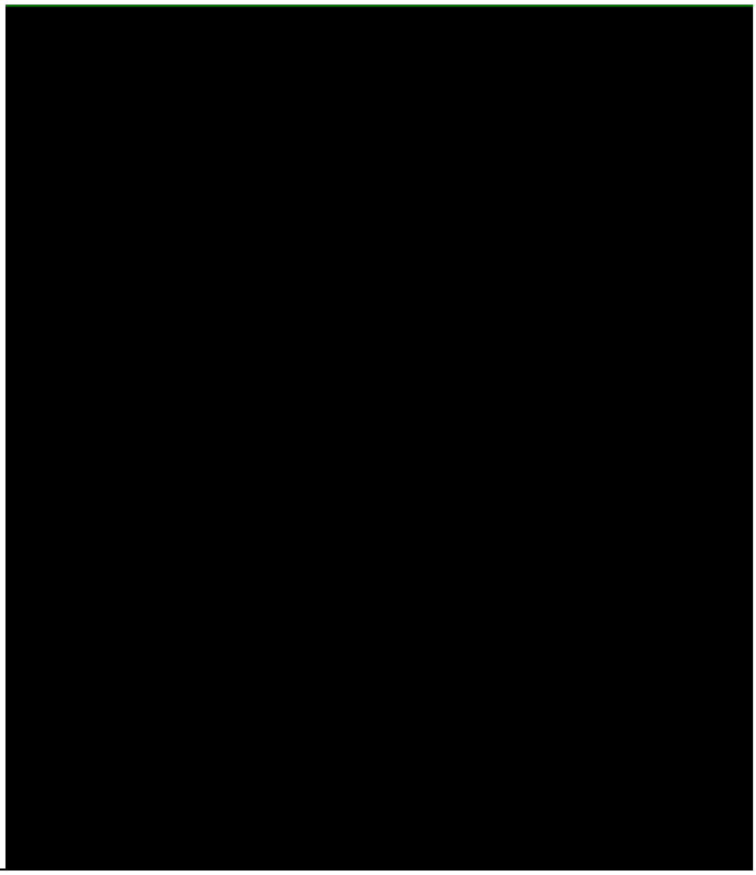
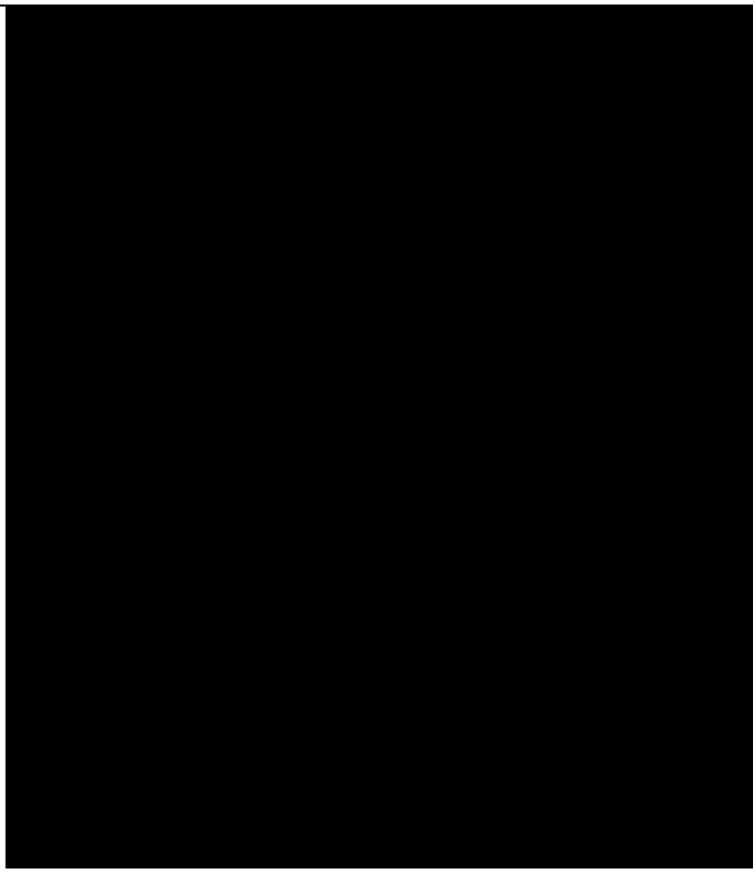


Assessment of Forest Management Practices for the Eden RFA

A report undertaken for the NSW CRA/RFA Steering Committee

22 October 1997



DRAFT
ASSESSMENT OF FOREST MANAGEMENT PRACTICES FOR THE EDEN RFA

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This draft report has been prepared for the NSW CRA/RFA Steering Committee under the direction of the ESFM Group. By releasing it as a draft, it has been possible to make the report available earlier so that it can contribute to the public consultation process.

This is consistent with the principle that all information related to the Comprehensive Regional Assessment process will be made publicly available. It is recognised that this draft may contain errors that require correction, but the report will be subject to review before finalisation and publication.

This project has been jointly funded by the New South Wales and Commonwealth Governments. The work undertaken within this project has been managed by the joint NSW / Commonwealth CRA RFA Steering Committee and overseen by the ESFM Technical Committee.

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GLOSSARY

ADD	Area of Deep Disturbance
AEMS	Area of Exposed Mineral Soil
CWR	Critical Weight Range
DEM	Digital Elevation Model
DLWC	Department of Lands and Water Conservation
DUAP	Department of Urban Affairs and Planning
EIS	Environmental Impact Statement
EMA	Eden Management Area
EPA	Environmental Pollution Agency
ESFM	Ecologically Sustainable Forest Management
GHA	General Harvest Area
GIS	Geological Information System
NPWS	National Parks and Wildlife Service
PDS	Percent Dispersable Soil
SEMGL	Standard Erosion Mitigation Guidelines
SEPP	State Environmental Planning Policy
USLE	Universal Soil Loss Equation
WPHR	Water Pollution Hazard Rating

EXECUTIVE SUMMARY

This report has been prepared for the joint Commonwealth/State Steering Committee which oversees the comprehensive regional assessment of forests in New South Wales.

The comprehensive regional assessments (CRAs) provide the scientific basis on which the State and Commonwealth governments will sign regional forest agreements (RFAs) for the major forests of New South Wales. These agreements will determine the future of the State's forests, providing a balance between conservation and ecologically sustainable use of forest resources.

This report was prepared by an Expert Group whose terms of reference required the assessment of practices that have an impact on forests of the Eden RFA area. The activities of the group were coordinated by the NSW CRA/RFA Ecologically Sustainable Forest Management (ESFM) Committee, as one of a number of related projects evaluating ESFM.

The assessment was made with reference to a suite of forest values based substantially on the work of a related committee (ESFM Project 3), which sought to define indicators and targets for ecologically sustainable forest management. The values are described in Chapter 1 and include flora, fauna, soil, water, timber production, recreation usage, use for grazing, bee keeping and mining, and contribution to global geo-chemical cycles (particularly carbon and implications for green-house gases).

The Expert Group included specialists in the areas of flora, fauna, fire ecology and management, soil and water impacts and timber harvesting. Inputs to the assessment were also made by members of the Eden Regional Forest Forum and the ESFM Group.

The assessment was conducted in two stages. In the first, a compilation of potentially relevant forest practices was developed and assessed for their impact (actual or potential) on the selected values. An initial practices list, prepared by the Experts, was presented to both the Eden Regional Forest Forum and to the ESFM Group for discussion, and a final list of 51 practices was defined (Chapter 1). Next, each of the practices was evaluated for its likely or potential impact on the selected values according to a High, Medium, or Low ranking. Preliminary results for this ranking were presented to the Eden Regional Forest Forum and the ESFM Group for comment. The agreed importance matrix is presented as Appendix A. Cells (combinations of practices and impacts) are blank where there was insufficient information to make a competent assessment, or where there was no likely significant interaction.

In the second stage, interactions (Practice impacts on value) were analysed in detail. This analysis was restricted to those cases where the interaction was assessed in the HIGH category because of the severe time constraint required to fit in with the timetable for the Eden CRA/RFA. Some 50 assessments were finally conducted for the interactions between these practices and the selected values.

A brief summary of the major themes identified by these assessments is presented here according to the major grouping of practices.

Practices relating to planning and managing land use were assessed as vitally important to the achievement and maintenance of ESFM. The establishment of a comprehensive, adequate and representative (CAR) reserve system as part of the RFA process is viewed as an important step, not an end point. Planning processes that incorporate systems for ongoing assessment of both conservation status and sustainable forest usage levels for both reserve and managed forest, and the capacity to track and respond to changes, are a key requirement for ESFM.

Roading is assessed as a very significant practice, primarily in relation to its potential impacts on water quality and flora and fauna, but also through improvement in fire control access, in the socio-economic aspects of forest access and improved timber values. The design of road drainage systems and the procedures required to assure timely maintenance were assessed as key practices in this area.

Fire is one of the most important factors influencing the forests of the Eden area. The region experiences an extreme fire climate and large destructive wildfires. Practices related to fuel management are implemented to attempt to reduce losses from wildfire. However, these practices can have adverse impacts on flora and habitat values and a careful balance is required in their use.

Practices that seek to secure protection of flora and fauna species and communities are vital to the maintenance of ESFM. These include survey and assessment methods required for identification of areas for protection or special management, and the development and implementation of sensitive management regimes. They must operate under the broad framework of the regional conservation and forest management plans noted above. There is a critical need to ensure that, in the longer term, monitoring programs effectively track conservation status, and that prescriptions continue to be adapted as necessary.

Protection of soil values during and after forestry operations is an important aspect of ESFM. Key practices include the identification of soil susceptibility to harm, and the adoption of appropriate prescriptions to be employed during forestry and related activities (e.g. roading, harvesting and controlled burning).

Protection of water quality values depends in part on the effective implementation of these soil protection practices, but also on the effectiveness of road management practices. Results of recent research into erosion processes in forests is making a considerable contribution to the improvement of these practices.

Timber production makes a very large contribution to the socio-economic benefits derived from the forests of the region. In general, there is a trade-off between the level of timber production that can be achieved and with correspondingly larger or smaller impacts on other forest values. Key practices in this areas seek to develop a suite of silvicultural and harvesting practices to limit adverse impacts. Greater adaptation of practices to site and conservation requirements should produce higher outputs and greater socio-economic benefit for any chosen level of impact.

The region’s forests possess considerable natural and cultural heritage values, and their enjoyment makes a significant socio-economic contribution. In this regard, practices, including those that regulate usage and direct management of impacts, are important for the protection of these values.

Other forest uses, such as grazing, bee-keeping and mining exploration or exploitation also contribute to the regional economy. The critical related practices are those that require flora surveys to prevent damage to endangered communities.

The requirement for a continuing evolution of practices in relation to ESFM was noted in regard to most values.

1. INTRODUCTION

1.1 METHODOLOGY

An Ecologically Sustainable Forest Management Group (ESFM Group) was formed to co-ordinate enquiry as one of the four streams preparing information for the CRA/RFA process in NSW. The ESFM Group defined seven projects. The project reported here (Project 4), assesses the impacts on forest values of key forest practices that are either in use , or that may be applicable as innovations for future use in the Eden RFA area.

An expert group was formed to undertake a practices assessment and report. The work involved two stages.

1.1.1 Stage 1

Identification of Practices and Values

The groups first task was the identification and description of important forest practices. These were then assessed in terms of impact on a range of forest related values. The original project objectives also called for the development of links between practices and a set of indicators and targets to be developed by another project group. In the event, time constraints for the Eden CRA meant that the Indicators panel was required to work in parallel, with rather than in advance of, the work of Practices Project. Because indicators were not available and it was decided that the assessment be made against the values for which the indicators were being developed. This set of values was developed by the ESFM Group and reflected a set of SFM principles.

Assessment of interaction/linkage between practices and values.

The stage one assessments were rated as high, medium or low in terms of the interaction or impact of the practice on the value. In those cases where there was no perceived linkage between a practice and a value, or where the information that would support an assessment of the linkage was not available the cell (practice – value combination) was left blank. Impacts of practices on values can be either positive or negative.

It was intended that only cells rated as HIGH would be assessed in the second stage and it was expected that time and resources would not permit a full stage two assessment of more than about 25 cells. The first stage assessment was presented to the Eden Regional Forest Forum and the ESFM Group for comment. Suggestion from these groups led to additions to both the values considered and the list of practices and the rating of a number of the cells was increased. A final Interactions matrix was developed (**Appendix A).**

1.1.2 Stage 2

In stage two, a detailed assessment was made of about 50 selected individual cells. The assessments were made under a number of general categories or headings. These were:

Statement of Practice and Value

A brief statement to identify the practice and value being considered

Nature of Practice

This section presents a more detailed description of the practice and the way in which it is applied in the Eden Region. The description might include considerations of

(a) *the mechanism of impact* – the way the selected practice has an impact on the specific value.

(b) *Evidence of importance in the Eden RFA region*.

(c) *Scientific commentary*

(d) *Risk Assessment*

Potential innovations

This section provides some consideration of modifications or alternatives in the application of the practice that might enhance its effectiveness or reduce any negative impact.

Assessment Statement

This section provides an assessment of the likely impact of the practice.

Guideline / Rule / Limit for Application

This section provides information to assist in the implementation of the practice.

Linkage to Indicators

This section was provided to allow the specification of the relevant indicators, where these were known to the Practices Assessment Expert Panel.

