Silvicultural Practice in the Jarrah Forest

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DEPARTMENT OF Conservation AND LAND MANAGEMENT
Conserving the nature of WA

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This Guideline supersedes Silviculture Guideline 1/95 and Silviculture Specifications 3/89 and 4/89. The Guideline content is the amalgamation of the three previous guidelines as amended by the requirements of Appendix 5 of the Forest Management Plan 2004-2013.

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1 Introduction

The strategies for the sustainable management of the jarrah forest in areas designated as State forest and Timber Reserves under the CALM Act are contained in the Forest Management Plan (2004-2013)

This document details the silvicultural guidelines for field application, in particular treemarking and silvicultural treatment to achieve the desired forest structure at the coupe level in areas from which timber is harvested.

1.1 Extensively Managed Areas

In areas such as the Donnybrook Sunklands, the proportion of sawlogs in the stand is low. In these areas the opportunity to thin and create regeneration gaps by commercial timber removal is limited. Nevertheless, the principles of these guidelines should still be applied. The resultant forest structure however, will be quite different because of the preponderance of unsaleable culls.

2 Regeneration survey

Detailed planning of the regeneration requirements will facilitate treemarking in areas of uncertain regeneration status.

Treemarking decisions will be significantly assisted by the early identification of areas requiring regeneration (shelterwood) establishment. Appendix 1 is a general guide to their locations. Where regeneration status is uncertain, broadscale ground surveys are necessary.

Ground surveys should be programmed following aerial burning or advance burning with the objective of eventually having all areas surveyed prior to harvesting. Specification 3/90 details this procedure. Appendix 1 provides a general guide as to location of potential shelterwood areas.

Two types of post-harvest surveys of regeneration are required in areas where the silvicultural objective is regeneration release:

- Surveys of effectiveness of regeneration. These surveys will provide data to allow reporting of Key Performance Indicator 10 (Forest Management Plan 2004-2013) *Effectiveness of regeneration in native forest*. The purpose of these surveys is to determine the proportion of the annual regeneration release program that does not meet the required standard for regeneration. These surveys will be based on a sample of areas harvested to regeneration release; and
- Surveys to plan remedial treatments. A sample of 5 percent of the area harvested to regeneration release being those that appear to have the poorest regeneration, based on monitoring of all gaps greater than 2 ha. The purpose of these surveys is to identify those areas that may require remedial treatment.

Regeneration surveys are not required in areas where the silvicultural objective is to:

- Promote growth on retained trees (thinning);
- Release regeneration (gap) but the silvicultural outcome is a selective cut with > 12 m2/ha of culls; or
- Establish regeneration (shelterwood) but the silvicultural outcome is a selective cut with > 12 m2/ha of culls.

3 Integrated harvesting and regeneration plans

Prior to harvesting, detailed plans will be developed for each coupe.

From these plans appropriate silvicultural practices will be determined necessary to sustain appropriate values within the coupe (see Appendix 2).

Coupe planning is refined in the field as more accurate and detailed information becomes available through site inspection. It is important to field check those structural and species characteristics which will affect the prescription to be applied. Assistance from specialists may be required to assess some values.

4 Treemarking

4.1 General

Treemarking is the means by which stand objectives are marked out in the forest so that harvesting and treatment operations can proceed. By marking trees to be retained, a vision of the future development of the stand is provided.

Before marking commences, the management zones appropriate to each part of the coupe must be clearly shown.

Marking guidelines will vary in accordance with these zones (see Appendix 2).

One silvicultural objective will be determined for each group or patch. These are:

- Thinning - to promote growth on retained trees;
- Release regeneration (gap creation) - jarrah regeneration will be encouraged to develop unimpeded into saplings, poles and mature trees by the removal of competing overstorey;
- Establish regeneration (shelterwood) - seedlings will be encouraged to establish and develop into ground coppice by reducing the competition of the overstorey. A forest canopy is maintained to provide a continuity of forest values until the ground coppice is developed and capable of response to release; and
- Retain and promote resistant species and individuals on *Phytophthora cinnamomi* infested forest. The silvicultural method is termed ‘selective cut in dieback’.

The first task in marking a patch of trees is to determine its silvicultural objective (thinning, regeneration release, shelterwood or ‘selective cut in dieback’) and whether its boundaries are apparent. The process for making these decisions is outlined in "*Treemarking and Silviculture in the Jarrah Forest" (1987).*

Only after the objective has been identified for each patch can individual trees be marked.

Marking habitat trees and logs for retention is the first priority in each group or patch (see Appendix 5).

4.2 Marking to Promote Growth (Thinning)

Wherever possible stands should be thinned in preference to regeneration release or shelterwood. Thinning aims to increase the growth of selected crop trees.

4.2.1 Selection of crop trees

A crop tree is one with the capacity to grow vigorously into high value products. The key characteristics to look for are:

- an existing or potential for a well developed crown; and
- a bole capable of producing a high quality product of minimum specification.

Appendix 3 details the criteria for crop tree selection.

4.2.2 Thinning intensity

The desirable retained density of crop trees varies with their size. When crop trees are small, the aim is to grow individual trees rapidly to sawlog sizes. Once crop trees are of sawlog size, the aim is to maximise the growth of sawlog volume per hectare. To achieve that, a relatively higher basal area is retained as the average tree size increases.

Thinning regimes for different crop tree sizes are detailed in Appendix 4. In areas of high visual resource value and salt sensitivity additional trees must be retained (Appendix 2).

4.2.3 Diversity

To maintain diversity, up to 10% of the retained trees may be 'non crop tree' marri. Mark to protect examples of mature native pear, river banksia and examples of snoddygobble, peppermint, large blackboys etc. Additional diversity of size and density of retained trees is required in the first 150 metres of VLM Zone A (Appendix 2).

4.2.4 Technique

Mark to retain fauna habitat trees and logs (Appendix 5), the desired density of crop trees (Appendix 4), and elements for diversity. Where the number of acceptable crop trees exceeds the required thinning density, those of high commercial value need not be marked for retention.

The retained basal area must be regularly checked with a 2-factor prism.

4.2.5 Isolated large trees

Isolated large merchantable trees frequently occur in thinnable patches. Regardless of their crop status, they should be retained as part of the thinning if their removal would cause excessive damage to crop trees or destroy the integrity of the thinned patch. They may also be suitable for habitat trees.

4.2.6 Partially-stocked stands

Where the stocking of crop trees is less than specified in Appendix 4, but at least 50% of that density, all crop trees must be retained and sufficient non-crop trees to keep the stand at a minimum basal area of 10 m^2/ha (15 m^2/ha in the <1100mm rainfall zone).

4.3 Marking to Release Regeneration (Gap Creation)

Regeneration release by gap creation will be sought where there are insufficient crop trees to merit thinning (i.e. less than 50% of required stocking), but where the stocking of ground coppice and saplings will adequately regenerate the gaps created by harvesting.

4.3.1 Technique

Where it is evident that insufficient crop trees exist to enable a thinning, check that the stocking of ground coppice/saplings is adequate then determine the boundaries of the gap. In general, only retain habitat trees within the gap when it is over 1 hectare in size, however, where good examples occur in small gaps they should be retained. Sub-merchantable crop trees with very

good growth potential should only be marked for retention if they can be fully protected during harvesting and burning operations. Crop trees of commercial size will not be marked in gaps.

4.3.2 Gap size

Where the gap would exceed the maximum dimension (Appendix 2) temporary exclusion areas (TEAS) of uncut forest are required to confine the gap to that maximum. These must be at least 50-100 metres across depending on VLM zone (Appendix 2) and will not be available for timber harvesting until the next cutting cycle. Thinned or shelterwood patches also constitute acceptable separation types, provided special requirements apply for the <1100mm rainfall zone (see Appendix 2 and Appendix 4).

Although the precise location of each TEAS will be finally determined in the field, they should be broadly planned beforehand so that they can be designed to fit within a broader framework.

TEAS are to be accessible from current roading and where practical remain within a single hygiene category.

4.3.3 Diversity

Mature secondary storey species (e.g. sheoak) will also be marked and retained undisturbed, preferably in clumps, to enhance stand diversity.

4.4 Marking to Establish Regeneration (Shelterwood)

A shelterwood is created where there is an inadequate stocking of crop trees for thinning and where there is insufficient ground coppice and saplings available for immediate release.

The shelterwood overstorey is retained to provide seed for regeneration and a continuity of forest values until ground coppice has developed to the stage where it is capable of rapid growth following release.

4.4.1 Technique

Cutover stands - retain 8-10 m^2/ha.

Areas with < 8 m^2/ha of suitable shelterwood trees should be treated as shelterwood without harvesting.

Shelterwood trees should be relatively evenly spaced for seed dispersal and spacing should not exceed 1.5 x tree height.

4.4.2 Patch size

Where adjacent to a gap, a shelterwood group should be at least 50 metres in diameter. This may be achieved by not releasing regeneration in a portion of the gap.

4.5 Marking to Retain and Promote Resistant Species and Individuals in *Phytophthora cinnamomi* Infested Forest ('Selective Cut in Dieback')

On sites that are infested with *Phytophthora cinnamomi* it is likely that susceptible species will not persist in the long term. In some cases the loss of the susceptible species will be rapid (a

collapse), and in other instances will be slower and more progressive. The variation in the rate of change has been referred to as differences in 'impact' an observer will see at different points in time, which can be correlated to site and vegetation for which vegetation complexes are a useful surrogate. Therefore, where the predicted 'impact' is high or moderate it is important that individuals and stands of resistant species are retained and protected during any commercial harvesting operation, and any subsequent treatments. The resistant species will form the basis for the vegetation association that will gradually replace the ecosystem dominated by jarrah that was present prior to infestation by *Phytophthora cinnamomi*.

Three categories are recognised.

Protectable sites - sites that are not infested with *Phytophthora cinnamomi* and are considered to be protectable from autonomous spread of the pathogen - apply standard guidelines.

In low or slow impact sites (i.e. where the impact is predicted to be low or where progress to the disease climax state is predicted to occur over > 50 years) - apply standard guidelines.

In high impact sites (i.e. where the impact is predicted to be moderate or high and progress to the disease climax state is predicted to occur over < 50 years).

High impact sites are defined as sites already infested with *Phytophthora cinnamomi* or determined to be unprotectable from autonomous spread of the pathogen in the near future that are not low or slow impact sites.

High impact sites are to be treemarked according to the 'selective cut in dieback' silvicultural method.

4.5.1 Aim

The 'selective cut in dieback' silvicultural method aims to:

- Promote an ecosystem of resistant species on sites infested with *Phytophthora cinnamomi* or sites unprotectable from autonomous spread of the disease in the near future;
- Identify and retain individual trees and understorey plants that appear to be resistant to *Phytophthora cinnamomi*; and
- Retain the productive potential of the forest should the disease impact remain at low by retaining crop trees.

