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NATIVE FOREST SILVICULTURE GUIDELINE No. 6

This Guideline documents NRE's policy, principles, and recommended practices for preparing native forest sites for regeneration and reforestation. It sets out guiding principles covering aspects such as seedbed quality, environmental care and timing, then describes the planning requirements. Operational procedures, including appropriate machinery, are given for the full range of site preparation practices, such as burning, clearing, cultivation and chemical weed control. In addition, the recommended procedure for seedbed assessment is given.

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Native Forest Silviculture Guidelines are official NRE documents which have State-wide application. The Forest Research and Development Branch and some Research and Development Action Groups may produce more specific guidelines based on particular forest types; they are complementary documents.

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1 INTRODUCTION

1.1 WHAT IS SITE PREPARATION?

Site preparation is the manipulation of soil and vegetation to provide suitable conditions for the regeneration of eucalypt seedlings from natural seedfall, artificial sowing or planting.

The aims of site preparation are:

- to increase the chance of acceptable germination and survival of seedlings, by providing a seedbed that meets the required standards at the time of sowing or initial seedfall;
- to provide an environment in which factors such as water, light and nutrients, are favourable for the rapid growth of eucalypt seedlings so that they are sufficiently competitive to meet regeneration assessment standards;
- to maintain the quality of soil, water, air, flora and fauna habitat, visual landscape and fire protection in accordance with the Code of Forest Practices and Forest Management Area prescriptions; and
- to provide acceptable seedbeds, growing conditions and environmental care at reasonable cost.

1.2 THE IMPORTANCE OF SITE PREPARATION

Site preparation for regeneration is one of the major tasks undertaken by the Department. Approximately 9 000 ha of native State forest in Victoria receives some form of site preparation treatment each year, comprised of the following:

- *Routine site preparation.* Approximately 7 000 ha of forest is harvested annually using even-aged silvicultural systems (Murphy and Fagg 1996). These areas are routinely site-prepared in some way soon after harvesting;
- *Supplementary site preparation.* A small proportion of the routinely treated sites require supplementary work before sowing or planting, to avoid the much larger cost of later re-treatment;
- *Re-treatment or reforestation.* Routine regeneration operations can fail for various reasons, and otherwise good quality sites can be understocked with eucalypts because of wildfire or past clearing for agriculture. The Department has a program of re-treating or reforesting such sites each year.

A variety of site preparation techniques are used by the Department in this work. Some are widely used and are effective across a range of forest types and circumstances. Others are restricted in their application by cost, availability of equipment or the specialised circumstances required for their use. Inappropriate use of a site preparation treatment can lead to regeneration failure, a loss of site productivity, unnecessary cost or environmental damage.

1.3 PURPOSE OF THIS GUIDELINE

The purpose of this Guideline is:

- to outline the principles of site preparation in native State forests in Victoria;
- to describe planning requirements for site preparation;
- to set out the operational procedures, for each of the main techniques; and
- to detail the requirements for seedbed assessment.

2 GUIDING PRINCIPLES FOR SITE PREPARATION

2.1 POLICY

2.1.1 Code of Forest Practices

Departmental policy regarding site preparation in native State forests is based upon the Code of Forest Practices for Timber Production (NRE 1996). The Code provides the goals and guidelines for site preparation on recently harvested sites (2.2.1), reforestation sites generally (2.2.2), and reforestation sites to be planted (3.1.2.3).

2.1.2 Code of Fire Management

The Code of Practice for Fire Management on Public Land (CNR 1995) must be complied with in relation to use of fire for site preparation. Section 3 (Prescribed Burning) sets out the requirements for planning and safely conducting burning operations.

2.1.3 Code of Safety in Forest Operations

The Code of Practice for Safety in Forest Operations (Dept of Labour 1990) provides 'practical guidance concerning measures to be taken to prevent injury to persons engaged in forest operations' and must be followed by Departmental employees and contractors. It covers silviculture, site preparation, and fire protection, as well as all aspects of forest harvesting and cartage of forest produce.

2.1.4 Departmental Instructions

In addition to the above Codes, two Departmental instructions make reference to site preparation operations, and should be consulted.

Departmental Instruction 01-20-0141-2, "*Planning for Harvesting and Regeneration of Native Forests Using Even-aged Silviculture*" (NRE 1997), contains directions relating to seedbed surveys which refer to this Guideline.

Fire Protection Instruction No. 2, "*Conduct of Departmental Burning Operations*" (CNR 1993), contains guidelines for the conduct of prescribed burning operations in native forests.

2.2 ACCEPTABLE SEEDBEDS

2.2.1 Quality

Where eucalypts are being regenerated from seed, germination and survival is heavily dependent on the type and quality of the seedbed. The top 50 mm of the soil is most critical, as it is the medium for germination and early growth of the young seedling. The presence of litter or live vegetation can prevent eucalypt germination or survival by restricting seed/soil contact and competing with germinants for water, nutrients and light. Compacted soil restricts root growth and shoot emergence, and can reduce the entry of air and water to the soil to levels that will limit germination and growth.

Seedbeds suitable for eucalypt germination and growth are therefore broadly classified as uncompacted bare soil or uncompacted ashbed.

Within these broad receptivity classes, seedbed quality can be described in terms of soil physical, chemical and biological properties. High quality seedbeds will generally have the following soil properties:

- a structure that includes a range of aggregate sizes, so that permeability to air and water, seed/soil contact and adequate water availability are promoted;
- stability to reduce frost heave and soil erosion;
- a high organic matter content that will promote structural stability and ensure that aggregation does not disappear on wetting;
- a roughened surface that will provide microsites that remain relatively moist during hot dry conditions and give some shelter to germinants;
- high friability and therefore low resistance to root growth and shoot emergence; and
- soil microbial populations dominated by beneficial organisms.

Properly disturbed topsoil seedbeds, and burnt seedbeds resulting from moderate and high intensity fires, generally have the above properties.

There is potential to reduce sowing rates on very good quality seedbeds in some forest types (see Native Forest Silviculture Guideline No. 8: *Sowing and Seedfall*). For example, MARDAG (1995a) provides interim guidelines to circumstances where Mountain Ash sowing rates may be reduced by up to 40 %.

2.2.2 Distribution and quantity

The Department's objective for regeneration in even-aged stands is to achieve about 2 500 well-distributed seedlings per hectare by age 2–4 years. Success in doing so is measured against the following regeneration stocking standard (see Native Forest Silviculture Guideline No. 10: *Eucalypt Stocking Surveys, NRE 1997*):

- The target for stocking, 18–30 months following sowing/seedfall is that a minimum of 65 % of 4-milacre (~16 m²) plots, laid out on an 80 m x 20 m grid, should contain at least one acceptable seedling. No discrete area greater than 1 ha should be unstocked.

Site preparation must be directed at helping to achieve this stocking target. The following standard¹ for the distribution and quantity of receptive seedbed applies:

- A minimum of 75 % of 4-milacre plots, should each comprise at least 50 % receptive seedbed types. No discrete area greater than 1 ha should consist of plots < 50 % receptive.

This standard recognises that adequate *distribution* of receptive seedbeds is critical. If 65 % seedling stocking is to be achieved, site preparation should aim to produce a greater proportion of plots (75 %) containing receptive seedbed.

The *quantity* of receptive seedbed in each plot is not so critical; 50 % of a 4-milacre plot (~8 m²) is seen as an adequate area for the establishment of one acceptable seedling. (The 50% can be scattered or all together.)

Section 5 gives more detail on seedbed receptivity and seedbed assessment.

2.3 GROWING CONDITIONS

Site preparation should aim to optimise the growth of seedlings for any given level of investment, provided that environmental care guidelines are followed. A number of site factors can be manipulated to increase growth rates. These include the degree of competition from other vegetation, the structure of the soil, the nutritional status of the soil, and the incidence of browsing and disease.

2.3.1 Competition

Germination and survival of eucalypts may be achieved under a range of competition levels from both eucalypt and non-eucalypt vegetation. However, growth may be severely retarded through reduced availability of water, light or nutrients, or the production of inhibitory substances by roots or litter (allelopathy). The retention of more than about 5 well-distributed mature trees ha⁻¹, or 10 % of the basal area of the original stand, can reduce volume growth of regrowth by 20 % or more (Incoll 1979, Rotheram 1983)².

Competition from understorey species such as grasses, bracken fern, Christmas bush and wattles, may be considerable while seedlings are establishing. Introduced plant species can sometimes compete strongly, and should be controlled. However, it would be undesirable in native forests to try to eliminate non-eucalypt indigenous vegetation for economic and environmental reasons. Some non-eucalypt species may have a positive effect on eucalypt growth (e.g. leguminous species because they fix nitrogen) or wood quality (e.g. by facilitating branch-shed). The aim instead should be to reduce such competition to reasonable levels until the eucalypts are established.

2.3.2 Soil structure

¹This standard replaces the previous standard in CFL (1989b), but will be the subject of further research and review. In particular, the correlation between this seedbed standard and the seedling stocking standard of 65 % of 4-milacre plots needs to be firmly established.

² Methods for the removal of overwood competition are the subject of Native Forest Silviculture Guideline No. 12, and therefore will not be covered in any detail here.

Although there is some variation between species in the most suitable soil conditions for their growth, uncompacted topsoil generally provides the requirements for adequate aeration, water supply and friability.

Exposed, dense subsoils or compacted topsoils generally will not produce reasonable growth rates. If they are extensive enough to reduce productivity at the coupe level, some treatment should be considered to improve soil structure and hence growth rates on such soils (see Section 4.7).

2.3.3 Soil nutrition

Most soil nutrients are concentrated in the soil surface. Removal of topsoil, mixing of topsoil with subsoil, or mixing of litter and slash with topsoil during harvesting or site preparation may lead to a reduction in the availability of nutrients for plant growth.

