initiated by the Forestry Department in 1930, but the photographs were poor and yielded only limited information. World War II accelerated the development of equipment and techniques for the interpretation of aerial photographs. In 1946, a Photo-Interpretation section was formed, the first of its type in an Australian forestry agency. Using military photogrammetric methods and extensive local field research, the section made dramatic progress. By the end of 1946, different forest types and growth stages could be identified and, within two years, eucalypt stands could be subdivided into height and crown-density classes.

The earliest priority was for information about the resource; total heights and stand densities were readily measurable and significantly related to timber volumes.

The four original height classes were consistent with National Forest Inventory standards for that era (E1 > 180'; E2, 135 – 180'; E3, 90 – 135' and E4, < 90'). The tallest original class proved inadequate to describe the grandeur of trees which reached 300 feet, requiring the institution of the E1* class for heights above 250 feet. More significantly, the original E3 class (90–135 feet) was found to encompass unacceptably wide variation in sawlog volumes and to span the critical ecological division between dry and wet sclerophyll forest, which roughly coincided with a total height of 110 feet. The E-3 and E+3 classes encapsulate this distinction.

During the 1970s, attention turned to the assessment of cool temperate rainforest. It was originally broadly identified as myrtle forest and coded as MM. From 1952, typing had distinguished myrtle from other tall species and scrub, and height classes were introduced in 1964. Extensive trials found the only significant differences were between rainforest on fertile and poor sites; thus the codes M+ and M- were adopted from 1986 to represent rainforest communities, eclipsing most of the previous stand detail, though two height classes of myrtle regrowth were retained.

Colour photography replaced black and white prints from the late 1970s. Dependence on Forestry Department triangulation surveys to provide geodetic control diminished progressively and since 1980 the majority of Tasmania has been covered by the *Tasmap* 1:25,000 topographic series. Rectification and transfer of the distorted photographic line-work onto cartographically consistent maps was initially based on radial-line plotting, at first hand-drawn and then using slotted templates. In 1993 the process was automated using geographic information system (GIS) software and digital map data. Complete statewide PI-type mapping coverage was achieved in 1996.

11.1 Current typing procedures

The production of forest-type maps is today based around five principal activities.

1. Aerial photography

Forests are photographed from fixed-wing aircraft along parallel east–west flight lines around midday during summer months. Large format cameras shoot vertical photographs that overlap by 60% along the flight line and by 30% with adjacent lines. A flying height of 6800 m and a camera focal length of 305 mm results in 23 cm x 23 cm colour prints at a scale of about 1:20,000.

2. Photo-interpretation

Using a stereoscope to view overlapping pairs of photographs, interpreters divide the vegetation into patches which appear to be visually homogeneous and boundaries are drawn where the structure changes significantly, down to a minimum patch size of 3 ha. Each patch is scrutinised, described in terms of detailed stand attributes, then coded with a PI-type. Boundaries and PI-type codes are inked directly onto one photograph of each stereoscopic pair (Figure 11.1).

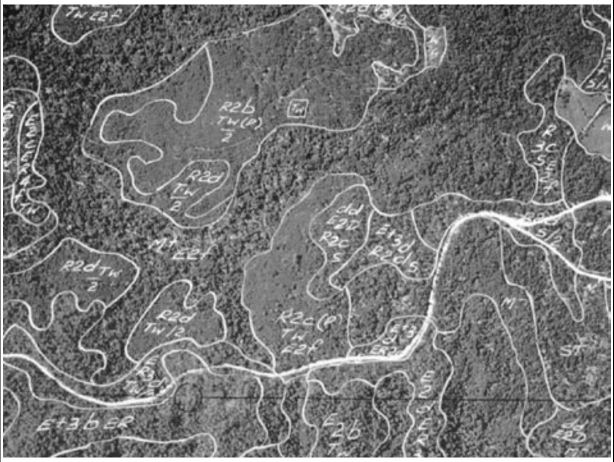


Figure 11.1. Interpreted aerial photograph.

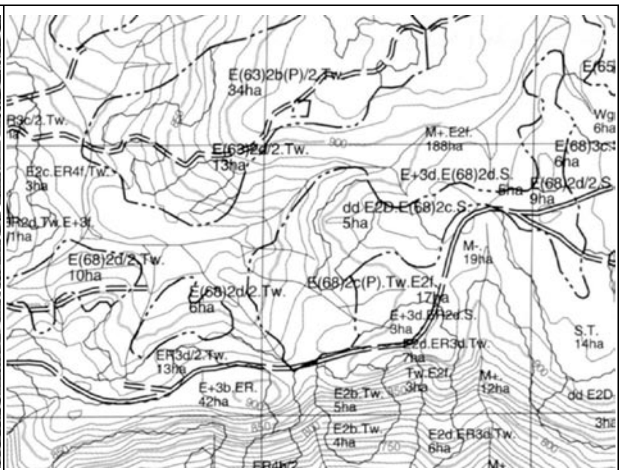


Figure 11.2. Native forest series map of the same area.

3. Digitisation and rectification

The forest patch boundaries are captured digitally onto Forestry Tasmania’s ARC/INFO GIS.

4. Map production

The GIS can be queried, overlaid with other thematic spatial information, or printed as a Native Forest Series map (Figure 11.2) which shows PI-types printed against land tenure and topographic information derived from *Tasmap* 1:25 000 base-mapping. A wavy line is used as the standard map symbol for PI-type patch boundaries, reflecting both its relative spatial accuracy and its subjectively interpreted nature.

5. Updating

PI-typing provides a static view of a dynamic natural resource, and forests are currently re-mapped on a rolling cycle averaging about 20 years. This covers changes in growing forests and the impact of wildfires and other changes. PI-type information is also updated at least annually for logging, roading, regeneration and plantation establishment. The boundaries of these changes are captured using spot aerial photography or Global Positioning System (GPS) receivers.

11.2 PI-type codes

A PI-type code is composed of a series of stand elements, each delimited with a full stop, and each representing a single species-group/age-class component of the stand being described. The order in which the elements are listed reflects their relative significance (i.e. the element which is most abundant or likely to determine the current management of the stand is listed first).

PI-types may be preceded by a condition-class code, indicating that the stand is dead, severely fire-damaged, over-mature, thinned, or cut-over in past selective logging.

Eucalypts are subdivided according to growth stage, each with stand height and percentage crown cover estimates where possible. Myrtle-dominated rainforest is separated by growth stage and crown size, with height class recorded only for regrowth stands.

Other native forest species are generally grouped as *other species* (if taller than 15 m) or *scrub*. However, locally important species (e.g. wattle) are coded as separate elements.

Whenever a forest patch does not contain a mature eucalypt element, evidence of the height of any previous mature eucalypts on the site is recorded as an indication of the growth potential of current and future eucalypt regrowth stands. The height-potential class may be measured from isolated mature trees, dead stags or fallen trees. In the case of stands regenerated after clearfelling, height-potential boundaries are transferred from older maps or from photographs of the original forest.

Table 11.1. PI type codes.

CONDITION CLASSES

co cut-over	fd severely fire-damaged	th thinned	dd dead	om over-mature

MATURE EUCALYPT

Height classes

E1* average height > 76 m	E+3 average height 34–41 m	E4 average height 15–27 m
E1 average height 55–76 m	E-3 average height 27–34 m	E5 average height < 15 m
E2 average height 41–55 m	E3 average height 27–41m	

Live crown density-classes

a 70–100% crown cover	c 20–40% crown cover	f < 5% crown cover
b 40–70% crown cover	d 5–20% crown cover	(P) Patches or scattered

Dead stem-count classes

A* > 60 stems/ha	B 25–39 stems/ha	D 2–14 stems/ha
A 40–60 stems/ha	C 15–24 stems/ha	F < 2 stems/ha

REGROWTH EUCALYPT

Height classes

ER1 average height < 15 m
ER3 average height 27–37 m
ER5 average height 44–50 m
ER2 average height 15–27 m
ER4 average height 37–44 m
ER6 average height > 50 m

Density-classes

a 90–100% crown cover
c 50–70% crown cover
f 1 – 10% crown cover
b 70–90% crown cover
d 10–50% crown cover
(P) Patches or scattered

Mature height potential

/1*, /1, /2, /3, /+3, /-3, /4, /5 as per eucalypt mature height classes

AGED REGENERATION

E(yy)m Eucalypt regeneration, where yy is year of regeneration in 1900s (yyy = 2000s), m is method.

Regeneration-method codes

A Artificially seeded **P** Planted (not for intensive plantation) **N** Natural seeded **W** Wildfire-seeding

PLANTATION

Ph(yy) Hardwood plantation (planting year yy or yyy for post 2000) Ps(96) Softwood plantation (1996)

NON-EUCALYPT SPECIES

S Scrub (< 15 m tall)
M+ Tall myrtle rainforest
M- Low myrtle rainforest
Tr Radiata pine (wild)
Tb Blackwood
T Secondary species (> 15 m tall)
Mr1 Myrtle rainforest regrowth < 15 m tall
Mr2 Myrtle rainforest regrowth > 15 m tall

Sb Bauera scrub
Sh Horizontal scrub
St Tea-tree scrub
Tc Celery-top pine
Tl Leatherwood
Th Huon pine
Tk King Billy pine
Ts Sassafrass
Tt Tea-tree
Tw Wattle

NON-FOREST

K Bracken
V Grazing
Vc Cultivated land
Vo Orchard
Vz Rough grazing
Vp Pasture
W Waste, bare
Wg Buttongrass
Wr Rock
Wm Mountain moor

UNSTOCKED FOREST SITE

U/p Un-regenerated forest site (with eucalypt potential p)
Z/S Un-regenerated former scrub site
Z/W Un-regenerated former waste site

Table 11.2. Examples of PI-type elements and codes.

PI type code	*Detail*
co E2c.Tw.S.	A previously cut-over stand of tall mature eucalypt of moderate density, over wattle and scrub.
ER1b.fd E-3f.	Dense short eucalypt regrowth, with sparse fire-damaged mature eucalypts of medium height.
M+.Tb.	Large-crowned myrtle rainforest, with blackwood.
E(76)A/1.T.	Eucalypt regeneration, artificially seeded in 1976, on an excellent site, with other unspecified species.
th E(34)4a/2.	Tall fully stocked eucalypt regrowth which has been thinned, on a good site.
Wg.E4d(P).	Buttongrass moorland, with patches of low-density, short mature eucalypts.
Vz/+3.	Pasture, with evidence that the site once had medium height eucalypts.

There are approximately 10 400 unique PI-type codes currently in use on 178 300 patches. The average patch is 37 hectares in size and has a perimeter of about 3000 m.

11.3 The PI-type database

PI-type information is stored digitally on Forestry Tasmania's GIS database in three conceptually separate 'layers':

- The 'base' layer stores the PI-types as originally interpreted, it is not updated and is retained to provide an archival snapshot for monitoring stand history and derivation of site potential.
- The 'changes' layer stores the details of stands whose PI-type codes have been updated as a result of forestry operations since the most recent base-mapping.
- The 'live' layer is an automated combination of the base and changes layers, providing up-to-date maps.

Intensive forest management of plantations requires higher levels of spatial resolution and is stored in the Plantation Area System (PAS), mapped primarily from GPS and ground-survey.

Light Detection and Ranging (LiDAR) airborne radar-based scanners represent a new and innovative approach to forest mapping. This introduces a new system capable of measuring the forest with great precision and efficiency.

12. Basal Area

Basal area is the cross-sectional area of a tree at breast height. It is often expressed as basal area per hectare. Stand basal area is a very useful parameter for quantifying a forest stand. It is a summary of the number and the size of trees in a stand. As individual tree basal area is related to tree volume, biomass, crown parameters, etc., so too stand basal area is related to stand volume, biomass, etc. Basal area is also correlated with competition or the density of a stand.

In Australian forests, stand basal area of fully stocked stands frequently lies in the range 20-50 m^2/ha. For heavily thinned stands and young poorly stocked crops, basal areas of 10-20 m^2/ha are common. In rare cases, on exceptionally good sites, stand basal area may reach 150 m^2/ha (Bracks 2010).

Stand basal area can be obtained by measuring the diameter at breast height (dbh) of all the trees on one hectare, or by using a basal area wedge. Basal area wedges commonly used in Tasmania are usually either glass prisms or string and block gauges. Regardless of the type of wedge used, it is critical to know the basal area factor.