4.5.2 Technique

Irrespective of existing structure:

- Mark 15 m^2/ha of healthy trees with good crown development if they are available. Aim for uniform distribution. Jarrah, blackbutt or marri regeneration over 10 m in height should be included in the basal area count;
- Retain habitat trees as specified in Appendix 5, but with preference for blackbutt or marri. If no suitable habitat trees are present then standing dead trees with similar structural characteristics should be retained;
- Favour the retention of tree species that are not susceptible to *Phytophthora cinnamomi* of crop tree standard, with an emphasis on blackbutt or marri;

- Retain any healthy jarrah, which have survived for a long period on *Phytophthora cinnamomi* infested sites and are exhibiting apparent field resistance to the disease. These trees may form an important genetic resource and potential source of seed;
- Retain any healthy secondary storey species that are susceptible, which have survived for a long period on *Phytophthora cinnamomi* infested sites and are exhibiting apparent field resistance to the disease. These trees may form an important genetic resource and potential source of seed;
- Favour the retention of secondary storey species that are not susceptible to *Phytophthora cinnamomi*; and
- Avoid disturbance to patches of healthy understorey.

Alternative approaches to management of moderate and high impact sites, such as through the Dieback Forest Rehabilitation program funded by Alcoa of Australia, may be considered as part of an adaptive management approach, subject to authorisation by the Department's Senior Silviculturist. Thorough records must be made of when, where and how this approach is implemented.

4.6 Marking in Stands With Small Patches

Frequently the existing stand structure consists of small patches of mature/overmature trees among small patches of thinnable forest, each below the minimum desirable size (i.e. 100m diameter). In these stands the aim is to push the group/gap towards the desirable size.

- Where crop trees are of commercial size and numbers are low, small groups of crop trees may be felled to enhance gap size.
- Where gaps are small and cannot be extended without considerable loss of crop trees, retain trees and avoid creating a gap. These large trees will frequently be required as habitat trees.

Gaps as small as 50 metres in diameter (2 x tree height) are acceptable.

4.7 Eastern Jarrah Forest

4.7.1 Defining eastern jarrah forest

Eastern jarrah forest is a broad description for forest that occurs generally east of the 900 mm rainfall isohyet. Eastern jarrah forest is characterised for the most part by more widely spaced trees and a low herbaceous understorey. The lignotuber pool is smaller and patchier than in the western forest. On the broad slopes it occurs in mixture with wandoo. Some areas contain thickets of sheoak and banksias but these are less common than in the west.

While the impact of climate change is unlikely to be significant in the short term, the change in rainfall and its seasonal distribution is expected to affect the biological diversity, productive capacity, ecosystem health and hydrology of the jarrah forest. This may change the notional representation of the 900 mm isohyet, and increase the area that needs to be treated as eastern jarrah forest. Monitoring climate change will be important in ensuring that the planning and management of these stands are able to be adapted in a timely manner.

Seedling regeneration is more difficult to achieve and its survival is less reliable because seasonal variation (drought stress) is more common and limiting in this area as opposed to in the

western jarrah forest. For that reason greater emphasis is placed on making maximum use of saplings and poles, as well as ground coppice, and creating stool coppice for regeneration. A lower stocking of regeneration is also acceptable in these naturally more open stands.

For the purposes of this guideline, eastern jarrah forest is indicated by:

- *Ecological Vegetation System (EVS)* – Vp1, Vp2, Ip3, Jp2, Jp3 and associated mixed jarrah/wandoo forest W11, W12; or
- *Vegetation Complexes (VC)* – Y5, Y6, D3, D4, DK1, FA1, and associated mixed forest DM2, MH, Pn, Ck.

The map of EVS's and VC's in the corporate geographic information system serves as a starting point for the field determination of eastern jarrah forest which is then subject to field interpretation where appropriate.

EVS Ip3 and *VC* D4 represent a transition type between east and west and occasional thickets of banksia and sheoak will be found in these areas. This unit also contains patches of thinnable poles. Where ground inspection indicates that areas within this unit clearly exhibit the characteristics of the western forest, then the western forest guideline may be applied. In such cases, the Senior Silviculturist with the Forest Products Commission and the Department's Senior Silviculturist should be notified.

Appendix 7 shows the extent and location of the eastern jarrah forest within State forest that is available for harvesting.

4.7.2 Aim

To apply the primary silvicultural objectives, where necessary adapted for the harsher environmental conditions of the eastern jarrah forest, whilst providing for habitat and diversity.

4.7.3 Adaptation to primary objectives

The application of the silvicultural objectives to the eastern forest will be the same as for the western forest except where specified below.

4.7.3.1 Promoting growth on retained trees

Thinning will be applied as follows:

Table 1: Density of crop trees to be retained in areas to be thinned in the eastern jarrah forest.

Mean dbhob of best 150 crop trees/ha	**Target crop tree density**	**Target stand density*# (m^2/ha)**	**Comment**
Less than 20 cm	150 stems/ha	15 m^2/ha (IRZ) 10 m^2/ha (LRZ)	Release 150 jarrah stems/ha from overtopping and crown abrasion. The objective is to maintain healthy crown development on future jarrah crop trees without promoting a permanent low crown break.

20 – 25 cm	12 m^2/ha (IRZ) 7 m^2/ha (LRZ)	15 m^2/ha (IRZ) 10 m^2/ha (LRZ)	This may be a non-commercial thinning. The thinning should leave more than 100 stems/ha but ensures that the stand is not left under-stocked.
25 – 40 cm	12 m^2/ha (IRZ) 7 m^2/ha (LRZ)	15 m^2/ha (IRZ) 10 m^2/ha (LRZ)	This is likely to be both a commercial and non-commercial thinning. The remaining trees are capable of reaching 50 cm dbhob without the stand becoming over-stocked.
> 40 cm	12 m^2/ha (IRZ) 7 m^2/ha (LRZ)	15 m^2/ha (IRZ) 10 m^2/ha (LRZ)	Thin from above where sufficient crop trees occur.

* Target stand density includes crop trees and habitat elements.

Note the requirement for the intermediate and low rainfall zones that 15m^2/ha must be retained on 30 per cent of each second order catchment.

4.7.3.2 Regeneration release

The acceptable stocking standard for regeneration release by gap creation is:
60 percent of sample points stocked at the rate of:

- 200 or more stems/ha of saplings or stool coppice from stumps <30 cm diameter; or
- 350 or more stems/ha of jarrah or marri saplings/stool coppice + jarrah ground coppice, marri or wandoo advance growth.

Greater than 20 percent of the regeneration should be jarrah where the overstorey is predominantly jarrah.

The sizes of patches suitable for regeneration release in the eastern jarrah forest are likely to be small. The aim should be to have patches with a minimum diameter of two tree heights (~50 metres). Where stand structure and regeneration status is suitable, gaps may be up to 10 ha in size.

4.7.3.3 Regeneration establishment

Mark to retain a minimum of 6 m^2/ha of overstorey trees, including habitat trees, with the emphasis to be placed on the retention of healthy jarrah. Retain sawlog trees only if no other suitable trees are available to meet 6 m^2/ha. The aim should be to have patches with a minimum diameter of two tree heights (~50 metres).

4.7.3.4 Unprotectable and **Phytophthora cinnamomi** *infested forest*

There are no required variations for the eastern jarrah forest.

5 Silvicultural treatment

5.1 Timing

Manual culling required in gaps and thinning patches should be carried out after tops burning to improve operator access and safety. Machine treatments must be done before post-harvest burning. All treatments should commence within 2 years of the completion of harvesting.

5.1.1 At the time of harvest

Some silvicultural treatments (e.g. disturbance for shelterwood regeneration, banksia scrub rolling) are better carried out during the commercial harvesting operation rather than as a separate operation and every effort should be made to encourage this where appropriate.

5.1.2 Following harvest

The aim of these operations is to complete the objectives of treemarking, which could not be achieved by commercial operations alone. Unless a stand is fully marked to indicate the silvicultural objective, interpretation for follow-up treatment will be difficult.

Where the silvicultural treatment cannot be fully achieved during the commercial harvesting operation separate treatments following harvesting are required.

5.2 Priorities for Treatment

Only treat those areas which are secure from disturbance (e.g. outside the 25 year bauxite mining envelope) and will remain available for timber production.
Only treat those areas which are either secure dieback free and uninterpretable.
Areas of high quality forest where the potential for growth is greatest.
Areas of shelterwood have highest priority. Regeneration must be established now so that it will be ready for release in the next felling cycle. Areas of thinning have second priority, areas of regeneration release have third priority.
Locate treatment in areas where minimal culling of potentially valuable trees would occur and to allow for a larger area to be completed with the available financial resources.
Areas of high landscape sensitivity where treatment is essential to meet the VLM objective.

5.3 Techniques for Culling

Culling may be done by:

Notching:	preferred where there are predominantly large culls, for very small gaps; and for thinning.
Felling:	*With herbicide treatment of stumps*. Preferred when there are adequate lignotubers available and for culling or thinning in visually sensitive areas (see Appendix 2).
	Without herbicide treatment of stumps. Only where coppice is required for regeneration.
Machine Pushing:	Preferred in gaps where there are a large number of small culls. Machine pushing should be restricted to culls with a

dbh of <30cm to limit the quantity of debris left on the forest floor (the actual limit should be set for each operation). The operator should concentrate on patches where harvesting has achieved most of the gap creation.

Where a significant number of culls exist >30cm in diameter, it may be necessary to follow up the machine pushing with a notching operation to remove sufficient culls to release regeneration.

The technique for establishing regeneration will depend on the availability of seed.

5.4 Protection of Soil, Understorey and Mid-Storey Elements

Mechanical disturbance of the vegetation and soil occurs incidentally during commercial timber harvesting but may also be undertaken after commercial timber harvesting to reduce competition to jarrah advance growth and to enable jarrah seedlings to establish following germination. The shelterwood silvicultural treatment is often accompanied by such disturbance to ensure jarrah seedlings are able to establish and develop a lignotuber.