The assessments are presented in Chapters 2 – 7. Each chapter presents the descriptions and assessments for the selected high impact cells for each value (e.g. Fauna). In some cases where related practices had a similar mechanism of impact on a value and these were assessed together. Individual chapters were prepared by the respective disciplinary experts from the Expert Group.

1.2 LIST OF PRACTICES (SUMMARY)

Practices were grouped into sets as a convenience to assist in presentation.

- Regional Land Use and Management Planning
  - Regional Land Use Determination
  - Regional Conservation Planning
  - Regional Wood Production Planning
- Roading
  - Road Corridor Location
  - Road Design
  - Road Construction
  - Stream Crossing Design
  - Stream Crossing Construction
  - Road and Crossing Use (and closure)
  - Road and Crossing Maintenance
  - Fire Trail Construction and Maintenance
- Fire
  - Wildfire - Suppression and Impact
  - Fuel Reduction Burning
  - Post Logging Burning
- Harvesting
  - Coupe Selection in Space
  - Coupe Operations Scheduling
  - Erosion Hazard Assessment
  - Pre Harvest Flora and Fauna Survey
  - Watercourse and Stream Protection Planning and Marking
  - Access Road and Landing Location and Construction
  - Snig Track Planning
  - Harvesting at Low Intensity
  - Harvesting at Medium – High-Intensity with Habitat Retention
  - Harvesting at High Intensity with no Habitat Retention
  - Regrowth Thinning
  - Regrowth Fertilization
  - Early Age Spacing
  - Stand Regeneration
  - Stocking Assessment
  - Wet Weather Soil Management
  - Post Harvest Erosion Control
  - Plantations
  - Site Selection
  - Establishment
  - Harvesting
- Recreation Use
  - Location of Campsite and Trails
  - Facilities Construction
  - Site and Trail Maintenance
  - Tourist Promotion

- 4WD and Trail Bike Use
- Camping Bushwalking

- Conservation and Heritage
  - Place / Site / Object Identification
  - Place / Site / Object Protection
  - Feral Animal Control
  - Weed Control
  - Habitat and Food Tree and Groundcover Protection
  - Species Management Flora and Fauna
- Other Uses
  - Grazing
  - Bee Keeping
  - Mining – Exploration and Development

1.3 PRACTICES - DETAILED DESCRIPTION

The three practices identified in this section are considered in further detail in the ESFM Project 6 (Systems). They are included here because of the expert group's concern that their fundamental important as practices supporting ESFM be recognised.

[1] Regional Land Use Determination

The broad systematic evaluation of land capability and of environmental, economic and social aspects related to alternative land uses in a regional context. [See Cell A1, page 9]

[2] Regional Conservation Planning

This broad group of practices flows from and supports maintenance of flora and fauna conservation values in a regional context over the longer time frame. At a minimum it includes processes for the development and maintenance of an information base for conservation status across tenures at the regional level and procedures for monitoring change. [See Cell A2, 2.2.1 page 10]

[3] Regional Wood Production Planning

The preparation and implementation of strategic forest management plans. In the context of the Eden RFA where most of the current timber production is drawn from public forest, the practice is centered on activities of State Forests of NSW. [See Cell F3 0 page 95]

[4] Road Corridor Location

The regional and catchment scale planning of road requirements down, and the on-ground selection of the road location. Such planning must balance economic needs with the environmental hazards associated with road construction and use.

[5] Road Design

Road design often requires choices between construction approaches and methods which can lead to different immediate and longer term impacts on the environment. For example, choices must be made about the permitted levels of cut and fill and about drainage system capacity and water disposal location for each section and site.

[6] Road Construction

Construction practices involve the choices of machinery and technique to be used, and the implementation of the job according to plan and to meet standards of environmental care.

[7] Stream Crossing Design

The selection of crossing points and design of stream crossing structures. It requires assessment of likely stream flow. Design of crossing approaches to control road runoff generated requires careful attention. [Cell D7, page 86]

[8] Stream Crossing Construction

Construction practices for stream crossing requires a range of specialist techniques to minimise disturbance of streambed and banks.[Cell D8, page 86]

[9] Road and Crossing Use (and closure)

Careful regulation of the use of forest roads and crossing systems is required in periods of wet weather. This is achieved on some tenures by automatic or notified road closures.[See Cell D9 page 88]

[10] Road and Crossing Maintenance

Preventative and remedial action to maintain the capability of the road surface and associated drainage systems to control direct rainfall and run-on water flow. This involves periodic grading to maintain road crowns, and keeping the drains and culverts cleared. [See Cell D 9 page 88]

[11] Fire Trail Construction and Maintenance

Rapid access to any fire outbreak is considered an important aspect of regional fire control strategy. This involves the construction and continued maintenance of unformed forest trails. Aspects of location of new trails and progressive remediation through closure and replacement of trails now located in environmentally hazardous locations are part of this practice. See Cell D11 page 89]

[12] Wildfire - Suppression and Impact

Practices associated with wildfire suppression and the broad questions of the impacts of wildfire.

[13] Fuel Reduction Burning

All managed use of fire except post logging burning. [See Cell A13, B13 page 14, 33]

[14] Post Logging Burning

This covers use of fire immediately following logging to reduce fuel and/or assist regeneration.

[15] Coupe Selection (Location in Space)

The selection of coupes for forestry operations (primarily harvesting). It involves the selection of proposed boundaries and the assessment of likely impacts of operations within these boundaries in relation to both immediate neighbours and the wider regional context. Cell A15, page 24]

[16] Scheduling of Operations (Timing)

Scheduling of coupe operations requires a consideration of the states of adjacent areas in relation to possible impacts operations, especially on vegetation structure and habitat. Consideration of management of neighbouring road networks is also required. [Cell A16, page24]

[17] Erosion Hazard Assessment

The assessment of the potential for soil erosion in the areas selected for operations. [Cell C17, page 64]

[18] Pre Harvest Flora and Fauna Survey

This involves both field and database enquiry to assess the general species composition of the selected area. Particular attention is paid to the presence or absence of targeted species or communities. [Cell B18, on page 49

[19] Watercourse and Stream Protection Planning and Marking

Protection of streams and water quality in relation to forestry operations relies in part on the use of protective buffers. This practice relates to the methods used to plan for and mark the boundaries of these buffers. [Cell D19, on page 90]

[20] Access road and landing location and construction

The field and office procedures used to determine location for these temporary access routes and loading facilities. It also covers construction and its supervision.

[21] Snig Track Planning

The planning, field location and marking of the primary, more heavily used snig tracks.

[22] Harvesting at Low Intensity

A group of silvicultural practices designed to maintain high levels of habitat value whilst allowing some timber production. The practices include:

- light selection logging – single-tree selection with minimised understory disturbance limited to approx 10% of canopy cover.
- medium-intensity selection logging – up to 30 % canopy removal
- small group selection.- groups up to 75 metres in diameter

[Cell F22, on page 102]

[23] Harvesting at Medium – High Intensity with Habitat Retention

A group of silvicultural practices that provide both general habitat value and timber yield. The practices include:

- Small patch cutting - felling gaps up to 125 m wide. Nesting habitat values to be concentrated in edge trees. Up to 20% coupe area in one cutting cycle, 4 –5 cutting cycles per rotation. Dozers, excavators could be used.

– Current practice - General clearfelling but with retention for seeding and habitat, and of advanced growth.

[Cell F23, on page 103]

[24] Harvesting at High Intensity with no Habitat Retention

This group of silvicultural practices is proposed for those areas where habitat and other non-timber values are either not present or their preservation is not required to meet regional ESFM targets. The primary approach involves clearfelling with seed trees where needed to maximise timber productivity. [Cell F24, on page 105]

[25] Regrowth Thinning

Thinning involves reduction in stand competition by the harvesting of the smaller trees in regrowth stands. It is currently limited to application toward mid rotation because a minimum harvested tree size is necessary for economic reasons.[Cell F25, on page 105]

[26] Early Age Spacing

The selective removal of a proportion of stems in overstocked stands, particularly those originating from wildfire. It is usually conducted in early years of the stand’s life and involves either mechanical removal or selective treatment by stem injection of herbicide. [Cell F26, on page 106]

[27] Regrowth Fertilization

The application of fertiliser to regrowth stands. [Cell C27, on page 74]

[28] Stand Regeneration

Practices directed to ensuring regeneration. It can involve use of fire or mechanical site disturbance.

[29] Stocking Assessment

The assessment of the stocking levels for seedling regeneration, usually one or two years after stand regeneration was initiated.

[31] Wet Weather Soil Management

The management controls and prescriptions used to regulate machine usage during periods when high moisture content reduces soil strength. [Cell C31, on page 77]

[32] Post-Harvest Erosion Control (Snig Track Closure)

The techniques and prescriptions used to endure effective drainage of snig tracks, landings and temporary roads after the completion of the timber harvesting operation. [Cell C32, on page 77]

[33] Landing restoration

The restoration of landings and their revegetation.

[34] Plantation Site Selection

Practices associated with assessing areas for plantation suitability. It includes both potential ecological impacts and economic factors. [Cell A34, on page 26]

[35] Plantation Establishment

Practices related to site preparation, weed and pest control, planting and fertilising. [Cell C34, on page 80]

[36] Plantation Harvesting

Practices relating to thinning and final felling of plantations. [Cell C35, on page 82]

[37] Location of Campsite and Trails

Assessment processes and criteria used to establish the citing of recreation facilities and trails. [Cell A37, on page 27]

[38] Recreation Facilities Construction

Procedures used during construction (site earthworks and construction methods and standards). [Cell A38, on page 27]

[39] Site and Trail Maintenance

Procedures used to assess the requirements for and to undertake necessary work.

[40] Tourist Promotion

Processes used to advertise and promote increased recreational usage of forested areas.

[41] 4WD and Trail Bike Use

Procedures and prescriptions used to regulate these forms of road and track usage within the forest to minimise adverse impacts of the usage.

[42] Camping and Bushwalking

Procedures and prescriptions used to regulate these forms of recreation usage and minimise adverse impacts.

[43] Place / Site / Object Identification

Processes and procedures used to report, locate, assess or record information concerning objects or places of heritage significance.

[44] Place / Site / Object Protection

Processes and procedures used to protect heritage objects or places.

[45] Feral Animal Control

Methods such as baiting or shooting used to control or eliminate feral animal pests in forested areas. [Cell B45, on page 51]

[46] Weed Control

Methods such as herbicide application and mechanical removal used to control infestations of weeds from forested areas. [Cell A46, on page 27]

[47] Habitat and Food Tree and Groundcover protection

Methods and procedures used to assess species requirements, and site capabilities in regard to food and / or cover requirements. [Cell B47, on page 53]

[48] Species Management for Flora and Fauna

The development of management prescriptions for selected fauna or flora species or communities. [Cell B48, on page 53]

[49] Grazing

The practice of grazing and procedures and controls used to minimise adverse effects. [Cell A49, on page 28]

[50] Bee Keeping

The practice of bee keeping and procedures and controls used to regulate it.

[51] Mining – Exploration

Mining exploration and development and procedures and controls used to minimise impact. [Cell A51, on page 28]

1.4 VALUES - DESCRIPTION

[A] Flora / Vegetation

This covers values related to retention of a full representation of the region's flora, including the presence of growth stages.

[B] Fauna

This covers all aspects of values related to retention of populations of regional fauna.

[C] Soil

This covers all values relating to the maintenance of soil resources, including its fertility.

[D] Water

This covers values related to maintenance of desired water quality and to water yield.

[E] Health, Pests and Diseases

This covers values related to the maintenance of forest health and vitality, including absence of pests and diseases.

[F] Timber Yield

This covers primarily socio-economic values associated with timber (log) production, including quantities, qualities and costs, and their delivery as raw material to the next stages of processing.

[G] Other Production uses

This parallels [F] in its concern with the socioeconomic aspects of a range of other (non-timber) production uses such as grazing, beekeeping and mining.

[H] Recreation Use

This covers the socioeconomic values associated with recreation and tourism.

[I] Heritage and Landscape

This covers values associated with the discovery and protection and enjoyment of natural and cultural heritage.

[J] Carbon – Geochemical

This covers the values associated with carbon cycles.

2. FLORA / VEGETATION

2.1 A1 REGIONAL LAND USE PLANNING AND FLORA

2.1.1 Statement of Practice and Value

The Effect of Regional Land Use Allocation on Flora/Vegetation

2.1.2 Nature of the Practice

As a practice, Regional Land Use allocation is in theory benign, but if done in a pseudo-scientific or political manner will in the long run lead to detrimental impacts on flora and vegetation and hence potentially lead to further loss of species and vegetation from the region. However, land use allocation at present is essentially a political rather than a scientific process, with various State Government Departments (NPWS, Land and Water, State Forests) competing for land or its control. Past land use allocation in the Eden Management Area, as in most areas of New South Wales and indeed Australia, has been ad hoc and opportunistic, relying on political rather than scientific responses to solve a variety of public pressures leading to a reserve system that, despite many additions over the past decade, still does not adequately represent all vegetation types and significant plant species. Attempts have been made in the past (Richards *et al.* 1990) to introduce more objective land use allocation methods to the Eden Management Area, but many including the Richards study suffer from the diffuse nature of the link between the environmental surrogates used for the allocation analysis and the biota they are reputed to measure (see RAC 1993 for a critique on the use of surrogates). The opportunity to create a CAR (comprehensive, adequate and representative) reserve system as part of the Eden CRA (Comprehensive Regional Assessment), across all tenures, is timely. A variety of techniques to facilitate the process are now available and could be used during the CRA process, such as Irreplaceability Analysis (see Pressey *et al.* 1996). Additionally, the effects of management regimes can be investigated using such programs as CAFE (Bradstock *et al.* 1996) for fire and a variety of Population Viability Analysis packages (see Brook *et al.* (1997) for a comparative evaluation, using real data, of INMAT, GAPPS, RAMAS/age, RAMAS/metapopp and VORTEX) for other management scenarios, provided they are suitably modified for flora. The Deferred Forest Areas are a temporary ameliorative measure until final agreement is reached on the Eden Regional Forest Agreement (RFA).