For example, Raison *et al.* (1991) found that the incorporation of slash into the topsoil on a lowland sclerophyll forest site during rough-heaping reduced Nitrogen(N)-mineralisation, N-availability and plant growth (high C:N ratios having caused immobilisation of N). However, this situation may be only temporary and there can be considerable inputs of N from the atmosphere.

Under different circumstances, disturbance and burning can increase the mineralisation of nutrients. One of the short-term effects of slash burning is to increase the availability of plant nutrients. However, the potential long-term effects of slash burning on sites of inherently low fertility are of some concern. For example, Hopmans *et al.* (1993) predicted that the elements calcium and boron might become limiting to plant growth in as little as two rotations (about 160 years) on one such site.

Site preparation operations need to be sensitive to these soil nutrient effects. For example:

- subsoil should not be exposed during mechanical operations;
- displacement of topsoil should be avoided and the chances of removal of topsoil through erosion should be minimised; and
- potential losses of nutrients and organic matter must be taken into account when considering slash burning on sites of inherent low fertility. Alternatives, such as a type of mechanical site preparation with fertilisers, could be considered.

2.3.4 Browsing

Several species of native and introduced animals can cause excessive mortality and reduced growth rates of seedlings through browsing. This is generally more severe when stocking and growth rates are low. Hence, part of the Department's strategy for control of browsing is the provision of conditions through site preparation, sowing and tending which promote the germination and rapid growth of the eucalypts.

Retaining or encouraging growth of non-eucalypt vegetation for protection or provision of an alternative food source has been shown to be ineffective (Avis 1992). It also provides harbour for browsing animals and produces competition for eucalypts.

If browsing is a problem in an otherwise apparently healthy stand then management/control as described in Clunie and Becker (1991) and CNR (1994a) is warranted.

2.3.5 Diseases

The diseases which occasionally affect the growth and survival of regenerating eucalypts are soil-borne fungal diseases such as damping-off (*Pythium spp.*) and root rot (*Phytophthora spp.*). Site preparation operations that encourage good drainage and dense, vigorous regeneration generally minimise the impact of these diseases (Marks and Smith 1991, Fagg 1987).

Where sites infested with fungal pathogens such as Cinnamon Fungus (*Phytophthora cinnamomi*) or Honey Fungus (*Armillaria luteo-bubalina*) are being regenerated, specific site preparation techniques, such as mounding or stump removal may be warranted and should be determined in consultation with specialist staff.

2.4 ENVIRONMENTAL CARE

2.4.1 Soil erosion

Vegetation removal, soil disturbance and compaction during harvesting may lead to an increased risk of soil erosion. Uncompacted topsoil can be easily eroded where there is increased water run-off on steep slopes.

Mechanical site preparation has the potential to either reduce the chance of soil erosion by reducing compaction and increasing infiltration, or, if carried out incorrectly, increase the chance of erosion by increasing soil exposure, compaction and destruction of erosion controls constructed during harvesting. Site preparation should aim to limit soil erosion to levels that do not affect site productivity or the surrounding environment.

2.4.2 Water quality

Sediment movement must be minimised so that there is no deterioration of water quality in drainage lines and creeks which drain the site preparation area. Where agricultural chemicals are used, their movement off-site to streams through run-off, deep drainage or spray drift must also be kept to acceptable levels through adherence to prescriptions controlling the use of chemicals.

2.4.3 Flora and fauna

Habitat trees should, as far as practicable, be protected during site preparation operations. Their survival during slash burning in particular can be assisted by a number of measures, which are detailed in Section 3.1 of this Guideline.

Larger areas or 'islands' of vegetation (both overstorey and understorey) may be retained for flora conservation and/or fauna habitat. These should also, as far as practicable, be protected during site preparation.

2.4.4 Smoke effects

Smoke from burning operations can adversely affect air quality and visual amenity. The conduct of burning operations close to large population centres may therefore be undesirable under conditions where prevailing winds will not carry the smoke away.

Fire Management Branch is responsible for consultation with the Environment Protection Authority about burning operations in the Port Phillip and Latrobe Valley air-sheds. Constraints on burning may require consideration of alternative site preparation methods.

2.4.5 Fire hazard

Harvesting and site preparation can have an influence on fuel levels and fire hazard. Site preparation plans need to take account of the strategies contained in relevant fire protection plans.

2.5 COST-EFFICIENCY

The cost-efficiency of many site preparation treatments increases with coupe size due to the reduced cost per unit area of travel time, planning and fireline preparation. Further, on small or irregularly-shaped coupes, edge effects from surrounding vegetation can increase the resources needed and the difficulty of obtaining a high intensity burn. Mechanical site disturbance can therefore be more cost-effective than slash burning on coupes less than about 5 ha in size, particularly where there are irregular boundaries (King, 1991).

The size of machinery used in mechanical disturbance and cultivation will also affect cost-efficiency. For every operation there is an optimum size of machinery because, although both machinery hire rates and productivity (hectares per hour) generally increase with size, they do so at variable rates.

Appendix 3 gives machinery classes, power ratings and hire rates for various makes and models of bulldozer.

2.6 TIMING

2.6.1 Importance of timing

The timing of site preparation is determined by timing of harvesting, subsequent weather, soil and fuel conditions and the regeneration requirements of the different forest types. The timing of sowing or natural seedfall and the timing of germination are important factors in obtaining satisfactory regeneration.

In order to maximise the competition-free period for germinating eucalypts, site preparation should be carried out before, but as close as possible to, the optimal time of sowing. However, the timing of site preparation operations can be restricted by cost-efficiency, growing and environmental conditions, so that it may be possible only over a limited period (e.g. slash burning).

Timing is also important in avoiding adverse effects on site productivity or environmental quality. For example, the optimal time of site preparation should be considered in the

planning of harvesting, so that coupes are finished in time to be prepared for regeneration during the same year as logging.

2.6.2 Optimal timing by forest type

The optimal timing of site preparation by Victoria's major forest types, in relation to seed supply and the preferred timing of germination, is given in Table 1. The silvicultural requirements of most of them are described by Campbell *et al* (1984), and McKinnell *et al* (1991).

Table 1 Optimal timing of site preparation by forest type, in relation to seed supply and preferred germination period

Forest type	Optimal timing of site preparation	Seed supply		Preferred germination period
		Preferred method*	Preferred timing	
Mountain Ash (<900m)	late summer/ autumn	artificial sowing	autumn, immediately after site preparation	autumn
Alpine Ash	late summer/ autumn	artificial sowing	autumn/ early winter	spring
High Elevation Mixed Species (and high elevation Mountain Ash)	autumn/ early winter	artificial sowing	early to mid- winter	spring
River Red Gum				
•frequently flooded sites	not required	natural seedfall or artificial sowing	spring	spring
•infrequently flooded sites	autumn/ winter	artificial sowing or natural or induced seedfall	spring	spring
Low to Middle Elevation Mixed Species (including Silvertop-Stringybark, Messmate-Peppermint and Box-Ironbark)	autumn	natural or induced seedfall	autumn	autumn/ winter

*In HEMS and Ash types, induced seedfall from standing seed trees may be used when seed cannot be collected for various reasons.

2.6.3 Operational constraints

Areas harvested at a time unsuitable for site preparation may await site preparation for over 12 months, during which time conditions may become less suitable or impossible for slash burning and require costly mechanical site preparation. However, careful scheduling of harvesting should reduce the occurrence of areas that need to be mechanically treated.

The timing of such site preparation could also be constrained by weather conditions because the work is ineffective and environmentally undesirable under wet soil conditions. However, even in winter, some better-drained sites may be suitable for mechanical site preparation.

Lower intensity broadcast burning and windrow burning may be carried out in autumn and winter.

Reference to 'Decision Flow Charts', where available, should assist in choosing the correct techniques and timing.

3 PLANNING FOR SITE PREPARATION

3.1 SITE PREPARATION FOLLOWING HARVESTING

3.1.1 Developing a site preparation program

Planning for site preparation should be closely linked with planning for harvesting. Forest Management Areas each currently prepare an annual Wood Utilisation Plan (WUP). These WUPs should take into account the resources and optimal timing required for site preparation and regeneration. Annual regeneration plans should therefore be developed in conjunction with WUPs and include a site preparation program.

At budget preparation time, the WUP for the coming year can be used to provide an estimate of resources required for regeneration and sufficient information for a first draft of the regeneration plan.

At the operational level, priorities should be based on the likely duration of the site preparation season, the wetness of the site and flammability of fuels (for slash burning) - often described as the 'window of opportunity'. Therefore site preparation priority should generally apply as follows:

- Priority 1 *Ash and Shining Gum*
- Priority 2 – *High Elevation Mixed Species*
- Priority 3 – *Mid Elevation Mixed Species*
- Priority 4 – *Low Elevation Mixed Species*

Within each forest type the following priorities should apply:

- Priority 1 – *Carry-over coupes and seed-tree coupes (with mature seed)*
- Priority 2 – *Coupes on southerly and easterly aspects*
- Priority 3 – *Routine coupes*

3.1.2 Selection of site preparation treatments

Regeneration 'Decision Flow Charts/Trees' (e.g. CNR 1994b), if available, should be used to help identify the best treatment and timing for site preparation in each coupe in the WUP.

Treatments applicable to coupes after harvesting are:

- broadcast slash burning
- head burning
- rough-heaping
- 'lyrebirding'
- no treatment.

There are two general scenarios in which the decision not to treat an area will be made:

- *The area is already stocked with eucalypts that are likely to survive.*

This may occur when harvesting takes place early in the season and seedlings establish from slash seed under favourable weather conditions or where lignotuberous stocks may be sufficient. In such circumstances a regeneration survey should be carried out before the decision is made. (See NFS Guideline No. 10, p5.)

- *The area already has sufficient seedbed created through harvesting.*

This may occur where very high levels of utilisation are achieved in integrated harvesting operations and on sites of low productivity and understorey development. It should also arise where there has been planned additional disturbance during harvesting. In such circumstances a formal seedbed assessment should be carried out before the decision is made (see Section 5).