While it is the intention of the silvicultural treatment to disturb the ground and reduce the competition from understorey species, the impact on flora diversity and abundance can be contained to acceptable levels by implementing the following guidelines:

- Pushing of understorey species to promote regeneration of jarrah will only be undertaken in areas where there is clear evidence of the past presence of jarrah, such as old stumps;
- Balga (*Xanthorrhoea preissii*) thickets should generally be preserved;
- Push down treatments of the understorey will focus on groups or clumps of species such as bull banksia (*Banksia grandis*) and sheoak (*Allocasuarina fraiseriana*) that are impeding regeneration establishment. Approximately 20 per cent of these groups or clumps of species should be retained as small clumps (0.02 hectare) or as scattered individuals. Avoid push down where these species occur as scattered (greater than 10 metres apart) individuals rather than clumps;
- Retain scattered mature individuals of species such as balga, woody pear *(Xylomelum occidentale)*, river banksia *(Banksia verticillata)*, snottygobble *(Persoonia longifolia)*, *Persoonia elliptica*, Western Australian peppermint *(Agonis flexuosa)*, Western Australian Christmas tree *(Nuytsia floribunda);* and
- Disturbance of the topsoil is to be avoided where reasonable and practicable in order to protect the potentially valuable understorey seed store, except in the situation where heavy rootstock regenerating understorey occurs (e.g. tea tree thickets in the southern forest). In this situation, physical disturbance of the top-soil to remove competing rootstock is necessary up to a limit of 50 per cent of the harvested area in a configuration to facilitate even seedling establishment.

5.5 Treatment of Thinning Groups

5.5.1 Techniques for jarrah stands

Remove all competing 'non-crop' trees (J, M, Allocasuarina) within 4m of a crop tree. Remove trees by:

- notching with an approved herbicide; and
- felling and stump poisoning.

Where trees appear to share a common root system with adjacent retained trees, fell without poisoning the stumps. In all other instances, stumps must be poisoned.

Culling by felling and treating stumps with herbicide may only be used where visual resource values are high (Appendix 2) and on burn boundaries.

Culls within 5 metres of fauna habitat trees should not be treated.

Do not individually release around retained trees which are not of crop tree standard.

5.5.2 Techniques for mixed jarrah / marri stands

Remove all culls within four metres of a crop tree that are located more than five metres from a habitat tree using methods described in section 5.5.1 above.

5.6 Treatment of Gaps

The objective is to encourage regeneration by the removal of competing culls, and in some cases coppicing of malformed stems. This can be done either by:

- immediately removing all culls after harvesting; or
- initially removing sufficient culls to allow regeneration to develop into saplings and then in 20-25 years removing remaining culls and releasing saplings to grow into poles.

Where the density of culls is high (>12m^2/ha) treatment should be deferred until more produce has been removed. These patches will be regarded as '**selectively**' cut.

Refer to section 5.4 for the requirements to protect soil, understorey and mid-storey elements.

5.6.1 Techniques for jarrah stands

5.6.1.1 Gap Size 0.25-2ha

Remove any unmarked non-crop trees <50cm in diameter and unmarked understorey such as mature Banksia grandis and sheoak by felling, pushing down or notching. Do not treat within 5 metres of habitat trees.

5.6.1.2 Gap Size > 2ha

As for the above, but only remove the following unmarked culls:

- DBH 20-50cm only if within 15 metres of other trees, including crop or habitat trees or other remaining culls; and
- DBH 10-20 cm if within 7 metres of other trees.

Consider trees less than 3 metres apart as one tree. See Appendix 6 for interpretation.

5.6.2 Techniques for mixed jarrah / marri stands

Where reasonable and practicable, the removal of trees inhibiting regeneration establishment or release, or competing with crop trees, is achieved as part of a commercial operation where they are felled and sold. However, this is difficult if only one species in a mixed stand is commercially desirable. This is the potential situation with jarrah/marri stands, due to very few marri trees being suitable for sawlogs. The availability of a market for marri as chipwood resolved that issue from the mid 1970s until recently when the original market ceased but a smaller one opened up.

Where trees cannot be removed as part of the commercial operation, additional work is required to reduce the competition on developing regeneration or retained crop trees to reasonable levels. This is generally referred to as culling or felling to waste and the trees to be removed are referred to as culls. They may be large trees, intermediate trees or small-sized trees depending on the particular situation.

With the reduced market for marri chipwood, there is a requirement to manage marri in harvesting operations. This must balance:

- the cost and waste, and the loss of biodiversity, resulting from culling; and
- the requirement to reduce competition to enable regeneration of jarrah removed as sawlogs.

The objective is to maximise the area suitable for regeneration with the minimum amount of culling, which will be achieved by implementing the following guidelines:

- No culling is to be done where the total basal area of retained trees remaining after the harvesting operation is more than 17 square metres per hectare as this will result in excessive waste;
- No culling is to be done where the total basal area of retained trees remaining after the harvesting operation is six square metres per hectare or less as it is unnecessary;
- Where the total basal area of retained trees remaining after the harvesting operation is between 17 square metres per hectare and six square metres per hectare then culling is acceptable:
    - in gaps of less than two hectares in area, remove trees less than 50 centimetres diameter that are located more than five metres from a habitat tree; and
    - in gaps greater than two hectares in area, remove trees less than 50 centimetres diameter that are located more than five metres from a habitat tree, while maintaining the total basal area above five square metres per hectare.

5.6.3 Creating stool coppice

Sprouts from malformed stems cut close to ground level provides an effective form of regeneration and should be considered in all areas cut to gap. Where the number or distribution

of ground coppice regeneration is insufficient to meet regeneration requirements, then greater emphasis should be placed on the use of stool coppice for inclusion in the regeneration cohort. This technique should be used to supplement ground coppice and saplings where their stocking is marginal or where it is required to increase the proportion of jarrah in the regeneration.

Stool coppice will tend to be faster growing than ground coppice because it is utilising an existing large root system. Creating stool coppice may be integrated with a notching program of other culls. Creating stool coppice should be applied instead of machine-pushing wherever the stocking of jarrah regeneration is marginal. Falling of malformed stems to create stool coppice is especially required:

- In eastern jarrah forest;
- Where the stocking of saplings and ground coppice is marginal; or
- Where the stocking of jarrah is less than 20 percent of the regeneration.

Where the creation of stool coppice is required, it is to be confined to malformed stems < 30 cm diameter at ground level. Malformed stems are crooked, damaged, forked, misshapen or scarred stems that are not capable of producing a minimum specification sawlog (3 m long).

Stems needed to provide stool coppice should be sawn off by harvester or chain saw as close to the ground as possible. Multiple stems will result, but no further treatment is required at least for the first twenty years, after which time consideration may be given to thinning to one stem per stool.

Where planting has been used as the source of regeneration, but monitoring has shown the form to be poor, then follow-up treatment to create stool coppice may be applied. This treatment should be applied approximately 10 years after planting where there are < 150 stems/ha of saplings with a bole length less than 3 m.

5.6.4 Infilling of understocked patches

All areas identified in post-harvest regeneration surveys as being unacceptably stocked will have under-stocked patches infill planted in the following winter before scrub competition develops.

Planting may be used in gaps to supplement stocking where surveys indicate that stocking is marginally below the target and to increase the percentage of jarrah to at least 20 percent of the regeneration. This option may be most successful in high rainfall forest south of the Blackwood River and east of the Blackwood Plateau, but may be used elsewhere as part of adaptive management trials when authorised by the Department's Senior Silviculturist. Thorough records must be made of when, where and how this approach is implemented.

Where planting is used, plant to bring the stocking up to 1000 stems/ha and allow for some mortality by planting at 1300 stems/ha, which is approximately 3 x 2.5 m spacing. For further details on the planting requirements refer to Section 5.10.

A regeneration survey is to be applied to all areas where infill planting is used, to measure planting success at the end of the summer following planting. All planted areas are to be monitored for stem form, 10 years after planting. Where there are less than 150 stems per hectare of well formed saplings, then create stool coppice by felling malformed and multi-stemmed saplings so that there is a well formed sapling or stool coppice at about 6 m spacing.

5.7 Treatment of Shelterwoods

The objective is to establish regeneration by competition removal, soil disturbance and seedling establishment. Refer to section 5.4 for the requirements to protect soil, understorey and mid-storey elements.

Remove mature *Banksia grandis* and unmarked sheoak.

Where regeneration is adequate in number but too small for immediate release, no additional treatment is required.

Culls should also be removed where total basal area of the shelterwood exceeds 10 m^2/ha.

In areas where there is severe understorey rootstock competition, remove competing rootstock understorey in swathes at least 3 metres wide and not more than 10 metres apart. Preferably use a tracked machine with a rake blade. Do not establish swathes within 3 metres of retained trees. This work must only be done in dry soil conditions to ensure that a receptive seedbed results. Install erosion barriers at the appropriate intervals (see *Manual of Management Guidelines for Timber Harvesting in WA)*

Soil disturbance should be done in dry soil conditions immediately prior to the tops burn. Pushing of banksia should not be done more than 12 months prior to the burn.

5.7.1 Natural seedfall

Examine the developing seed crop and where there is a viable and plentiful crop, aim to burn in spring or autumn.

5.7.2 Artificial seeding

Where there is a poor seed crop or poor success by natural seedfall, broadcast seed is an alternative. Use a cultivator to lightly scarify the soil along the prepared swathes. Simultaneously seed and fertilise using a mixture of:

- 20,000 viable jarrah seed per ha; and
- 400 kg/ha No. 1 superphosphate.

Apply seed and fertiliser to disturbed soil during autumn after burning.

5.7.3 Planting

If necessary plant at the rate of 1000 spha. Planted seedlings should receive the same follow-up treatment as seed regeneration i.e. subjected to regular burns until the lignotuber is sufficiently developed for release.

5.7.4 Establishment survey

For both natural seedfall and artificial seeding, undertake regeneration survey in the following February.

Even where regeneration is established by planting in shelterwood areas, continue to burn on a regular cycle in the same way as seeded establishment.

5.8 Retain and Promote Resistant Species and Individuals in *Phytophthora cinnamomi* Infested Forest ('Selective Cut in Dieback').

On **protectable sites** or **low or slow impact sites** (see Section 4.5) the post-harvest silvicultural treatment will be as specified for areas treemarked to the other three silvicultural objectives.

The 'selective cut in dieback' silvicultural method is applied on **high impact sites**.

The purpose of post-harvest silvicultural treatment in areas harvested to 'selective cut in dieback' is to retain and promote resistant species and individuals in *Phytophthora cinnamomi* infested forest.

In areas where treemarking and harvesting have resulted in the retention of 15 m^2/ha of healthy trees, then no regeneration treatment is required.

In areas where treemarking and harvesting have not resulted in the retention of 15 m^2/ha of healthy trees, then the following work should be considered:

- Determine the status of existing regeneration;
- Identify areas where regeneration stocking is inadequate;
- Undertake seed-bed preparation and plant or seed with *Phytophthora cinnamomi* resistant plants. Where *Phytophthora cinnamomi* resistant seed is proposed for use, then the use of this seed from any locality is acceptable;
- In stocked areas consider the application of fertiliser to approximately 750 stems/ha of established seedlings and ground coppice;
- Where the forest is *Phytophthora cinnamomi* infested and understorey impacts have been high, supplementary seeding with 500 g/ha of local acacia seed;
- Ensure that any site preparation treatments do not result in the loss of resistant seedling coppice or ground coppice and that disturbance to healthy patches of understorey is avoided;
- On infested high impact sites close to an existing track, consider falling and removing dead trees < 50 cm dbhob, so that the likelihood of illegal firewood collection and associated disturbance on the site is reduced; and
- On infested high impact sites with limited ground habitat, consider not burning heaps of log debris.