2.1.3 Potential Innovations

The CRA process itself is in theory an innovation compared to past practice.

2.1.4 Assessment

The long-term prognosis for conservation of the flora and vegetation of the Eden Management Area should be greatly improved provided that a CAR reserve system is created and benign management regimes are devised and adhered to. However, as the CAR system can include species or vegetation types being protected via management as well as formal reservation, the impacts of management on all tenures will still be a factor in conservation. Thus the dedicated reserve system will be only one aspect of regional conservation and hence in those areas outside the reserve system it will still not be a case of *anything goes.* A Regional Conservation Plan (see Cell 2.2 below) is therefore important.

2.1.5 Guidelines/Rules/Limits for Application of Practice

Regional land use allocation can succeed only if detailed data on the distribution and abundance of the flora and vegetation types found in the Eden Management Area exist. This would appear to be the case, with information on flora provided by Keith and Ashby (1992) and on vegetation types by Keith and Sanders (1990) as well as recent updates arising from the IA and CRA processes. Where there are gaps in knowledge, two approaches are possible:

- flora and vegetation surveys could be designed and undertaken to fill in the gaps
- a conservative approach could be taken during the allocation process.

2.2 A2 REGIONAL CONSERVATION PLANNING IMPACT ON FLORA

2.2.1 The Effect of a Regional Conservation Management Plan on Flora/Vegetation

2.2.2 Nature of the Practice

A Regional Conservation Management Plan would be complementary to the Regional Land Use Allocation process. While the allocation process would decide on which areas were to be dedicated as reserves, a conservation management plan would ensure appropriate management across all tenures and ensure that those features not protected in formal reserves were still identified and managed. Part of this process would be the completion of Species Recovery Plans for appropriate flora in the Eden Management Area, none of which exist at present. The completion of Management Plans for National Parks and Nature Reserves would also form part of the process, although these plans are tenure specific. The proposed Native Vegetation Conservation Act provides for the creation of Regional Vegetation Management Plans which would ensure that private land was also considered in the process. Current ameliorative measures operating include SEPP 46 and provisions of the Soil Conservation Act. The Threatened Species Conservation Act will also be relevant for those species on Schedules 1 (Endangered Species, Populations and Ecological Communities) and 2 (Vulnerable Species) across all tenures.

2.2.3 Potential Innovations

The proposed Native Vegetation Conservation Act will be an innovation and in theory will simplify the process of protecting flora and vegetation while extending the cover afforded by legislation. The Threatened Species Conservation Act will still be operational as a further protection. Protection of flora and vegetation in National Parks, Nature Reserves, State Recreation Areas and Flora Reserves will remain unchanged. However, the problematic issue of conservation on freehold title will still need careful consideration.

2.2.4 Assessment

Regional conservation planning, given existing and proposed legislation, has the potential to afford the greatest protection so far achieved in New South Wales for flora and vegetation. The only potential area where difficulties will arise is regarding the exemption to clear 2 hectares per year without approval. This loophole will contribute to the attrition of small remnants which are seen to be adequately represented elsewhere and hence the level of vegetation loss at the local scale may still be great over time. This effect could contribute to the isolation of remnants into discrete islands, with sharp boundaries between cleared and uncleared areas, and will impact on remnant vegetation in areas such as the Bega Valley in the short term.

2.2.5 Guidelines/Rules/limits for Application of Practice

The implications of the 2 hectare per year clearance exception must be thought through as this loophole will pose a real threat to some remnants in the long term, particularly if is is not considered in relation to a Regional Conservation Plan..

2.3 A4 ROAD CORRIDOR LOCATION IMPACT ON FLORA

2.3.1 Statement of Practice and Value

The effect of Road Corridor Location on Flora/Vegetation

2.3.2 Nature of the Practice

The location of road corridors has a potentially negative effect on flora and vegetation if planning does not take into consideration the location of plants or vegetation types of significance, or types such as swamps which are likely to be more sensitive to this practice, both in terms of altered hydrological characteristics and the potential for weed invasion. The construction of roads will obviously have a local effect on flora and vegetation due to the clearing necessary for their construction, but this will be of major importance where stands of significant species or vegetation types are located. This practice is particularly relevant to the State Forest areas, where roading is an on-going practice. It will also be relevant in other areas such as National Parks where new fire trails are to be constructed. The Eden EIS does not state specifically whether existing location information is checked or any flora surveys done as part of the process of locating road corridors.. In the case of National Parks, an internal Review of Environmental Factors is undertaken prior to such activity so that new roads are not located in sensitive vegetation types or populations of significant plant species. State Forests may undertake the same procedure, but this is not stated in the EIS.

2.3.3 Potential Innovations

The process of road corridor location should always take into consideration in an explicit manner known populations of significant plant species or locations of unusual vegetation types. Current knowledge of such information must we understand be made freely available between government agencies.

2.3.4 Assessment

This practice has potential adverse impacts in the area, but if adequate planning is undertaken, the impact of this practice in the Eden Management Area will not be significant for flora or vegetation.

2.3.5 Guidelines/Rules/limits for Application of Practice

Some form of pre-roading flora survey may be required.

2.4 A6 ROAD CONSTRUCTION IMPACT ON FLORA

2.4.1 Statement of Practice and Value

The Effect of Road Construction on Flora/Vegetation

2.4.2 Nature of the Practice

If the process of Road Corridor Location (A4) avoids areas of significant plant species and sensitive vegetation types, the impact of the practice will be only at the local level and could be considered to have an insignificant impact on flora and vegetation. The physical removal of vegetation to construct the road will have implications for other values, such as water quality, but will not of itself be a significant impact. Certain species which favour disturbance and have greater light requirements (such as many members of the Asteraceae) or tolerance to exposed conditions will be favoured by road construction. In certain areas, weed infestation may be a possible outcome of road construction and the more *formal* the road the greater the potential is for this, particularly where bitumen and gravel are used.

2.4.3 Potential Innovations

In order to minimise local impact, as little vegetation should be disturbed as possible. The more vegetation cover that is retained during construction, the less impact there will be on other values.

2.4.4 Assessment

If roads are adequately planned, their construction should entail no significant impact on flora or vegetation.

2.4.5 Guidelines/Rules/limits for Application of Practice

As for Cell A4.

2.5 A12 WILDFIRE - FLORA

2.5.1 Statement of Practice and Value

Practice: Wildfire

The occurrence of unplanned fire of high-intensity that cannot be immediately controlled by fire suppression practices. Wildfires occur due to a range of ignition sources including arson, accident, lightning, and escapes from legal and illegal prescribed burning.

Objectives of fire management to control wildfires include:

- minimizing the occurrence of wildfires

- mitigating the potential impact of wildfire to forest, environmental, social and economic values
- preventing escape of fire to adjoining land
- provide fire suppression capacity.

Value: Flora

Conservation values of flora include:

i) Community composition, biodiversity and local presence of species

ii) Community structure, life stage and age distribution

iii) Rare and threatened species protection.

2.5.2 Nature of the Practice

a) Mechanism of impact

The impact of fire on conservation values of plant communities varies greatly and depends on:

- Characteristics of fire behaviour such as amount and rate of heat energy released, residence time, areal extent and distribution, which determine the extent and intensity of combustion.
- The fire regime which includes frequency, intensity, season of burning, areal extent and pattern
- Environmental conditions during and after the fire
- Characteristics of plant species life history s which determine their resilience and resistance and hence capacity to regenerate.

Specific mechanisms of the impact of fire on flora include:

- Vegetation is exposed to high temperatures. The temperature and residence time of the fire determine degree of leaf scorch, cambial damage, mortality, seed survival and scarification of seed required for germination.
- Impacts related to fire regimes are discussed in cell 13A in relation to imposed regimes of repeated fires.
- Environmental conditions preceding and during the fire, such as temperature, moisture and wind, influence the degree of combustion and damage.
- Environmental conditions are altered after the fire, such as increased radiation, evaporation and temperature ranges, and this influences regeneration.
- Enhanced growth of seedlings occurs in ashbeds due to increased availability of nutrients and possibly also a reduction in inhibitory chemical substances and microbial populations (Walker *et al.* 1986; Renbuss *et al.* 1973).
- Eucalypt species have a wide variety of characteristics which influence resilience and resistance to fires, for example, accessory buds in the stem and lignotuber, bark thickness and flammability, seed stored in woody capsules in the crowns or soil. Regeneration will vary among species in response to the degree of expression of these characteristics.
- Understorey species regenerate from sprouting or seeding or a combination of these processes, depending on the fire intensity. The proportion of different species in the regenerating vegetation is influenced by the extent of fire damage.
- Some species require high-intensity fire for seed germination and thus their persistence in the community is dependent upon occasional wildfires.
- Fire has been a major agent of disturbance during the evolution of these eucalypt forests. Fires create diversity in the composition, structure and age distribution of plant communities.

b) Importance to Eden RFA area

Forests in the Eden region are highly fire prone and have experienced fires for a long time, in both Aboriginal and pre-human periods. Fire histories have been inferred from a range of sources, but there is no definitive fire regime that can be considered ‘natural’. Climate records indicate that seasons with severe fire weather occur on average once in seven years in the dry forest areas (Duggins and Saunders 1978), but only some areas burn during these conditions. Vines (1974) suggested that the natural frequency of severe fires in dry forests is approximately once in 13 years on a regional basis, not the return period at one site. In wet forest, wildfires of sufficient intensity to kill trees are considered to be infrequent, and possibly occur once in one to three centuries (Ashton 1981; Barker 1991). Fire frequency was assessed by Banks (1990) using fire scar histories from *E. fastigata* in Glenbog S.F. This study included fires of sufficient intensity to damage tree boles. The average frequency of fires was once in 8 years in dry sclerophyll forest and once in 14 years in wet sclerophyll forest. The frequency of wildfires has increased since European settlement of the region, and frequency of ignition is closely related to population density. Increasing population density, particularly near forested ares, and large numbers of seasonal visitors are major threats to fire control.

Although species in the region are generally able to regenerate after the occurrence of fire, some species and communities are sensitive to fire and change in the fire regime may alter vegetation composition and structure, and boundaries between communities. Most of the forests in the region consist of mixtures of eucalypt species which each have variable characteristics of resilience and resistance to fire. Although all species have the capacity to regenerate after fire, it is likely that their relative capacities to regenerate under different fire regimes vary, and hence there is the potential for shifts in species abundances and boundaries between species. The main fire sensitive species and communities occur in the rainforest types (Dry Rainforest, Coastal Warm Temperate Rainforest, Hinterland Warm Temperate Rainforest and Cool Temperate Rainforest) (Keith *et al.* 1995).

c) Scientific commentary

The main aspects of wildfire that control plant responses and post-fire vegetation patterns are fire intensity and areal extent, and post-fire weather conditions.

Fire intensity determines the degree of damage and mortality of plants, and hence the mechanisms of regeneration. Plant succession following fire is generally determined by the initial floristic composition in wet and dry sclerophyll forests. Relative abundance may change over time, the change reflectes life history attributes and associated life forms (Clark 1988).

The areal extent of heterogeneity of fire characteristics within a burnt area determines the capacity of refugia to persist and recolonization. Fire produces highly heterogenous conditions for regeneration by affecting soil properties, surviving plants, location of debris and micro-climatic conditions at the soil surface. This patchiness influences post-fire dynamics of plant regeneration at a small scale. Potential impacts on plant communities need to be assessed at a regional rather than a point scale.

Both rainforest communities and individual species have highly discontinuous distributions. The cabbage tree palm (*Livistonia australis*) is an example of a species that exists as isolated populations and remnant individuals in gullies on private land near Tanja and in Mumbulla and Murrah State Forests (Harewood pers. comm.). Protection from wildfire and deliberate burning on surrounding land is critical for the conservation of these rainforest remnants.

The potential for regeneration is highly dependent upon post-fire weather conditions, and this hinders the ability to predict impacts on plant communities. Wildfires most commonly occur during times of severely hot, dry weather and so post-fire drought conditions are likely.

d) Gaps in knowledge

The long-term cumulative impacts of repeated fires of varying behaviour on ecosystem processes, community boundaries and species occurrence are unknown.

The relative importance of different fuel characteristics are not known, such as the amount, structure, arrangement and connectivity, and frequency of drying under extreme weather conditions. Relationships between fuel load and characteristics, and type and age of the vegetation are required to be able to predict fuels from vegetation maps (Dovey 1994).

e) Currently applied ameliorative measures

Fire detection and suppression techniques have reduced the extent and damage caused by wildfire relative to the number of ignitions (BVSC 1997).