A special case exists with River Red Gum forests which experience regular flooding (Table 2). Adequate seedbed can be guaranteed after flooding and seedbed assessments are not required.

3.1.3 Coupe Plans and Burn Plans

Operational requirements for site preparation must be specified in Parts A and B of each *Coupe Plan*. These should detail the method, timing, and any harvesting techniques that can be used to facilitate site preparation.

Such harvesting techniques might include:

- those that facilitate slash burning:
 - a coupe layout that will assist in the control of the slash burn
 - leaving clear pathways for hand lighting crews
 - removal of stags near coupe boundaries
 - ensuring that the prescribed number of habitat or retained shelterwood trees survive by:
 - locating trees near coupe edges or gullies
 - clearing accumulations of slash from around the base of trees
 - selecting sound trees that are less likely to ignite
 - selecting more trees than necessary in anticipation of losing some.
- those that facilitate rough-heaping:
 - felling trees in a direction that facilitates pushing of logging slash.
- those that reduce the need for extra site preparation:
 - creating additional disturbance during harvesting
 - minimising the extent of compacted and subsoil-disturbed areas.

Landing rehabilitation is the responsibility of the Logging Team Leader. Landings should be rehabilitated by using techniques which will provide suitable soil conditions for the establishment and growth of vegetation. These techniques include:

- draining the site;
- dismantling skids;
- dispersing accumulations of bark;
- ripping to reduce soil compaction; and
- re-spreading topsoil.

Landing rehabilitation practices are under review; however, a useful guide is *Landing Management and Rehabilitation* (MARDAG 1995b).

Snig tracks should be properly drained in accordance with FMA Prescriptions. If snig tracks with badly damaged soil structure are extensive enough to reduce productivity at the coupe level then they should also be deep-ripped soon after harvesting, or during rough-heaping or fireline construction.

If there is some doubt as to the effectiveness of site preparation, or if there is a delay in sowing, coupes should be assessed against seedbed standards following site preparation and before sowing (see Section 5.3).

Burn Plans (Form 1230) are required for all coupes where prescribed burning is intended. Such plans contain a map of the area to be burned, and incorporate the specifications and conditions under which the operation is to be conducted. Full details are set out in Section 3.2.2 of the Code of Fire Management (CNR 1995).

3.2 SITE PREPARATION FOR REFORESTATION/BACKLOG REGENERATION

3.2.1 Developing a reforestation program

Each FMA Management Plan should include a strategy, including targets, for the reforestation and backlog regeneration³ of unstocked or understocked areas. This strategy should provide guidelines for determining priorities on the basis of economic and environmental considerations. Annual reforestation programs should include the highest priority areas consistent with the available level, of resources such as finance, seed, and equipment.

The standards to be used in identifying unstocked or understocked areas are given in Native Forest Silviculture Guideline No. 10: *Eucalypt stocking surveys*.

3.2.2 Selection of site preparation treatments

Usually, reforestation involves a number of site preparation treatments such as:

- clearing
- rough-heaping
- root raking
- chemical control of grass, herbaceous and small woody competition
- cultivation / ripping

Though not strictly site preparation treatments, fertilisation of seedlings and browsing control may also be considered in the planning stages. Treatments will vary, depending on whether the site is to be sown or planted. MARDAG (1992b), reviews the current practice, and is also generally applicable to species other than Mountain Ash.

3.2.3 Reforestation/Backlog Regeneration Plans

A Reforestation/Backlog Regeneration Plan must be completed for each coupe or area before work commences, as required by the Code of Forest Practices (2.2.2). It should include details of:

- preferred timing of operations
- clearing technique
- debris disposal
- cultivation (if required)
- remedial or follow-up treatment (if required).

Where commercial harvesting of timber is involved, the area should be included in the WUP and a Coupe Plan prepared in addition to the Reforestation/Backlog Regeneration Plan.

4 OPERATIONAL TECHNIQUES & PROCEDURES

Site preparation techniques must provide suitable conditions for germination, survival and growth of eucalypts while maintaining environmental quality. The most appropriate and cost-effective technique that can be used for a particular area will depend on several variables such as:

- the size and shape of the area to be prepared;
- the size, quantity, distribution and moisture content of logging slash and litter;
- the size, quantity and distribution of any remaining unwanted live vegetation;
- any requirement for improvement of site productivity.

Tender documents for contract site preparation operations must refer to the need for the contractor and his/her employees to follow the *Code of Practice for Safety in Forest Operations*, which covers risk assessment and control, machine safety, personal protective equipment, and training and supervision.

The techniques available, where they might be used and indicative costs, are summarised in Table 2 and are described in the following sections.

4.1 BROADCAST SLASH BURNING

4.1.1 Description of technique

Broadcast slash burning is the burning of logging slash, litter, and other fuel right across a coupe.

This method is the most cost-effective for clear-felled and seed-tree coupes of regular shape greater than about 5 ha in area.

The amount of material burnt is determined by the intensity of the burn, which is affected by the moisture content and size distribution of the fuel. Generally high intensity burns are carried out to produce slash-free ashbeds and to reduce competition from understorey or overwood. Usually, they may be safely carried out only in late summer or autumn. They are dependent on the sufficient curing of slash (at least 4–6 weeks), the availability of fine fuels and the absence of dense understorey regrowth.

³ 'Backlog regeneration' refers to retreatment of coupes that have failed to regenerate satisfactorily. Funds are disbursed annually for reforestation plus backlog regeneration of coupes older than 5 years.

Table 2. Details of common site preparation operations in native forests

Operation	Where applied	Method/equipment	Indicative cost (\$/ha 1998)*
Broadcast slash burning	Small clear-felling or seed-tree coupe (<15 ha)	hand or aerial ignition	150
	Large clear-felling, shelterwood, or seed-tree coupe (>20 ha)	hand or aerial ignition	80
Head burning	Selection logging coupe	hand ignition	160
	Clear-felling or seed-tree coupe with light slash	hand ignition	80
Windrow burning	Cleared reforestation site or rough-heaped coupe	hand or aerial ignition	50
Rough-heaping	Clear-felling or seed-tree coupe - light slash	100kW bulldozer with root-rake	350
	Clear-felling or seed-tree coupe - heavy slash	130kW bulldozer with root-rake	700
Clearing	Light scrub	Windrow/heap with 100kW bulldozer	460
	Heavy scrub	Windrow/heap with 130kW bulldozer	800
	Pole to mature size vegetation	Track, chain and windrow with 130kW bulldozers	1700
Root-raking	Cleared reforestation sites or rough-heaped coupes	100kW bulldozer with root-rake	120
Lyrebirding	Crusted mineral soil surface	Boot scuff	40
	Litter and/or weed covered surface	Rake-hoe	90

Table 2. Detail of common site preparation operations (cont'd)

Operation	Where applied	Method/equipment	Indicative cost (\$/ha 1998)*
Cultivation - deep ripping -mounding /discing -shallow ripping + mounding - deep ripping + mounding	Gradational soil type	Wing-rip to 50 cm depth (100kW bulldozer)	140
	Duplex soil type	Wing-rip to > 50 cm depth (130kW bulldozer)	160
	Adequately drained site	Small mound plough/discs (100kW bulldozer)	160
	Poorly drained site	Large mound plough (130kW bulldozer)	180
	Adequately drained site	Wing-rip and small mound in one pass (130kW bulldozer)	180
	Poorly drained site	Wing-rip and small mound in one pass (150kW bulldozer)	230
Chemical weed control See App. 4 for chemical trade names and toxicity data.	Pre-planting grass control in reforestation or backlog regeneration	Broadcast or strip spray with glyphosate + simazine	140
	Post-planting grass control	Strip or spot spray with fluazifop butyl	150
	Pre-sowing grass or wattle control	Broadcast boom spray with glyphosate	100
	Pre-sowing blackberry control	Broadcast boom spray with triclopyr or metsulfuron	320
	Pre-sowing bracken control	Broadcast boom spray with metsulfuron + glyphosate	150

* Direct costs- labour, materials, vehicle and machinery hire

4.1.2 Operational procedures

The Fire Management Branch of the Department is responsible for issuing standards and guidelines for the planning and conduct of prescribed burning operations. Key reference documents in this regard are:

- Code of Practice for Fire Management (Section 3)
- Fire Protection Instruction No. 2, "*Conduct of Departmental Burning Operations*".

In addition, most Regions have developed complementary guidelines to cover such aspects as: local approvals and notifications, resources, control lines, fuel moisture contents, weather conditions, and lighting methods/patterns, etc.

Appendix 1 deals with those aspects of burning operations (including safety issues) relevant to site preparation, and must be read in conjunction with the above documents.

4.2 HEAD BURNING

4.2.1 Description of technique

Head burning is the burning of logging slash, litter, and vegetation in small areas within a coupe.

The lighting of fuels is carefully controlled to limit the intensity and spread of the fire from heads to the surrounding vegetation. This method avoids burning of vegetation that has been retained as growing stock, such as in selection silvicultural systems, and helps to protect flora and fauna values in even-aged silvicultural systems.

Head burning may also be used in situations where a broadcast slash burn may be desirable but fuels are too light to sustain a high intensity burn. This method may be used in conjunction with disturbed soil seedbeds produced during harvesting. Head burning is preferred to broadcast slash burning in low productivity forests where nutrients need to be conserved, but by itself it may not produce enough receptive seedbed to meet minimum seedbed standards.

Head burning may be used in conjunction with disturbed soil seedbeds produced during harvesting.

4.2.2 Operational procedures

See **Appendix 1** (p. 37), which sets out details of the recommended methods and the necessary safety precautions.

4.3 ROUGH-HEAPING

4.3.1 Description of technique

Rough-heaping is the pushing by machinery of logging slash (predominantly) into heaps or windrows. The heaps may or may not be subsequently burnt.