Fires planned in these areas should be of low enough intensity to have minimal scorch on the overstorey trees.

Alternative approaches to management of moderate and high impact sites, such as through the Dieback Forest Rehabilitation program funded by Alcoa of Australia, may be considered as part of an adaptive management approach, subject to authorisation by the Department's Senior Silviculturist. Thorough records must be made of when, where and how this approach is implemented.

5.9 Eastern Jarrah Forest

The purpose of post-harvest silvicultural treatment in the eastern jarrah forest is to complete the implementation of the silvicultural objectives, where necessary adapted for the harsher environmental conditions of the eastern jarrah forest.

In most eastern jarrah forest, silvicultural treatment will result in a patchy harvest of individual trees or small groups. The final outcome is expected to be small groups of fully treated forest (gaps, shelterwood, thinning) in a matrix of selectively cut forest.

Post-harvest silvicultural treatment of the eastern jarrah forest will be managed in the same way as in the western forest, with the following adaptations.

5.9.1 Promoting growth on retained trees (thinning)

Where promoting growth on retained trees is the silvicultural objective then the post-harvest silvicultural treatment will be to remove competition within a 6 m radius of a crop tree.

Where trees felled as part of the commercial harvesting operation are treated with herbicide immediately after felling to stop subsequent sprouting, or where sprouts from stumps are treated with herbicide during post-harvest silvicultural treatment, great care needs to be taken to ensure that control of sprouts is undertaken only in areas where the silvicultural method is thinning as sprouts are an important source of regeneration in areas with a silvicultural method of gap and shelterwood.

5.9.2 Regeneration release (gap)

In the eastern forest it is unlikely that harvesting will occur over the whole harvest area. In these cases post-harvest silvicultural treatment should focus on the immediate areas where trees have been harvested. The aim should be to create patches with a minimum diameter of two tree heights (~50 metres).

The adaptations to post-harvest silvicultural treatment are:

- Where > 12 m^2/ha of culls remain after harvesting then no culling will be undertaken. Defer culling until more produce can be removed commercially. During the period of deferral, the silvicultural outcome will be regarded as *selectively cut*;
- Gaps of all sizes are treated in the same way;
- Where machine push-down is being considered, creation of stool coppice should be completed first;
- There will be an increased focus on creating stool coppice by falling malformed saplings and other cull trees < 30 cm dbhob; and
- Planting may be considered as part of an adaptive management approach, subject to authorisation by the Department's Senior Silviculturist. Thorough records must be made of when, where and how this approach is implemented.

5.9.3 Regeneration establishment (shelterwood)

In the eastern forest it is unlikely that harvesting will occur over the whole harvest area. In these cases post-harvest silvicultural treatment should focus on the immediate area of harvesting. Every opportunity should be taken to promote the use of coppice to avoid the necessity of establishing new seedlings under shelterwood. The aim should be to create patches with a minimum diameter of two tree heights (~50 metres).

Where it is necessary to undertake regeneration establishment treatment the adaptations to post-harvest silvicultural treatment are:

- Where > 12 m^2/ha of culls remain after harvesting then no culling will be undertaken. Defer culling until more produce can be removed commercially. During the period of deferral, the silvicultural outcome will be regarded as *selectively cut*;
- Where regeneration is adequate in number, but too small for immediate release then apply herbicide to cull trees to reduce the basal area to 6 m^2/ha, except where > 12 m^2/ha of culls remain after harvesting;
- Create stool coppice by falling malformed saplings and other cull trees < 30 cm dbhob to the maximum extent possible in the area requiring establishment of regeneration;
- Where competition control by machine push-down is being considered, creation of stool coppice should be completed first;
- Whilst it is the intention to achieve adequate establishment of new seedlings at the first opportunity, it is recognised that this recruitment may need to be achieved through multiple regeneration events;
- Where possible, plan the harvesting and regeneration establishment treatments to coincide with an adequate seed crop, however in any event the post-harvest burn is to be done within 2 years of the harvest. This reflects the priority to protect the advance growth released through the harvesting, from potential damage that would be caused by delayed burning;
- Where inadequate regeneration has resulted following the post-harvest burn then future recruitment will be achieved by the use of fire, timed to coincide with an adequate seed crop; and
- Infilling of under-stocked patches is not generally required however artificial seeding or planting can be considered as part of an adaptive management approach. Thorough records must be made of when, where and how this approach is implemented.

5.10 Planting Jarrah

5.10.1 Where to plant

Planting of jarrah may be undertaken:

- In gaps with marginal stocking;
- In gaps and shelterwood where jarrah stocking is < 20 percent;
- In shelterwood areas where regeneration establishment is inadequate;
- On landings and snig tracks; or
- On areas rehabilitated following basic raw material extraction.

In the high rainfall zone of the southern jarrah forest, east of the Blackwood Plateau, planted jarrah is expected to develop satisfactorily into saplings. However, elsewhere, planted jarrah may not develop beyond ground coppice for some time or may develop into a multi-stemmed sapling.

Outside the high rainfall southern jarrah forest, jarrah planting may be used as part of adaptive management trials when authorised by the Department's Senior Silviculturist. Thorough records must be made of when, where and how this approach is implemented.

All planted jarrah is to be recorded in SILREC and monitored after 10 years, and appropriate action scheduled where the stocking or form is inadequate.

5.10.2 Seedling quality

Nursery procedures will aim to produce containerised seedlings to the following specifications:

- Seedlings will be grown from seed sourced from the appropriate seed zone (see Appendix 8);
- 10 to 20 cm in height;
- 2 mm or greater in diameter at soil level;
- Single erect stem; and
- Well-developed root ball, which allows seedling to be removed from the tray with soil mass intact.

Unacceptable defects in plants are:

- Multiple leaders;
- Less than 7.5 cm in height; and
- Unthrifty (dehydrated, partially dead, root-bound, with mildew or fungus attack).

Seedlings exhibiting the above defects are to be discarded.

5.10.3 Site preparation

Where planting is to be used to achieve regeneration in regeneration release areas (gap), regeneration establishment areas (shelterwood), in 'selective cut in dieback' areas, or where regeneration surveys after harvesting in areas cut to gaps have revealed under-stocking, some site preparation is necessary to prepare the area before planting. The purpose of this site preparation is to reduce competition from the understorey as well as producing soil conditions suitable for seedling establishment, whilst maintaining biodiversity and soil values. Attention needs to be focused on undertaking only that work necessary to achieve the desired result as too much site preparation may impact on existing advance growth as well as biodiversity and soil values. Disturbance to existing patches of regeneration within the treatment area is to be avoided.

Where it has been determined during the coupe planning process that planting will be the method used to achieve regeneration of gaps, undertake site preparation after harvesting as would be done for shelterwood.

Where regeneration surveys after harvesting in areas cut to gaps have revealed under-stocking, undertake the following work under dry soil conditions and preferably using a tracked machine fitted with a rake blade:

- Scarify in swathes, at least 3 m wide and not more than 10 m apart, those areas that have been identified as under-stocked. If need be these areas are to be identified for the machine operator using flagging tape;
- Do not establish swathes closer than 3 m to retained trees;
- Do not push retained thickets or individuals of sheoak and banksias; and
- Where necessary install erosion barriers.

See Section 8 for rehabilitation of landings and snig tracks.

5.10.4 Time of planting

Before planting commences, the soil must be thoroughly moist (a clod of soil can be formed by squeezing in the hand) to a depth of 25 cm. A silviculture officer should walk over the planting site and examine soil profile moisture before the decision to start planting is made. The planting season is usually limited to the months of June and July. Planting should cease during periods of no rainfall of more than 7 consecutive days in duration, particularly in early June.

Permission to commence planting, or to continue it after July 31st, must be obtained from the Department's Senior Silviculturist.

5.10.5 Care of plants

Plants will be delivered to the field in an enclosed truck to avoid desiccation during transport. Where possible no more than 3 days planting requirements of plants are to be delivered to any planting site in the field at any one time. The scheduling of plant deliveries to the field is to ensure that a minimum number of plants are held in field storage dumps during weekends e.g. (do not deliver 3 days planting requirement on a Friday).

Storage of plants in the field is to be in an easily accessible site protected from exposure, particularly wind and sun. The site chosen must be out of view from roads regularly used by the public or industry, to minimise the risk of theft or vandalism. Plants must be stored as follows:

- Off all road surfaces so that plants are not inadvertently run over;
- Must not be stored in running water or in a position where flooding may occur; and
- Must not be left to dry for a period exceeding 2 days. If delays in planting have occurred, and plants stored in the field have been without rain for a period exceeding 2 days, the plants must be watered.

Records of all plants and their destination must be kept by the Forest Products Commission should any queries relating to quality arise in future.

Either during or at the end of the planting season all plant trays must be collected and returned to the nursery. All rubbish (e.g. tray liners) must be collected and disposed of appropriately.

5.10.6 Method of planting

Planting will generally be by means of a Potti Putki planting spear. Plants must be broken out of plant trays carefully to avoid damage to roots or shoots.

During the planting of seedlings the following requirements must be adhered to:

- It is preferred to plant seedlings on the edge of ashbeds;
- Avoid planting in straight rows;
- Aim to position plants immediately on the edges of any rip lines where possible;
- Plants must not be planted closer than 1 metre to logs and stumps;
- Do not plant beneath the crowns of retained trees;
- Planting lines must not commence within 3 metres of the edge of any road;
- Plants must be planted so that the top of the root mass is 1-2 cm below the soil surface;
- Plants are to be heeled or toed in to remove air pockets from around roots and to ensure they are firmly positioned. Plants should not be able to be removed from the soil when held firmly by the stem and a gentle lifting motion applied;
- The stem of planted seedlings must be vertical or near vertical;
- Regular checks of planting stocking rates must be completed. This must be done at least twice daily on each planting site. The method of assessing stocking will be random point sampling; and
- Spacing will be altered as necessary to ensure the correct stocking is achieved.

Plant trays and liners are to be handled carefully and stacked neatly at the plant dump for later collection.

5.10.7 Fertiliser application

No fertiliser application is necessary following planting in the field. It is standard nursery practice to apply a complete fertiliser (NPK plus trace elements) at the rate of about 0.028 g of nitrogen, 0.013 g of phosphorus and 0.024 g of potassium per seedling about 5 days prior to the seedlings leaving the nursery. This provides an equivalent response to the field application of much larger quantities of fertiliser.