Fuel reduction has mitigated fire behaviour and reduced damage in some circumstances. However, under extreme fire weather conditions, forest fires can burn out of control even when the fuel load is very light.

Retention of trees within a coupe after harvesting provides a potential seed source if the young regrowth is killed by wildfire (Bridges 1983).

2.5.3 Potential Innovations

Human sources are the main form of ignition of wildfires, and illegal sources are of particular importance. Changes in human practices to reduce the use of fire, both through legislative and educational means, would help to reduce the occurrence of wildfire. Such changes in practices could potentially include a reduction in the use of prescribed fire on private land and State Forests to reduce fuel loads following harvesting an increase in the proportion of biomass used for wood products, and mulching residues. Greater legislative restriction of burning-off on private land may be necessary.

Fire suppression practices must be managed to ensure that activities such as bulldozing, use of chemical retardants and back-burning are not deleterious to areas with high conservation value. There should be a plan for rehabilitation of areas disturbed by fire suppression activities, including erosion mitigation and revegetation.

A system for identifying and monitoring plant responses to fire has been developed by Gill and Bradstock (1992). A comprehensive list of plant species in the region is required. This system should be used to compare responses of plant species and communities to various fire regimes. Specific characteristics of species that should be investigated include:

- time to reach reproductive maturity and produce seed
- temperature required for seed germination
- temperature and residence time that cause damage and mortality.

2.5.4 Assessment Statement

A variety of fire regimes is necessary to conserve floristic diversity and habitat. Fire management in conservation areas aims to restrict fires to only a part of the distribution of a vegetation type at any one time so as to maintain a range of age classes (NPWS 1997).

The occurrence of wildfire does have a role in conservation management as some species require high-intensity fire for their persistence (Catling 1991; Whelan and Muston 1991). It is unlikely that total fire exclusion from the region will be achieved, and so the occasional unplanned fire should be sufficient for conservation of these species in some areas. The objective for fire management should remain to suppress all unplanned fires on all land tenures.

Management practices must provide protection from wildfires in the Eden region as it is a highly fire-prone environment and there are many social, economic and environmental resources that could be destroyed by wildfire. The main questions concern the relative benefit of investing resources in fire detection and suppression capabilities and fuel reduction to mitigate the effects of wildfires. There must be a minimum standard for protection of life and property that is consistent across all land tenures.

2.5.5 Guidelines / Rules / Limits for Application of Practice

There are some guidelines for the critical fuel load required below which it should be possible to control wildfires; this is approximately 8 t ha^{-1} (Gill 1986). Plans are required to develop strategic zones of fuel reduction, that can help to control fires at these locations.

There are some data on temperatures required for seed germination, but this is highly variable among species (Gill and Bradstock 1992).

Guidelines could probably be developed to predict the damage and mortality experienced by different species and their rates of recovery under varying conditions of fire behaviour.

2.6 A13 FUEL REDUCTION BURNING - FLORA

2.6.1 Statement of Practice and Value

Practice: Fuel reduction burning.

Fuel management has become the main preventative measure to reduce the risk of wildfire. Of the factors controlling wildfire behaviour - weather, terrain and fuel - fuel load is the most feasible to alter.

The objective of fuel management is to reduce fuel load and modify fuel arrangement so as to limit the intensity and rate of spread of wildfire and to create conditions in which it is safe to deploy fire suppression resources.

Various forms of fuel reduction burning are practiced according to the objectives for fuel reduction and the type of vegetation:

i) Broad area fuel reduction burning is practiced over large areas of older, multi-aged native forest in State Forests. Fire frequency is once in 5 - 7 years and the aim is to reduce fuel levels to 5 - 6 t ha^{-1} over a minimum of 30% of the gross area and to burn 50% of the gross area in any one fire.

Burning is done mainly on ridges and drier slopes using aerial and some ground ignition. This produces a mosaic of fuel age classes and discontinuous fuel loading (FCNSW 1991). The current practice in State Forests aims to burn a gross area of 20000 - 25000 ha annually which includes a net area that is actually burnt in the mosaic pattern of 10000 ha. The area burnt varies each year, depending on weather conditions and resources available.

ii) Strategic fuel reduction burning is practiced in areas surrounding settlements and high value assets. The aim is to reduce fuel levels to as low as possible in over 80% of the specified gross area and to burn every 3 - 5 years (FCNSW 1991). Strategic burning is used to protect fire sensitive communities such as rainforest. Fuel reduction burning is practiced around the boundaries of National Parks to help control the spread of wildfires onto adjoining land tenures at a frequency of once in 5 - 7 years and approximately once in every 3 years near centres of population (NPWS 1990).

iii) Burning in regrowth is commenced when trees have a diameter greater than 9 cm or height greater than 12 m which is at an age of 12 - 20 years. Fuel loads in a 15 year-old stand are approximately 7 - 10 t ha^{-1} of fine surface fuel and 3 - 4 t ha^{-1} of fine near-surface and elevated fuel. The basis of this tree size and the conditions for burning is research by the CSIRO Bushfire Management Group on fire behaviour and tree damage in regrowth forests of the Eden region (Gould 1996). Burning is then continued at a frequency of once in 3 - 5years with the aim of maintaining fuel loads at 5 - 6 t ha^{-1} (SFNSW 1991).

iv) Burning for species and habitat management is practical in limited areas, based on knowledge of fire-free periods required, temperatures required for germination and other life history attributes (NPWS 1990). Burning to enhance conservation values requires diversity in the season, intensity, frequency and sequence of fires.

All these forms of burning are carried out under prescribed conditions of the fuel and weather so as to control fire behaviour. These forms of burning are considered together in this section as they all involve frequent, low-intensity fires under controlled conditions. Some differences in frequency, intensity and areal extent should be considered when assessing and comparing impacts.

Value: Flora

(see cell A12)

2.6.2 Nature of the Impact

a) Mechanism of impact

The mechanisms stated in cell A12 are relevant here. Some differences in the impacts will be apparent as a result of generally lower intensity but higher frequency of fires. In this section the impacts of repeated fires as a fire regime will be emphasised. A human-imposed change in the fire regime (frequency, intensity, season and areal extent) will potentially cause changes in the state of the vegetation in terms of species composition, abundance and structure. These changes will occur as a result of:

- losses of species that cannot regenerate and produce seed during the inter-fire period (Gill 1975; Benson 1985)
- depletion of soil stored seed due to combustion in fires and inadequate time for replenishment
- losses of species that require a higher intensity fire for germination
- increase in species that regenerate rapidly after fire, e.g. sprouting shrubs
- a long-term depletion of regenerative capacity of re-sprouting species (Tolhurst 1994)
- increased mortality of trees due to repeated damage and invasion by diseases and termites. (Gill and Bradstock 1995).

b) Importance to Eden RFA area

(see cell A12)

Little is known about life history attributes of many forest species in the Eden region that are critical in determining plant responses to fire.

Protection of small areas of fire-sensitive communities from the effects of various types of prescribed burning is a major issue for conserving biodiversity in the region.

Changes in species composition and structure over broad areas of mature forests are observed in some areas as a result of repeated fires. At Dr George Mountain and Black Range, for example, the vegetation type has changed from dry sclerophyll forest to a sparser open woodland. Areas of coastal forest have been regularly burnt for grazing purposes and the remaining old trees are damaged and their persistence is threatened (Harewood pers. comm.). The general change in vegetation type that occurs in the region under a regime of frequent fires is that the shrub layer is largely eliminated and an open grassy ground cover (e.g. *Danthonia* sp.) remains in the dry forests. Shrubs that do remain are mainly leguminous (e.g. *Daviesia, Pultenea, Oxylobium* and *Heardenbergia*). In the wet forests, bracken fern (*Pteridium* sp.) or wiregrass (*Tetrarrhena juncea*) predominates (Harewood pers. comm.). Encouragement of these near-surface fuels may increase the flammability of these forests.

In the CRA process for Eden, rare and threatened species and communities were identified and predictions developed about their responses to various disturbance regimes (Bradstock R. and Keith D., NPWS, pers. comm.). There are significant populations of rare and threatened species and fire-sensitive species outside the reserve system. Management for their conservation on other land tenures is a major issue. Mechanisms to deal with this issue include prescription zones within State Forests, conservation agreements and the Threatened Species Conservation Act (1995) administered by NPWS, and the proposed Native Vegetation Conservation Act administered by the Department of Land, Water and Conservation (Keith D., NPWS, pers. comm.)

c) Scientific commentary

The main aspects of prescribed burning that determine plant responses are frequency, intensity and proportion of area burnt, and in particular the cumulative effects of repeated fires under the regime. Investigations of species life history attributes have identified a range of plant responses to prescribed fire. Previous studies in a range of vegetation types have found:

- local extinction of some fire-sensitive species when the inter-fire period was not long enough (Bradstock 1990; Hamilton *et al.* 1991; Burgman and Lamont 1992;). Obligate seeding species are particularly at risk under fire frequencies of one in 5 years or less (Benson 1985). Fourteen years has been suggested as a minimum time required for species to mature and produce a seed bank (Gill and Bradstock 1994).
- reduction in abundance or loss of species requiring high-intensity fires for germination; there is great variability in temperatures required (Bradstock and Auld (1995)
- changes in the structure of the understorey, with a reduction in height and abundance of shrubs and dominance of a grassy layer under a regime of frequent fires, resulting in a simplified community structure (Lamb *et al.* 1981; Birk and Bridges 1989; Tolhurst *et al.* 1992)
- change in the composition of the understorey with the number of sprouting species increasing relative to seeding species as fire frequency increases (Benson 1985)
- increased mortality of trees due to repeated damage.

Some studies show no decline in species richness under frequent burning (Fox and Fox 1987; Christensen and Abbott 1989,). However, measures of diversity should include abundance and density. Continual reductions in these attributes may lead to local extinction in the long term.

Knowledge of life history attributes allows the planning of fire regimes that will ensure conservation of species diversity and community structure. However, life history attributes of species can vary geographically and this makes it difficult to extrapolate plant species' responses to other regions (Gill and Bradstock 1992; Morrison and Cary 1994).

An imposed fire regime of frequent, low-intensity fires across the landscape will have the long-term effect of reducing the diversity and structural complexity of plant communities and environmental conditions in the areas that are burnt, but increasing the differential between communities at the boundary of burnt and unburnt areas. The gradual transitions between communities and ecotone communities will thus be reduced. This will have the effect of limiting the distribution of species and the movement of fauna.

Post-fire weather conditions, often over several years, are very important in determining regeneration and vegetation dynamics. This dependence on weather patterns limits the ability to predict responses of vegetation.

Fires of high-intensity in specific areas may be required to allow breaking of seed dormancy. This process is important for the families of Fabaceae, Laminaceae and Rhaminaceae and may be required by some rare species (Auld and O'Connell 1991).

Prescribed burning in young regrowth often leaves dead biomass from plants that are killed but not completely combusted by the fire, for example *Allocasuarina littoralis* seedling regeneration. This creates a problem by increasing the fuel load in these stands.

d) Gaps in knowledge

- Document species life history attributes:
  - time to reach reproductive maturity and to replenish seed banks
  - fire intensity required for seed germination
  - longevity of species that require fire to reproduce.

These attributes should be considered in terms of trophic groups to better understand their functional relationships.

- Identify sensitive species and communities and define adequate buffer zones in which fire is excluded around these communities.
- Monitor impacts of fire regimes on vegetation dynamics in the long term.
- Improve methods of selecting optimum species, populations and sites to monitor and identify critical ecosystem processes to monitor.
- Develop techniques to measure long-term productivity which can detect small changes (often < 10%) in spatially variable natural vegetation. Currently used methods of measuring bole growth by diameter over bark often have problems with bark dynamics after fire. Increments in wood rings from the stem can give useful measures of growth, but this technique is restricted to environments where annual rings are formed. Other potentially useful measurements of forest productivity that should be investigated include leaf area index, annual leaf production and leaf fall mass and nutrient content. Foliage dynamics should show a rapid response to recovery from disturbance and changes in environmental conditions.
- Information on fuel characteristics and their relationship with fire behaviour is required, both to improve predictions of fire behaviour and to determine optimum means of reducing fuel. Given the generally low fuel loads of 10 t ha^{-1} or less (FCNSW), it appears that characteristics other than weight contribute to the highly flammable nature of these forests. The significance of different components within the total fuel complex needs to be investigated (Good 1996). For example, near-surface fuel was found to be the fuel factor which had the greatest influence on rate of spread and flame height under prescribed burning conditions (Gould 1996). Drying patterns and fuel moisture regimes at different times of year on different aspects are required to complete the Burning Guide for young regrowth developed by CSIRO Bushfire Research Unit. Information is required for different forest types about the temporal pattern of fuel weights both with and without fire. A relationship needs to be developed between fuel load and vegetation type and rates of decomposition which would allow spatial prediction of fuels from vegetation maps (Dovey 1994).

The Eden Burning Study established by State Forests of NSW in 1985 (Binns and Bridges 1997) should provide information for assessing impacts of burning on flora. The large scale of the experiment and treatments at an operational level are a major asset. However, extrapolation of results to plant communities and species outside the experimental area will require research on life history attributes in other communities. It is unfortunate that there are no measurements of soil properties and nutrient cycling processes as changes in these processes often indicate longer-term trends in forest productivity.

e) Currently applied ameliorative measures

- The burning prescription results in a mosaic of burnt and unburnt patches which provides:
  - refugia for fauna
  - seed sources for colonization

- Individual sites are not necessarily burnt in every fire event.