When carrying out a prism sweep, you must hold the prism over the plot point and move around the prism. If using a string and block gauge, the assessors eye must be positioned over the plot point.

The wedge should be held vertically, and oriented horizontally so that it is at right angles to the line of sight. The assessment of each tree should be made at breast height. Start the sweep at a memorable feature on the plot and sweep through 360°. Special care with alignment should decide whether the borderline trees are 'In' or 'Out'. Select a wedge that gives a count in the range of 7-12. The basal area factor should be about 10% of the estimated stand basal area. A small factor wedge in dense stands results in a high count and increases the chance of trees being obscured; a large factor wedge results in a small count, with less likelihood of making a wrong count but a large error if a miscount is made.

Trees are considered "IN" if their wedge displacement overlaps with the rest of the stem (Figure 12.1). Trees are considered 'OUT' if their wedge displacement is clearly separated from the rest of the stem. Trees with a displacement lining up very closely to the outside of the stem should be considered 'Borderline'. Borderline trees should be checked using the critical distance tables (Tables 12.1 and 12.2) by measuring the slope-corrected distance from the plot point to the middle of the object tree, and the dbhob of the tree.

The basal area can then be calculated by multiplying the number of trees that were "IN" by the basal area factor of the prism or block.

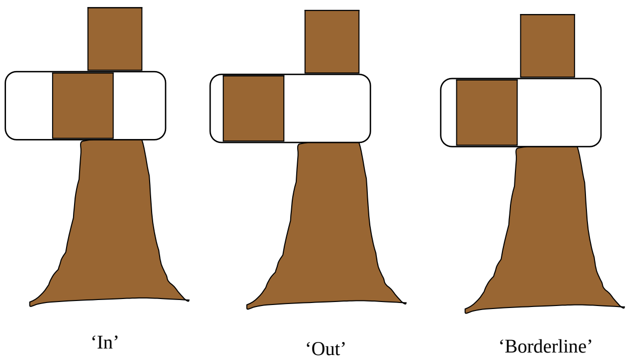


Figure 12.1. Using a prism wedge to determine if a tree is "in" or "out".

12.1 Spacing and basal area tables

Table 12.1. Critical distance tables for a **factor 2** wedge.

DBH	Distance	DBH	Distance	DBH	Distance	DBH	Distance
10	3.54	58	20.51	106	37.48	154	54.45
11	3.89	59	20.86	107	37.83	155	54.80
12	4.24	60	21.21	108	38.18	156	55.15
13	4.60	61	21.57	109	38.54	157	55.51
14	4.95	62	21.92	110	38.89	158	55.86
15	5.30	63	22.27	111	39.24	159	56.21
16	5.66	64	22.63	112	39.60	160	56.57
17	6.01	65	22.98	113	39.95	161	56.92
18	6.36	66	23.33	114	40.31	162	57.28
19	6.72	67	23.69	115	40.66	163	57.63
20	7.07	68	24.04	116	41.01	164	57.98
21	7.42	69	24.40	117	41.37	165	58.34
22	7.78	70	24.75	118	41.72	166	58.69
23	8.13	71	25.10	119	42.07	167	59.04
24	8.49	72	25.46	120	42.43	168	59.40
25	8.84	73	25.81	121	42.78	169	59.75
26	9.19	74	26.16	122	43.13	170	60.10
27	9.55	75	26.52	123	43.49	171	60.46
28	9.90	76	26.87	124	43.84	172	60.81
29	10.25	77	27.22	125	44.19	173	61.16
30	10.61	78	27.58	126	44.55	174	61.52
31	10.96	79	27.93	127	44.90	175	61.87
32	11.31	80	28.28	128	45.25	176	62.23
33	11.67	81	28.64	129	45.61	177	62.58
34	12.02	82	28.99	130	45.96	178	62.93
35	12.37	83	29.34	131	46.32	179	63.29
36	12.73	84	29.70	132	46.67	180	63.64
37	13.08	85	30.05	133	47.02	181	63.99
38	13.44	86	30.41	134	47.38	182	64.35
39	13.79	87	30.76	135	47.73	183	64.70
40	14.14	88	31.11	136	48.08	184	65.05
41	14.50	89	31.47	137	48.44	185	65.41
42	14.85	90	31.82	138	48.79	186	65.76
43	15.20	91	32.17	139	49.14	187	66.11
44	15.56	92	32.53	140	49.50	188	66.47
45	15.91	93	32.88	141	49.85	189	66.82
46	16.26	94	33.23	142	50.20	190	67.18
47	16.62	95	33.59	143	50.56	191	67.53
48	16.97	96	33.94	144	50.91	192	67.88
49	17.32	97	34.29	145	51.27	193	68.24
50	17.68	98	34.65	146	51.62	194	68.59
51	18.03	99	35.00	147	51.97	195	68.94
52	18.38	100	35.36	148	52.33	196	69.30
53	18.74	101	35.71	149	52.68	197	69.65
54	19.09	102	36.06	150	53.03	198	70.00
55	19.45	103	36.42	151	53.39	199	70.36
56	19.80	104	36.77	152	53.74	200	70.71
57	20.15	105	37.12	153	54.09	201	71.06

Table 12.2. Critical distance tables for a **factor 4** wedge.

DBH	Distance	DBH	Distance	DBH	Distance	DBH	Distance
10	2.50	58	14.50	106	26.50	154	38.50
11	2.75	59	14.75	107	26.75	155	38.75
12	3.00	60	15.00	108	27.00	156	39.00
13	3.25	61	15.25	109	27.25	157	39.25
14	3.50	62	15.50	110	27.50	158	39.50
15	3.75	63	15.75	111	27.75	159	39.75
16	4.00	64	16.00	112	28.00	160	40.00
17	4.25	65	16.25	113	28.25	161	40.25
18	4.50	66	16.50	114	28.50	162	40.50
19	4.75	67	16.75	115	28.75	163	40.75
20	5.00	68	17.00	116	29.00	164	41.00
21	5.25	69	17.25	117	29.25	165	41.25
22	5.50	70	17.50	118	29.50	166	41.50
23	5.75	71	17.75	119	29.75	167	41.75
24	6.00	72	18.00	120	30.00	168	42.00
25	6.25	73	18.25	121	30.25	169	42.25
26	6.50	74	18.50	122	30.50	170	42.50
27	6.75	75	18.75	123	30.75	171	42.75
28	7.00	76	19.00	124	31.00	172	43.00
29	7.25	77	19.25	125	31.25	173	43.25
30	7.50	78	19.50	126	31.50	174	43.50
31	7.75	79	19.75	127	31.75	175	43.75
32	8.00	80	20.00	128	32.00	176	44.00
33	8.25	81	20.25	129	32.25	177	44.25
34	8.50	82	20.50	130	32.50	178	44.50
35	8.75	83	20.75	131	32.75	179	44.75
36	9.00	84	21.00	132	33.00	180	45.00
37	9.25	85	21.25	133	33.25	181	45.25
38	9.50	86	21.50	134	33.50	182	45.50
39	9.75	87	21.75	135	33.75	183	45.75
40	10.00	88	22.00	136	34.00	184	46.00
41	10.25	89	22.25	137	34.25	185	46.25
42	10.50	90	22.50	138	34.50	186	46.50
43	10.75	91	22.75	139	34.75	187	46.75
44	11.00	92	23.00	140	35.00	188	47.00
45	11.25	93	23.25	141	35.25	189	47.25
46	11.50	94	23.50	142	35.50	190	47.50
47	11.75	95	23.75	143	35.75	191	47.75
48	12.00	96	24.00	144	36.00	192	48.00
49	12.25	97	24.25	145	36.25	193	48.25
50	12.50	98	24.50	146	36.50	194	48.50
51	12.75	99	24.75	147	36.75	195	48.75
52	13.00	100	25.00	148	37.00	196	49.00
53	13.25	101	25.25	149	37.25	197	49.25
54	13.50	102	25.50	150	37.50	198	49.50
55	13.75	103	25.75	151	37.75	199	49.75
56	14.00	104	26.00	152	38.00	200	50.00
57	14.25	105	26.25	153	38.25	201	50.25

Table 12.3. Number of stems per hectare for a range of diameters (dbh) and basal areas (ba).

	dbh																
ba	*16*	*18*	*20*	*22*	*24*	*26*	*28*	*30*	*32*	*34*	*36*	*38*	*40*	*45*	*50*	*55*	*60*
10	497	393	318	263	221	188	162	141	124	110	98	88	80	63	51	42	35
12	597	472	382	316	265	226	195	170	149	132	118	106	95	75	61	51	42
14	696	550	446	368	309	264	227	198	174	154	138	123	111	88	71	59	50
16	796	629	509	421	354	301	260	226	199	176	157	141	127	101	81	67	57
18	895	707	573	474	398	339	292	255	224	198	177	159	143	113	92	76	64
20	995	786	637	526	442	377	325	283	249	220	196	176	159	126	102	84	71
22	1094	865	700	579	486	414	357	311	274	242	216	194	175	138	112	93	78
24	1194	943	764	631	531	452	390	340	298	264	236	212	191	151	122	101	85
26	1293	1022	828	684	575	490	422	368	323	286	255	229	207	163	132	109	92
28	1393	1100	891	737	619	527	455	396	348	308	275	247	223	176	143	118	99
30	1492	1179	955	789	663	565	487	424	373	330	295	265	239	189	153	126	106
32	1592	1258	1019	842	707	603	520	453	398	352	314	282	255	201	163	135	113
34	1691	1336	1082	894	752	640	552	481	423	374	334	300	271	214	173	143	120
36	1790	1415	1146	947	796	678	585	509	448	397	354	317	286	226	183	152	127
38	1890	1493	1210	1000	840	716	617	538	472	419	373	335	302	239	194	160	134
40	1989	1572	1273	1052	884	753	650	566	497	441	393	353	318	252	204	168	141
42	2089	1650	1337	1105	928	791	682	594	522	463	413	370	334	264	214	177	149
44	2188	1729	1401	1157	973	829	715	622	547	485	432	388	350	277	224	185	156
46	2288	1808	1464	1210	1017	866	747	651	572	507	452	406	366	289	234	194	163
48	2387	1886	1528	1263	1061	904	780	679	597	529	472	423	382	302	244	202	170
50	2487	1965	1592	1315	1105	942	812	707	622	551	491	441	398	314	255	210	177

Table 12.4. Distance between retained stems for various diameters (dbh) and basal areas (ba).

	dbh																
ba	16	18	20	22	24	26	28	30	32	34	36	38	40	45	50	55	60
10	4	5	6	6	7	7	8	8	9	10	10	11	11	13	14	15	17
12	4	5	5	6	6	7	7	8	8	9	9	10	10	12	13	14	15
14	4	4	5	5	6	6	7	7	8	8	9	9	9	11	12	13	14
16	4	4	4	5	5	6	6	7	7	8	8	8	9	10	11	12	13
18	3	4	4	5	5	5	6	6	7	7	8	8	8	9	10	11	13
20	3	4	4	4	5	5	6	6	6	7	7	8	8	9	10	11	12
22	3	3	4	4	5	5	5	6	6	6	7	7	8	9	9	10	11
24	3	3	4	4	4	5	5	5	6	6	7	7	7	8	9	10	11
26	3	3	3	4	4	5	5	5	6	6	6	7	7	8	9	10	10
28	3	3	3	4	4	4	5	5	5	6	6	6	7	8	8	9	10
30	3	3	3	4	4	4	5	5	5	6	6	6	6	7	8	9	10
32	3	3	3	3	4	4	4	5	5	5	6	6	6	7	8	9	9
34	2	3	3	3	4	4	4	5	5	5	5	6	6	7	8	8	9
36	2	3	3	3	4	4	4	4	5	5	5	6	6	7	7	8	9
38	2	3	3	3	3	4	4	4	5	5	5	5	6	6	7	8	9
40	2	3	3	3	3	4	4	4	4	5	5	5	6	6	7	8	8
42	2	2	3	3	3	4	4	4	4	5	5	5	5	6	7	8	8
44	2	2	3	3	3	3	4	4	4	5	5	5	5	6	7	7	8
46	2	2	3	3	3	3	4	4	4	4	5	5	5	6	7	7	8
48	2	2	3	3	3	3	4	4	4	4	5	5	5	6	6	7	8
50	2	2	3	3	3	3	4	4	4	4	5	5	5	6	6	7	8

13. Priority and Threatened Native Vegetation Communities

This table summarises the communities which should not be scheduled for harvesting on State forests, as listed in the Tasmanian RFA (Commonwealth of Australia and State of Tasmania 1997) and the Nature Conservation Act 2002. **WARNING**: for a full and up-to-date list of priority communities always refer to the lists in the Forest Management System under the heading 'Threatened Native Vegetation Communities', as these change over time.