In areas where the edge of the gap has been pushed in during burn preparation or rough heaping has occurred prior to planting then the planted seedlings off ashbeds are fertilised following planting, to supplement for the loss of ashbed. The fertiliser applications used are:

- 50g per tree of Di-ammonium Phosphate (DAP); or
- 25g per tree of Doublephos.

Alternative formulations that provide a similar nutrient dose are acceptable. The Department's Senior Silviculturalist must be notified at the planning stage for each planting season of the intended fertiliser formulations and doses for both nursery and field application.

5.10.8 Monitoring planting density

The planting rate will be 1300 stems/ha unless otherwise specified. This equates to a spacing of 3 m x 2.5 m.

Regular checks of planting stocking rates must be completed. This must be done at least twice daily on each planting site. Random point sampling will be the method used to check the stocking rate. Spacing will be altered as necessary to ensure the correct stocking is achieved.

5.10.9 Re-planting understocked areas

A regeneration survey in early summer following planting is to be applied to all planted or replanted areas to monitor planting success.

Experience has shown that infill planting in the second winter when understorey competition has become established is generally unsuccessful. The lack of success in the first instance can often be attributed to compacted soil. Therefore areas identified for replanting must be ripped during dry soil conditions to improve soil structure and impede developing understorey competition. Ripping specifications (outlined in the Manual of Management Guidelines for Timber Harvesting in WA) are to be complied with.

6 Burning and protection

Burning and protection requirements vary according to silvicultural objectives. The detailed specifications are contained in Specification 1/91. The options available are discussed in *Silvicultural Guidelines for Virgin Southern Jarrah Forest. (1986).*

6.1 Response to Fire Damage in Regrowth

While it is highly unlikely that wildfire will kill healthy jarrah saplings or small poles, it may cause damage to the bole or the growing tip. This is most likely to occur in stands that have been exposed to the centre of the fire front. Damage of this nature can seriously reduce the value of the tree for sawlog production in the future.

All stands that are burnt with moderate to high intensity fire (i.e. sapling or pole stands which are fully scorched, sapling stands burnt with SDI > 1000) should be assessed for fire damage. Where there are found to be < 150 stems/ha of undamaged dominant or co-dominant stems remaining, then do the following:

- Where the co-dominant pole size trees have been dry sided, consider creating stool coppice on stems up to 40 cm dbhob. There is likely to be a component of salvage involved in this operation;
- Where the co-dominant jarrah saplings have had tip damage at < 4 m height that is likely to cause a kink or fork, consider creating stool coppice on jarrah stems;
- Where the stand is predominantly jarrah, consider creating stool coppice on all stems; and
- Where the stand is predominantly marri, consider creating stool coppice on all jarrah stems and all other stems within a 4 m radius of the jarrah.

This work should be carried out as soon as the damage is evident and while access and visibility are still satisfactory. The optimum period is likely to be 12 to 18 months after fire. In sapling stands, the coppice that results will achieve the original height in a short time.

Areas that have been burnt may not display the full extent of damage for some time after the event. All stands that are burnt with moderate to high intensity fire (i.e. sapling or pole stands which are fully scorched, sapling stands burnt with SDI > 1000) should be recorded in SILREC for monitoring 12 to 18 months after the event. Recommendations for treatment (or no treatment) of fire-damaged stands must be considered for endorsement by the Department's Senior Silviculturist.

All areas that are given post-fire treatments must be accurately mapped and recorded in SILREC.

This work should not be undertaken on sites that are planned for mining or on sites infested with *Phytophthora cinnamomi* and where the disease may lead to high impact.

7 Predator control

Increased vulnerability to introduced predators following disturbance has been identified as one of the principal factors threatening the persistence of western ringtail possum and other species in the critical weight range through the timber harvesting process.

Where the Fauna Distribution Information System (FDIS) recommends increased predator control then the additional baiting programme will be implemented as required. The elements include timing, intensity, frequency and spatial extent of baiting (see the Forest Products Commission *Manual for the Fauna Distribution Information System*, when approved).

Increased control of predators before, during and after timber harvesting activity is likely to provide for greater protection and survival for a range of species.

8 Landing and snig track rehabilitation

8.1 Purpose

The purpose of landing and snig track rehabilitation is to provide for the resumption of ecological processes on these areas following harvesting, through the establishment of an indigenous vegetation cover which includes both understorey and overstorey species.

While the return period for the next harvest may be well into the future, many of the landings and snig tracks will remain a part of the infrastructure for future harvesting. For that reason there is no intention to return them to full productivity and stocking from a timber production viewpoint, but to revegetate them to a state where they will contribute a range of the other forest values.

Procedures for the physical rehabilitation of landing sites are described in the *Manual of Management Guidelines for Timber Harvesting in WA.*

8.2 Revegetation

Sow on to recently ripped landings and snig tracks in autumn before the first winter rains, using approximately 1.5kg / hectare of local seed, as outlined below. Simultaneously fertilise with 400 kg/ha of Di-ammonium phosphate (DAP) or an equivalent rate of an approved fertiliser.

Reseeding on landings and snig tracks is aimed at re-establishing the nutrient cycling in the soil by contributing to the carbon and nitrogen cycles. To do this seed should be collected from the local area targeting species with the following attributes:

- Nitrogen fixers;
- Non-mycorrhizal;
- Easy to collect; and
- Likely to accumulate organic matter quickly.

These will include *Allocasuarina*, 4 or 5 *Acacia* species, and 4 or 5 legumes (*Bossiaea*, *Gompholobium*, *Hardenbergia*, *Hovea*, *Kennedia*, etc). The mix will be supplemented with small amounts of jarrah, blackbutt, marri and wandoo seed where the characteristics of particular coupes or landings dictate. It is expected that this sowing will be supplemented by natural seed dispersal from adjacent vegetation to provide establishment of other local species.

The proposed seed mix for all areas to be revegetated is to be approved by the Department's Senior Silviculturalist.

8.3 Monitoring

Success of revegetation is to be monitored no sooner than the end of the first summer following seeding. Monitoring is based on a stocked quadrat method with samples of each landing.

8.3.1 Method

Locate 5 sample points on each landing, subjectively chosen to include 1 plot in what is visually the best, 1 in the worst and 3 plots throughout the range. The centre point of each plot must be selected to allow the whole plot to fit within the rehabilitated area;

- Mark the centre point of each plot;
- Search for understorey plants within a radius of 1.13 m (4 m^2) – the plot is stocked if 1 understorey plant occurs within that area (equates to 2500 seedlings/ha); and
- Search for overstorey plants within a radius of 2.26 m (16 m^2) – the plot is stocked if 1 overstorey plant occurs within that area (equates to 625 stems/ha).

8.3.2 Success criteria

The landing can be recorded as successfully regenerated if at least 3 of the 5 sample plots are recorded as stocked with understorey and overstorey seedlings. The same plot does not necessarily need to be stocked with both understorey and overstorey seedlings for this success criterion to be achieved.

This success rate equates to 60 percent stocking at the rate of 2500 understorey seedlings/ha and 625 overstorey seedlings/ha.

8.4 Remedial Action

- If the landing is not stocked with understorey but is stocked with overstorey no remedial action need be taken;
- If the landing is stocked with understorey but not with overstorey, infill planting is to be arranged for the following winter at the rate of 625 overstorey seedlings/ha; and
- If the landing is not stocked with understorey or overstorey seedlings the landing is to be re-scarified, re-sown with understorey seed and planted with overstorey seedlings at the rate of 625 seedlings / ha in the following winter.

9 Records

Good silvicultural records are essential for future managers to ascertain the condition and needs of the forest without having to undertake detailed assessment. The aim is to have an accurate description of the condition of the forest when the operation is completed. This will allow subsequent adjustments to be made to management if required.

The silvicultural objective of harvesting and completed operations are entered in the GIS database annually as a basis for performance recording and silviculture planning.

10 References

Bradshaw, F.J. 1986. Silvicultural Guidelines for Virgin Southern Jarrah Forest. Technical Report No. 4, Department of Conservation and Land Management, Western Australia.

Bradshaw, F.J. 1987. Treemarking and Silviculture in the Jarrah Forest. Training Brief. Department of Conservation and Land Management, Western Australia.

Havel, J.J. 1975. Site Vegetation Mapping in the Northern Jarrah Forest (Darling Range). 1. Definition of Site Vegetation Types. Bulletin 86, Western Australian Forests Department.

Strelein, G.J. 1988. Site Classification in the Southern Jarrah Forest of Western Australia. Research Bulletin No. 2. Department of Conservation and Land Management, Western Australia.

Appendix 1: A Guide to Silvicultural Objectives

Attribute	Predominant	Silvicultural objective
History and API type	More common in virgin forest of types below	Shelterwood
Site vegetation types	*Northern Jarrah (Havel 1975)* Types: B, F, J D, E, Z on sandy soils H,P with dense sheoak S occasionally with dense banksia *Southern jarrah (Strelein 1988)* Types: X,N,Y K with karri understorey S,Q,I,P with dense understorey and sandy soils	
History	Most virgin or light selection cut 1940 Fire damaged stands	Regeneration release
API Type	Massed stands Pole stands with 30% crown density in upper strata	
Site preparation	Not applicable	
History	Heavily cutover and treated prior to 1940	Thinning
API Type	Pole stands with 20% or less in upper strata (but will contain groups of varying size)	
API Type	Flats, rock outcrops, "C" class forest. S and P stands when upper and lower strata are the same.	Other than timber
Site type	*Northern jarrah (Havel 1975)* Types: A,G,J B (without regeneration) *Southern jarrah (Strelein 1988)* Types R,B,F,A *Sunklands (McCutcheon)* Type 6	