However the hypothesis that this prescription satisfies conservation requirements has not been tested to determine:

- the effectiveness of this burning pattern for conserving flora and fauna
- whether the differential between burnt and unburnt sites is being increased.

- Areas with rare and threatened species and sensitive communities are excluded from prescribed burning. However, the effectiveness of fire control at the boundary of such areas and the adequacy of buffer zones needs to be tested. Further work is required to identify those communities that require protection.

2.6.3 Potential Innovations

A greater degree of planning is required to provide different fire regimes for specific purposes and to provide protection for resources without the use of broad-area fuel reduction burning.

Strategic burning

Prescribed burning should be limited to those areas where there is a need for strategic protection of assets and for creating fire break zones, for example along fire trails. These areas may require is currently practiced to ensure that fuel loads are maintained at a level low enough to provide some protection from wildfire. The model of bushfire behaviour and risk developed for the Eden region by Dovey (1994) may be useful for identifying areas of high priority where there are high value assets and a high incidence of ignition. Modification of the model is required for use in detailed planning, as described by Dovey (1994), and including improvements such as the relationship between vegetation type and fuel load and dynamics, and fire weather categories defined spatially. A reduction in the area burnt in individual fires would enhance the potential for recolonization by various species. The objective is to use fire more effectively to reduce wildfire hazard, covering a smaller area and optimizing location and timing. The extensive road system throughout State Forests should make burning of small areas and containment more feasible.

Fuel management

At present the main form of fuel management is prescribed burning to reduce fine fuels. However, there are other fuel characteristics that influence fire behaviour, including structure of litter fuel, shrub fuel, elevated fuel, bark on trees, proportion of green and dead material, flammability of different species, distribution and continuity of fuel load, and moisture of each fuel component (Cheney *et al.* 1992). It may be possible to modify these other characteristics to help mitigate the impact of wildfire, and therefore all fuel characteristics should be included when assessing the effectiveness of fuel management methods.

Alternative practices for fuel reduction should be investigated and where appropriate implemented to reduce the amount of burning required. Grazing and slashing are currently used to reduce fuels around settlements, parks, roadsides, vacant Crown land, private land, pine plantations and power lines. There is potential to increase the extent to which these practices are used (BVSC 1997).

Prescriptions and monitoring

Prescriptions for fuel reduction burning should specify weather and fuel conditions, fire behaviour, and outcomes in terms of fuel reduction and environmental impacts. Guidelines should consist of an allowable range of conditions for each of these parameters and assessment of the practice should be based on these guidelines. Timing of ignition of fires is a major factor that could improve control of fire behaviour and hence impact. Improved weather forecasting that is specific for the region would be beneficial. Flexibility in the time of day of ignition can be helpful, for example burning in the afternoon has the advantage of decreasd temperature and dewfall during the evening.

Greater control of the edge of fires is required to ensure burning is confined within set boundaries and does not impinge upon buffer zones and sensitive areas. Encroachment of fire in small rainforest and ecotone communities is a major threat. Forest edges are subject to desiccation and increased light which tends to promote regeneration of sclerophyll species (Unwin *et al.* 1985; Horne and Hickey 1991). Defining adequate buffer zones is also a major issue.

The frequency at which prescribed burning is practiced should be varied in relation to forest types. A frequency of once in 5 years may be satisfactory in dry forest, but would have a significant impact by drying out the environment of wet forests and a lower frequency would be highly preferable. The differences in communities in relation to aspect and their requirements should be taken into account in planning fire prescriptions. The wetter communities on southern slopes are less tolerant of frequent fire, for example, than the drier communities on northern slopes. Retention of the shrub layer is important for the maintenance of community structure and diversity, as habitat for birds, small mammals and invertebrates, and for nutrient cycling through the litter layer. Any prescription for broad area burning should be planned in accordance with life history attributes of the species occurring in the area.

Monitoring of the outcomes of fire management practices is an important means of demonstrating that the practice as implemented is following prescriptions, and that this can be seen and evaluated by the public. Monitoring of areas that have been prescribed burnt needs to be improved to give an assessment of environmental impact. SFNSW has a monitoring system in operation but greater attention is needed assessing the degree of damage, such as proportion of canopy scorch, amount of cambial damage on trees, proportion of the gross area that was burnt, the amount of mineral soil exposed, proportion of the litter layer remaining, and whether the edge of the fire was within prescribed boundaries. Maps of areas burnt are required to build up information about fire history at the site level and areas burnt at the regional level. This information about impacts must be regularly assessed and input to improving the prescriptions and operational management for burning. A standard monitoring system should be used by all people practicing prescribed burning. It is imperative to start collecting baseline data so the effects of various fire regimes can be assessed against a baseline that represents minimal disturbance, and to provide data for assessing long-term cumulative impacts. Monitoring should include attributes of species occurrence and functioning of ecological processes. Monitoring these processes is essential for conserving the habitats required by individual species.

Developing a monitoring system is an important task. The scale of measurement, in terms of space, timr and taxonomy, must be sufficiently sensitive to detect changes. Measurements need to be at the scale of individual populations of species or representative functional groups. Information about life history attributes and species and community distributions provides a good basis for selecting indicator species and the location of populations to measure. Targeting individual populations that are determined to be representative is considered to be a more useful approach than general performance measures of the vegetation (R. Bradstock and D. Keith, NPWS, pers. comm.). Information about population dynamics is essential to be able to assess long-term changes in the vegetation.

Species Requirements

Flora surveys in the region should identify species and communities that are fire sensitive or have specific requirements for a fire regime. All areas that are going to have prescribed burning should be surveyed beforehand. Further work will be required to define species life history attributes and expand the register developed by Gill and Bradstock (1992). Research on fire requirements of rare and threatened species is a priority. Protection of habitats for these species is essential across all land tenures, particularly moist gullies and rhyolite outcrops. There is probably an adequate frequency and range in fire behaviour from wildfires and prescribed fires across the region to provide conditions necessary for germination of species that require fire (Harewood pers. comm.). Fire sensitive communities must be protected from prescribed burning and consideration should be given to strategic burning in surrounding areas to afford protection from wildfire in both State Forests and National Parks. Habitat types that should be protected from fire include rainforests, wet forests along gullies, old-growth forests, rocky outcrops, water courses and swamps, rotting logs, moss and deep litter layers. Strategic burning around fire-sensitive communities must have the highest level of fire control to contain impacts within nominated boundaries. The risk of fire spread requires careful assessment.

Training and Education

Improved training of staff who implement prescribed burning is required in order to achieve the prescriptions during operational burning. Improved skill in monitoring and awareness of the ecological impacts of fire is also required. Prescribed burning for species and habitat management and in young regrowth requires higher levels of skill. Maintaining continuity of experienced staff in a region is important.

2.6.4 Assessment Statement

The fire regime in the Eden region will always consist of a combination of imposed fires and wildfires. The balance between these various types of fire and the trade-offs between forest values that this involves is the issue to be assessed in the RFA. Fire management represents two main objectives of protection of life, property and resources, and the conservation of environmental values. These two objectives are contrary for some areas and fire practices.

The practice of fuel reduction burning should be assessed in terms of improving the capacity to control wildfire and minimizing the damage caused, and also in the ecological impact of an imposed fire regime.

- Reduction of fuel loads and the risk of wildfire. The effectiveness in reducing fuel loads should be assessed in terms of the reduction in fuel weight and height, the length of time for which these fuel loads are reduced, and the advantage of a reduced surface fuel load in reducing wildfire intensity, rate of spread and spotting.
  - Information about the reduction of rates of spread and intensities of wildfires in areas that had been treated with fuel reduction burning are mainly based on experience rather than empirical evidence. Reduction in fuel load does assist fire suppression by reducing the rate of spread and spotting potential (Cheney 1996; Incoll 1996). Fuel reduction burns up to 10 years old can assist in the suppression of wildfires because of a reduction in elevated fuels and bark on trees (Incoll 1996). However, there has been no quantitative assessment of the effectiveness of prescribed burning in reducing the risk and impact of wildfires. (This, of course, is a difficult question to test experimentally.) The question is how best to use the practice of prescribed burning to achieve objectives of reducing the risk of wildfire. There is general agreement from experience in fire suppression that areas with low fuel loads that have been strategically burnt at high frequency around high value assets is effective for fire control (ABRG 1984; Cheney 1996). However, there is not general agreement about the effectiveness of broad area burning where the fuel load of the whole area cannot be maintained at very low levels and the actual distribution of fuel is not known (RAC 1992; Rawson 1984).
  - Based on models of fire behaviour using fuel and weather variables, Gill (1986) demonstrated that if the fuel load was below a critical level, such as 8 t ha^{-1} then there were fewer days when a high-intensity wildfire could occur and the chances of wildfire control were improved (Underwood *et al.* 1985). Steady state fine fuel loads in mature dry sclerophyll forests are approximately 10 t ha^{-1} up to 15 t ha^{-1} (FCNSW, Bridges pers. comm.). Fuel loads are higher (up to 18 t ha^{-1}) in dense regeneration following wildfire.
  - The period of effective fire protection by fuel reduction burning, however, is limited due to the rapid accumulation of fuel. Rapid re-accumulation of the litter layer occurs because litterfall rates are maintained whilst the mass of the forest floor (and hence the quantity of litter decomposing annually) is greatly reduced by burning. For example, accumulation above the critical level for control occurs within 3 - 6 years in many forest types (Raison *et al.* 1983; Underwood *et al.* 1985; Birk and Bridges 1989). Litterfall rates in mature forests have been measured in the Eden region to be 2 - 5 t $ha^{-1}yr^{-1}$. Hence, the litter layer would return rapidly to a steady state value after fuel reduction burning (FCNSW). Fuel accumulation in dry forests is 80% - 90% of the long-term quantity within 3 - 5 years (Bridges pers. comm.). In these forest it appears that burning would have to be at least at 3 - 5 year intervals to remain effective in significantly assisting wildfire control. Much of this effectiveness is achieved by gradually changing the understorey from a shrub to a grass layer after repeated fires. Fuel accumulation rates in young regrowth are approximately 80% after 3 years and 100% or more after 5 - 6 years, and cover of near-surface fuels is more that 60% after 3 years and elevated fuel reaches 70% of pre-burn height after 6 years. Hence prescribed burning is likely to be effective for 4 -6 years (Gould 1996). Even though fuel load may re-accumulate quite rapidly, the vertical structure and height of fuels and bark on trees is reduced for longer periods, up to 10 years or more in dry sclerophyll forests (Tolhurst 1996). All

fuel characteristics should be taken into account when assessing the reduction in fire hazard.

- It is not possible to assess the relative effectiveness of strategic burning compared with broad area burning for providing protection from the risk of wildfire using experimental or quantitative evidence. However, there are several advantages of a strategic burning policy. There will always be limited resources available for fire management and these can be used most efficiently to reduce fuels in areas close to the asset that requires protection. Burning smaller areas means that greater control of fire behaviour is possible, for example there is less effect of changes in aspect which influence burning conditions. There are also advantages of using strategic burning to create wildfire control zones that utilize natural boundaries such as roads, clearings and rocky outcrops to extend a zone of low fuel levels (R. Bradstock., NPWS, pers. comm.).
- Deliberate use of fire under any form of prescribed conditions always carries the risk that fire will escape or re-ignite and burn large areas.

■ Ecological effects of a regime of frequent, low-intensity fires considered in the long term.

- The mosaic pattern of burning and retention of vegetation patches as refugia is claimed to be of conservation value but it has not been scientifically demonstrated in forests of the east coast. The spatial arrangement and characteristics of the unburnt patches are important, but there has been little assessment of optimum prescriptions. There are potential problems with this pattern of burning, for example the burnt patches may experience increased grazing pressure, and there may be increased differentiation between burnt and unburnt areas with repeated burning.
- Assessment of ecological effects at the regional scale needs to take into account the interaction of spatial and temporal impacts. Maps of actual areas burnt will allow identification of which areas have been burnt, how often and in what type of fire. This information can be superimposed on distributions of species and sensitive habitats.
- Scientific knowledge of species responses to fire in relation to their environment is too limited to identify the optimum fire regime for maintaining conservation values in forests. This information is accumulating and a good basis for monitoring has been provided by Gill and Nicholls (1989), Gill and Bradstock (1992) and Wardell-Johnson *et al.* (1989) that can be used for continual modification of management practices. Changes in vegetation characteristics will be long-term and cumulative.
- Ecological effects on species and communities need to be considered in terms of the overall regime of disturbance that includes wildfires, prescribed fires and timber harvesting. Some work has already been done through the CRA process to assess plant responses to the interaction of these disturbance processes in terms of spatial distributions of species. Vulnerable species, and disturbance regimes and processes that are potentially threatening, have been identified (R. Bradstock and D. Keith NPWS, pers. comm.).

The current system of fire management used by NPWS involves defining bushfire management zones and implementing strategic burning to protect high risk areas or for ecological requirements. The system has been used successfully in some district Bushfire Management Committees. Documentation of specific fire management plans is currently in progress and is expected to be completed for all fire-prone National Parks and reserves by 2002 (A. Ferguson NPWS, pers. comm.). This system could be implemented across all land tenures, varying the fires regimes used according to the objectives of the land tenure. A range of fire regimes is desirable to maintain ecological diversity.