Table 13.1. Priority forest communities (as listed under the *Tasmanian Regional Forest Agreement*).

Vegetation community	*RFA Code*	*Qualifying comment*
*Inland *Eucalyptus amygdalina* (black peppermint) forests	AI	
Eucalyptus brookeriana (Brookers gum) wet forest	BA	
E. viminalis /E. ovata / E. amygdalina / E. obliqua damp sclerophyll forest	DSC	Oldgrowth only
Eucalyptus viminalis and/or *E. globulus* coastal shrubby forest	G	
Grassy *Eucalyptus globulus* (blue gum) forest	GG	
King Island *Eucalyptus globulus/E. brookeriana/E. viminalis*	KG	
Shrubby *Eucalyptus ovata/E. viminalis* forest	OV	
Eucalyptus pauciflora on Jurassic dolerite	PJ	Oldgrowth only
Eucalyptus risdonii (Risdon peppermint) forest	RI	
Eucalyptus rodwayi forest	RO	
Eucalyptus sieberi forest on granite	SG	Oldgrowth only
Eucalyptus sieberi on other substrates	SO	Oldgrowth only
Inland *Eucalyptus tenuiramis* (silver peppermint) forest	TI	
Grassy *Eucalyptus viminalis* forest	V	
Furneaux *Eucalyptus viminalis* (white gum) forest	VF	
Wet *Eucalyptus viminalis* (white gum) forest on basalt	VW	
Banksia serrata (saw-tooth banksia) woodland	BS	
Callitris rhomboidea (Oyster Bay Pine) forest	CR	
Melaleuca ericifolia (coast paperbark) forest	ME	
Notelaea ligustrina / *Pomaderris apetala* forest (native olive-dogwood-pinkwood)	NP	

* During 2005-06, Inland *E. amygdalina* was separated into:

- Inland *E. amygdalina/E. viminalis/E. pauciflora* on Cainozoic deposits - RFA priority community
- *E. amygdalina* on mudstone (oldgrowth only) - RFA priority community

For further information about all the communities above, and about the split of inland *E. amygdalina*, see Harris and Kitchener (2005).

Table 13.2. Other forest communities listed as threatened (as listed in the *Nature Conservation Act 2002*).

Forest community	**RFA Code**	**Tasveg Code**
Allocasuarina verticillata woodland/forest	AV	NAV
Allocasurarina littoralis forest (Bull oak forest)	n/a	NAL
Eucalyptus amygdalina (black peppermint) forest on sandstone	AS	DAS
Eucalyptus barberi woodland	n/a	DBA
Eucalyptus cordata forest	n/a	DCR
Eucalyptus globulus/E. brookeriana/E. viminalis woodland on King Island	n/a	DKW
Eucalyptus morrisbyi (Morrisby's gum) forest	MO	DMO
Eucalyptus nitida forest in the Furneaux group	NF	DNF
Eucalyptus pauciflora on other (non-dolerite) substrates	PS	DPO
Eucalyptus perriniana woodland	n/a	DPE
King Billy Pine rainforest	X	RKP
King Billy Pine with deciduous beech	F	RKF
Pencil Pine forest	PP	RPP
Pencil Pine open woodland	n/a	RPW
Pencil Pine with deciduous beech	PD	RPF

n/a – not RFA mapped

Note that, within some bioregions, there may be further constraints for some of the other communities as per the Permanent Native Forest Estate policy, updated in December 2009. In particular, non-threatened forest communities must be maintained at a level no less than 75 per cent of the 1996 CRA native forest area, or a minimum of 2000 hectares, for each community in each IBRA region. The FPA will further advise on this.

14. The history of the development of silvicultural systems for use in native eucalypt forests in Tasmania

Extracted and revised from Hickey, J.E. and Wilkinson, G.R. (1999). The development and current implementation of silvicultural practices in native forests in Tasmania. *Australian Forestry* 62(3): 245-254.

14.1 Introduction

Tasmania has 3.1 million ha of native forest of which 47% is reserved (BRS 2009). About one third is classified as multiple-use forest on public land and used for multiple purposes including wood production. Another 30% occurs on private land.

In 2008/09 about 6 300 m³ of veneer logs, 215 700 m³ of peeler logs, 300 000 m³ of sawlogs, 12 500 m³ of special species logs and 2 million m³ of pulp logs were produced from native forest in Tasmania, with a mill door landed value (the estimated market value of logs at the mill door or 'at wharf' for export logs) of $163 million (Forestry Tasmania 2009c).

Native forests are, and will continue to be, a major source of forest products although plantations are increasing in area and importance. Native forests used for wood production have an important role in habitat conservation and silvicultural systems are being applied, and modified where necessary, to achieve conservation objectives.

This section broadly describes the development and current implementation of silvicultural practices for native forest in Tasmania. It summarises current practices and briefly describes research needs and future trends.

14.2 History of silvicultural treatment

Eucalypt forests

Exploitation of Tasmania's forests began shortly after colonial settlement in 1803. Processing was carried out in the forest by hand-hewing and later by pit-sawing. The sawn timber and beams were extracted on trolleys drawn along wooden tramways by horses. Up to the 1840s convict labour was also used to drag and carry timber from the forest (Carron 1985). The first sawmill was established in Hobart in 1828 and by the 1850s sawmills were being established in northern Tasmania (Rodger 1929). Major changes to the forest industry occurred after the introduction of steam in the 1870s. The early water-powered sawmills were replaced by steam-powered sawmills and in 1884 steam-powered winches introduced the era of mechanised logging (Simpson 1991). For the next 50 years bullock-teams or steam-driven yarders extracted logs to landings where they were loaded onto trolleys and transported by gravity, horses or locomotives along tramways to the mill (Penny 1910; Simpson 1991; Kostoglou 1996).

Improved technology for extracting logs resulted in increased impacts on the forests. By 1886 the first Conservator of Forests, G.S. Perrin, expressed concern at the waste and destruction of logging operations (Carron 1985). A major impact associated with logging in the wet eucalypt forests was a dramatic increase in the incidence of fire. Fire was often used before logging to improve access by clearing away the dense understorey. After logging the slash was usually burnt, either deliberately to remove the fire risk from around logging equipment and camps, or else unintentionally by subsequent uncontrolled fires.

At this time eucalypt regeneration processes were poorly understood. The light-demanding nature of the eucalypts and the success of concentrated fellings in producing regeneration had been noted and it was generally assumed that eucalypts would “reproduce themselves” providing that the young crops were protected from fire (Steane 1932). Various silvicultural treatments were tried, including ringbarking to induce seedfall, sowings and attempts to encourage coppice (Steane 1934). Attention was given to thinning (Rodger 1929) although most of the 3200 hectares thinned during the 1930s was destroyed by wildfires in 1939/40 (Lockett and Keenan 1985).

In 1942 the successful establishment of eucalypt regeneration was regarded to be “largely a matter of adequate fire protection” (Steane 1942). Natural regeneration was relied upon and fire hazards were reduced by the systematic lopping and burning of the heads of felled trees (Steane 1945). By 1947 emphasis was given to the retention of seedtrees. However there were still problems in achieving regeneration on some areas and a need for further study was identified (Forestry Commission 1947).

The problem of poor regeneration was acute by the mid-1950s. Forest utilisation had increased since the late 1930s with the introduction of modern tractors and with the commencement of pulpwood operations to supply paper plants at Burnie (1938) and Boyer (1941). Integrated logging for sawlogs and pulpwood often resulted in the clearing of virtually all eucalypts. Improvements in fire control had significantly reduced the area of regeneration produced as a result of the burning of cut-over forest by wildfire. The silvicultural practice of leaving seedtrees together with some top disposal burning was not producing reliable results (Forestry Commission 1956).

The establishment of ‘clearfell burn and sow’ silviculture

In the late 1950s, research by Gilbert (1959) and Cunningham (1960) identified the key factors necessary for the successful regeneration of wet eucalypt forests. These were to provide a receptive mineral seedbed by removing vegetation and slash barriers, and to ensure an adequate supply of seed.

These findings heralded a major change in the focus of forest management. Up to the late 1950s the Forestry Commission had concentrated on the urgent problem of protecting existing forests from fire. In 1959 a Legislative Council Select Committee reported that whilst adequate regeneration had established without assistance in the more open forest types, the regeneration of the wet forests, with a denser understorey, was not adequate (Select Committee 1959). The Committee recommended the immediate implementation of recent research findings and a change in emphasis to pursue a “vigorous policy of regeneration”.

Regeneration practices for the wet forests continued to be developed during the 1960s. Methods for assessing regeneration were developed (Mount 1961). Operations were confined either to areas where pulpwood sales allowed fully integrated logging or to areas remote from the likelihood of future pulpwood sales (Gilbert and Cunningham 1972). Seed trees were marked for retention and the understorey was felled by contract fellers (Korven-Korpinen and White 1972). Slash burns were of high intensity and were carried out in March. The burns usually killed the seed trees and induced a heavy fall of seed onto the receptive seedbed. The seed tree system generally resulted in excellent regeneration. However, its disadvantages were a small increase in logging costs and an increased fire hazard, both during the regeneration burn and afterwards in the regrowth stand (Korven-Korpinen and White 1972). Aerial sowing was introduced in 1965 (Forestry Commission 1967) and seed tree systems were phased out.

By 1972 a further Select Committee inquiry was able to report on “a well planned programme of continuous regeneration and restocking of newly harvested areas in addition to the old forests” (Select Committee 1972). Over the preceding decade 25,000 hectares of wet forest had been regenerated, of which 11,000 hectares of harvested forest were burnt without prior treatment, and 14,000 hectares were prepared by chainsaw felling and bull-dozer clearing of residual stems before burning. However, the regeneration programme was still constrained by the lack of pulpwood markets; of the 96,000 hectares logged during the decade, 81,000 hectares remained unregenerated pending the future utilisation of residual stems as pulpwood.

In the drier open forest types obtaining regeneration was not perceived to be a problem provided that adequate gaps in the canopy were created and the regeneration was subsequently protected from damage. However, most of the drier forests were considered to be in a degraded condition due to a history of selective logging, repeated burning and grazing by domestic stock.

The development of an export pulpwood market in 1971 provided new opportunities for the management of Tasmania's forests. In the wet eucalypt types, integrated logging could ensure full utilisation and facilitate the preparation of coupes for burning and regeneration establishment. In the drier forest types integrated logging was seen as a means of ensuring the continued viability of sawlog production. Selective logging of the drier forests was not considered to be appropriate because of their degraded condition and the lack of sufficient growing stock suitable for retention (Gilbert and Cunningham 1972). Generally, clearfelling was regarded as the appropriate regime for converting the cut-over forests to vigorous, high quality stands. During the 1970s clearfelling of dry forests increased to a rate of 4,000 to 5,000 hectares per year.

The development of partial harvesting methods in high and dry forests

By the end of the decade silvicultural practice for most eucalypt forests could be summarised as clearfelling followed by a slash burn and aerial sowing. Exceptions to this regime were applied on sites which contained a good stocking of advance growth (Felton and Lockett 1983). However, it was apparent that the clearfelling regime was not always reliable or appropriate in certain forest types. Problems were identified with the regeneration of high altitude (> 600 m) forests and a number of silvicultural regimes including shelterwood systems were developed and implemented during the 1980s (Keenan and Candy 1983; Bowman 1986; Keenan 1986; Ellis *et al.* 1987; Battaglia and Wilson 1990). Difficulties with regeneration were also experienced with low quality open forests, particularly those associated with a grassy understorey. Subsequent investigations led to the withdrawal of some forest types from wood production and the development of partial harvesting techniques in other types.