Rough-heaping may be carried out in intensively harvested areas (such as clear-felled coupes) where:

- slash and vegetation are difficult to burn, e.g. on damp aspects or on coupes harvested over more than one season, where fine fuels have disappeared and live vegetation such as dense wattle, dominates;
- harvesting finishes after the burning season;
- regeneration is likely to be more successful on disturbed soil than on burnt seedbeds;
- maintenance of air quality is critical;
- fire risk to valuable assets warrants treatment with alternative methods;
- site fertility is low and the loss of nutrients is to be minimised.

Where *selection silvicultural systems* are used, the need to protect retained overwood and growing stock may preclude the use of fire for site preparation. Logging disturbance may provide sufficient receptive seedbed, but if not, additional soil disturbance by limited rough-heaping may be required.

4.3.2 Identification of treatment areas

To ensure efficient use of machinery and to prevent damage to retained vegetation, the boundary of treatment areas and individual retained trees should be marked. Generally, markers used to regulate the harvesting operation will be adequate for identification of treatment areas unless the coupe is to be treated by more than one site preparation technique.

4.3.3 Suitable operating conditions

Care must be taken so that the adverse effects of harvesting on soil structure are not compounded during rough-heaping. One aim of rough-heaping should be to ameliorate any adverse changes in soil structure caused by harvesting. The use of rough-heaping may be limited by steep slopes, rock, extremely heavy slash, poor visibility or wet soil conditions.

Operations should be restricted to periods when soil moisture is low enough to promote soil friability. A rough, crumbly, mineral earth surface should be produced. A smooth, glazed surface is unacceptable. *Use of a root-rake in preference to a blade will increase the quality of the seedbed and extend the upper range of soil moisture under which an acceptable result will be obtained.* Topsoil should not be heaped up with vegetation.

A measure of the suitability of the seedbed is its strength or resistance to insertion of a steel probe, under moist soil conditions (see Seedbed Surveys - **Appendix 2**). A friable surface will be easily penetrated by the probe, but a smooth, glazed (i.e. compacted) surface will resist penetration.

4.3.4 Selection of machinery and implements

The machinery and implements selected for a rough-heaping operation depend on the following factors:

- the presence or absence of large logs (related to whether the harvesting was integrated or sawlog only, and the level of defect in the original stand)
- any requirement to push over large trees
- whether logging slash or live understorey vegetation dominates the material to be heaped
- the steepness of, and access to the site.

Although bulldozers are generally used for rough-heaping, other machinery may be suitable for some tasks. For example, excavators can be fitted with attachments to clear vegetation, move or heap logs and rip the soil (see Section 4.6).

Machinery must be fitted with the required protective structures and be operated by qualified operators (Dept of Labour 1990).

Machine power requirements

Generally, clear-felled or seed-tree coupes will require a bulldozer of 100 kW power (Caterpillar D6D or equivalent—see **Appendix 3**) or more, for efficient heaping of large quantities of slash.

Coupes with large amounts of residual logs or tree pushing will require bulldozers of 130 kW power or more (Caterpillar D6H or equivalent). However, on steeper slopes and/or highly dissected terrain, larger bulldozers may be limited by their manoeuvrability. It may be better to choose a smaller machine and rely on the assistance of downhill pushing in such circumstances.

In selectively harvested coupes where there are only light accumulations of slash and the main objective is to provide soil disturbance 50 kW bulldozers (e.g. Caterpillar D3) or machines of similar capability are suitable.

As a general principle, the lower the ground pressure of the machine the less compaction and the more suitable the machine is for the task. In general, the higher the power rating of the machine the greater the ground pressure. *For example, the ground pressures of some Caterpillar bulldozers with standard width tracks are:*

- D6H - 59 kPa
- D7H - 73 kPa
- D8L - 104 kPa

These ground pressures can be reduced by increasing track width or selecting the model with low ground pressure configuration. Ground pressure can also be reduced by selecting tracked machines instead of wheeled machines and flexible-tracked instead of rigid-tracked machines.

Pushing/ripping implements

The choice of pushing implement will also influence the quality of the job. Bull blades are generally more efficient than root-rakes for pushing large logs but the quality of seedbed produced may be poor and large quantities of soil may accumulate in windrows and heaps. *Apart from this situation, root-rakes are the preferred implements for seedbed preparation.* Suitable designs for root-rakes are given in Section 4.6.4.

Where an excessive area has been compacted by logging machinery and rehabilitation is not the responsibility of the harvesting contractor (e.g. on snig tracks), the rough-heaping machine should be fitted with rippers. Refer to Section 4.7 for guidelines on ripper selection. Generally, deep sandy soils will require deeper ripping (up to 100 cm depth) than loamy or clayey soils (up to 50 cm depth) to alleviate heavy compaction by logging machines.

4.3.5 Rough-heaping procedure

*Rough-heaping should aim to produce at least 75 % of the area clear of logs, heavy slash and live vegetation. Within this area at least 50 % should be receptive seedbed (uncompacted topsoil). The operation must be monitored to ensure that the treated area meets the minimum seedbed receptivity standard (Section 5.3 and **Appendix 2**), or will meet the standard if the heaps are burnt and there is a reasonable prospect of doing so.*

Windrows and heaps should be formed to the following specifications:

- at 20° - 40° to the contour on slopes over 12° (*to restrict soil erosion, and reduce the risk of logs rolling downhill*)
- debris packed tightly (*to reduce their area and to enhance burning without stoking*)
- not wider than 6 m (*to maintain site productivity*)
- minimal soil accumulation (*to minimise topsoil removal*)
- no closer than 20 m to retained regrowth, reserves and boundaries, and 6 m to retained habitat trees (*to protect this vegetation from fire damage*)
- spaced at approx. 50m intervals (*to minimise the time spent in pushing fallen vegetation and logs whilst maximising the rate of heaping*)
- long windrows to have gaps at least every 100 m and at least wide enough for machine access (*to assist in possible later thinning operations or firefighting access*).

The following slope restrictions should apply:

- soils of moderate to high stability - up to 30°
- soils of low stability - up to 22°

All overwood not required for habitat, seed or other management purposes should be felled, pushed over, ring-barked or poisoned. (See NFS Guideline No. 12: *Treatment of Unmerchantable Trees* for further information.)

If compacted areas, other than on landings, are extensive enough to reduce productivity they should be ripped or loosened to a suitable depth as indicated in Section 6.2.3. Riplines should be on the contour. All erosion controls constructed at the time of harvesting should be maintained to prevent the concentration of run-off. All buffers along streams, drainage lines, reserves and other areas marked for exclusion must not be disturbed during rough-heaping and must remain free of debris.

Disturbance should be restricted to the top ~10 cm of the soil and must result in a rough rather than a smooth surface to assist in the germination process. Incorporation of undecomposed plant material into the topsoil should be avoided.

Burning of windrows and heaps is not essential if they are kept to less than 6 m in width (tree roots can utilise the soil under such heaps). However, burning can reduce the fire hazard, provide some growth boost, and allow easier access to the future stand for later silvicultural operations such as thinning. For burning procedures, refer to **Appendix 1 - Burning Operations.**

4.4 CLEARING

4.4.1 Description of technique

Clearing is the mechanical removal of live vegetation and subsequent pushing of this vegetation and other debris into windrows or heaps.

Clearing differs from rough-heaping in that predominantly live vegetation rather than logging slash is removed. It is generally carried out on sites to be reforested and those which have failed to regenerate adequately after routine site preparation (see Figure 1).

4.4.2 Identification of treatment areas

Stocked areas as small as 100 m² may be excluded from clearing depending on their position and whether they can be easily delineated. Often it will be more practical to instruct machine operators to avoid such areas (under adequate supervision), because they will be difficult to identify and mark before clearing.

Any trees to be retained for management purposes should be marked, especially where harvesting is integrated with clearing.

4.4.3 Suitable operating conditions

The same guidelines apply to clearing as to rough-heaping (see Section 4.3.3).

4.4.4 Selection of machinery and implements

Similar guidelines apply to clearing as to rough-heaping (see Section 4.3.4), though one key difference is the greater abundance of live vegetation in reforestation areas. When this material is generally less than 10 cm dbh it is most effectively removed and heaped using a blade. Blades will be more efficient than root-rakes in detaching and heaping such dense vegetation and will generally produce a reasonable seedbed because uprooted vegetation leaves the surface soil in a loose condition. However, larger material, such as tree-size wattle, may be more effectively removed by *chaining*, followed by windrowing.

4.4.5 Clearing procedure

The same guidelines apply to clearing as to rough-heaping (see Section 4.3.5).

4.5 LYREBIRDING

4.5.1 Description of technique

Lyrebirding is the localised, manual removal of litter and/or vegetation and the sowing of seed in small spots located across a coupe or part of a coupe.

Lyrebirding is used as a supplementary treatment in coupes to boost existing stocking or increase the amount of receptive seedbed. Small sections or dispersed parts of coupes may be treated by lyrebirding at a lower cost than by other methods of site preparation.

Lyrebirding will only be effective in controlling small live vegetation (e.g. wattle germinants) and should not be used in coupes with well-established competing vegetation. Thus the technique will not usually be applicable to carry-over coupes or areas identified as understocked in stocking surveys.

Figure 1 A cleared/rough-heaped coupe, in the Bendoc area, which failed to regenerate to a satisfactory standard. 1991



Figure 2 A suitable heavy duty root-rake fitted to a bulldozer. Tyne spacing is 30cm. 1995



4.5.2 Identification of treatment areas

Identifying treatment areas where lyrebirding is used in coupes that already contain areas with suitable seedbeds or some regeneration may be a difficult task. Maps prepared during seedbed assessments could be used to identify and mark out treatment areas, or clear guidelines could be given to crews for deciding which areas to treat.