There is insufficient evidence at present to assess the effectiveness of fire management in the Eden region because there has been no large scale systematic monitoring of the impacts of these practices. Prescribed burning has significant impacts on conservation values. These impacts cannot be fully evaluated until further research identifies and quantifies a greater range of specific impacts and their interactions for communities in the region. In the meantime the precautionary principal should be applied to fire management such that the use of fire is limited to essential objectives of protection or where ecological objectives are certain. It is unlikely that a single prescribed fire regime will be able to meet the objectives of both fuel reduction and species conservation in a range of community types (Morrison *et al.* 1996). Therefore, prescribed fire regimes will have to be selected according to the primary objectives of land use, while acknowledging the impacts caused on other forest values and not compromising values of adjoining land tenures. Selection of fire regimes should be flexible and directed towards meeting local objectives with in the context of a regional plan. There needs to be a set of minimum standards for both protection of assets and conservation values in the legislative responsibility of all land tenures.

Planning for fire management for both protection and conservation must be coordinated across all land tenures in the region; the regional Bushfire Management Committee provides a good mechanism for this. Issues of regional coordination include improving the control of burning to prevent escapes or re-ignition from burning-off on private land and post-logging burning, reducing ignition sources and defining buffer zones between land tenures. The latter may potentially be an important problem for the many small National Parks and Nature Reserves that have extensive boundaries.

Fire management plans on all land tenures should include the same prescriptions for burning practices and procedures for monitoring ecological effects of fire, damage to timber resources and rehabilitation of soil and vegetation disturbed by fire management operations. There is a need to improve the system of monitoring, recording, evaluating reports and reviewing fire management prescriptions. The dual aims of assessing fire management prescriptions are to minimize effects on environmental values and to maximize the effectiveness of fuel reduction.

Impacts of fire management practices should be considered at both a site specific and regional spatial scales, and at both a direct and long-term cumulative temporal scale. At a site level it may not be possible to conserve all species that could potentially occur at the site under all practices. However, at a larger scale, e.g. catchment or region, these values should be conserved. Most impacts are cumulative and so should be assessed in terms of the degree of the immediate impact, the rate of recovery and the cumulative effect of multiple impacts over long time scales.

2.6.5 Guidelines / rules / limits for application of practice

Frequent burning will cause some changes in community composition and structure, but the degree of impact will vary with vegetation type. Hence, prescribed burning should be limited to areas where the objectives of the land use determine that the beneficial effects of fuel reduction burning outweigh the deleterious effects on ecological values.

It should be possible to develop guidelines to define maximum frequency of prescribed fire and the range of intensity to maintain species diversity for the Eden region, using species' life history attributes and thresholds, and the register of Gill and Bradstock (1992) and the GIS database used by NPWS (Ferguson, NPWS, pers. comm.).

2.6.6 Linkage to Indicators and Targets

Monitor changes in species composition, abundance and structure at reference sites with known fire regimes. Indicator species and methods to measure community structure require definition.

2.7 A14 POST-LOGGING BURNING - FLORA

2.7.1 Statement of Practice and Value

Practice: Post-logging burning

Prescribed burning to reduce fuel loads resulting from harvesting operations. Fuel loads can be up to 10 t ha^{-1} of fine fuel and 200 t ha^{-1} of heavy fuel (Bridges 1983), and hence there is a great range in the intensity of fires and the proportion of fuel combusted. This practice is mainly used in State Forests, but there is also some burning of slash on private land. Approximately 5000 ha is burnt annually in State Forests. The objective is to reduce the weight of logging slash by 35% and of fine fuel by 80% and to burn 60% - 80% of the coupe area (SFNSW 1991).

Value: Flora

(see cell A12)

2.7.2 Nature of Practice

a) Mechanism of impact

- Regeneration on burnt slash dumps is inhibited for many years and this may result in uneven regeneration and stocking across the coupe.
- Retained trees are often damaged and this is exacerbated by the cumulative damage caused by later fuel reduction burning.
- Induced hydrophobicity of soils results in reduced water-holding capacity and hence availability for regenerating plants.
- Regeneration of leguminous shrubs is often stimulated after a high-intensity fire and growth can be very dense. These species are useful for providing nitrogen to the site. However, the dense shrub layer increases the fuel load.
- Soil nutrient availability is increased in the short term with the deposition of ash and this helps to stimulate regeneration.
- There is a long-term reduction in site nutrient availability because a high proportion of nutrients is lost from the slash material in high-intensity fires (Raison 1980, 1981). This decline in nutrient availability will result in reduced growth rates and potential changes in species composition.

b) Importance to Eden RFA area

The potential for change in the composition of regenerating vegetation after post-logging burning has not been assessed for the vegetation types in the region.

Damage to retained habitat and seed trees during post-logging burning and later fuel reduction burning in some places has as impact on the strategy of conserving some old-growth habitat throughout production forests.

c) Scientific commentary

Post-logging fire is not necessary for regeneration of eucalypts in dry forest such as the silvertop ash / stringybark types in the Eden region (Bridges and Dobbyns 1991). Even in the wet forests of the region, regeneration can be adequate after removal of overstorey and sufficient mechanical disturbance of mineral soil (Raison 1980).

Regeneration may be hindered by post-logging fire because the fire destroys seed in the fallen crowns and some of the seed bank in the soil, and kills some of the advance-growth seedlings and small trees that would have allowed rapid regeneration of the site. If regeneration is dependent on the trees retained in the coupe, this will seriously restrict the genetic diversity of the regeneration. If viable seed is not produced at a time when weather conditions are favourable for germination and establishment, then adequate stocking of the regenerating stand may be jeopardized.

d) Gaps in knowledge

Burning of logging slash both in dumps and spread across the coupe causes a high degree of heterogeneity in the post-fire environment. The extent to which these conditions alter species composition and distribution across the coupe needs to be investigated.

e) Currently applied ameliorative measures

Some of the slash is spread in piles across the coupe so as to distribute the biomass and combustible material.

2.7.3 Potential Innovations

Methods should be developed to permit slash management by methods other than burning. Such practices would allow the maximum amount of nutrients to be returned to the soil after harvesting and protect the soil surface from erosion. This would be achieved by:

- Greater utilization of wood is desirable so as to reduce the amount of slash remaining in the coupe.
- The remaining slash of leaves and branches should be mulched and spread across surface soil over the whole coupe.
- In such mechanisms for slash management, the amount of mechanical traffic, compaction and soil disturbance across the coupe should be minimized.
- In areas where post-logging burning is used, practices should be modified to keep logging slash away from the base of retained trees so that the wslash does not smoulder and radiate heat directly to the tree during the fire or in subsequent fuel reduction fires.

2.7.4 Assessment Statement

Higher intensity fires required to reduce the fuel load after logging have significant impact on environmental conditions for regeneration and the seed source available. Alternative methods for reducing the amount of slash remaining and managing the slash left in the coupe should be investigated and developed.

Post-logging burning does increase the risk of escape of uncontrolled fire, particularly as high intensifies are used and piles of logs can remain smouldering for a long time.

2.8 A15 COUPE SELECTION IMPACT ON FLORA

2.8.1 Statement of Practice and Value

The effect of harvesting (coupe selection in space) on flora/vegetation

2.8.2 Nature of the Practice

The selection of coupes for harvesting needs to consider the spatial positions of vegetation types in relation to environmental variables and hence their representation in the region. There will obviously be a bias, in terms of harvesting, to those vegetation types which are on terrain that is not too steep and which will provide a reasonable economic return of sawlogs and woodchips. Hence, vegetation on rocky outcrops and vegetation in steep gorges will not be considered for harvesting, and these areas are very often those which are placed into PMP areas. The spatial impact on vegetation is therefore concentrated on ridges and moderate slopes. In the Eden Management area, because of the terrain, there is a consistent difference between exposed and protected slopes - the exposed slopes typically having a sclerophyllous heathy or grassy understorey and the protected slopes having a more mesic understorey. The understorey will therefore respond differently to harvesting, depending on the aspect, although this effect is less noticeable on higher quality soils such as basalt and at higher elevations.

2.8.3 Potential Innovations

For the purposes of broad scale protection of flora and conservation values, environmental factors need to be considered when the harvesting plan is created. There should be an opportunity for incorporating a representative array of ridges and slopes and aspects into the PMP system, possibly on some rotational basis whereby the harvesting frequency is lessened. Most importantly, the heterogeneity of the landscape needs to be kept in mind at all levels of planning so that uniform prescriptions are not applied across areas which are different in terms of, for example, understorey composition (see Wardell-Johnson and Horwitz 1996).

Assessment

Coupe selection, if not integrated with overall environmental assessment, will lead to a differential impact between vegetation types such that uncommercial forests will never be logged and higher productivity forests will always be logged. More flexibility may be required to spread the impact across vegetation types (excluding of course areas sensitive based on other values).

2.8.4 Guidelines/Rules/limits for Application of Practice

Coupe selection and PMP selection need to be more closely integrated such that PMP areas are not just those areas left over after the coupes have been selected.

2.9 A16 SELECTION OF CUTTING SEQUENCE

2.9.1 Statement of Practice and Value

The effect of harvesting (coupe selection - time) on flora/vegetation

2.9.2 Nature of the Practice

The interval between harvests, along with the type of harvesting and fire regime, will determine the nature of the understorey. The more frequent the disturbance, the more favoured will be short-lived species and species adapted to more open environments. Longer rotations will enable more mesic vegetation to develop, unless fire is too frequent. The rotation length in isolation will not be a critical factor for most plant species or vegetation types. Where moist eucalypt forest has rainforest elements underneath (for example *Atherosperma moschatum*, *Elaeocarpus holopetalus*), such as around Brown Mountain, short rotations may eliminate these species or at least restrict them to gully environments (see Hickey 1994 for a Tasmanian example). Alternate coupe logging will not mitigate this potential impact.

2.9.3 Potential Innovations

The possibility of longer rotations in wetter vegetation types may need to be investigated in areas where mesic understoreys predominate.

2.9.4 Assessment

Rotation length has the potential to change species composition in the long term in those vegetation types where the individuals do not reach reproductive age during the now-proposed rotation.

2.10 A18 PREHARVEST SURVEY AND FLORA

2.10.1 Statement of Practice and Value

The effect of Harvesting (Pre-harvest flora survey) on flora/vegetation

2.10.2 Nature of the Practice

Pre-harvest flora surveys should be an essential part of forest management. They assist not only in location of significant species but provide a benchmark for monitoring change in the forest, whether due to forest operations or environmental factors. The important factor in their use is adequate stratification of the environment, replication and a suitable plot size. Ideally, full floristics using a suitable cover abundance scale should be used, with plot sizes of 20 m x 20 m or 20 m x 50 m to capture the spatial variation within the vegetation, but without crossing environmental boundaries. A potential problem arises when a coupe wraps around the topography or crosses some environmental boundary in which case more than one plot may be required. Random walks through the coupe in addition to measured plots would enable species which are more sparsely distributed to be picked up.

2.10.3 Potential Innovations

Long-term monitoring plots should be established in a representative and replicated subset of logging coupes.

2.10.4 Assessment

Provided that the pre harvest surveys are completed by a competent botanist familiar with the full floristics, they will provide a valuable tool for forest management.

2.10.5 Guidelines/Rules/limits for Application of Practice

All coupes should be surveyed before logging and a representative and replicated subset should be monitored after logging to provide an ongoing measure of change in the forest.

2.11 A22 SELECTIVE HARVESTING IMPACT ON FLORA

2.12 A23 HARVESTING WITH HABITAT RETENTION IMPACT ON FLORA

2.12.1 Statement of Practice and Value

The effect of selective harvesting on flora/vegetation

2.12.2 Nature of the Practice

Selective harvesting has the least potential impact on flora and vegetation values, but the degree of disturbance within the coupe will be a major factor in assessing this impact. That is, if patches of unsuitable trees are left with intact understorey, there will be less impact than if trees are selectively harvested uniformly over the coupe. This will obviously depend on the species of trees being harvested.

2.12.3 Potential Innovations

Retention of patches of vegetation within the coup that remain largely undisturbed.

2.12.4 Assessment

This form of harvesting will have a minimal impact on flora, on its own, but will interact with fire regime and rotation length (A16).

2.13 A24 HIGH INTENSITY HARVESTING AND FLORA

2.13.1 Statement of Practice and Value

The effect of harvesting at high-intensity with no habitat retention on flora/vegetation

2.13.2 Nature of the Practice

This is effectively clearfelling and is probably most similar to the practices undertaken in eastern Victoria and Tasmania. Impacts of this type of operation are intense in the short term, but the long-term effects are largely speculative for flora as the rotation length and fire regime will both interact with the harvesting intensity. The most likely potential impact is the loss of regenerative capacity of resprouting species by gross disturbance due to physical damage and hence leading to greater susceptibility to death after slash or control burning (Murphy and Ough 1993).

2.13.3 Potential Innovations

Habitat retention, i.e. Cell A24 would be a more conservative approach.

2.13.4 Assessment

This form of high-intensity harvesting may be inappropriate in the Eden Management Area due the high fire frequency and the risks associated with the interaction of gross soil disturbance and fire regime. Species such as *Eucalyptus sieberi* are probably favoured by this approach, as evidenced by some of the earliest coupes in the area.

2.13.5 Guidelines/Rules/limits for Application of Practice

Any use of this practice would be contingent upon suitable habitat being adequately represented in the Reserve system.