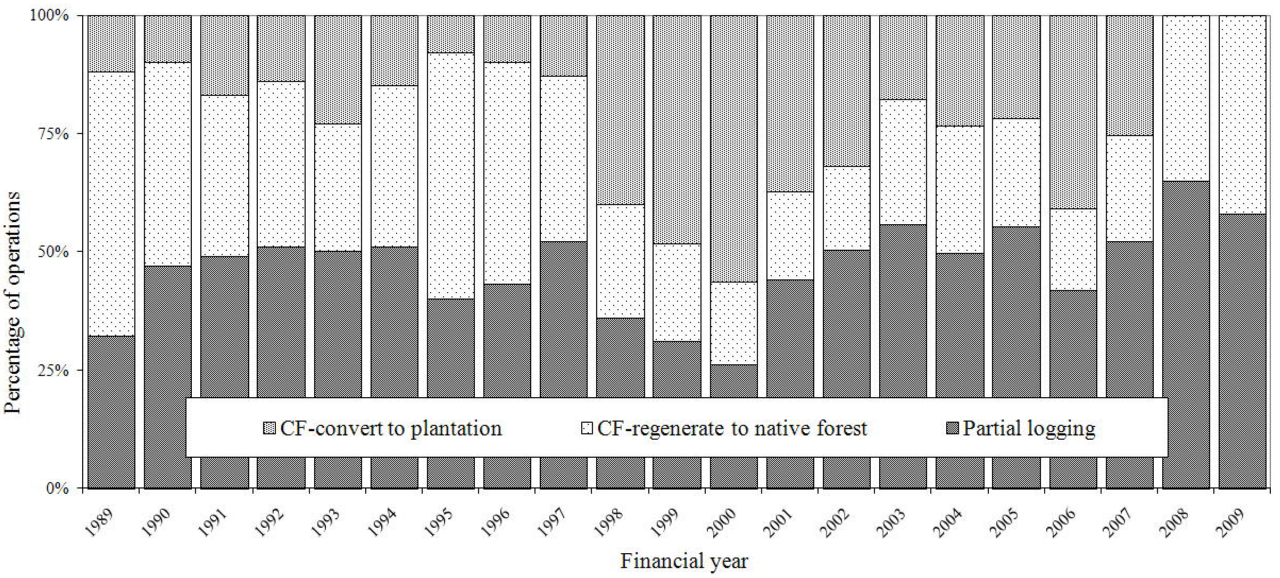
Photos 14.1 and 14.2. A partially harvested coupe in the eastern highlands, immediately after burning (left) and three years later (right).

The 1980s was a decade of rapid change. Whilst the basic regime of clearfell, burn and sow remained the predominant treatment for the wet forests it had been increasingly replaced by modified regimes in the more open drier and highland forests. Changes to the implementation of silvicultural practices were also brought about from an increased emphasis given to environmental, ecological and cultural values with the introduction of the Forest Practices Code (Forestry Commission 1987).

In the lowland wet forests, the structure of the stands and requirements for regeneration dictated that clearfelling, followed by high intensity slash burns and aerial sowing remained the optimum silvicultural regime for wood production. In dry, open forests the structure of the stands and regeneration requirements provided greater opportunities for regimes other than clearfelling (McCormick and Cunningham 1989) and the majority of dry and highland eucalypt forests were being logged using partial harvesting systems. Nevertheless, clearfelling continued to be used for dry forests that had been previously cut-over, contained very little growing stock suitable for retention and where factors such as frost, drought or grass competition were unlikely to impede regeneration. It was also used in dry forests harvested using cable yarding techniques.

Wilkinson (1992) reported that, for State forest, 27% of the dry forest harvested from 1990-92 was clearfelled while 73% was partially harvested (which included retention of advance growth, live seedtrees, shelterwood; group or single stem selection). For wet forest, 93% was clearfelled and 7% was partially harvested over the same period. Since that time the proportion of forest that is harvested by non-clearfelling methods has steadily increased. Figure 14.1 shows trends, over the last two decades, in harvesting methods and future land use for native forest on State forest in Tasmania. Partial harvesting has been the dominant harvesting method over that time. The proportion of harvesting by partial means was low during two periods of increased plantation establishment in the late 1990s and the mid 2000s but has recently returned to more than 50% of the harvest. Commencement of new harvesting operations in State native forest for plantation establishment ceased on the 1st of June 2007 (i.e. some existing operations were completed after this date but no new conversions were started).

Figure 14.1. Percentage of native forest harvesting operations on State forest by harvesting method and future land use from 1988-89 to 2008-09 (from annual reports of the Forest Practices Board).



The decade of the 1990s saw renewed interest in thinning of ash-type eucalypts because large areas of silvicultural regeneration had reached a commercially thinnable age. Silvicultural research had indicated significant growth responses to thinning (e.g. Goodwin 1990; Brown 1997; LaSala *et al.* 2004), a market was available for regrowth pulpwood and improved fire management could reduce the risk of wildfires which had lead to the virtual cessation of thinning in the 1940s. Thinning was also seen as a means of improving the productivity of native forest so that sawlog supply targets could be maintained despite a transfer of some forest areas from wood production to reservation tenures (Forests and Forest Industry Council 1990; Commonwealth of Australia and State of Tasmania 1997).

The Regional Forest Agreement (RFA) and the Warra silvicultural systems trial

As part of the RFA process (Commonwealth of Australia and State of Tasmania 1997), an independent expert advisory group assessed ecologically sustainable forest management of Tasmania's forests (on all tenures). The Group made 68 recommendations (Independent Expert Advisory Group 1997) of which five relate specifically to the development and implementation of silviculture in native forests. These were to: identify areas of wet regrowth forest that have potential for the application of more flexible silvicultural systems to promote the production of specialty timbers, especially in the south and north-west sub-regions; initiate training and certification programs for personnel responsible for the implementation of silvicultural prescriptions; develop appropriate audit systems and indicators for reporting on regeneration success and trends; provide stable resourcing and encourage collaboration to facilitate development of criteria and indicators of ecologically sustainable forest management at the Warra Long Term Ecological Research (LTER) site and other sites; and document the scientific basis for current silvicultural practices, establish demonstration areas of a range of systems (especially in wet forest) and initiate specific multi-disciplinary research trials aimed at resolving contentious aspects of these systems.

The last two recommendations were addressed through a silvicultural systems trial established in wet *Eucalyptus obliqua* forest (Hickey *et al.* 2001) at the Warra LTER site (Warra Policy Committee 1997) in southern Tasmania. The objectives of the trial were to: compare potentially feasible alternative systems with the routine clearfell, burn and sow system; develop alternatives for areas where habitat, special species timbers or aesthetic values have additional emphasis; and develop soil and biodiversity sustainability indicators at the coupe level (Hickey *et al.* 2001). The trial draws on, but does not duplicate, the comprehensive Silvicultural Systems Project in Victoria (Squire 1990) which included a broader array of treatments but was necessarily confined to small coupe sizes.

The Warra trial implemented the following silvicultural systems: clearfell, burn and sow (CBS) with understorey islands (40 m by 20 m areas excluded from ground-based machinery), stripfelling, patchfelling, dispersed retention, aggregated retention, single tree/small group selection and group selection (Hickey *et al.* 2006). The coupes have been monitored for the following performance indicators: timber production rates and worker safety (Neyland *et al.* 2009b), damage to retained trees and ease of fire management (Neyland 2004), quality and quantity of eucalypt and special species timbers regeneration (Neyland *et al.* 2009a), costs to the forest grower (Nyvold 2001), effects on soil physical properties (Pennington *et al.* 2001) and biodiversity (Grove and Neyland 2005). The first review of the trial indicated that the most useful alternative for broader application was aggregated retention (Hickey *et al.* 2006) and this was confirmed by a more wide-ranging review in 2009 (Forestry Tasmania 2009a). In aggregated retention coupes the majority of the harvested area of the coupe must be under forest influence, which is the biophysical effects of the residual trees on the surrounding environment, including effects on microclimate, light availability, seed- and litter-fall and evapotranspiration. Forest influence is estimated to extend one tree-height into the harvested area.

The Tasmanian Community Forest Agreement and the Variable Retention program

In 2005 the Tasmanian Government adopted a policy to reduce the use of clearfelling as a silvicultural technique in oldgrowth forest on public land. This policy was recognised and supported by the Commonwealth Government in the Tasmanian Community Forest Agreement(TCFA) (Commonwealth of Australia and State of Tasmania 2005). The 2005 Advice to Government recommended that the most practical silvicultural alternative to clearfelling was aggregated retention, but this recommendation was made with only a little understanding of the likely success or otherwise of the regeneration treatments. A program of research and field trials was established following the TCFA, and the focus of the silvicultural research was on the success of regeneration in aggregated retention treatments. To date nearly 1000 ha of tall oldgrowth wet eucalypt forest have been successfully harvested and regenerated to an aggregated retention prescription. Longer-term assessments of regeneration, survival of retained trees, sapling and tree growth and biodiversity recovery are planned. The early indications are that aggregated retention coupes can be successfully regenerated, but the work is still in progress.

Current research focus

Other current research programs in native forest silviculture in Tasmania include: development of stand management regimes for native forest regrowth and for blackwood rich native forest regrowth, development of new approaches to harvesting for use in special timbers zones and research into the carbon stocks and carbon cycles in native forests.

Future silvicultural research in native forests is likely to be increasingly focussed on modification and adaptation of silvicultural techniques to achieve specific conservation and community objectives while allowing some wood production, particularly of special timbers and other forest products not able to be grown commercially in plantations.

14.4 Implementation of silvicultural practices

The silviculture of native forests is currently guided by a series of Native Forest Silviculture Technical Bulletins prepared by Forestry Tasmania. The Technical Bulletins are prepared primarily for management of native forest on public land but are also used widely on private land and as teaching materials for the Certificate IV in Forest Growing & Management and for training of Forest Practices Officers in implementation of the Forest Practices Code (Forest Practices Board 2000) on public and private land. A manual has been prepared specifically for dry forests on private land (Orr 1991). Research staff at Forestry Tasmania provide ongoing silvicultural advice, including annual quality standards monitoring, to support operations on State forests. A separate agency, Private Forests Tasmania, provides silvicultural advice to private forest owners.

Tasmania's forests were classified into 50 mappable types as part of the Comprehensive Regional Assessment for a Tasmanian Regional Forest Agreement (RFA) (Commonwealth of Australia and State of Tasmania 1997). Thirty-two forest types are uncommercial or excluded from timber harvesting under the RFA and/or the *Nature Conservation Act 2002*. The remaining 18 types are grouped in Table 14.1 according to their silviculture and the relevant silvicultural Technical Bulletin.

Table 14.1. Silvicultural manuals and systems, extent and reservation of commercial forest types in Tasmania (reservation derived from Commonwealth of Australia and State of Tasmania 2007).

Technical Bulletin	Main silvicultural systems	Mappable Forest Communities	Total Area (ha)	Proportion of total area reserved (%)
2	AGR/SHW/	Dry *E. delegatensis*	287 000	36
	PSR/CBS	Tall *E. delegatensis*	272 000	37
		Total	**559 000**	
3	AGR/	*E. amygdalina* on dolerite	175 000	20
	PSR/	Coastal *E. amygdalina* dry forest	185 000	38
	SED	*E. pulchella/E. globulus/E. viminalis* grassy shrubby dry forest	150 000	32
		Dry *E. obliqua* forest	159 000	36
		E. sieberi on granite	18 000	31
		E. sieberi on other substrates	46 000	27
		E. viminalis/E. ovata/E. amygdalina/E. obliqua damp forest	38 000	34
		Total	**771 000**	
8	CBS/	Tall *E. obliqua*	396 000	32
	ARN	*E. regnans*	68 000	27
		Tall *E. nitida*	74 000	92
		Total	**538 000**	
9	GS	Callidendrous and thamnic rainforest on fertile sites	186 000	77
		Thamnic rainforest on less fertile sites	376 000	87
		Huon pine	9 000	85
		Total	**570 000**	
10	FIB	*Acacia melanoxylon* on flats	9 000	31
	GS	*Acacia melanoxylon* on rises	13 000	39
		Total	**22 000**	
No manual	CBS	Silver wattle (*Acacia dealbata*)	**50 000**	26

CBS – clearfell burn and sow, ARN – aggregated retention, AGR – advance growth retention,
PSR – potential sawlog retention, SED – seed tree, SHW – shelterwood,
GS – group selection, FIB – fenced intensive blackwood.