Appendix 2: Jarrah Silviculture Spectrum

	MANAGEMENT ZONES								
SILVICULTURE OBJECTIVE	**VLM A**			**VLM B**		**VLM C**			
Regeneration	VISIBLE 0-150M OR VISIBLE SLOPE >20 DEGREES *	VISIBLE >150m *	NOT VISIBLE *	VISIBLE *	NOT VISIBLE	VISIBLE	NOT VISIBLE	SALT SENSITIVE <1100MM	WITHIN 250M NATIONAL PARK or CONSERVATION PARK
- Gap size	0.2 – 0.5ha (2-3 tree hts)	< = 1ha (2-4 tree hts)	< = 10ha	< 1ha (2-4 tree hts)	< = 10ha	< = 10ha Vary gap size along travel route including log road	< = 10ha	As for VLM Zone	As for VLM A
- Min. TEAS width between gaps	50 metres	50 metres	100 metres	100 metres	100 metres	100 metres	100 metres	As for VLM Zone	As for VLM A
- Min. cutting cycle	20 years 3 stages	20 years 3 stages	20 years 2 stages	20 years 2 stages	10 years 2 stages	10 years 2 stages	10 years 2 stages	As for VLM Zone but min 15 years	As for VLM A
- Post harvest silvicultural treatment	Fell or scrub roll	Fell or scrub roll	Notch, fell or scrub roll	Fell or scrub roll Fell on focal points	Notch or scrub roll	Notch or scrub roll	Notch or scrub roll	As for VLM Zone	As for VLM A
- Habitat trees	Only on edge of gap. Locate to visual advantage	Only on edge of gap	Normal	Normal. Locate to visual advantage	Normal	Normal	Normal	As for VLM Zone	As for VLM A
- Other	Travel route zone up to 20 metres *	Travel route zone up to 20 metres *		Travel route zone up to 20 metres *					
Thinning - Intensity (see Appendix 4)	Retain up to 5m2/ha extra for diversity with variation in size and density	Normal	Normal	Normal	Normal	Normal	Normal	Min 15 m2/ha **	As for VLM A
- Post-harvest silvicultural treatment	Fell and poison stumps	Fell and poison stumps	Notch	Fell and poison stumps first 50m	Notch	Notch	Notch	Notch	As for VLM A
- HABITAT	Normal, prefer close to road	Normal	Normal	Normal, prefer close to road	Normal	Normal	Normal	Normal	As for VLM A
Shelterwood	Normal except travel route zone up to 20 metres *	Normal	Normal	Normal, except travel route zone up to 20 metres *	Normal	Normal	Normal	Normal	As for VLM A
TEAS								30% 2nd Order catchment > 15 m2/ha or not cut	
ACCESS	Rationalise access, close roads/tracks not required, limit access to management areas								
ROTATION	>200 years		> = 100 years						
PRIORITY FOR COMPLETION	High - aim for less than 2 years		Moderate			Low			
PRIORITY FOR RESIDUE REMOVAL	1	3	4	2	4	3	4		

NOTE: * Landscape Planner to assist with design ** See Appendix 4 for detail

Last updated: 5 November 2004
Custodian: Manager, Policy and Practices Branch
Approved by: Director Sustainable Forest Management

Appendix 3: Criteria for Selection of Crop Trees

Select crop trees to retain using the following considerations:

- Crop tree selection is based on the following species priority:
    - Jarrah/Blackbutt (referred to as jarrah in the text);
    - Marri;
    - Sheoak;
- Eucalypt crop trees should be in the dominant level, with a healthy well structured crown. Trees with primary crowns are capable of expansion to take advantage of the space available. Secondary crowns show less capacity for expansion.

Trees with a deep, broad crown grow five times faster than trees with a narrow, shallow crown. Crown vigour is much more significant than bole length.

e.g.

Original diameter	30cm	30cm
Bole length	5m	10m
Crown condition	Deep, broad	Shallow, narrow
Diameter in 20 years	50cm	34cm
Volume on 20 years	63cu.m	5cu.m
Time taken to reach sawlog size (50cm)	20 yrs	100yrs

Crop trees should have a bole free of any defect that would preclude its use for either a sawlog or a pole (minimum defect free bole should be 3m for sawlogs).
In general, larger diameter trees will increase in diameter faster than smaller ones.

Sheoak crop tree selection should be based on the following criteria:

- healthy, well structured deep but narrow crown.

Minimum bole length of 1.8m with at least 50% of the diameter defect free.

Appendix 4: Jarrah Thinning Intensity

Mean DBHOB of best 150 Stems/ha at first thinning	Crop tree basal area (m^2/ha)	Schedule
Less than 20cm	N/A	Release 200 jarrah stems/ha from overtopping and crown abrasion. The objective is to maintain healthy crown development on future jarrah crop trees without promoting a permanent low crown break.
20-25cm	#*10m^2/ha	This will usually be a non-commercial thinning. It will leave more than 150 stems/ha but ensures that the stand is not left understocked. A further thinning will be required before the crop trees reach 50cm dbhob
25-30cm	#*10m^2/ha	This is likely to be both a commercial and non-commercial thinning. The remaining trees are capable of reaching 50cm dbhob without the stand becoming overstocked (50 years). More conservative thinning in the future will maximise sawlog volume/ha
40cm	18m^2/ha	Thin again when crop trees reach 50cm dbhob. Above comments apply
50cm	20m^2/ha	

* An additional 5m^2/ha of the following may be retained:

Trees within 5cm of becoming a power transmission pole or sawlog
Sheoak crop trees
Second grade sawlogs in areas which will have follow-up non-commercial thinning.

\# In the Intermediate Rainfall Zone - 15m^2/ha
In the Low (<900mm) Rainfall Zone - 15m^2/ha - 30% TEAS
- 10m^2/ha - 70%

Appendix 5: Criteria for Management of Fauna Habitat

1. Objective

To ensure the sustained availability of suitable refuge hollows for fauna through the retention of a sufficient number and age structure of trees and ground logs within timber harvesting coupes.

2. Standing trees as habitat

2.1 Characteristics of habitat trees

2.1.1 Definitions

Two types of habitat trees are recognised:

- primary habitat trees, being habitat trees that have a moderate to high probability of bearing hollows; and
- secondary habitat trees, being habitat trees that have a lower probability of bearing hollows at the time of treemarking, but provide for the sustained availability of hollows through time. These trees also contribute to structural diversity in the harvested coupe.

Depending on the silvicultural objective of harvesting both types of habitat tree may need to be retained to ensure the sustained availability of refuges (see 2.2 below).

In all harvest areas, habitat trees receive priority for marking.

2.1.2 Primary habitat trees

Primary habitat trees are those with the physical characteristics to provide a range of habitat niches for fauna. The most important of these are hollows in the braches and bole, which provide refuge and breeding sites for a range of species. Whilst it is important that habitat trees provide a range of sizes of existing and developing hollows, large hollows are least frequently encountered and the retention of trees likely to provide large hollows will also provide a range of hollow sizes. Habitat trees may also provide heavy forks and branches that provide nest construction sites, which may otherwise be limited for many years in a developing regrowth stand. These structural values are especially important for the larger vertebrate fauna.

Priority must be given to trees that show current signs of use by fauna (e.g. possum scratch-tracks), contain visible holes, or broken branch stubs with the potential to develop hollows.

Trees should be mature to senescent, > 70 cm dbhob, tall but wind-firm with a minimum amount of hollow butt, which must be < 50 percent of the circumference at ground level. Leaning trees provide better access for fauna but trees with extreme lean are to be avoided because of their instability. Trees that have major termite infestation should be avoided. Where a choice exists, retain non-sawlog trees as habitat, but do not compromise the quality of the habitat trees to achieve this.

Crowns should show some deterioration including dead branches with obvious hollow formation and be within crown structure categories 3-8 (Figure 1).

No tree species preference need be shown although the treemarker should be cognisant of the composition of the overstorey and the other elements that are likely to be retained following post-harvest silvicultural treatment.

2.1.3 Secondary habitat trees

Secondary habitat trees provide habitat elements, including small hollows for smaller mammals and birds, but have not yet developed large hollows. Secondary habitat trees are retained in addition to primary habitat trees, so as to provide for the sustained availability of a range of hollow sizes, including large hollows, through time. These trees also contribute to structural diversity in the harvested coupe.

Secondary habitat trees should have the following characteristics:

- Crowns should show some potential for deterioration and be within crown structure categories 2-4 (Figure 1), but the trees must be healthy and capable of surviving for a very long time.
- Be immature to mature, 30-70 cm dbhob. Some small hollows and/or broken branch stubs with the potential to develop hollows should be visible;
- Be wind firm with a minimum amount of hollow butt, which must be < 50 percent of the circumference at ground level; and
- Where trees show signs of apparent field resistance to *Phytophthora cinnamomi* these trees should be preferentially retained.

2.2 Rate of retention

On all areas harvested an average of 5 primary habitat trees per hectare are to be marked for retention.

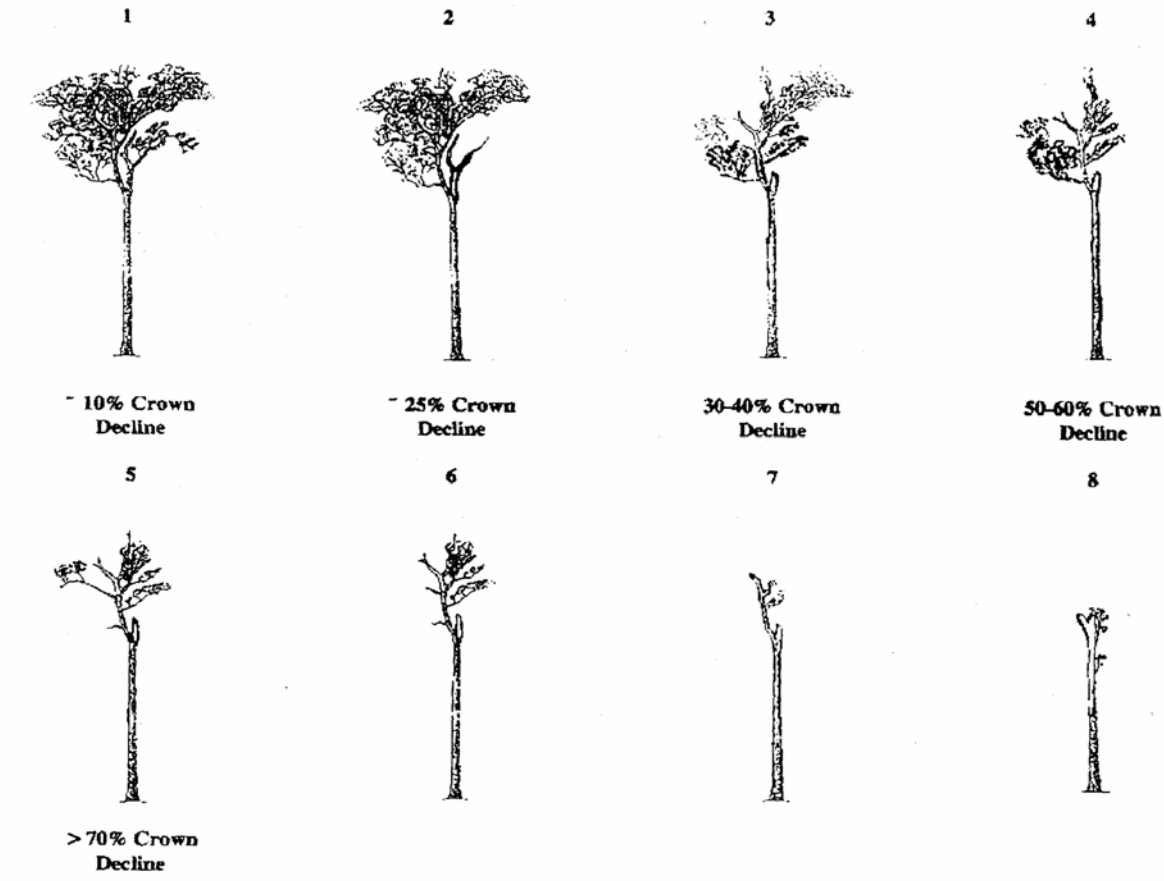
Where suitable primary habitat trees are not present on every hectare, a retention rate of 25 primary habitat trees per 5 hectares must be marked for retention.