2.14 A27 FERTILISING AND FLORA

2.14.1 Statement of Practice and Value

The effect of intensive stand management (fertilising) on fora/vegetation

2.14.2 Nature of the Practice

The potential impact of this practice will be dependent on where in the landscape the stands are located and how much fertiliser is applied. The soils in the Eden Management area are generally nutrient poor and accordingly species have adapted to these conditions. Studies in the Sydney area (Clemens and Franklin 1980; Clements 1983; Lambert and Turner 1987) have shown that increased nutrient load in streams from nutrient-enriched urban stormwater runoff and sewage lead to invasion by weed species, particularly in riparian environments. However, the relationship between these nutrient levels and those potentially to be used is unknown.

2.14.3 Potential Innovations

Impact minimisation should be investigated i.e. hand application versus machine application versus aerial application.

2.14.4 Assessment

Trials and monitoring to assess whether weeds would become a problem under this practice are needed, particularly if aerial application was being considered.

2.14.5 Guidelines/Rules/limits for Application of Practice

No aerial application of fertilizer should be attempted until the impact is assessed.

2.15 A34 PLANTATION SITE SELECTION AND FLORA

2.15.1 Statement of Practice and Value

The effect of plantation site selection on flora/vegetation

2.15.2 Nature of the Practice

In many ways, the effect of this practice is similar to that of Road Corridor location (Cell A4). However, the area potentially involved in this practice is much larger. Given the provisions of SEPP 46, it may be that all future plantations will be on cleared land. Certainly, given the factors involved with the economics of plantation, they are most likely to be in areas with soils of reasonable nutrient status on gentle terrain. These areas are those which have suffered most from the impact of past clearing and hence any vegetation left in these areas is highly likely to be of conservation significance.

2.15.3 Potential Innovations

Plantation site selection must be integrated with Regional Land Use Allocation (Cell A1) and a Regional Conservation Management Plan (Cell A2).

2.15.4 Assessment

Plantations of native species covers only a small area at present in the Eden Forest Management Area.

2.15.5 Guidelines/Rules/limits for Application of Practice

No native vegetation should be cleared for plantations.

2.16 A37 CAMPSITE LOCATION AND FLORA

2.16.1 Statement of Practice and Value

The effect of campsite and trail location on flora/vegetation

2.16.2 Nature of the Practice

This will principally be a practice undertaken on the National Park estate, but may also be relevant to State Forest. All factors which are pertinent to the location of road corridors are pertinent here and will not be repeated.

2.16.3 Potential Innovations

As for A4.

2.16.4 Assessment

As for A4.

2.16.5 Guidelines/Rules/limits for Application of Practice

As for A4.

2.17 A38 FACILITIES CONSTRUCTION AND FLORA

2.17.1 Statement of Practice and Value

The effect of recreation facilities construction on flora/vegetation

2.17.2 Nature of the Practice

This will principally be a practice undertaken on the National Park estate, but may also be relevant to State Forest. All factors which are pertinent to the location of road corridors are pertinent here and will not be repeated.

2.17.3 Potential Innovations

As for A4.

2.17.4 Assessment

As for A4.

2.17.5 Guidelines/Rules/limits for Application of Practice

As for A4.

2.18 A39 RECREATION SITE MAINTENANCE AND FLORA

2.18.1 Statement of Practice and Value

The effect of recreation site and trail maintenance on flora/vegetation

2.18.2 Nature of the Practice

This will principally be a practice undertaken on the National Park estate, but may also be relevant to State Forest. All factors which are pertinent to the location of road corridors are pertinent here and will not be repeated.

2.18.3 Potential Innovations

As for A4.

2.18.4 Assessment

As for A4.

2.18.5 Guidelines/Rules/limits for Application of Practice

As for A4.

2.19 A46 WEED CONTROL AND FLORA

2.19.1 Statement of Practice and Value

The effect of weed control on flora/vegetation

2.19.2 Nature of the Practice

Weed control in the Eden Forest Management Area, where undertaken, is generally seen to have a beneficial impact on native flora and vegetation. However, as most of the major weeds will be in agricultural lands, the practice will not be of critical importance in most of the forest estate. The exception to this will be the control of declared noxious weeds such as blackberry, but once again, these infestations are in previously cleared or agricultural lands (State Forests of New South Wales 1994).

2.19.3 Potential Innovations

Weeds may become an issue if fertilisers are used for intensive silvicultural treatments, but this will depend on many variables such as rate of application and position in the landscape. Ongoing surveys for weeds should be instituted to monitor the effect of fertilisers, if this action is undertaken in future.

2.19.4 Assessment

Weed control in the Eden Management Area is either neutral or beneficial to native flora and vegetation.

2.19.5 Guidelines/Rules/limits for Application of Practice

Broad acre spraying in plantations should be avoided so that drift does not affect adjacent areas of native vegetation.

2.20 A49 GRAZING AND FLORA

2.20.1 Statement of Practice and Value

The effect of grazing on flora/vegetation

2.20.2 Nature of the Practice

Grazing of livestock is not permitted in the NPWS estate, but small areas within State Forest are grazed, primarily by cattle. In those areas where pre-existing leases from the Crown have been gazetted as State Forest, grazing could be seen as a legitimate land use. However, the issuing of Occupation Permits and Grazing Permits over other areas of State forest is questionable. Although these areas are small, the potential damage could be great in areas such as freshwater wetlands and montane swamps. FCNSW (1994) states that ‘the main areas of grazing value in the EMA are on the tablelands on cleared country associated with terminated leases or on grassy areas and *open forest adjacent to small scatterred swamps*’. These latter areas are those likely to be most sensitive to grazing and trampling by domestic stock. The broader issue of the impact of grazing animals on remnants of native vegetation in the EMA needs to be addressed, particularly the effect of this practice on remnant vegetation in the Bega Valley.

2.20.3 Potential Innovations

Identification of important remnants on freehold and negotiation with landholders on the potential for fencing off areas or adjusting the grazing regime, as appropriate.

2.20.4 Assessment

This practice will have most impact on small isolated forest remnants and in swamp and wetland vegetation. Although the area of Crown timbered lands grazed is relatively small, the potential for impact on sensitive vegetation such as montane swamps and wetlands is great, despite reassurances to the contrary in FCNSW (1994) that ‘changes to plant communities likely to be caused by this activity would have already occurred’. In addition, the likely interaction between grazing regime and fire regime can have a much greater impact than either practice alone, and the size of grazing animal will also have an influence on this interation (see Leigh and Holgate 1979 for a discussion on the interaction between browsing by native mammals and fire). There is no specific literature on the impacts of domestic livestock grazing in the EMA, but studies from the subalpine areas of Victoria and New South Wales all point to a profound impact of cattle grazing on species composition (see Wahren, Papst and Williams 1994 for a recent review, based on the Bogong High Plains but citing and discussing the work done in Kosciusko National Park).

2.20.5 Guidelines/Rules/limits for Application of Practice

A more detailed assessment of all existing Occupation and Grazing Permits is required so that the impact on vegetation types and species can be assessed. The practice of grazing in State forest areas, other than pre-existing Crown Leases should be reviewed.

2.21 A51 MINING AND MINERAL EXPLORATION AND FLORA

2.21.1 Statement of Practice and Value

The effect of mining and mineral exploration on flora/vegetation

2.21.2 Nature of the Practice

Whilst limited in extent, the potential impact on flora and vegetation of mining and mineral exploration is great at the local scale. These activities are not undertaken in existing conservation reserves but are undertaken in State forests and in remnant areas on freehold. At present, National Parks and Wildlife Service reviews all applications for mineral exploration licences to see if there are potential environmental problems associated with exploration in the given area, which is usually an area previously identified as being of potential interest to NPWS. However, there is no statutory mechanism for preventing exploration or necessarily influencing the techniques used, other than the relevant provisions of Part V of the Environmental Planning and Assessment Act and the Threatened Species Act which will apply only in certain cases.

2.21.3 Potential Innovations

A Code of Practice for mining and mineral exploration in forested areas needs to be developed.

2.21.4 Assessment

Apart from the Pambula goldfields, mining has in the past not been a major form of land use in the Eden area. Pyrophyllite mining occurs in part of Nullica State Forest and small areas of loose rock and gravel pit extraction areas exist in the area (FCNSW 1994). The specific impacts of these past activities is not assessed in the Eden EIS but a process to assess the environmental impact of new quarry sites is outlined (FCNSW 1994). Given adequate baseline information on the distribution of significant flora, the potential impacts of mineral exploration be minimised, but some form of training in environmental assessment may be necessary for those involved in mineral exploration. The impact of any larger mining operation could only be assessed on a case by case basis, if the situation arose, and would come under Part V of the Environmental Planning and Assessment Act.

3. FAUNA

Definitions

Harvesting at low intensity

Selective harvesting on rotations of 40-100 years, limited to a maximum 30% canopy removal and a maximum 30% basal area removal of large stems (those > 40cm dbh), which maintains an uneven-aged structure throughout the forest and retains habitat trees, recruitment trees, seed trees and food trees at a density and spacing above minimum requirements under Conservation Protocols.

Harvesting at Medium Intensity

Selective harvesting on rotations of 25-100 years, limited to a maximum 60% canopy removal and maximum 60% basal area removal of large stems (those > 40 cm dbh), which maintains an uneven-aged structure throughout the forest and maintains habitat trees, recruitment trees, seed trees and food trees as required under Conservation Protocols.

Small group selection, gaps using up to 40 m diameter over not more than 40% of the loggable forest area in a matrix of selectively harvested forest, with retained habitat trees, recruitment trees, seed trees and food trees as required under Conservation Protocols.

Integrated harvesting with retention of unmerchantable stems over more than 40% of the loggable area, and retention of habitat trees, recruitment trees, seed trees, and food trees as required under Conservation Protocols

Harvesting at High Intensity

Integrated harvesting with retention of habitat trees, recruitment trees, seed trees and food trees as required under Conservation Protocols and where the cover of retained unmerchantable stems is less than 40% of the loggable area;

Small gap felling, using gaps up to 80 m diameter over not more 60% of the loggable area ringed by habitat and recruitment trees and a selectively harvested matrix, with retention of habitat trees, recruitment trees, seed trees, and food trees as required under Conservation Protocols.

3.1 B12 IMPACT OF WILDFIRE ON FAUNA VALUES

3.1.1 Statement of Practice and Value

This assessment considers the long-term effects of infrequent intense wildfire regimes on fauna, particularly rare and restricted species.

The study area is reported to have one of the highest frequencies of high-intensity wildfire in Australia. On average 7362 ha of forest (approximately 2.5% of the total State forest and national park estate) has been burnt each year in the study area and average fire patch size is 2822 ha (approximately 1% of the State forest and national park estate, SFNSW 1994). Dry sclerophyll forests which dominate the mid and low elevations are most affected, with fires occurring approximately every 15 to 40 years, while many areas of high elevation wet sclerophyll forests may not have been burnt for hundreds of years. Studies in Glenbog State Forests have suggested fire frequencies of one in every 8 years in dry sclerophyll and one in every 14 years in wet sclerophyll over a 210 year period, with an increasing frequency since European settlement but falling towards pre-European levels over the last 20 years (Banks 1990 in SFNSW 1994).

With the exception of extensive areas around Bega and Candelo the study area is largely forested. As there are few cleared and fragmented areas to act as fire breaks, relatively natural fire patterns are expected to prevail.

Fire is a pulse disturbance event which causes a direct decline in fauna abundance followed by a period of recovery as habitat and resources regenerate. The magnitude of initial decline and the degree of subsequent recovery varies with the frequency, intensity, scale and pattern of fire and the topography of the site and life history strategy of fauna species and forest vegetation. Species re-invade fire regrowth habitats as their essential habitat components regenerate. Species which inhabit the ground layer generally recover first, followed by species of the shrub layer and then the mature canopy. Individual species are generally well adapted to prevailing wildfire regimes within their preferred habitat.

Long-term declines after wildfire are only expected only where populations have been substantially reduced and confined to small remnants by other cultural disturbances such as predation by exotic carnivores, disease, prescribed burning and timber harvesting. Species most susceptible to wildfire are generally those which do not use shelter, have low reproductive rates and limited powers of dispersal such as the koala. These species rely on recolonization from unburnt refuges and forest patches after wildfire.

3.1.2 Nature of Practice

a) Mechanism of Impact

Wildfire at natural frequencies is generally expected to have a beneficial long-term effect on fauna diversity at a regional scale through :

- accelerated development of tree hollows (e.g. in smaller diameter stems) and cavities in ground logs;
- creation of a mosaic of forest patches of different age and structure;
- creation of uneven-aged forest structure in previously even-aged wet and dry sclerophyll forests;
- temporary destruction of insect pests resulting in vigorous epicormic leaf growth;
- renewal of shrub and ground cover species which depend on fire for germination and survival and which provide key food resources for fauna (eg *Acacia* and *Casuarina*).

Wildfire is expected to have a detrimental impact on fauna diversity only in the following exceptional circumstances:

- natural fire frequencies are abnormally high;
- fire refuge areas (e.g. rock piles, moist gullies and rainforests) are lacking or limited in extent;
- fauna populations have been significantly reduced by other threatening processes (e.g. predation) which limit their capacity to survive and recover after fire;
- reserves and national parks are smaller than the maximum area which may be subject to wildfire.

b) Evidence of Importance at Eden

The average patch size and frequency of wild fire in the Eden area should not represent a threat to most fauna species. Wildfire frequency may have been unusually high in parts of the south east dominated by silver top ash.