Silvicultural prescriptions for specific forest types are underpinned by additional Bulletins which describe techniques for seed collection and sowing (Forestry Tasmania 2010), silvicultural systems (this bulletin), regeneration surveys and stocking standards (Forestry Tasmania 2003), remedial treatments (Forestry Tasmania 2009b), silvicultural use of fire (Forestry Commission 1993) and thinning regrowth eucalypts (Forestry Tasmania 2001). Most of the Bulletins follow a similar format with a Part A which includes prescriptions for implementation by field staff and a Part B which is a review of relevant literature and provides a scientific rationale for the prescriptions. The Bulletins are reviewed at least every 10 years and revised where necessary.

Silvicultural prescriptions are developed by field staff after considering a number of key factors which include: forest type, site factors (e.g. frost or drought), fire management, commercial factors (e.g. pulpwood markets), operational constraints (e.g. slope), resource allocations (e.g. quotas to particular mills), non-wood values (e.g. burning restrictions for protection of threatened fauna habitat (Threatened Fauna Advisor, Forest Practices Authority)) and community attitudes. This consideration often results in selection of a silvicultural system that aims to meet a range of objectives rather than solely to maximise wood production. A common example in drier forests is the selection of partial harvesting systems, rather than clearfelling, to achieve habitat and aesthetic objectives.

On public land the expected harvesting method (e.g. aggregated retention, advance growth retention, shelterwood) is listed in Three Year Wood Production Plans which are annually updated and include details on coupe sizes, locations, product volume estimates, harvest method, machinery type, year scheduled, and management zone status. Forest Practices Plans are subsequently prepared for every coupe, on public and private land, as required under the Forest Practices Act (1985). The Forest Practices Plans include silvicultural prescriptions for harvesting and reforestation.

Harvesting is generally carried out by contractors hired by timber processors or land owners. Clearfelling is readily practiced by contractors but partial harvest methods are more complex and require greater silvicultural knowledge and commitment by contractors and supervisors in order to achieve satisfactory results. Most coupes in dry and highland eucalypt forests include a mosaic of structural forest types and require the application of several partial harvesting treatments including shelterwood retention, potential sawlog retention and advance growth retention. Formal pre-logging assessments assist in the formulation of detailed site-specific prescriptions for some areas where partial harvest methods are to be applied. The long term trend (Figure 14.1), is a gradual increase in the proportion of forest harvested by partial means. This trend has been facilitated further recently by the development of aggregated retention for use in wet forests, and it is anticipated that the proportion of forest harvested by non-clearfelling methods will continue to increase.

15. Silvicultural Glossary

term:	*(alternative term or acronym) definition.*
advance growth:	seedlings and saplings up to 20 cm dbh established prior to the current planned harvest, usually as the result of a previous disturbance (e.g. wildfire or past harvesting). It is assumed that these trees have future sawlog potential.
aggregate:	an area of standing forest retained for variable retention purposes and intended to be kept for at least the next rotation. *edge aggregate:* an area of trees that is contiguous with standing forest outside of the coupe. *island aggregate;* a free-standing patch of trees retained within a coupe.
aggregated retention:	(ARN) a form of variable retention harvesting in which patches of intact forest are retained either as island, peninsula or edge aggregates.
allelopathy:	the influence which one living plant exerts upon another via chemical exudates.
ash group:	the ash group of eucalypts in Tasmania includes *Eucalyptus delegatensis, E. obliqua* and *E. regnans* which are the preferred native eucalypt species for sawmilling. Botanically, the ash group also includes *E. pauciflora* and *E. sieberi,* which are less-preferred sawmilling species.
ash-bed:	the heated and nutrient enriched soil found on coupes following regeneration burns.
basal area:	the cross-sectional area of a tree stem at 1.3 m above ground. Stand basal area is expressed in square metres per hectare (m^2/ha).
basal area increment:	the difference in basal area between one measurement and the next.
biodiversity:	the diversity of all life forms including genetic, species and ecosystem diversity. Biodiversity can be assessed at a variety of levels; for example, niche, harvesting area, catchment, landscape, national and global.
biological anchor:	a biologically important feature or legacy used as to centre an aggregate. Possible biological anchors include class 4 streams, a single large stag, a patch of large-diameter live trees, large decaying logs, etc.
biological legacy:	important features from the oldgrowth stand (large live and dead standing trees, decaying logs and patches of undisturbed understorey) that are retained into the regenerated stand.
biota:	all the life forms present at a particular place or time.
blocks:	Tasmanian State forests are subdivided into numbered compartments within named blocks, for descriptive and record-keeping purposes. These units are for administrative purposes only and have no direct effect on the management of the forests.
bole height:	height above ground where the lowest branch carrying green foliage meets the stem.

bract: a small undeveloped leaf adjoining (and with eucalypts initially enclosing) an inflorescence.

browsing: damage to eucalypt seedlings nominally caused by possums and wallabies.

browsing surveys: assessments carried out to monitor damage caused by native mammal browsing. Browsing is the predominant cause of understocking and growth losses in newly regenerated areas. Local knowledge of browsing pressure and regular surveys may avoid excessive damage.

cable harvesting: harvesting undertaken using cables and winches to pull the harvested timber to a landing over steeper slopes.

cambium: tissue in a tree stem situated between the bark and the sapwood, and from which new bark and sapwood are formed.

capsule: the fruit of a eucalypt in which the seeds are contained.

CAR reserve: comprehensive, adequate and representative (CAR) reserve system, established during the 1997 Tasmanian Regional Forest Agreement.

carbon sequestration: the capture and long-term storage of carbon.

carbon sink: a carbon pool which accumulates atmospheric carbon, during a given time, such that more carbon is flowing into it than out of it. The opposite of a carbon source.

carbon source: a carbon pool that is a source for atmospheric carbon, during a given time, such that more carbon is flowing out of it than into it. The opposite of a carbon sink.

carbon stock: the quantity of carbon held within a pool at a specified time, for example, forest wood products.

catchment: a discrete area of land which drains water to the same lowest point such as a river or swamp. Scale is important – a number of small stream catchments may all contribute to a larger river catchment.

clearfelling: the removal of all trees on a harvesting area in a single operation, and the subsequent regeneration of an even-aged stand. A canopy opening of four to six times mature tree height may be considered the lower limit for clearfelling. In the tall wet eucalypt forests of Tasmania, the minimum clearfell size is about five hectares. In practice, most clearfelled production coupes in Tasmania range between 10 to 100 hectares.

clinometer: an optical instrument for measuring angles in a vertical plane.

co-dominant tree: a tree receiving full light from above but little or no side light; its crown is at about the same height as those of its neighbours.

cohort: an aggregation of trees that starts as the result of a single disturbance. All the trees within a cohort are consequently of the same age.

cold air ponding the settling of cold air in natural depressions.

commercial/marketing factors: the ability to utilise various forest products and achieve an acceptable commercial return.

compartment: areas of between 100 and 500 hectares in size, and typically bounded by roads, drainage-lines, and other visible topographic features. Each compartment is identified by a three-digit number, unique within its Block, (e.g. AR024).

confidence limit: a statistical limit normally calculated from measurements of some attribute on a sample. It defines the level above which (lower confidence limit) or below which (upper confidence limit) the corresponding value for the whole population has a specified probability of falling (e.g. 95%).

conversion/clearing: the permanent or long-term removal of significant areas of native vegetation and its replacement by non-native vegetation, such as orchards, crops or pastures, different native species such as a blue gum plantation; or unvegetated developments, such as artificial water bodies, buildings and other infrastructure.

coppice: shoots that arise from strands of bud-producing tissue that originates from leaf axils and persists within the phloem. They generally arise on cut or broken stumps.

cording: cording of snig tracks comprises logs and heavier understorey material laid perpendicular to the flow of traffic to reduce the contact between machinery and the soil surface.

coupe: for harvesting, forests are subdivided into discrete areas called coupes. Most coupes in Tasmania are between 10 and 100 ha.

coupe containing oldgrowth: a coupe that contains at least 25 per cent oldgrowth, based on area.

cotyledons: the first pair of leaves to emerge as a seed germinates. Eucalypt cotyledons are different in form from later leaves.

crop tree: a tree that is selected for retention during a thinning operation.

cull trees: trees greater than 20 cm dbh which contain no timber of commercial value.

damage: damage to the stems of plants that exposes the cambium and inevitably leads to the entry of decay-causing organisms. Minimisation of damage to retained trees during harvesting is an essential part of good forest management.

density: (stand density) the number of individuals (trees) per unit area. e.g. the number of stems per hectare.

dbh: stem diameter at breast height. Measured at 1.3 m above mineral soil on the high side of the tree, perpendicular to the stem axis; dbhob is dbh over bark; dbhub is dbh under bark.

dieback: the gradual decline and sometimes the death of trees. Usually episodic e.g. in the north-east, gully dieback was related to an unusually intense drought.

dispersed retention: (DRN) a form of variable retention harvesting in which single trees or small clumps of trees are retained evenly dispersed throughout a coupe.

dominant tree: a tree receiving full light from above and some side light, its crown projects above those of its neighbours.

dormancy: a state in which viable seed is unable to germinate even though external conditions favour germination. Dormancy may be primary (present at seed

	maturity) or secondary (due to a relapse into the dormant state after primary dormancy has been aborted).
downer:	a dead tree trunk lying on the forest floor.
dry eucalypt forest:	short to moderately tall forest dominated by eucalypts and typically found in lower rainfall areas, with understoreys dominated by grasses, small shrubs, heath, sedges or bracken. The forests are usually less than 40 m in height.
E2, E3, E4 etc.:	see 'PI type'.
ecological niche:	the functional role and position of a species (population) within a community or ecosystem, including the resources it uses, how and when it uses the resources, and how it interacts with other populations.
ecosystem	a community of organisms, plant and animal, living together in a defined region or habitat, and interacting with each other and their environment.
emergent stratum:	individual trees which have their crowns above the main vegetation canopy.
endemic:	known only from a particular area e.g. Tasmania.
epicormics:	small, leafy branches which develop on the main stem of some plants from dormant buds in response to stresses such as drought or defoliation by insects or fire.
epiphyte:	a plant that grows on or is supported by other plants, but is not parasitic.
eucalypt sawlogs:	logs suitable for sawmilling. See Section 9, Forest Product Classes for details.
excavator heaping:	(rough heaping) mechanical heaping of fine fuels (generally less than 20 cm diameter) following harvesting, generally using a small (12 to 15 tonne) excavator.
felled area:	area within the planned coupe from which trees have been removed.
fire break:	a strip of land around a harvested area from which all the vegetation and harvesting debris has been removed to reduce the risk of fire spreading.
fire management:	the use of fire for the establishment of regeneration, fuel reduction or the protection of forests from wildfire.
forest:	an area incorporating all living and non-living components, dominated by trees usually with a single stem and a mature (or potential mature) stand height exceeding five metres, with potential projective foliage cover of overstorey strata greater than one-third of the ground.
forest influence:	the biophysical effects of the residual trees on the surrounding environment, including effects on microclimate, light availability, seed- and litter-fall and evapo-transpiration.
Forest Practices Code:	a set of guidelines established under the *Forest Practices Act 1985* which prescribes the manner in which forest practices must be conducted in order to provide reasonable protection to the environment.