4.5.3 Lyrebirding procedure

Lyrebirding spots should be located with a view to producing spacing at the desired overall stocking rate while using areas which are relatively free of vegetation and litter (provided they are not compacted). The desired density of spots is 1200 per ha (~3m x 2.8m) where lyrebirding is the only source of stocking and proportionally less where seedlings from lyrebirding will only partially contribute to the overall stocking.

Spots are prepared with rake, rake-hoe or boot scuff to produce a rough, uncompacted mineral soil seedbed free of live vegetation including rootstocks. The treated spot should be a circle or square of ~1 m²—any smaller will allow adjacent vegetation to compete with the seedlings.

For sowing rates and methods refer to NFS Guideline No.8: *Sowing and Seedfall*.

4.6 ROOT-RAKING

4.6.1 Description of technique

Root-raking is the removal of unwanted sticks or vegetation, usually after clearing or rough-heaping, by a heavy-duty rake attached to the front of a tracked machine. A root-rake allows most soil to pass through the rake, thus minimising the shifting of top soil.

Where cultivation, e.g. ploughing, is to be carried out, root-raking may remove debris which could impede the cultivation operation. The vegetation and debris removed by the root-rake may be distributed across the site in small heaps, or large quantities may be deposited in the same heaps or windrows established during clearing.

Root-raking is used to roughen-up a surface after clearing, or in its own right where non-eucalypt vegetation has germinated prior to sowing or planting. It is preferred to lyrebirding where competition is likely to be severe or extensive and on larger areas. Root-raking is carried out as close as possible to the planned time of sowing or planting.

4.6.2 Identification of treatment areas

Selection of treatment areas may be based on the results of seedbed surveys (see Section 5.3 and **Appendix 2**).

Large contiguous areas of receptive seedbed (> 1 ha) in an otherwise unreceptive coupe should be marked in the field to prevent unnecessary treatment. Smaller areas of receptive seedbed (down to 100 m²) should not be re-treated, but need not be marked - the machine operator can be advised to avoid these.

4.6.3 Suitable operating conditions

The same guidelines apply to root-raking as to rough-heaping (see Section 4.3.3). There is an opportunity to overcome the adverse effects of harvesting or other mechanical compaction if the soil is friable.

4.6.4 Selection of machinery and implements

Root-rakes are generally designed as multiple-purpose tools for pushing and scarification and often are custom-built to suit a particular type of machine. Thus the root-rake/machine combinations generally available are for 100 kW bulldozer or greater. These machines have more power than is required for root-raking. Smaller machines (50 kW bulldozer or greater) would be adequate if fitted with the correct implement.

The root-rake should be designed to produce a roughened, crumbly surface. Generally rake teeth should be far enough apart (~40 cm) and long enough (~30 cm) to allow filtering of small slash and accumulated soil through the rake and which will prevent smoothing of the soil surface by accumulated debris. A suitable root-rake is shown in *Figure 2*. Blade-mounted rakes are available and have proved effective in the Otway Ranges (White 1996).

A recent development has been the mounting of a root-rake (with winged tines) on the boom of a tracked excavator-base (Holden 1997). This rake can be pushed or pulled and any soil can be shaken out before the slash is finally heaped. Further field trialling of this equipment is, however, necessary before it could be widely recommended.

4.6.5 Root-raking procedure

The same guidelines apply to root-raking as to rough-heaping in respect to:

- seedbed standards
- windrow specifications
- treatment of compacted areas
- slope restrictions
- degree of disturbance.

On sites that have been previously rough-heaped or cleared, raking should be done approximately parallel to the contour within the limitations imposed by windrows/heap locations. On sites where erosion is likely to be a problem, undisturbed strips 1.5 m wide should be retained on the contour at 12 to 15 m intervals.

4.7 CULTIVATION (RIPPING, MOUNDING, DISCING)

4.7.1 Description of technique

Cultivation is the physical manipulation of the soil to improve the germination of seed, or the ease of planting and the survival and growth of seedlings.

Cultivation is either carried out in strips to coincide with planting rows, or over all the area to be sown. In general, cultivation can only be used where there is little accumulation of slash such as on cleared reforestation sites or rough-heaped coupes.

Cleared sites to be planted are sometimes cultivated in order to increase the chance of securing an economic return on the high investment in clearing, the purchase of planting stock, and planting.

The type of cultivation is matched to the soil properties of the site. Deep ripping and mounding is carried out on poorly drained sites. On better-drained sites ripping alone may be used, but ripping in combination with mounding or discing is often used to improve soil drainage, weed control and planting efficiency. Root-raking (Section 4.6) is also a form of shallow cultivation.

Cultivation may also be carried out on compacted or subsoil-exposed areas in coupes. In these circumstances, deep ripping (in dry conditions) to at least 50 cm depth with a winged ripper is the preferred method.

Cultivation prior to sowing is used in River Red Gum forests not subject to regular flooding. This operation involves disc-ploughing to create a cloddy surface which may remain receptive for up to two years.

4.7.2 Selection of treatments, machinery and implements

Cultivation treatments, machinery and implements commonly used in native forest site preparation are given in Table 3. Figure 3 shows a mound plough.

Table 3. Cultivation operations in native forest site preparation

Operation	Objective	Machine power	Implement
Ripping			
Shallow ripping (up to 50 cm)	Alleviate compaction	100 kW or greater	Chisel plough or winged ripper (winged ripper preferred)
Deep ripping (up to 100 cm)	Alleviate compaction and increase drainage in dense subsoils	130 kW or greater	Winged ripper
Mounding			
Small mounds (mounds up to 1.5 m wide x 0.25 m high)*	Improve soil structure, reduce frost frequency, increase nutrient availability and reduce competition	100 kW or greater	Small mound plough
Large mounds (mounds 2.0 m wide x 0.50 m high)	As above plus improved drainage	130 kW or greater	Large mound plough
Ripping and mounding	Provide advantages of ripping and mounding in one machine pass	130 kW or greater for shallow ripping 150 kW or greater for deep ripping	Winged ripper and small mound plough
Discing/Ploughing			
Shallow discing	Weed control, improve soil friability	50 kW or greater	Connor Shea 'Small Giant' or equivalent
Deep discing	Improve soil structure to 20 cm depth	100 kW or greater	Connor Shea 'Giant' or equivalent

* mound height refers to unconsolidated height measured from furrow either side of mound to top of mound

Figure 3 Small mound plough (Manufactured by 'Savannah') working over rip lines in the Yarram area. Mounted on the hydraulic system of a Komatsu D60E bulldozer. 1991



Figure 4 A receptive seedbed – moderate burn intensity, with vigorous Silvertop seedlings, in the Club Terrace area. 1996



4.7.3 Timing of operations

Cultivation should be carried out when soil moisture conditions will lead to an effective result.

If the site is to be sprayed after cultivation, then sufficient time should be allowed for regeneration of competing species prior to spraying. In the absence of spraying, the time between cultivation and sowing/planting should be minimised to take greatest advantage of any weed control given by the treatment.

For effective cultivation the soil needs to be sufficiently dry so that it is friable (i.e. it should break down into smaller aggregates during cultivation). The opportunity for effective cultivation of subsoils (i.e. deep ripping) is relatively limited because of their greater depth and clay content, however, suitable conditions are generally available during late summer and autumn.

4.7.4 Cultivation procedure

Cultivation should be carried out on the contour except on poorly drained sites. On poorly drained sites, cultivation lines should slope at 3–4° into drainage lines for controlled drainage of the site. On these sites consideration should be given to orienting rows to avoid wind ‘tunnels’ and toppling of seedlings under wet, windy conditions.

Cultivation lines should be at intervals consistent with:

- planting espacement (rows are usually 3 m apart)
- need for access by other machinery between the cultivation lines.

Where deep ripping and mounding or discing are to be carried out as two separate operations on a site, deep ripping should be carried out first, followed by ploughing which should be centred over the rip line.

The following results should be *avoided* during soil cultivation:

- Excessive cloddiness which will lead to difficult planting conditions, and air pockets around plant roots.
- Open rip lines or trenches which are an indication of ineffective cultivation, poor subsoil shattering and lifting of displaced soil to the surface.
- Pulverised soil (soil broken down into very small aggregates or primary particles), which provides a very poor environment for plant growth. (This condition is a result of cultivation at too low soil moisture content, or use of an inappropriate implement.)

Cultivation should not be carried out within 5 m of drainage lines, within 20 m of streams or on unstable slopes where excessive soil movement may occur. In general, clearing and rough-heaping boundaries will delineate the boundary of cultivation areas except where cleared slopes are too steep for safe cultivation operations.

4.8 CHEMICAL WEED CONTROL

4.8.1 Description of technique

Chemical weed control is the treatment of competing vegetation with herbicides.

Chemical weed control is reserved for situations where competition is likely to be excessive and mechanical treatment or burning alone will be ineffective, more costly or likely to cause environmental problems. Although chemical control is also generally confined to areas with good access such as on rough-heaped or cleared sites, manual spot spraying on burnt coupes may be an option.

Broadcast spraying may be carried out on windrowed sites by a boom mounted on the back of a tractor or under aircraft travelling parallel to the windrows. Spraying may also be carried out using a hand-held hose from a vehicle-mounted spray unit.

Sometimes spraying is limited to strips or spots located where planting is to be carried out in order to minimise the cost of the operation. The non-spray, wiping method is appropriate in some situations such as bracken areas. The chemical type and rates are chosen to control the spectrum of weeds on the site and to prevent toxicity problems to eucalypts.