On areas where the silvicultural method is gap, shelterwood or ‘selective cut in dieback’, mark to retain 6 to 8 secondary habitat trees per hectare in addition to the retention of primary habitat trees. Secondary habitat trees to meet this requirement should be selected from cull trees, including those that may otherwise be removed in cull removal operations. Marking of secondary habitat trees is not required where the silvicultural method is thinning as appropriate trees with the characteristics of secondary habitat trees will be retained through application of these guidelines.

If insufficient primary habitat trees exist which meet the above criteria, mark additional secondary habitat trees to retain the required total number of habitat trees.

During harvesting and post-harvest silvicultural treatment (including regeneration burns) care should be exercised to avoid disturbance or damage to habitat trees.

Figure 1: Categories of crown structure and deterioration in jarrah trees.



2.3 Pattern of retention

Primary habitat trees must be deliberately marked for retention with a large white "H" and secondary habitat trees marked with a large white "H" (underlined).

Priority should be given to quality over spacing and where possible, habitat trees or small groups of habitat trees should be distributed throughout the coupe. Where post-harvest fuel levels are high, it is preferable to retain habitat trees in groups to facilitate their protection during post-harvest burning, and it is important that tops disposal is carried out to protect these trees or groups from damage that would affect their long-term survival.

Where possible, secondary habitat trees should be retained in association with primary habitat trees as a small group.

In forest that consists of small thinning patches and regeneration gaps of 1 hectare or less, aim to mark habitat trees to form groups near the boundaries of these patches.

Isolated large merchantable trees frequently occur in thinning patches. These may be difficult to remove as part of a harvesting operation without damaging the integrity of the thinning patch.

Where this situation occurs it is preferable to retain these large trees as habitat trees if they meet the selection criteria for a habitat tree, rather than to remove them.

Where the perimeter of a coupe is intended to be a strategic burn boundary then the pattern of retention of habitat trees should recognise the need for subsequent burn security requirements. In this instance trees within the first 100 m of the burn boundary, which catch fire and cannot be extinguished, are likely to be felled as part of the prescribed burn security. Consequently, it is preferable to bias the retention of habitat trees away from the strategic burn boundaries. Where habitat trees are selected close to the boundary bias their selection towards trees with less deterioration in the crown than would otherwise be applicable.

3. Balga (grass trees)

Research has shown that where western ringtail possum occur in the jarrah forest, the dead grass skirts beneath the live heads of balga are regularly used as refuge sites. When used, large multi-headed balga with long unburnt heads are preferred to small balga with recently burnt heads.

Balga are used by western ringtail possum but not by brushtail possum. This may be particularly advantageous for conserving western ringtail possum given that competition with brushtail possum for refuges may have a significant impact on western ringtail possum numbers.

All balga may be used as refuge if adequate grass skirts are present. Any balga may therefore be suitable for retention. Since they are slow growing, the larger balga, particularly those with multiple heads, will take the longest to be replaced if removed and because of their size they are also likely to provide the greatest potential as refuge.

3.1 Characteristics of balga for retention

Where balga occur, the largest (minimum height of 50 cm, but preferably greater than 2 metres tall with multiple heads) should be marked for retention, preferably with intact grass skirt. Only live, healthy balga should be selected for retention.

A thicket of balga has the following characteristics:

- Individual balga are generally greater than 50 cm in height;
- Individual balga are generally close to one another, with fronds touching or in such close proximity that walking between balga is impeded; and
- It should extent over an area of at least 50 metres in diameter i.e. 0.2 hectares.

3.2 Rate of retention

Where suitable balga occur, provide for the retention of at least 4 large balga per hectare. Where possible these are to be clearly marked with a white painted ring and are to be protected from physical damage during harvesting and post-harvest silvicultural treatment.

Thickets of balga should generally be preserved. However, where these patches are extensive and their preservation would compromise achievement of the primary silvicultural objective, they should be referred to the Department's Senior Silviculturist for advice, prior to marking.

3.3 Pattern of retention

Balga should preferably be retained in groups. Where groups occur, groups of 2 to 3 large balga per group are preferable to 4 scattered individual balga. Groups or individuals should be evenly dispersed over each hectare if possible.

Where possible, retain balga in a small group with habitat trees. Groups should ideally comprise primary habitat trees, secondary habitat trees and balga and be distributed throughout the coupe.

Since balga pose no significant aerial hazard during the mop-up and patrol phase of prescribed burning and fire suppression, there are no restrictions on the retention of these in the 100 m strip along strategic burn boundaries.

Where balga thickets occur as a transition zone between informal reserves such as stream reserves or diverse ecotype zones and harvestable forest the balga thickets should be demarcated out of the harvest coupe using white painted crosses. Where balga thickets occur as small patches within the harvest coupe they should be retained in conjunction with other required habitat elements as a habitat group and the thickets should be demarcated with a double white band on individual balga around the outside of the thicket. Where thickets of balga occur extensively throughout a harvest coupe and some disturbance is unavoidable, reliance will be placed on minimising unnecessary disturbance through training of fallers and machine operators.

4. Ground habitat

Ground habitat in the form of hollow logs, stumps and leaning trees are also important refuge sites for forest fauna such as Chuditch, Brushtail Possum and Quenda.

4.1 Characteristics

Logs:

Diameter:	30-100 cm
Pipe diameter:	6-15cm diameter extending into log
Length of log:	pipe at one end – 1.5 metres minimum
	Pipe at both ends – 3 metres minimum

Natural hollow logs appear to be preferred by western ringtail possum compared to logs that have been sawn off.

Stumps and Leaning Trees:
Stumps which have been lifted creating a protection underground cavity due to a leaning tree or some other agency.

4.2 Rate of retention

Where available, retain at least 1 suitable ground habitat log or stump per hectare, even if it shows no obvious sign of use. Retain all natural hollow logs with a pipe > 10 cm diameter and length > 3 m.

All ground habitat logs and stumps that are to be retained must be marked by the treemarker with a large “H”. These marked logs or stumps should not be unnecessarily disturbed by the harvesting activities. They must not be pushed into heaps. This protection of the ground habitat

against disturbance will prevent the habitat being degraded or lost at the time of the next silvicultural burn.

5. Training

Operators should be trained to recognise and retain suitable logs and stumps.

6. Refuge site protection

In areas where threatened species are known to occur, then any proposed fire management must be consistent with the requirements of approved or interim Recovery Plans.

6.1 Advance burning

In forest known to contain populations of western ringtail possum or where there is a high likelihood of populations existing, then advance burning prior to timber harvesting is recommended. This is more likely to provide a mosaic of understorey vegetation age within the landscape, is more likely to leave large balga with unburnt heads and reduces the likelihood that riparian vegetation will be burnt at high intensity during the post-harvest burn. Advance burns should be prescribed to achieve low fire intensities and leave patches unburnt in creeks and swamps.

Where the Fauna Distribution Information System or ground inspections indicate that quokka are using dense vegetation in the stream zones then fire management regimes should be developed to address the presence of this species.

It is important to recognise that where there is a potential conflict between advance burning and *Phytophthora* dieback detection, diagnosis, mapping or demarcation then advance burning will be of secondary importance. In such cases the timing and intensity of any post-harvest burn must be reviewed to ensure that the habitat values are not lost. The most practical method to achieve this will be by tops disposal, and pushing away of debris, and by managing the timing of lighting and the technique to reduce the fire intensity around these features.

6.2 Tops disposal

Tops and other residues larger than 7.5 cm diameter are to be removed for at least 1 m from around marked habitat trees and groups and ground refuge sites to ensure subsequent protection from fire.

Heaps of harvesting debris should be removed from beneath the crowns of retained habitat trees and away from marked logs and stumps during tops disposal operations.

Appendix 6: Guidelines for Culling

Figure 1: Treatment of culls in gaps over 2ha.

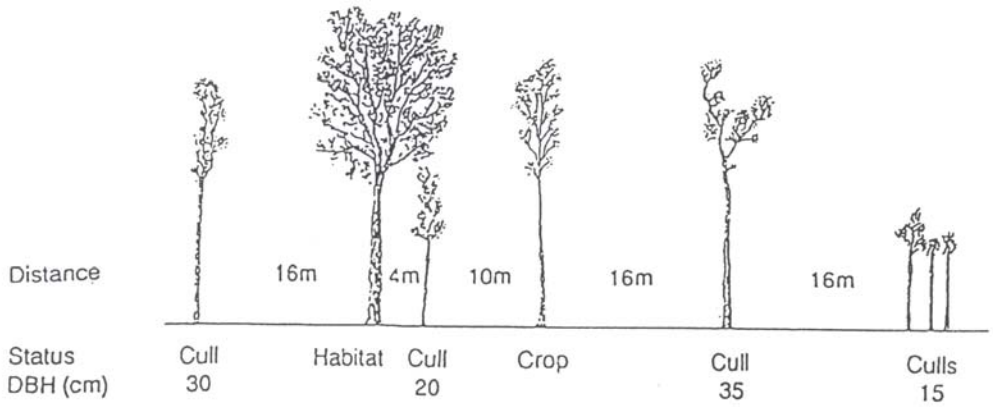


Figure 1A: Gap containing 2-3m²/ha culls which are widely spaced and do not require treatment.

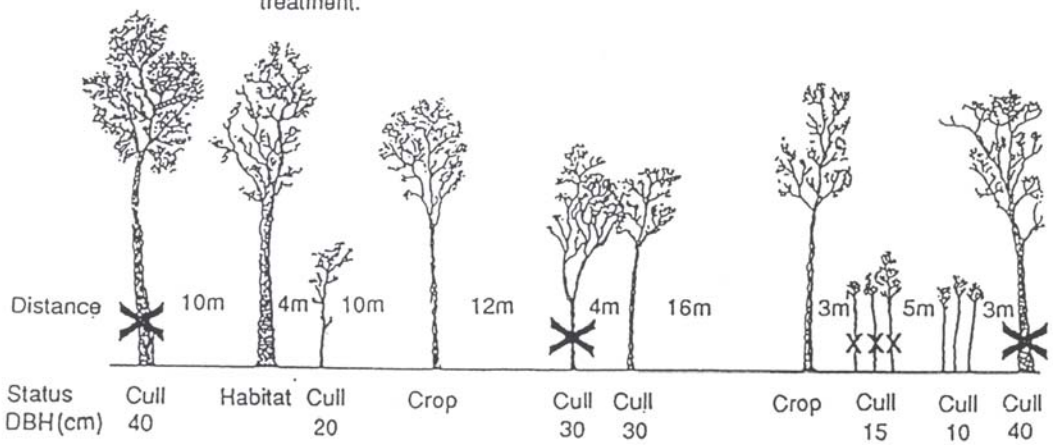


Figure 1B: Gap containing about 8m² /ha of culls, X indicating those to be removed.