Forest Practices Plan:	A plan for forest operations, specified in Section 18 of the *Forest Practices Act 1985*. It includes sections on conservation, roading, harvesting and regeneration.
forest providing influence:	(FPI) areas of standing forest adjacent to the felled area of variable retention coupes. To provide forest influence, these areas must consist of native forest at least 15 m tall that will remain unharvested for at least the next rotation. These areas must be designated as Special Management Zones (FlVr).
forest type:	the species composition and characteristics, age, structure and condition of the stand, as affected by previous history of silviculture or wildfire.
frost heave:	the formation of ice columns in the soil lifts the surface layer and any small seedlings. This often causes root exposure and subsequent drought death.
fuel reduction burn:	(low intensity prescribed burn) a fire of low intensity carried out under closely controlled conditions to reduce the quantity of accumulated fuel on the forest floor, without damaging standing timber.
gene pool:	the total complement of genes present in a particular population.
genetic adaptation:	the evolution in a population of attributes which assist their offspring in perpetuation within a particular environment.
genetics:	the science of heredity, dealing with resemblances and differences of related organisms flowing from the interaction of their genes and the environment.
genotype:	the genetic constitution of a particular organism. Differences in genotype may not always be detectable from outward appearances.
geomorphology	geomorphology is the study of the evolution and configuration of landforms.
geoconservation:	is the identification and conservation of geological, geomorphological and soil features, assemblages, systems and processes (geodiversity) for their intrinsic, ecological or heritage values.
germinate:	a seed is deemed to have germinated when the primary root and hypocotyl (shoot) together exceed four times the length of the seed, provided all the structures which have developed are intact.
germinative capacity:	the percentage of fertile seeds which will germinate under favourable conditions.
germinative energy:	a measure of the promptness and evenness of seed germination.
giant tree:	trees which are at least 85 m tall or greater than 280 m^3 in volume.
girdling:	the severing or killing of a complete ring of tissue around the stem which will cause the tree to die.
group selection:	an uneven-aged silvicultural system in which small groups of trees are removed in a dispersed cutting sequence.
growth check:	an extreme form of growth impediment resulting from the complex interaction of adverse environmental conditions. No one factor alone can be given as the cause of growth check. However, frost and severe competition from dense *Poa* grass have been implicated as major factors (Webb *et al.* 1983; Ellis 1985b). 'Growth check' is not an "on-off" condition, nor a diagnosable disease. It is the growth

response to adverse growing conditions which in any one year may be caused by the independent or interactive effects of many factors including frost, browsing, grass competition, soil nutrition or insect attack. Growth checked trees tend to have bushy rounded crowns with a loss of apical dominance. They have smaller, thicker and more leathery leaves than vigorously growing individuals and heavy infestation of insects and fungi. Trees may be growing slowly and exhibit all or none of these attributes. Growth check as a condition may persist for periods from a few years to greater than 20 years. On some sites under favourable conditions, seedlings have recovered from check and resumed reasonable growth rates. see Photo 5.2 of growth checked seedling

gum group: the largest group of eucalypts in Tasmania, characterised by the main bole of the tree having smooth gum type bark. Includes blue gum (*E. globulus*) white gums (e.g. *E. viminalis*), alpine white gums (e.g. *E. gunnii*) yellow gums (e.g. *E. johnstonii*) and black gums (e.g. *E. ovata*). Generally, gum group species are less desired as sawlogs than ash group species.

gum vein: (kino vein) pockets of a group of red to red-black substances occurring in stem wood, usually as a result of stress (e.g. drought, fire, insects attack).

habitat tree: a tree containing features attractive to animals, particularly hollows.

harvesting disturbance: disruption of undergrowth and the litter layer to expose mineral seedbed caused by machinery movement during harvesting.

heritable: capable of being passed on genetically from parent to offspring.

high intensity regeneration burn: (HIB) a burn usually prescribed for clearfelled forests with a dense understorey in order to ensure the removal of slash and organic layers, to expose maximum seedbed and to maximise the ashbed effect.

humus layer: the surface soil rich in organic matter.

hypocotyl: the stem of a newly-germinated seedling below the cotyledons.

in-breeding: sexual reproduction between two closely related individuals which may give rise to undesirable attributes.

indicator plots: small fenced/unfenced paired plot established routinely in sown coupes to provide essential information on early germination and likely browsing pressure.

inflorescence bud: an umbel or cluster of developing flower buds surrounded by enclosing bracts.

influence: (forest influence, edge influence) the biophysical effects of the residual trees on the surrounding environment, including effects on microclimate, light availability, seed- and litter-fall and evapo-transpiration.

influence level: the proportion of the felled area of the coupe that is within one tree height of a tree, aggregate or edge that provides influence.

intensive forest management: (IFM) silvicultural management beyond the minimum required to ensure regeneration. Usually refers to thinning native forest, or establishing and managing plantations.

key tree: the tree that is selected in a thinning operation, as the basis for selecting which of the surrounding trees are to be either removed or retained.

kino: (gum vein) pockets of a group of red to red-black substances occurring in stem wood, usually as a result of stress (e.g. drought, fire, insects attack).

landing: an area to which logs are pulled and where they are de-barked, sorted, cross-cut if necessary, and loaded onto trucks.

lifeboating: the process whereby biological legacies retained within a variable retention coupe provide refugia for species during harvesting and allow re-colonisation of the new stand (Franklin *et al.* 1997).

lignotuber: a swelling on a seedling at or just below ground level which is made up of a mass of dormant buds and food reserves. This is built up over a number of years and is an important survival adaptation capable of resprouting after damage by fire or other stress.

lowland wet eucalypt forest: forest with dense multi-layered understoreys occurring at altitudes generally below 600 m.

matting: waste bark from the landing that is spread over cording (tree head waste and understorey material laid across snig tracks) to further improve trafficability and reduce rutting by machinery.

mature forest: forest containing a majority of trees more than 110 years old. Mature forest encompasses oldgrowth forest.

mean dominant height: the mean of the heights of the dominant tree on each $1/30^{th}$ of a hectare (Forestry Commission 1964).

mechanical disturbance: the physical manipulation of the soil to improve the receptivity of the seedbed. Excavator (rough) heaping of fuels is often part of the treatment.

mesic: an environment in which water is neither abundant nor scarce.

microsite: a narrowly defined, highly localised site.

mixed forest: forest which comprises a tall open eucalypt overstorey over a dense understorey dominated by rainforest species.

morphological: relating to form and structure.

native forest: forest consisting of tree species that are native to Tasmania, other than in plantations. Native forests include old-growth, mature, regrowth and regenerating forests.

net harvestable area: that part of the coupe which is managed primarily for wood production – i.e. the area that is available after wildlife habitat strips, habitat clumps, streamside reserves, special value areas, rocky knobs, etc, have been demarcated.

niche: the functional role and position of a species (population) within a community or ecosystem, including the resources it uses, how and when it uses the resources, and how it interacts with other populations.

nitrification:	the conversion, by aerobic soil bacteria, of organic nitrogen compounds into nitrates which can be absorbed by green plants.
oldgrowth forest:	forest which is ecologically mature and where the effects of disturbances are now negligible.
operational constraints:	the accessibility of a stand and the availability of appropriate harvesting technology which is environmentally and economically acceptable.
outrows:	nominally parallel, felled corridors in a stand along which harvesting machinery transports timber to the landing from the thinned 'bays' between the outrows.
ovary:	the hollow structure at the base of a flower which encloses the ovules. In eucalypts it is divided into several chambers (locules) which expand in size as the capsule matures after flowering.
overmature:	a tree or stand that is approaching old age and in which growth has slowed or ceased.
ovules:	the structures which contain the female sex cells and develop into seeds following fertilisation.
partial harvesting:	harvesting systems which include the retention of some trees; for example, seed tree, shelterwood, advance growth retention, potential sawlog retention, thinning and variable retention systems.
pedicel:	the stalk attaching an individual flower or capsule.
peduncle:	the single stalk from which the pedicels branch.
peeler logs:	(peelers) logs suitable for peeling on a lathe to produce veneer for a range of solid wood products. The veneer produced from rotary peeling is generally used for structural grade plywood, whereas veneer produced by slicing high quality logs is furniture grade (e.g. for table tops).
peppermints:	the peppermint group of eucalypts in Tasmania includes *E. pulchella* and *E. amygdalina* (dry forests), *E. nitida* (wet west coast forests) and *E. coccifera* (high altitude forests). Peppermint species are not favoured for sawn timber production, but they split well and make durable fence posts and shingles.
phloem:	the inner living area of bark and the tissue through which upward and downward translocation of carbohydrates takes place.
PI type:	photo-interpretation type (see Section 11).
piece size:	the size, in volume or weight, of individual pieces of timber being handled in a harvesting operation.
photosynthesis:	the process in green plants by which carbohydrates are synthesised from carbon dioxide and water using light as an energy source, releasing oxygen as a by-product.
pollination:	the process where the male pollen is transferred from the stamens of a flower to the stigma, where fertilisation of the ovules is initiated.

potential sawlogs:	regrowth eucalypts, 20 to 60 cm dbhob, that have the potential to produce at least a 2.5 metre log anywhere within the stem, which is free of defect, damage or limbs greater than 30 mm diameter (dead or alive).
preferential outcrossing:	a natural system which ensures by various means that most of the fertile seed produced by any individual tree has been fertilised by pollen from another tree.
prescribed area:	the area managed using the variable retention prescription, which includes both the felled area plus all edge and island aggregates. The prescribed area is used to calculate the number of oldgrowth hectares managed by non-clearfell methods for SFM reporting. It is analogous to the coupe boundary for a partially harvested coupe (i.e., the area within which harvesting takes place). The prescribed area is recorded in FOD as the asset shape.
primary dormancy:	a condition in which fertile seed is initially incapable of germinating. The condition may be removed in various ways, most commonly by subjecting moistened seed to a period of cold.
propagule:	any structure capable of growing into a new plant.
provenance:	the geographic origin or source of seeds or species. Seed provenance refers to the specific area in which the plants that produced the seed are located. Sowing seeds of the correct provenance is important for conserving the local genetic diversity.
pulpwood:	logs below sawlog quality but suitable for manufacturing pulp and paper.
radicle:	the initial root of a newly-germinated seed.
radiative frost:	frost caused by radiative heat loss, as opposed to that caused by cold air ponding.
rainforest:	forest dominated by tree species such as myrtle, sassafras, celery-top pine and leatherwood, in which eucalypts comprise less than five per cent of the crown cover.
regeneration:	young plants, usually of seedling size. The term may also refer to any tree crop arising following harvesting, irrespective of age, i.e. silvicultural regeneration.
regeneration burn:	(slash burn) the planned combustion of debris remaining after harvesting to reduce fire hazard and/or to create a receptive seedbed, either high or low intensity.
regeneration surveys:	a systematic assessment of the new crop to provide the formal record of stocking. Regeneration surveys must be timed after seedlings are sufficiently established i.e. their future growth and development is reasonably assured, but before the opportunities for low cost remedial treatments are lost i.e. whilst sufficient receptive seedbed remain.
regrowth forest:	*aged:* silvicultural regeneration or even aged regrowth forest that has been logged and regenerated, generally since 1960, using deliberate site preparation and seeding techniques. The year of sowing is documented and the age of the trees may be determined. *unaged:* forest regenerated after wildfire or other disturbances, and containing a majority of trees less than 110 years old, where there is no deliberate site preparation or seed sowing. Unaged regrowth forest may contain scattered individuals or stands of ecologically mature trees.

reserves:	*forest:* an area of State forest, formally gazetted for long-term intent, to be managed for recreational, scientific, aesthetic, environmental or protection purposes. *formal:* a reserve equivalent to the International Union for the Conservation of Nature and Natural Resources (IUCN) Protected Area Management Categories I, II, III, IV or VI as defined by the World Commission on Protected Areas (http://www.iucn.org). The status of formal reserves is secure, in that revocation requires approval of the Tasmanian Parliament. A forest reserve on State forest is a formal reserve. *informal:* a reserve other than a forest reserve. In State forests, this comprises an area identified as a protection zone under the Management Decision Classification (MDC) system. It also includes other administrative reserves on public land managed to protect CAR values.
respiration:	a life-sustaining process by which all living things obtain energy from the breaking down of food materials within their tissues. During the process oxygen is consumed and carbon dioxide is released.
retainer:	a tree that might have been harvested but has been retained for a reason, e.g. for seed or habitat; also known as crop tree in thinned forests.
retention level:	the percentage of the coupe that has been retained unharvested. Calculated as (prescribed area – felled area)/prescribed area x 100.
rhizome:	an underground stem from which vegetative shoots arise.
ripping:	the disruption of surface vegetation, the litter layer and the A and B soil horizons by mechanical means.
rotation:	the planned number of years from establishment of a tree crop or stand to harvesting.
roundwood:	logs below sawlog quality but suitable for manufacturing posts and poles.
sawlog:	a log suitable for processing into sawn timber.
scarification:	the removal of ground vegetation and the litter layer by mechanical means, often with the blade of a bulldozer or the tines of an excavator.
sclerophyll:	‘sklero’ (hard) ‘phyllon’ (leaf) referring to the hard, leathery leaves of the eucalypts and some understorey species.
seed tree:	a harvesting system where 7 to 12 well spaced trees per hectare are retained on the coupe to provide a source of natural seedfall.
self pollination:	(selfing) pollination of a flower by pollen originating from the same plant.
shelterwood:	silvicultural system in which some trees are retained at the first harvest to provide a source of seed and shelter for the next cohort of regeneration. The retained trees are removed when the regeneration is established and greater than 1.5 m tall.
shrub:	a woody plant with a mature height less than about 8 metres tall, often with many stems.
silvicultural system:	a regime of operations applied to a forest to produce or enhance forest values such as wood production, water yield, wildlife habitat, soil conservation and