Situations where chemical weed control may be used in native forests are:

- High elevation and red gum sites with grassy understorey. Vigorous grass competition may smother eucalypt regeneration. Spraying followed by mechanical disturbance should increase the chance of regeneration success.
- Bracken areas. On cleared sites where dense bracken is likely to be a problem (competition with seedlings and harbour for browsers). The most effective means of reducing this competition before sowing, re-sowing or planting may be by spraying or wiping with rope-wick equipment.
- Blackberry sites. Dense blackberry growth is most effectively controlled by spraying. Dead canes can then be cleared or burnt to prepare a seedbed at a suitable time after spraying.
- Wattle competition. Control of wattle seedlings that develop after seedbed preparation, but before sowing, may be particularly beneficial on HEMS sites where there can be a long delay between site preparation and sowing.
- Ex-pasture sites. The control of grass and other agricultural weeds/plants on ex-pasture sites is essential for successful eucalypt establishment. This is generally carried out after cultivation and after germination and regrowth of competitive species has occurred. Spraying prior to cultivation may be required for species that only grow in summer.
- Enrichment planting/sowing. Where planting or spot sowing is used to boost natural regeneration but disturbance of the whole coupe is not desired, spot spraying may be used. (See NFS Guideline No.9: *Eucalypt Planting.*) Where spot sowing is planned, lyrebirding will be needed.

4.8.2 Identification of areas to be treated and protected

Areas needing treatment may not occupy the entire area, in which case they should be clearly marked in the field.

4.8.3 Selection of chemicals and application rates

Only herbicides registered for use on the target vegetation should be used, at rates and by methods in accordance with the product label. The *Forestry Pesticide Manual* (Manderson and Hateley 1987) should also be referred to.

Chemicals and rates recommended for some common weed control situations in native forests are:

- grass (pre-planting) - glyphosate + simazine (1.5 + 3 kg a.c./ha)⁴, or amitrole + simazine (2 + 3 kg a.c./ha); (simazine should not be used on areas to be sown)
- grass (post-planting) - fluazifop (1 kg a.c./ha)
- bracken - glyphosate CT (2.2 kg a.c./ha + 1% Pulse surfactant)
- blackberry - triclopyr (170 mL/100L), or metsulfuron methyl (10g/100L)
- wattle seedlings - glyphosate + simazine (1.0 + 3 kg a.c./ha); or clopyralid (3 kg a.c./ha) applied to the soil.
- thistle species - MCPA + clopyralid (0.7 + 0.1 kg a.c./ha)

Appendix 4 lists trade names and other data for the above herbicides.

Eucalypts are less sensitive to clopyralid than wattles are. This may be used to selectively treat wattles amongst eucalypts. However it is advisable to avoid spraying eucalypt foliage.

Some chemical mixtures are effective in controlling a range of weed species. For example a mixture of glyphosate and metsulfuron methyl may be used to control a range of annual and perennial weeds (including bracken and blackberry).

Native Forest Silviculture Guideline No. 9: *Eucalypt Planting*, contains some further information in relation to chemical weed control prior to planting. NFS Guideline No. 12: *Treatment of Unmerchantable Trees*, contains information relating to the chemical treatment of unwanted trees.

4.8.4 Chemical application procedures

The handling and application of chemicals should comply with the chemical label, FMA prescriptions and the *Forestry Pesticide Manual*. Certain herbicides require users to hold an *Agricultural Chemical User Permit (ACUP)*. For more information, contact the Regional Chemical Standards Officer.

⁴a.c.=active constituent.

Mixing rates, calibration and machine travel speeds should produce spraying rates that are consistent with manufacturer's label recommendations for the control of the target vegetation. Spraying must be carried out under conditions that prevent excessive drift and volatilisation of chemicals, and maximise contact with the foliage (for foliar absorption sprays) or soil (for root absorption). **In general, do not spray:**

- if wind is gusting, is in excess of 10 kph, or direction is variable
- if air temperature is less than 10°C or exceeds 25°C
- if foliage is wet, due to frost or rain, or there is a possibility of rain within 12 hours of spraying (foliar spray)
- if soil is saturated (soil-absorbed chemical)
- if wind is calm or temperature inversions exist (which may lead to prolonged suspension and off-site drift of ultra-fine chemical droplets).

Correct timing of chemical application is important for optimal weed control and to allow for appropriate follow-up treatment. For example:

- Grass is generally sprayed in the autumn prior to root-raking or after cultivation and prior to winter planting. In coastal areas, summer grasses may have to be sprayed in summer before cultivation.
- Silver wattle should be sprayed in early autumn before autumn or winter sowing.
- Blackberry control is best carried out in summer before seed set.
- Bracken can be sprayed with glyphosate in summer or autumn but follow-up cultivation should be delayed as long as possible, up to 6 months, for the treatment to have best effect.

Sometimes the situation requires the control of a number of species with different growing seasons and chemical requirements. In such cases one must decide whether to spray with a mixture of chemicals and accept a sub-optimal response of one or more species or conduct more than one spraying operation.

5 SEEDBED ASSESSMENTS

5.1 WHY ARE SEEDBED ASSESSMENTS NEEDED?

Together with 'seed supply' and 'conditions for seedling survival', 'seedbed' is the essential third factor in determining the success of any regeneration operation (by seed).

Seedbed receptivity declines over time, from the time of site preparation, at a rate depending on site preparation technique, climatic factors, and species of colonising plants. *In most forest types, sites burnt or soil-disturbed in autumn will not have adequate receptivity 9 months later.* On unreceptive seedbeds, even the use of extra or highly viable seed will result in very few or no seedlings. Therefore, sowing on weed or litter covered seedbeds, or where the soil is heavily compacted, is extremely wasteful (Squire *et al.* 1991, p8).

For a site to become satisfactorily stocked with seedlings, an adequate quantity and distribution of receptive seedbed should be present (see Table 3), as determined by a seedbed assessment .

Seedbed assessments are used to:

- assess the type, quantity and distribution of seedbeds;
- determine the need for, and assist in the planning of supplementary site preparation prior to sowing;
- identify sites with good quality seedbeds where sowing rates may be reduced.

The Department's requirements and recommended procedures for seedbed assessments were previously described in CFL (1989), Squire *et. al.* (1991) and MARDAG (1992a). The requirements and procedures listed below supersede these.

5.2 SEEDBED TYPES AND STANDARDS

Receptive seedbeds are generally described as 'bare, uncompacted topsoil' or 'uncompacted ashbeds.' Table 3 contains descriptions of the seedbed types likely to be encountered during seedbed assessment and indicates their receptivity. Figure 4 depicts a 'moderately burnt' (receptive) seedbed.

The minimum acceptable standard for seedbed receptivity is:

- **at least 75% of 4-milacre (2.27 m radius) plots assessed should comprise at least 50% receptive seedbed, and**
- **there should be no large (> 1 ha), contiguous areas of plots <50% receptive.**

Unless the site is to be planted, seedbed assessments are required for:

- *clearfelled, seed-tree and shelterwood coupes*♦
- *backlog regeneration operations*
- *reforestation areas.*

♦ For systems that rely on induced seedfall, there will usually be no opportunity to do any supplementary preparation prior to seedfall, but the seedbed assessment results will be valuable in interpreting burn quality and stocking results.

Table 3. Description and receptivity of major seedbed types

Receptivity	Seedbed type	Code	Description
Receptive	Disturbed soil	D	Disturbed, friable mineral soil which is not compacted or greater than 50 % covered by slash.
	Burnt - high intensity	Bh	Fuels > 7 cm diam. have been reduced to charcoal; reddish oxide powder has been produced; duff layer has been removed.
	Burnt - moderate intensity	Bm	Fuels 2–7 cm diam. have been reduced to charcoal; duff layer has been removed.
Unreceptive	Undisturbed soil	U	Litter, rocks, understorey or logging slash overlying undisturbed soil.
	Slash	S	Moderate to dense logging slash overlying disturbed soil. Slash covers greater than 50 % of the soil surface.
	Burnt - low intensity	Bl	Fuels > 2 cm have not been reduced to charcoal; duff layer has not been removed.
	Compacted	C	Mineral soil which has been heavily compacted.
	Recolonised	R	Previously receptive seedbed that has been recolonised to the extent that it is no longer receptive.

5.3 SEEDBED ASSESSMENT METHODS

5.3.1 Seedbed reconnaissance

To economise on the use of limited resources and avoid unnecessary formal surveys of well prepared sites, a seedbed reconnaissance should take place initially. The objective of this is to identify those sites which are clearly well prepared (which do not require any further action prior to sowing) and those coupes which need a formal survey.

A reconnaissance survey can take the form of either a thorough ground inspection, or aerial observation validated by a later ground inspection. Ground inspections should include coverage of those parts of a coupe (e.g. gullies) most likely to contain the poorest seedbed, but which are usually the highest site quality for tree growth. Roadside inspections alone are not adequate, as they are prone to error.

The reconnaissance survey should visually estimate the extent of receptive seedbed. If the seedbed is:

- clearly greater than 75% of the coupe area, and
- no large (>1 ha), contiguous areas of unreceptive seedbed exist,

then the coupe may be considered satisfactory and no formal seedbed survey or extra site preparation is required prior to sowing. Results should be recorded in the Coupe Plan. If the coupe does not clearly meet this standard then a formal seedbed survey should be undertaken (see below).

5.3.2 Seedbed survey

A formal seedbed survey, as described in **Appendix 2**, must be carried out before sowing, where:

- the reconnaissance, described above, shows that the standard for receptive seedbed has not been clearly achieved; or
- there is a significant time-lag between site preparation and sowing, and concern that recolonising species may have reduced seedbed receptivity; and/or
- reduction in sowing rates are being considered (see MARDAG 1995a).

5.4 SUPPLEMENTARY SITE PREPARATION

If a seedbed assessment indicates that all or part of a coupe to be artificially sown has inadequate seedbed then supplementary site preparation work will be required before sowing. Possible treatments are set out in Section 4.

The immediate treatment of poor seedbeds after site preparation may save the much larger cost of clearing large quantities of vegetation at a later date (Table 2).

The following factors should be considered when planning supplementary treatments:

- the size, quantity and flammability of slash, litter and live vegetation (observed during seedbed surveys);
- conditions such as slope, rockiness and wetness of the site that may limit the use of machinery;
- the impact on soil quality of additional mechanical disturbance and the possible advantages of chemical spraying or low intensity treatments such as lyrebirding.