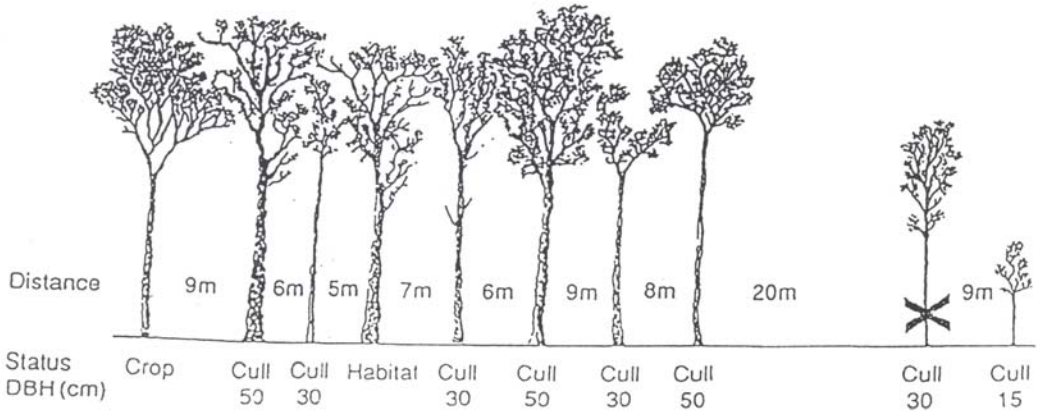
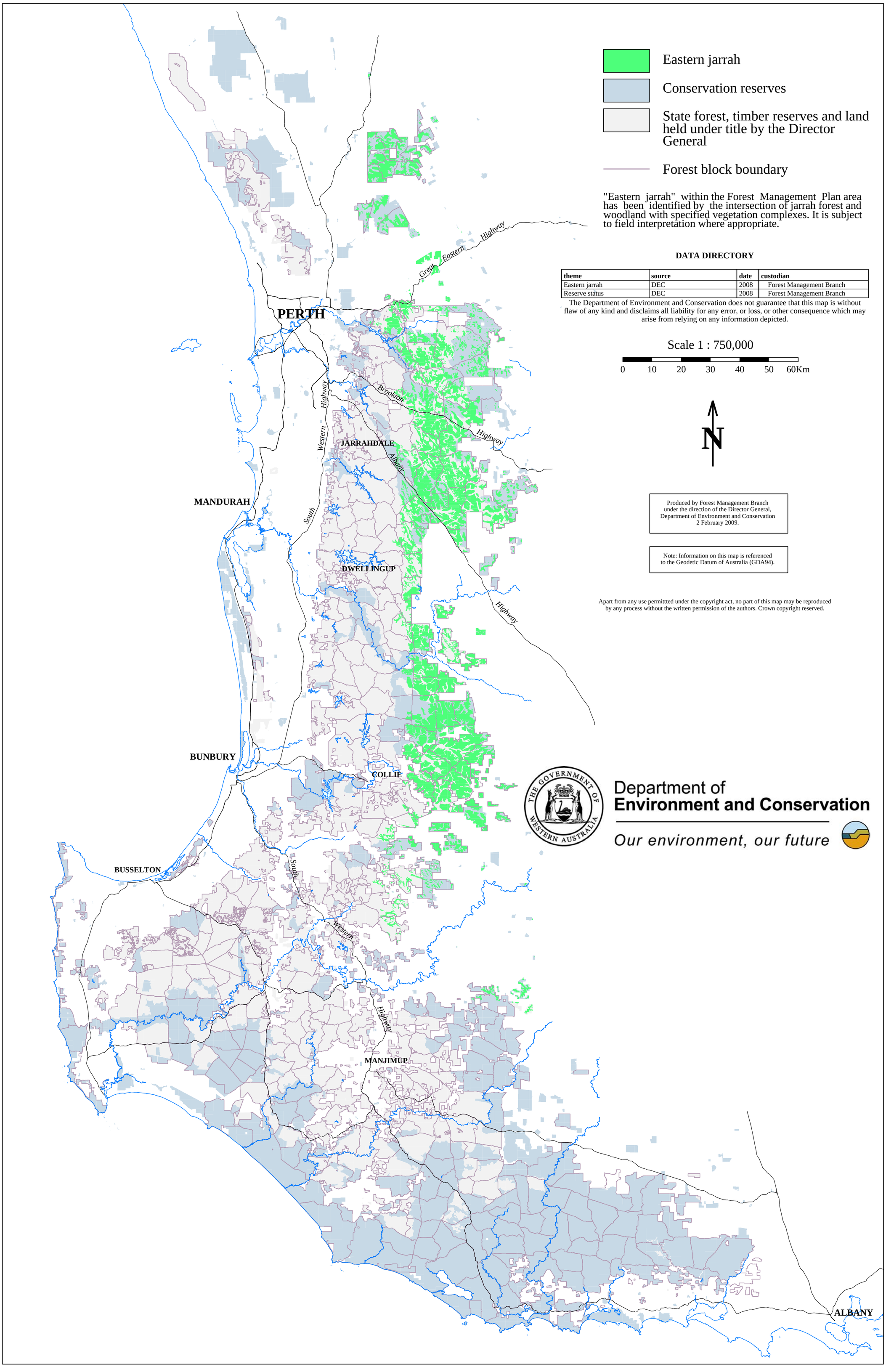


Figure 1C: Gap with a dense group of culls (> 12m²/ha) which should not be treated. Gap at right may be treated if 50 metres in diameter.

Appendix 7: Map of Eastern Jarrah

Supersedes Appendix 7 in Silvicultural Guideline 1/2004



DATA DIRECTORY

theme	source	date	custodian
Eastern jarrah	DEC	2008	Forest Management Branch
Reserve status	DEC	2008	Forest Management Branch

The Department of Environment and Conservation does not guarantee that this map is without flaw of any kind and disclaims all liability for any error, or loss, or other consequence which may arise from relying on any information depicted.

Scale 1 : 750,000

0 10 20 30 40 50 60Km

N

Produced by Forest Management Branch
under the direction of the Director General,
Department of Environment and Conservation
2 February 2009.

Note: Information on this map is referenced to the Geodetic Datum of Australia (GDA94).

Department of
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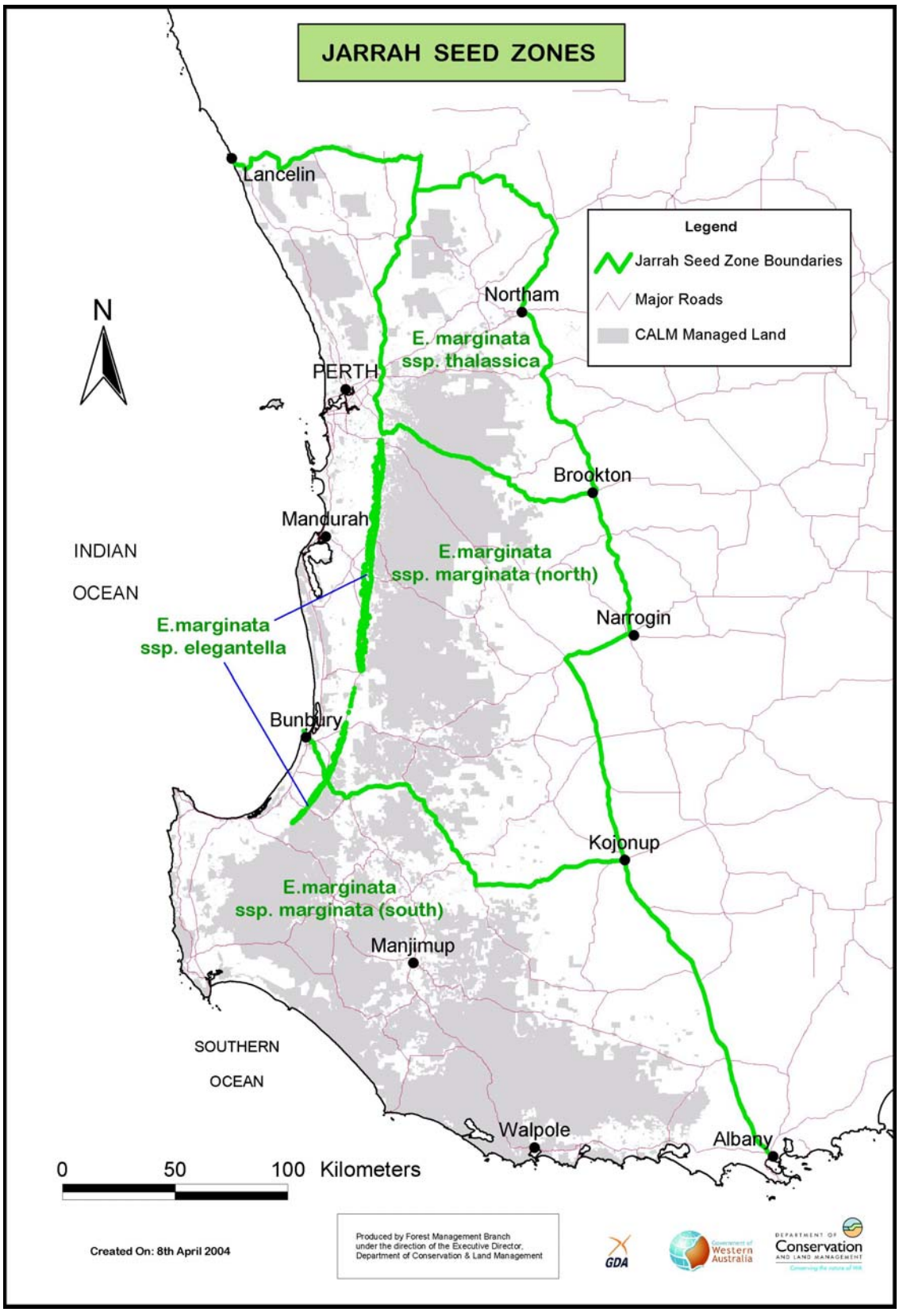
Last updated: 13 February 2009
Custodian: Manager, Forest Policy and Practices Branch
Authorised by: Director, Sustainable Forest Management

Appendix 8: Zones Used for Genetic Management of Jarrah



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