	landscape aesthetics. A silvicultural system normally comprises a management objective, a harvesting operation, a regeneration treatment and monitoring of and protection from browsing.
silviculture:	the art and science of guiding the establishment, growth, composition, health and quality of forests to meet diverse needs and values on a sustainable basis.
single tree selection:	an uneven-aged silvicultural system where individual trees are harvested to suit demand.
site factors:	the environmental factors that determine the availability of moisture, nutrients and temperatures suitable for growth and the likelihood of factors such as frost and drought.
site index:	the height that trees on a particular site are expected to reach at age 50 years.
slash:	the debris arising from harvesting, comprising the heads of the felled eucalypts and the pushed or felled understorey.
slash burn:	(regeneration burn) the controlled burning of slash remaining after harvesting.
snigging:	pulling or carrying harvested logs from the felling point to the landing.
snig track:	the track along which logs are pulled from the felling point to the landing.
soil damage:	damage to soils occur when the different soil horizons are mixed or compacted.
spacing:	the deliberate retention of potential sawlogs at a pre-determined spacing based on the mean dbh of the retained trees and the desired basal area.
special timbers:	myrtle, sassafras, celery-top pine, blackwood, silver wattle, Huon pine and King Billy pine.
special timbers zone:	(old term was special timbers management unit or STMU) areas of forest managed particularly for the sustainable production of special species timbers. There are three major special timbers sources: blackwood forests, rainforests and eucalypt forests that are rich in special timbers.
species adaptation:	a genetically determined characteristic of form, function or behaviour that makes an organism suited to live in its environment.
squash test:	the squashing of all un-germinated particles left at the end of a germination test to find how many of them were fertile, as identified by an oily white smear.
stag:	standing dead tree, often emergent from the surrounding forest canopy.
stand:	a contiguous group of trees sufficiently uniform in species composition, arrangement of age classes, site quality, and condition to be a distinguishable unit.
stocking:	an indication of the area occupied by trees, usually measured in terms of either basal area per hectare or the percentage of sample plots that are stocked within a surveyed coupe.
stocking standard:	a measure that specifies the minimum levels of growing stock to be retained or regenerated in order to maintain productive native forests after harvesting.

	Stocking standards vary according to the forest type and silvicultural system being applied, and are described in detail in Technical Bulletin No 6.
stratification:	the holding of seed in moist and cold conditions for a period in order to break dormancy.
strip felling:	harvesting of alternate strips, leaving the retained strips to provide a seed source for regeneration.
style:	the stalk in the centre of the flower which supports the stigma on which the pollen is deposited.
sub-dominant tree:	a tree that receives only overhead light but with less than half of its crown over-topped.
succession:	the gradual change from one community of plants to another on the same site.
suppressed tree:	a tree that receives little or no overhead light, its crown being mostly over-topped.
sustainable forest management:	management to maintain and enhance the long-term health of forest ecosystems while providing ecological, economic, social and cultural opportunities for the benefit of present and future generations.
sustainable yield:	the level of commercial timber (or product mix) that can be maintained harvested under a given management regime, without reducing the long-term productive capacity of the forest.
sward:	a dense cover of grass.
thinning intensity:	the proportion of the stand which is removed in a thinning operation, usually expressed as a percentage reduction of basal area.
thinning:	a silvicultural treatment applied to overstocked regrowth stands to release final crop trees from competition. There is no intention or need to induce regeneration as the stand is always maintained in a stocked condition.
top disposal burning:	a planned burn used to remove the elevated dry fuel from felled tree heads when the fuel on the ground is too wet to burn.
transpiration:	the loss of water vapour through the stomata.
tree:	a woody plant with a mature height more than about 5 metres tall with usually a single well-defined stem.
tree percent:	(seedling percent) the number of trees (seedlings) established for each 100 seeds sown.
variable retention (VR):	an approach to harvesting and silviculture that emphasises retention of biological legacies and structures across the harvested area for at least one rotation.
vegetative:	relating to non-sexual regeneration of a plant, e.g. from coppice and epicormics.
veneer log:	log suitable for producing veneer, either by slicing or peeling, for panel products.
viable seeds:	seeds capable of growing into new plants.

virgin forest:	forest that has not been previously logged.
wet eucalypt forest:	forest with dense multi-layered understoreys which can be dominated by rainforest species (called mixed forests), or by a variety of broad-leaved tall shrubs and small trees (called wet sclerophyll forests).
wildfire:	unplanned, out-of-control fire.
windthrow:	uprooting of trees by wind action often caused by the trees not having a sufficiently deep root system to cope with the extra wind pressure following partial canopy removal.
woodland:	a community formed of trees whose crowns cover less than one-third of the ground.
xeromorphic:	adapted to very dry conditions.
xylem water potential:	the amount of energy in the water-carrying vessels of a plant. A measure of plant drought stress, it is measured by applying external pressure to a leaf, to the point at which sap is exuded from a cut stem.
yarder:	a cable-harvesting machine used to drag logs to a central landing.

16. References

Alcorn, P.J. (2002). *The effects of light availability on the growth of Eucalyptus obliqua seedlings*. Hons Thesis, The Australian National University, Canberra.

Ashton, D.H. (1976). The development of even-aged stands in *Eucalyptus regnans* F. Muell. in central Victoria. *Australian Journal of Botany* 24: 397-414.

Ashton, D.H. and Willis, E.J. (1982). Antagonisms in the regeneration of *Eucalyptus regnans* in the mature forest. In: *The plant community as a working mechanism* (ed E.I. Newman), British Ecological Society Special Publication No. 1. pp. 113-128. Blackwell Publications, Oxford.

Bachelard, E.P. (1985). Effects of soil moisture stress on the growth of seedlings of three eucalyptus species. 1. Seed germination. *Australian Forest Research* 15(2): 103 - 114.

Baker, S., Grove, S., McElwee, D., Neyland, M., Scott, R., Read, S. and Wardlaw, T. (2009). Ecological goals, biodiversity outcomes and performance measures for aggregated retention coupes. Division of Forest Research and Development Technical Report No. 03/2009. Forestry Tasmania, Hobart.

Battaglia, M. (1997). Seed germination model for *Eucalyptus delegatensis* provenances germinating under conditions of variable temperature and water potential. *Australian Journal of Plant Physiology* 24: 69-79.

Battaglia, M. and Reid, J.B. (1993). The effect of microsite variation on seed germination and seedling survival of *Eucalyptus delegatensis*. *Australian Journal of Botany* 41: 169-181.

Battaglia, M. and Wilson, L.P. (1990). Effect of shelterwoods on stocking and growth of regeneration in dry high altitude *Eucalyptus delegatensis* forests. *Australian Forestry* 53 (4): 259-265.

Boland, D.J., Brooker, M.I.H. and Turnbull, J.W. (1980). *Eucalyptus seed.* C.S.I.R.O., Australia.

Bowman, D.M.J.S. (1984). *The ecology and silviculture of Eucalyptus delegatensis (R.T.Baker) on dolerite in Tasmania*. Ph.D. Thesis, University of Tasmania, Hobart.

Bowman, D.M.J.S. (1986). Review of silvicultural systems for harvesting *Eucalyptus delegatensis* forests on dolerite plateaux in Tasmania. *Australian Forestry* 49: 63-68.

Bowman, D.M.J.S. and Kirkpatrick, J.B. (1986). Establishment, suppression and growth of *Eucalyptus delegatensis* R.T. Baker in multi-aged forests. Part III. Intraspecific allelopathy, competition between adult and juvenile for moisture and nutrients, and frost damage to seedlings. *Australian Journal of Botany* 34: 81 - 94.

Bracks C. (2010) Stand basal area. Accessed online at http://fennerschool-associated.anu.edu.au/mensuration/s_ba.htm Accessed 13/7/2010.

BRS (2009) *Australia's forests at a glance 2009*, Bureau of Rural Sciences, Canberra.

Brown, G. (1997). Growth responses to thinning in eucalypt regrowth forests. *Tasforests* 9: 105-122.

Brown, G. and Laffan, M. (1993). *Forest soil conservation manual*. Forestry Commission, Tasmania, and the National Soil Conservation Program, Canberra.

Carron, L.T. (1985). *A history of forestry in Australia*. Australian National University Press, Rushcutters Bay, NSW, Australia.

Chuter, R. (2007). Feasibility of burning debris from wet eucalypt forests harvested to an aggregated retention prescription. Division of Forest Research and Development Technical Report No. 10/2007. Forestry Tasmania.

Commonwealth of Australia and State of Tasmania (1997). *Tasmanian Regional Forest Agreement between the Commonwealth of Australia and the State of Tasmania*. (online) Accessed online, 23 July 2009, http://www.daff.gov.au/__data/assets/pdf_file/0003/49278/tas_rfa.pdf.

Commonwealth of Australia and State of Tasmania (2005). Supplementary Tasmanian Regional Forest Agreement. Commonwealth of Australia and State of Tasmania, 23 pp.

Commonwealth of Australia and State of Tasmania (2007). Sustainability Indicators for Tasmanian Forests 2001-2006. Prepared by the Tasmanian and Australian Governments for the 2007 Ten Year review of the Tasmanian Regional Forest Agreement

Cremer, K.W. (1965). Emergence of *Eucalyptus regnans* seed from buried seed. *Australian Forestry* 29: 119-124.

Cremer, K.W., Cromer, R.N. and Florence, R.G. (1978). Stand establishment. In: *Eucalypts for wood production* (eds W.E. Hillis and A.G. Brown), pp. 81-135. CSIRO Div. Build. Res., Melbourne.

Cunningham, T.M. (1960). The natural regeneration of *Eucalyptus regnans*. Bulletin No. 1. University of Melbourne, School of Forestry, Melbourne.

Dixon K.W, Roche S, Pate JS. (1995) The promotive effect of smoke derived from burnt native vegetation on seed germination of Western Australian plants. *Oecologia* 101: 185-192.

Dunlap, J.M. and Helms, J.A. (1983). First year growth of planted Douglas fir and white fir seedlings under different shelterwood regimes in California. *Forest Ecology and Management* 5: 255-268.

Ellis, R.C. (1985a). The relationships among eucalypt forest, grassland and rainforest in a highland area in north-eastern Tasmania. *Australian Journal of Ecology* 10: 297-314.

Ellis, R.C. (1985b). Soil conditions in relation to eucalypt seedling growth check. In: *Current research in Tasmanian high altitude eucalypt forest.,* R.J. Keenan. Proceedings of a seminar held at the University of Tasmania. March 19, 1989.

Ellis, R.C., Ratkowsky, D.A., Mattay, J.P. and Rout, A.F. (1987). Growth of *Eucalyptus delegatensis* following partial harvesting of multi-aged stands. *Australian Forestry* 50(2): 95-105.

Ellis, R.C., Webb, D.P., Graley, A.A. and Rout, A.F. (1985). The effect of weed competition and nitrogen on the growth of seedlings of *Eucalyptus delegatensis* in a highland area of Tasmania. *Australian Forest Research* 15: 395-408.

Felton, K.C. and Lockett, E.J. (1983). Silvicultural practice in Tasmanian eucalypt forests. In: *Facing Forestry's Future, 10th Triennial Conference,* pp. 111-114. Melbourne. Institute of Foresters of Australia, University of Melbourne.

Flint, L.E. and Childs, S.W. (1987). Effect of shading, mulching and vegetation control on Douglas-fir seedling growth and soil water supply. *Forest Ecology and Management* 18: 189-203.

Florence, R.G. (1996). *Ecology and silviculture of eucalypt forests*. CSIRO, Collingwood, Victoria.

Forest Practices Authority (2007). State of the Forests Tasmania 2006. Forest Practices Authority, Hobart.

Forest Practices Board (2000). *Forest Practices Code*. Forest Practices Board, Hobart, Tasmania.

Forestry Commission (1947). *Annual report for the year ending 30th June 1947*. Forestry Commission, Tasmania.

Forestry Commission (1956). *Annual report for the year ending 30th June 1956*. Forestry Commission, Tasmania.

Forestry Commission (1964). *Provisional site index and yield tables for eucalypts in southern Tasmania*. Forestry Commission, Tasmania.

Forestry Commission (1967). *Annual report for the year ending 30th June 1967*. Forestry Commission, Tasmania.