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Appendix 1

BURNING OPERATIONS

For full details and procedures for burning operations, refer to Fire Protection Standing Instruction No.2 (CNR 1993), and to the Fire Management Techniques Course Notes (CNR 1995). The information below is only a summary of the key points. The video on prescribed burning (NRE 1998) is also a useful resource.

People engaged in prescribed burning operations must be satisfactorily trained, aware of the potential hazards involved, and provided with (and use) protective equipment.

1 LIGHTING METHODS AND PATTERNS

1.1 Methods

Methods and currently used for lighting burns for site preparation are described below.

1.1.1 Hand lighting

Hand lighting of slash fuels is generally by drip-torch although fusees may be used for small areas. Flamethrowers (hand-held and vehicle-mounted), propelled incendiaries (from shotguns or special launchers), and electrical ignition ('blivets') are also ground-based manual methods which are less commonly used.

1.1.2 Aerial lighting

Aerial ignition techniques are often used for broadcast slash burns and windrow burning. Gel-petrol (from the 'Fire-dragon' aerial drip-torch), or incendiary capsules ('ping pong balls') are used as ignition sources and are generally applied from a helicopter during conditions of light wind.

Experience has shown that 'ping pong balls' often result in unsatisfactory lighting of (damper) slash in HEMS forests. In that forest type they should now only be used as a last resort and then only under optimum conditions.

1.2 Lighting Patterns

The principal lighting patterns used are central lighting, strip lighting and moving convection columns for *broadcast slash burns*, and spot lighting for *head burns*.

Central convection lighting patterns are generally used on flat to moderately sloping terrain under light wind conditions (< 16 kph). Central lighting by hand is unsafe on slopes greater than 10°. Firstly, fires are lit at or near the centre of the coupe, on a knob, or in a heavy accumulation of slash. More fires are lit in a circle of 20 to 40 m radius around the initial fire as soon as in-draught winds are established. Subsequent fires are lit in concentric circles up to the burn perimeter. The perimeter must not be lit too early or spot-overs could result.

Strip lighting is often used on slopes greater than 10°. Initial fires are lit on the most vulnerable edge (e.g. upslope or downwind). Where there is wind across the slope ignition should start at the downwind end of each strip. The initial strip should be completed satisfactorily before progressing to prevent subsequent fire from crossing the control line. Further strips are ignited progressively down slope commencing on the downwind side. Lighting is continued to the bottom of the slope.

Moving convection columns are generally used on areas too large or narrow for central lighting. The method combines both strip and central convection lighting. Initially, strips are lit through the centre of the coupe. As soon as in-draught winds occur, subsequent strips are lit up parallel to the central strips. Successive strips are then lit between the central strips and the perimeter.

Grid lighting procedures are essentially as for strip lighting, but with wider spacing. Lighting commences at the most vulnerable edge or downwind if there is any wind. Lighting of this portion of the coupe should be completed before progressing. In situations where damage to retained vegetation is to be avoided, lighting spots must be spaced sufficiently frequently to reduce the area of more severe fire behaviour at junction zones. The coupe may have to be lit in two stages to achieve this.

2 FUEL MOISTURE CONTENTS

All slash burns should be conducted under fine fuel moisture contents (FMCs) that are sufficiently low in the coupe to produce the required seedbed but high enough outside the coupe to prevent fire spread outside should a spot-over occur. The difference in FMCs is termed the '*fuel moisture differential*'.

Fine FMC varies widely according to time of day, site, and exposure on a site. A guide to FMCs and the relative flammability of fine eucalypt fuels is given in Table 1 and reference should be made to the Fire Management Techniques notes (CNR 1995).

TABLE 1. Fuel moisture content and flammability for fine eucalypt fuels (Dexter 1975)

Fuel moisture content	Flammability
>28 %	Fuel non-flammable
22–28 %	Fuel very difficult to ignite. <i>Burning very difficult to sustain.</i>
16–22 %	Fuel very difficult to ignite. <i>Burning difficult to sustain.</i>
13–16 %	Fuel moderately easy to ignite. <i>Burning is sustained.</i>
9–13 %	Fuel easy to ignite. <i>Burning readily sustained.</i>
5.5–9 %	Fuel very easy to ignite. <i>Burning is sustained day and night.</i>
<5.5 %	Fuel very easy to ignite. <i>Burning very readily sustained and control is difficult due to spotting</i>

If fuels are drying rapidly, greater care is required. Days which are hot, windy and very dry with strong sunlight, can cause very rapid drying and thus reduction of the FMCs.

Prior to the ignition of all slash burns, measure the FMC of fine eucalypt fuel samples (% of Oven Dry Weight). Measurement should be done preferably with a quality instrument (e.g. 'Wiltronics TH Electronic Fuel Moisture Meter'), as this enables a number of samples to be taken and averaged. The 'Speedy Moisture Meter' can also be used, but is slower.

FMCs regarded as suitable for burning operations are based upon samples taken as follows:

- *Inside the control line:* sheltered, dead, undecomposed eucalypt leaves at ground level or on the litter surface
- *Outside the control line (preferably on the more exposed sites, as these will be drier):* dead, undecomposed eucalypt leaves on the litter surface.

2.1 Suitable FMCs for broadcast slash burning

- *Inside the control line:*

Hand lighting	–	6–14 % (6–12 % in HEMS)
Aerial drip-torch	–	6–14 % (6–12% in HEMS)
Aerial incendiaries	–	6–8 % (6–10 % where there is continuous slash cover)

(The temptation to use aerial ignition techniques at higher FMCs than specified above must be avoided. Whatever ignition techniques are used at high FMCs, inadequate amounts of litter will be removed and the resultant seedbed will be poor.)

- *Outside the control line :* >14 %
- *Gully control lines :* >40 % (obvious free moisture visible)

2.2 Suitable FMCs for head burning

- *Inside the control line:*

Where the objective is to provide a receptive seedbed with no requirement for avoiding damage to surrounding trees and where such areas are surrounded by mineral earth breaks such as snig tracks : 6–14 %

Where there is a requirement to protect retained vegetation and produce seedbed in adjacent areas : 9–14 %

- *Outside the control line :* >14 %

2.3 Suitable FMCs for windrow burning

- *Inside the control line:*

Heavy fuels should have FMCs less than the fibre saturation point (about 30 % on an oven dry weight basis) and preferably less than 18–20 % in the outer 6 mm of the stem. Lower FMCs are not required in windrow burning because extra heat can be applied to ignite the heavier fuels

Once alight, the compacted fuels will produce sufficient heat to dry out and consume the damp fuels. As heavy fuels do not respond quickly to high relative humidity or light rain there is likely to be a greater period over which windrows can be burnt compared with broadcast slash burning.

Burn windrows as late in the season as possible to maximise drying and to minimise the chance of escapes, without scorching any seedlings that may have become established in adjacent areas.

- *Outside the control line :* >14 %

2.4 Curing times for logging slash

Curing times to reduce FMCs to equilibrium with air (in summer):

- elevated leaves - 2 weeks
- fine branches (< 20 mm diameter) - 3 weeks
- small branches (< 50 mm) - 6–8 weeks
- large branches (> 100 mm) not cured after 8 weeks

To provide sufficient surface heating for an effective ashbed to be created there must be burning of heavier fuel - both in size and quantity. Provided there is sufficient cured fine fuel to ignite heavier fuel, it is not essential for heavier fuel to be 'air dry'.

FMCs for heavy fuel should be as described above for windrow burning. This is generally achieved at around the same time that small branches reach 'air dry', within a minimum of 6 weeks after logging in summer. On shaded or damp aspects this period may increase to 10 weeks after logging.

3 WEATHER CONDITIONS

The combinations of weather variables that will produce fire intensities for acceptable seedbeds but still minimise the risk of fire escapes are given in Table 2. These values apply to all forest types where the fuel within the control line is dominated by cured logging slash and the Overall Fuel Hazard rating (McCarthy *et al* 1998) outside the control line is less than Very High, provided that the guidelines above for suitable FMCs (Table 1) are followed.

In applying Table 2 ('max. result'), it is assumed that all normal perimeter controls are in place, and that adequate resources are available for lighting, mopping up and patrol.

TABLE 2. Suitable weather conditions for broadcast slash burns

Weather factor	Minimum silvicultural result	Maximum silvicultural result (and safe limit)
Temperature	18°C (min)	28°C (max)
Relative humidity	60 % (max)	35 % (min)
Wind speed - ground level	0 km/h (min)	10 km/h (max)
Wind speed - 10 m elevation	0 km/h (min)	20 km/h (max)
Drought Index	20 (min)	75 (max)
<i>*Fire Danger Index for the day</i>	<i>3 (min)</i>	<i>10 (max)</i>
Fire Danger Index for the next day	18 (max)	18 (max)

* the most critical factor

Note: The values in Table 2 are not absolute and should be considered relative to one another. For example, a minimum acceptable silvicultural result may be achieved on a day of 16°C maximum temperature if wind speed was 10 km/h. Weather conditions for steep slopes should be milder than those specified. The trade-off between different variables must be based on sound local knowledge.

Where the Overall Fuel Hazard rating outside the control line is **Very High** or **Extreme**, any burning should be carried out with ground level wind speeds of < 5 km/hr (= wind at 10 m no more than 10-12 km/hr) if the Elevated Dead FMC in the outside fuels is less than 15%.

Where fuels within the control line are generally less flammable than cured logging slash, but sufficiently flammable to produce a suitable seedbed, burning should be carried out under conditions closer to the safe limit than to those required for the minimum silvicultural result. Note that seasonal restrictions on burning mean that even if the conditions in Table 2 are met, approval to burn may be refused by the regional fire manager.

Conditions suitable for head burning should be close to those for the minimum silvicultural result.