Forestry Commission (1987). Forest Practices Code. Forestry Commission, Hobart.

Forestry Commission (1993). Silvicultural use and effects of fire. Native Forest Silviculture Technical Bulletin No. 11. Forestry Commission, Tasmania.

Forestry Tasmania (2001). Thinning Regrowth Eucalypts. Native Forest Silviculture Technical Bulletin No. 13. 2nd edn. Forestry Tasmania, Hobart.

Forestry Tasmania (2003). Regeneration surveys and stocking standards. Native Forest Silviculture Technical Bulletin No. 6. Forestry Tasmania, Hobart.

Forestry Tasmania (2005a). High intensity prescribed burning. Forestry Tasmania, Hobart.

Forestry Tasmania (2005b). Low intensity burning manual. Forestry Tasmania, Hobart.

Forestry Tasmania (2009a). A New Silviculture for Tasmania's Public Forests: a review of the variable retention program. Forestry Tasmania, Hobart.

Forestry Tasmania (2009b). Remedial treatments. Native Forest Silviculture Technical Bulletin No. 7. Forestry Commission, Tasmania.

Forestry Tasmania (2009c). Stewardship report. Forestry Tasmania, Hobart.

Forestry Tasmania (2010). Eucalypt seed and sowing. Native Forest Silviculture Technical Bulletin No. 1. Forestry Tasmania, Tasmania.

Forests and Forest Industry Council (1990). *Secure futures for forests and people*. Forests and Forest Industries Council of Tasmania, Hobart.

Franklin, J.F., Berg, D.R., Thornburgh, D.A. and Tappeiner, J.C. (1997). Alternative silvicultural approaches to timber harvesting: variable retention harvest systems. In: *Creating a forestry for the 21st century: The science of ecosystem management* (eds K.A. Kohm and J.F. Franklin), pp. 111-139. Island Press, Washington, D.C.

Gibson, A. and Bachelard, E.P. (1987). Provenance variation in germination response to water stress of seeds of some eucalypt species. *Australian Forest Research* 17: 49-58.

Gilbert, J.M. (1959). Forest succession in the Florentine Valley, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* 93: 129-151.

Gilbert, J.M. and Cunningham, T.M. (1972). Regeneration of harvested forests 1. State forests in Tasmania. *Appita* 26: 43-45.

Goodwin, A. (1990). Thinning response in eucalypt regrowth. *Tasforests* 2(1): 27-34.

Grove, S.J. and Neyland, M.G. (2005). How 'natural' is the response of biodiversity to clearfelling and to alternative silvicultural systems in Tasmanian wet eucalypt forest? In: *The International Forestry Review*, Brisbane. Commonwealth Forestry Association.

Harris, S. and Kitchener, A. (2005). *From forest to fjaeldmark: Descriptions of Tasmania's vegetation*. Department of Primary Industries, Water and Environment, Hobart, Tasmania.

Hickey, J.E., Neyland, M.G. and Bassett, O.D. (2001). Rationale and design for the Warra Silvicultural Systems Trial in wet *Eucalyptus obliqua* forests in Tasmania. *Tasforests* 13(2): 155-182.

Hickey, J.E., Neyland, M.G., Grove, S.J. and Edwards, L.G. (2006). From little things big things grow: The Warra Silvicultural Systems Trial in Tasmanian wet *Eucalyptus obliqua* forest. *Allgemeine Forst und Jagdzeitung* 177: 113-119.

Incoll, W.D. (1979). Effect of overwood trees on growth of young stands of *Eucalyptus sieberi*. *Australian Forestry* 42(2): 110-116.

Independent Expert Advisory Group (1997). Tasmania-Commonwealth Regional Forest Agreement. Background Report Part G. Assessment of Ecologically Sustainable Forest Management Systems and Processes: Final Report. Tasmanian Public Land Use Commission, Hobart.

Jackson, J. and Taylor, R. (1994). *Threatened fauna manual for production forests in Tasmania*. Forest Practices Board.

Jackson, W.D. (1968). Fire, air, water and earth - an elemental ecology of Tasmania. *Proceedings of the Ecological Society of Australia* 3: 9-16.

Jacobs, M.R. (1955). *Growth habits of the eucalypts*. Forestry and Commonwealth Timber Bureau, Canberra.

Keenan, R.J. (1986). Review of the shelterwood system and its potential for application in Tasmanian eucalypt forests. *Australian Forestry* 49: 226-235.

Keenan, R.J. and Candy, S. (1983). Growth of young *Eucalyptus delegatensis* in relation to variation in site factors. *Australian Forest Research* 13: 197-205.

Kellas, J.D. (1987). Silvical characteristics of messmate stringybark and narrow-leaved peppermint under partial cutting conditions in the Wombat forest. 1, Establishment report. Research Report No. 326. Research & Development Section Lands and Forests Division Department of Conservation, Forests and Lands, Victoria.

Korven-Korpinen, E. and White, M.G. (1972). Regeneration of harvested forests in Tasmania. II. Forestry practices at ANM Ltd. *Appita* 26: 45-46.

Kostoglou, P. (1996). Historic timber-getting in the Southern Forests. Industry overview and assessment of its technology. Archeology of the Tasmanian timber industry report No. 8. Report to Forestry Tasmania, and the Tasmanian Forest Research Council, Hobart.

Kozlowski, T.T. and Gunn, C.R. (1972). *Importance and characteristics of seeds*. Seed biology. Volume I. Importance, development, and germination, Academic Press, New York and London.

LaSala, A.V., Dawson, J.K. and Goodwin, A.N. (2004). Productivity and economic implications of various silvicultural thinning regimes in Tasmanian regrowth eucalypt forests. *Tasforests* 15: 19-28.

Lockett, E.J. and Candy, S.G. (1984). Growth of eucalypt regeneration established with and without slash burns in Tasmania. *Australian Forestry* 47(2): 119-125.

Lockett, E.J. and Keenan, R. (1985). Silvicultural practices. EIS. on Tasmanian Woodchip Exports Beyond 1988, Working Paper No. 3. Government Printer, Hobart.

McCormick, N.D. (1988). Conditional forest ages. Unpublished report. Forestry Commission, Tasmania.

McCormick, N.D. and Cunningham, J. (1989). Uneven-aged forest management in Tasmania's dry sclerophyll forests. *Tasforests* 1(1): 5-12.

Mount, A.B. (1961). Regeneration surveys for cut-over areas of ash type eucalypt forests. *Appita* 15: 77-86.

Neyland, M., Hickey, J., Beadle, C., Bauhus, J., Davidson, N. and Edwards, L. (2009a). An examination of stocking and early growth in the Warra silvicultural systems trial confirms the importance of a burnt seedbed for vigorous regeneration in *Eucalyptus obliqua* forest. *Forest Ecology and Management* 258: 481-494.

Neyland, M., Hickey, J. and Edwards, L. (2009b). Safety and productivity at the Warra silvicultural systems trial. *Tasforests* 18: 1-15.

Neyland, M.G. (2004). Selection, harvesting damage, burning damage and persistence of retained trees following dispersed retention harvesting in the Warra silvicultural systems trial in Tasmania. *Tasforests* 15: 55-66.

Nunez, M. and Bowman, D.M.J.S. (1986). Nocturnal cooling in a high altitude stand of *E. delegatensis* as related to stand density. *Australian Forest Research* 16: 185-197.

Nunez, M. and Sander, D. (1981). Frost protection in a high altitude *Eucalyptus delegatensis* shelterwood: a preliminary assessment. Dept. of Geography Occasional Paper, University of Tasmania, Hobart.

Nyvold, U. (2001). Alternative Silvicultural Systems in Wet *Eucalyptus obliqua* Forest. An assessment of timber values. Department of Economics and Natural Resources. Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Orr, S. (1991). *Managing your dry forests*. Private Forestry Council, Tasmania.

Pennington, P., Laffan, M., Lewis, R. and Otahal, P. (2001). Assessing the long-term impacts of forest harvesting and high intensity broadcast burning on soil properties at the Warra LTER site. *Tasforests* 13(2): 183-192.

Penny, J.C. (1910). *Tasmanian forestry timber products and sawmilling industry*. Government Printer, Hobart.

Potts, B.M., Vaillancourt, R.E., Jordan, G.J., Dutkowski, G.W., da Costa e Silva, J. McKinnon, G.E., Steane, D.A., Volker, P.W., Lopez, G.A., Apiolaza, L. and Li, J., Marques, C. and Borralho, N.M.G. (2004) *Exploration of the* Eucalyptus globulus *gene pool.* In: Eucalyptus in a changing world. International IUFRO Conference, 11-15 Oct 2004, Aveiro, Portugal. pp 46-61.

Pryor, L.D. (1960). The 'ash-bed' effect in eucalypt ecology. *I.F.A. Newsletter* 2(9): 23-26.

Rodger, G.J. (1929). Forest survey of Tasmania. In: *Report on afforestation and reforestation in Tasmania* pp. 15-110. Development and Migration Commission, Government Printer, Canberra.

Rotheram, I. (1983). Suppression of growth of surrounding regeneration by veteran trees of Karri (*Eucalyptus diversicolor*). *Australian Forestry* 46(1): 8-13.

Select Committee (1959). *Regeneration of eucalypt forests. Report of the select committee of the Legislative Council, Parliament of Tasmania*.

Select Committee (1972). *Forest regeneration. Report of the select committee of the Legislative Council, Parliament of Tasmania*.

Simpson, J. (1991). History of cable logging in Tasmania. *Tasforests* 3: 1-9.

Squire, R. (1990). *Report on the progress of the silvicultural systems project July 1986 - June 1989*. Department of Conservation and Environment, Melbourne.

Steane, S.W. (1932). *Report of the Forestry Department for the year ending 30th June 1931*. Government Printer, Tasmania.

Steane, S.W. (1934). *Report of the Forestry Department for the year ending 30th June 1934*. Government Printer, Tasmania.

Steane, S.W. (1942). *Report of the Forestry Department for the year ending 30th June 1942*. Government Printer, Tasmania.

Steane, S.W. (1945). *Report of the Forestry Department for the year ending 30th June 1945*. Government Printer, Tasmania.

Stoneman, G.L. (1994). Ecology and physiology of establishment of eucalypt seedlings from seed: A review. *Australian Forestry* 57: 11-30.

Stoneman, G.L. and Dell, B. (1994). Emergence of *Eucalyptus marginata* (jarrah) from seed in Mediterranean-climate forest in response to overstorey, site, seedbed and seed harvesting. *Australian Journal of Ecology* 19: 96-102.

Tasmanian and Australian Governments (2007). Sustainability Indicators for Tasmanian Forests 2001-2006. Tasmanian and Australian Governments, Hobart and Canberra, Australia.

Wardlaw, T.J. (1996) The origin and extent of discolouration and decay in stems of young regrowth eucalypts in southern Tasmania. *Canadian Journal of Forest Research*, **26**: 1-8.

Warra Policy Committee (1997). *Warra Charter*. Forestry Tasmania.

Webb, D.P., Ellis, R.C. and Hallam, P.M. (1983). Growth check of *Eucalyptus delegatensis* (R.T. Baker) regeneration at high altitudes in northeastern Tasmania. Information Report No. O-X-348. Great Lakes Forest Research Centre, Canada.

Wellington, A.B. (1984). Leaf water potentials, fire and regeneration of mallee eucalypts in semi-arid, south-eastern Queensland. *Oecologia* 64: 360-362.

West, P.W. and Mattay, J.P. (1993). Yield prediction models and comparative growth rates for six eucalypt species. *Australian Forestry* 56: 211-225.

White, D.A. and Kile, G.A. (1991). Thinning damage and defect in regrowth eucalypts. In: *The young eucalypt report - some management options for Australia's regrowth forests* (eds C.M. Kerruish and W.H.M. Rawlins), pp. 152-177. CSIRO, Australia.

Wilkinson, G.R. (1992). Current trends in the silvicultural treatment of native eucalypt forests in Tasmania. In: *Paper presented to the combined meeting of Australian Forestry Council Research Working Groups 4, 6 and 10*, Creswick, Victoria. December 1992.

Wilkinson, G. (2008). Population differentiation within *Eucalyptus obliqua*: implications for regeneration success and genetic conservation in production forests collection site. *Australian Forestry* 71: 4–15.

17. List of Tables, Figures and Photos

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