Appendix 2

SEEDBED SURVEYS

1 INTRODUCTION

Section 5 in this Guideline describes when and why seedbed assessments are needed, and describes the seedbed reconnaissance technique. This Appendix sets out the methods for undertaking a **formal seedbed survey**.

2 SURVEY METHOD

2.1 Timing

- Seedbed surveys should generally be conducted as soon as possible after site preparation (within days), so as to maximise the time available to respond to the results before the scheduled time of sowing.

2.2 Sampling

- *Equipment needed:* coupe map with survey grid, compass, hip-chain (optional), plot sheets (photocopy attached sheets), pencils, 2.27 m stick, pig-tail pin (optional).
- Formal seedbed surveys on coupes > 5 ha in size should use a grid of 80 m x 20 m. On smaller coupes, the grid size should be reduced, to enable a minimum of 30 plots per coupe to be assessed.
- The survey grid should cover the entire coupe (including heaps, windrows, etc.) and the 80 m transects should be followed using a compass. The distance between plots (20 m) on each transect may be measured using a hip chain to facilitate accurate mapping of the results.
- The first transect and the first plot in each transect should be located in an unbiased manner to ensure that any point in the coupe has an equal chance of being sampled.
- The direction of the transects will generally be determined by the characteristics of the coupe, but they should run approximately at right angles to the long axis of the coupe or the orientation of the major snig tracks, so as to reduce the possibility of systematic sampling bias.
- As each sample point is reached, the plot centre should be marked and the plot boundary determined using a stick cut to 2.27 m length (4-milacre) to measure the plot radius.

2.3 Seedbed assessment

- Subjectively assess the plot for the predominant seedbed type (see Table 3, p.32) and for the proportion (nearest 5%) of the plot that comprises receptive seedbed types.
- Record these data on the pro-forma 'Seedbed Survey Record Sheet' attached.
- A standard pig-tail pin (3 mm x 80 cm) can be a useful aid to determining whether a seedbed is compacted. Under moist soil conditions, if the pin is inserted under steady hand pressure and consistently fails to penetrate further than 5 cm, the seedbed can be considered compacted. Under dry soil conditions the soil should be considered compacted if the pin fails to break the soil surface (1 cm). Visual means should also be used to identify compacted soils.
- Comments should also be recorded as appropriate, to facilitate the delineation of areas requiring supplementary site preparation, choice of treatment where needed, and mapping of the results.
- In some cases it may be appropriate or feasible to mark areas requiring supplementary treatment as the survey progresses.

3 DATA ANALYSIS AND RECORDING

3.1 Analysis

- Using the 'Seedbed Survey Summary Sheet', and the field map, analyse the survey data to determine:

whether > 75 % of plots comprise > 50 % receptive seedbed;

whether large (> 1 ha) contiguous areas of plots < 50 % receptive exist; and

what, if any, supplementary site preparation treatment is required.

- To facilitate this, the data and comments recorded during the assessment should be used to prepare a scale map of the coupe. Spot aerial photographs, if available, are a very useful aid to mapping.

3.2 Recording

- A summary of the results and subsequent recommendations should be recorded in Part B (*Silvicultural planning and recording*) of the Forest Coupe Plan, or in the Reforestation/Backlog Regeneration Plan, as appropriate. The Regeneration Plan should be modified if necessary. The Seedbed Assessment Record Sheets, maps and accompanying recommendations should be attached to these plans as Appendices.

Forests Service

SEEDBED SURVEY SUMMARY

COUPE IDENTIFICATION

FMA/ Block / Compartment / Number:		Coupe / Site name:	
Work Centre & Assessor:	Date:	Area (ha):	Date site prepared:
Site preparation method:		Plot radius:	2.27 m
		Grid size:	80x20 m

SUMMARY OF RESULTS

PREDOMINANT SEEDBED TYPE									
Code	Receptive			Unreceptive					Total (T)
	D	Bh	Bm	U	S	Bl	Com	R	
No. of plots									
% of plots									

SEEDBED ADEQUACY

- Percent of plots > 50% receptive ($\frac{D+Bh+Bm}{T} \times 100$) =
- Contiguous areas of plots < 50% receptive (ha) =
(see attached map)

OVERALL RESULT

Seedbed: satisfactory / not satisfactory

Recommended actions:

(eg. supplementary site prep, adjusted sowing rates)

Name:

Date:

Appendix 3**MACHINERY CLASSES, POWER RATINGS AND HIRE RATES**

From: *Construction Equipment Hire Manual 1994/95 (latest edition). Australian Earthmovers and Road Contractors Federation (Victorian Branch).*

ERG class* 1	Make	Model	Classifying power (kw)*2	Hourly hire rate*3
2(37–52 kw)	Case	450B	40	\$70.00
	International	TD7C	42	
	Fiat	505CM	43	
	International	TD7E	45	
	Massey Ferguson	MF300	47	
	Dresser	TD7E	48	
	Caterpillar	D3B	49	
	Fiatallis	FD5	49	
	Allis Chalmers	4D68	50	
	Allis Chalmers	HD68	50	
	JI Case	550E	50	
	Caterpillar	D3CII	52	
	Dresser	TD7G	52	
	Fiatallis	FD5	52	
	John Deere	4504	52	
	John Deere	450G	52	
Komatsu	D31E-20	52		
3(52–67 kw)	Case	450C	53	\$70.00
	International	TD9B	56	
	Komatsu	D375-5	56	
	Fiat	605CM	58	
	Caterpillar	D4C II	60	
	Caterpillar	D4E	60	
	Dresser	TD8G	60	
	John Deere	550G	60	
	JI Case	850E	63	
	Fiatallis	FD7	63	
	Fiatallis	AD7D	64	
	Liebherr	PR711	66	
	Case	850D	67	
	Caterpillar	D5C	67	
	Hanomag	D400D	67	
	John Deere	650G	67	
Komatsu	D41A-3	67		

ERG class*1	Make	Model	Classifying power (kw)*2	Hourly hire rate*3
4 (67–95 kw)	Caterpillar	D6 & D6B	69	\$102.00
	Caterpillar	D4H II	71	
	Liebherr	PR712 Litronic	75	
	Case	1150C	78	
	Caterpillar	D4H III XL	78	
	Caterpillar	D5B	78	
	Fiatallis	FD9	79	
	John Deere	750	82	
	JI Case	1150 E	84	
	Liebherr	PR721C	85	
	Caterpillar	D5H P/S	87	
	Caterpillar	D5H II	90	
	International	TD15B	90	
	John Deere	750B/6525	90	
	Fiatallis	10 B&C	91	
	Allis Chalmers	HD11 B&E	92	
	Fiatallis	FD10E	93	
	Hanomag	D540E	93	
	Komatsu	D53A-17	93	
5 (95–127 kw)	Liebherr	PR722 Litronic	96	\$128.00
	Caterpillar	D5H II XL	97	
	Case	1450B	104	
	Caterpillar	D6D	104	
	Dresser	TD12C	104	
	Dresser	TD15C	104	
	Komatsu	D63E-1	104	
	International	TD15C	104	
	Hanomag	D600C	107	
	John Deere	850	108	
	Fiatallis	14 B&C	112	
	JI Case	1550 Std	112	
	JI Case	1550 Long track	112	
	Hanomag	D600D Super	113	
	Liebherr	PR73C	115	
	Caterpillar	D6H P/S	116	
	International	TD20B	119	
	Fiatallis	FD14	120	
	Caterpillar	D6H P/S	123	
	Caterpillar	D6H II	123	
	Dresser	TD15E	123	
	Fiatallis	FD14E	123	

ERG class*1	Make	Model	Classifying power (kw)*2	Hourly hire rate*3
5 (95–127 kw) (cont.)	Hanomag	D670E	123	
	Hanomag	D680E	123	
	John Deere	850B/6545	123	
	Komatsu	D65E-8	123	
	International	TD20 C&E	127	
6 (127–175 kw)	Allis Chalmers	HD16 B&D	128	
	Caterpillar	D6H II XL	130	
	Caterpillar	D6H II XR	130	
	Liebherr	PR732 Litronic	132	
	Liebherr	PR732-L Litronic	132	
	Komatsu	D65EX-12	142	
	Fiatallis	16B	145	
	Caterpillar	D6G P/S	149	
	Caterpillar	D7G	149	
	Hanomag	D700D	150	
	Hanomag	D700D Super	150	
	Terex	82-20B	153	
	Liebherr	PR741C	154	
	Caterpillar	D7H P/S	160	
	Caterpillar	D7H II	160	
	Fiatallis	FD20	166	
	Dresser	TD20G	168	
	Komatsu	D85A-21	168	
	Komatsu	D85E-21	168	
	Liebherr	PR742 Litronic	172	
Fiatallis	FD20	173		

*1 Class given by 'Equipment Research Group Ltd'

*2 Based on net flywheel power

*3 Indicative cost - includes cost of ownership, fuel, repairs, operator, and overheads.

Appendix 4

HERBICIDE DATA

Chemical name (Active constituent)	Some product names (as at 1997)	Toxicity LD50 (acute oral - rats) mg/kg
amitrole (+ ammonium thiocyanate)	Weedazol TL Plus (250 g/L + 220g/L) Amitrole T	amitrole 1,100-24,600 amm.thio. 750
clopyralid	Lontrel L (300 g/L)	>4,300-5,000
fluazifop	Fusilade (212 g/L)	3330
glyphosate	Roundup (360 g/L) Roundup CT (450 g/L) Wipe-out 360 (360 g/L) Nufarm Glyphosate 360 (360g/L)	4320
MCPA*	Thistle Killem (500g/L) Farmoz MCPA 500 (500g/L)	700
metsulfuron methyl	Brush-off (600g/L)	>5000
simazine	Flowable Gesatop 500FW (500g/kg) Farmoz Simazine 500 (500g/L)	>5000
triclopyr*	Garlon 600 (600g/L)	715

* Users of these chemicals must hold an Agricultural Chemical User Permit.