The absence of an extensive network of moist gully and rainforest refuges in this region may explain why there are so few records of the koala although this could also be attributed to fox predation, disease and scarcity of preferred food tree species.

Fire refuges are likely to be of particular importance for maintaining biodiversity in the Eden region particularly for species which have been reduced to remnant populations by fox predation and other European disturbance. Extensive mid- to high-elevation wet sclerophyll forests and moist gullies and rainforest in low-elevation forests are likely to provide the most important fire refuges.

c) Scientific Commentary

There no studies which evaluate the effect of wildfire on fauna species and populations at the regional scale due to experimental difficulty and lack of adequate fire records for retrospective analysis of regional survey data. We may reasonably assume that native fauna are adapted to survive natural wildfire patterns and frequencies in the Eden region but effects on threatened and declining species remain largely unknown.

d) Currently-Applied Ameliorative Measures

None, current management plans aim to suppress rather than maintain wildfire regimes.

e) Risk Assessment/Consideration of Sustainability

There appears to be some risk that rare species with restricted and reduced distribution patterns (eg koala, squirrel glider, brush-tailed phascogale, smoky mouse) could be adversely affected by intensive wildfire where it encompasses entire remnant populations.

3.1.3 Potential Innovations

The beneficial effects of wildfire in maintaining fauna biodiversity need to be recognized and taken into account in the management of reserves and national parks, particularly those with large areas of dry sclerophyll forest. There is some scope for implementation of policies which foster natural wildfire regimes in the core areas of large national parks where there are no neighbourhood consequences. Reserve management agencies could take steps to achieve a wider community acceptance of the importance and need for wildfires in national parks to counter the community fears and misconceptions arising from recent urban bushfires. Steps could also be taken to clarify and reduce legal responsibility for wildfire emanating from national park and to clarify minimum requirements for wildfire suppression on the periphery of national parks.

Where wildfire poses a threat to rare and restricted fauna populations, strategic burning could be applied to suppress or reduce the intensity of wildfire impact.

3.1.4 Guidelines/Rules limits for application of Practice

Research and mapping is required to estimate historical wildfire, frequencies throughout the Eden region as a foundation for maintaining a target level of wildfire disturbance.

All fauna populations at risk of destruction by wildfire because of small size and limited dispersal capability, could be identified and mapped for protection under approved fire management plans.

3.1.5 Linkage to Indicators and Targets

Recommended Indicators

The relative area and pattern of forest at different post fire seral (structural) stages.

3.2 B13 IMPACT OF PRESCRIBED BURNING ON FAUNA VALUES

3.2.1 Statement of Practice and Value

This assessment considers the long-term impacts of prescribed burning on shrub-understorey-dependent fauna, particularly small mammals and birds.

Three types of prescribed burning practice are recognized in the Eden RFA-

- post-harvest burning of slash and woody debris;
- prescribed burning for wildfire suppression;
- prescribed burning for fauna habitat manipulation;

Post-logging burning is carried about one year after harvesting and thinning to reduce the volume of litter on the forest created by timber harvesting. It is followed by a period of 15-20 years without prescribed burning to allow regeneration to establish. The risk of fire is reduced during this stage because litter under the closed regrowth canopy tends to be more moist.

Prescribed burning on a 5-7 year scale recommences when regrowth reaches a diameter of about 10 cm. State Forests are fuel-reduction burnt on a frequency of 5-7 years with the aim of removing the shrub layer; forests are burnt until the shrub layer is gone (SFNSW interview). On average a gross area of about 23300 ha and a net area of about 10000 ha will be burnt every year. The purpose of fuel reduction burning is solely to protect regrowth timber values by slowing the rate of spread of fire and increasing the chance of wildfire suppression (SFNSW interview).

Regrowth thinning increases the volume of litter on the forest floor but may not be followed by post-logging burning because of the risk of damage to the wood resource. Where slash is compacted by the traffic of thinning machines it is not considered to represent an increased fire hazard (SFNSW interview).

There are no prescribed burning plans in the Eden RFA designed specifically to enhance habitat for threatened or protected fauna. Frequent burning is recognized as a potential threat to the threatened long-footed potoroo. The draft recovery plan recommends fire impact research as a substitute for action.

3.2.2 Nature of Practice

a) Mechanism of Impact

Prescribed burning imposes a frequency, intensity, pattern and season of fire which has no equivalent in nature. Prescribed burning represents a shift from infrequent, intense summer wildfire to frequent (3-7 year), low-intensity (10% crown scorch) winter fire. The interval between burns is likely to be too short for full recovery of the shrub understorey and the intensity of fire may be insufficient to promote germination of some floristic elements. Frequent fire is also likely to accelerate the removal of fallen logs and standing dead trees which provide shelter for many species. Prescribed burning is expected to reduce the floristic and structural complexity of the understorey and cause a concomitant decline in species richness and abundance of understorey and ground-cover dependent fauna.

The potential harmful effects of prescribed burning on fauna include:

- reduction in the species richness and abundance of bird, reptile and mammal species which inhabit the shrub layer;
- reduction in the species richness and abundance of small ground mammals and CWR vertebrates (small and medium sized mammals and birds threatened by fox and cat predation) which depend on logs and dense vegetation to provide cover and shelter from predators;
- reduction in abundance and diversity of subterranean (hypogeous) fungi which are an important food resource for threatened bandicoots, potoroos and native mice in the genus *Pseudomys*;
- reduction in the abundance of nitrogen-fixing plants in the genera *Acacia* and *Casuarina*. which require longer intervals between fire for persistence. This may impact on general fauna biomass and biodiversity as well as individual species which depend on high-nitrogen foliage or the seeds of *Acacia* and *Casuarina* for survival and reproduction.

Most detailed long-term studies suggest that frequent mild fires will lead to the decline and loss of some bird species which are now perceived as common and little affected by fire. Inappropriate fire management is now a factor in the threatened status of at least 51 nationally recognized threatened bird taxa, second only to clearing and fragmentation, and is now the main threat to most declining bird species (J. Woinarski, unpublished). In general threatened and fire sensitive protected bird species will benefit from a longer interval (>10 years) between fires. At least 8 threatened species in the Eden region have been listed under the Response to Disturbance Project as requiring prescribed burning intervals of greater than 10 -15 years.

The effects of prescribed burning are likely to be compounded by the effects of grazing, post-logging burning and physical destruction of the shrub layer during thinning operations. State Forests in the study area are not extensively used for grazing. Some grazing occurs in the Tablelands but coastal forests are generally not in demand due to poor soils and lack of grass. Grazing use is controlled by issue of grazing permits and occupation permits. Grazing rights apply on Crown leases which have subsequently been dedicated as State forest. The total area of forest affected by grazing on State forest is 4798 ha. This activity generates a revenue of $37500 (SFNSW 1994).

b) Evidence of Importance at Eden

Fire planning and management deserves more consideration in the Eden region than in other wood production regions of NSW because of the apparently high natural fire frequency, the relative scarcity of moist fire refuges and the compounding effects of arson. In a spatial context prescribed burning is likely to have most economic benefit and least biodiversity impact in silvertop ash dry sclerophyll forest which has been subject to a high natural fire frequency.

c) Scientific Commentary

Fauna studies have shown that the floristic and structural complexity of the understorey and the species richness and abundance of shrub birds and small mammals is lower at survey sites in frequently burnt forest (Catling and Burt, 1995; Smith *et al.* 1995). These findings have not been spatially extrapolated to evaluate regional impacts due to lack of mapped information on understorey type and structure and fire history. There have been no studies which project burning frequencies into the future to identify long term effects on fauna habitat quality and distribution. However, logic dictates that regional impacts will be proportional to the magnitude and extent of understorey reduction and loss.

Belief in the effectiveness of prescribed burning as a tool for reducing the frequency, intensity and extent of wildfire is based more on the intuition and opinion (SFNSW interview) than quantitative scientific study.

Theoretical considerations indicate that prescribed burning is likely to reduce the intensity of fire up to 3-5 years after burning, but thereafter and at any time under severe conditions, prescribed burning may not prevent the spread of intense wildfire. If correct this implies that prescribed burn areas should be burnt very frequently or not at all.

3.2.3 Currently-Applied Ameliorative Measures

Despite the seriousness of prescribed burning as a threat to birds and mammals there has been little or no translation of ecological findings and predictions into forest planning and management. Procedures for prescribed burning in State Forests are described in the Protocol for Fuel Management Eden Management Area (Eden EIS). This protocol has a timber production focus and does not require or consider the collection and analysis of information essential for ecologically sustainable forest planning and management.

The management plan for Mt Imlay National Park aims to use prescribed fire to minimize the risk of wildfire to neighbouring fire-sensitive habitat.

No threatened species recovery plans include provisions for fire management in the Eden RFA despite the recognized threat of fires to the koala, and the potential threat of frequent burning to the Long-footed Potoroo.

Prescriptions described in SFNSW Fuel Management Protocols aim to achieve a maximum burn of 50% of the gross burn area and a maximum total crown scorch of less than 10% of trees. This may reduce the magnitude of short-term fauna decline but will not prevent long-term declines caused by changes to understorey structure and habitat complexity. Protocols do not specify minimum areas which must be protected from frequent fire, but identify sensitive areas such as flora reserves which are not subject to prescribed burning.

Conservation Protocols call for prescribed burning to be varied by season, intensity and interval to reflect the ecological requirements of threatened species, to promote and maintain an understorey mozaic, and to minimize impacts on understorey vegetation and fallen logs (>40 cm dbh and 5 m length). Conservation Protocols are currently incompatible with the Protocol for Fuel Management. There is no quantitative monitoring data available to indicate whether or not prescribed burning Conservation Protocols are being applied in the Eden region.

3.2.4 Risk Assessment/Consideration of Sustainability

Localized decline in biodiversity is a natural feature of forest communities after wildfire. The extent to which the effects of prescribed burning exceed those of wildfire will be determined largely by the scale and pattern of prescribed burning. The following lines of evidence suggest that the extent of biodiversity decline associated with prescribed burning has not stabilized but is increasing in the Eden region:

- the area of uneven-aged forest which will be subjected to integrated logging and conversion to logging regrowth is increasing;
- the effect of repeated prescribed burns on understorey structure is likely to be cumulative over time;
- It is the stated intention of forest managers to reduce the forest understorey.

Current plans to replace existing fire-degraded forest with higher quality sawlog forest in the Eden region depend for success on the effectiveness of prescribed burning in excluding wildfire from regrowth forest within planned harvest rotations of 40-80 years. Given the high wildfire frequency in the region and the observation that only prescribed burning every 3-5 years is likely to sustainably reduce fuel levels one may reasonably conclude that either the probability of excluding wildfire is remote or that prescribed burning practice will need to be greatly intensified. It would certainly be inappropriate to base timber yield calculations and projections of the extent of mature forest available to fauna on any assumption that wildfire can be suppressed in all regrowth forests. From a biodiversity perspective prescribed burning should be considered a high-risk practice.

3.2.5 Potential Innovations in Practice

Amelioration of prescribed burning impacts is largely only possible at regional scale by manipulation of the scale and pattern of burning to minimize the total area subject to prescribed burning and by selectively targeting areas for protection through such practices as:

- use of manual and helicopter fire-starting to improve locational accuracy
- concentrating burning on ridge tops and immediate boundaries of fire trails
- protecting compartments with an existing well-developed shrub layer from burning
- exclusion of burning from compartments with populations of CWR-threatened fauna
- confining frequent burning to strategic locations
- concentrating frequent burning in low-biodiversity regrowth silvertop ash
- exclude prescribed burning from wet sclerophyll forest
- identifying, mapping and protecting wildfire refuge areas (with a low frequency and risk of wildfire)
- redistribution of large woody debris (as well as bark residue) from log dumps across coupes
- cessation of grazing under grazing and occupation permits
- identification and mapping the habitat of threatened species sensitive to prescribed burning
- use of strategic burning corridors to reduce the overall extent of forest subject to broad-area prescribed burning.

Minimum target areas or percentages need to be set for protection of representative fauna habitats and understorey types from prescribed burning.

The SFNSW Protocol for Fuel Management needs to be revised to incorporate the principles and practices of ecological sustainability and to overcome the current wood protection focus. This should include mandatory procedures for collection of information on understorey floristics and structure in addition to fuel loads before and after burning, and mapping and recording the pattern and extent of burns.

Incompatibilities between the Conservation Protocols and Protocol for Fuel Management need to be removed to make these plans consistent.

There is a clear need for more detailed regional planning prior to prescribed burning in the Eden region. It is recommended that more detailed fire management plans be prepared jointly by SFNSW and NPWS prior to initiation of any prescribed burning.

3.2.6 Assessment Statement

Prescribed burning is likely to have a high local and regional impact on understorey and ground-cover-dependent protected and threatened fauna in the Eden Region.

Adverse prescribed burning impacts are likely to increase over time.

There is likely to be pressure to intensify prescribed burning practice (to levels required for protection of plantation forests) as the area and proportion of regrowth forest in the Eden region increases.

Sawlog production and wildfire are largely incompatible in dry forest types of the Eden region.

Amelioration of prescribed burning impacts is largely only possible by manipulating the location and extent of prescribed burns to minimize the total area burnt. This requires a higher level of strategic planning and commitment to data collection, mapping and analysis than is currently practiced.

Prescribed burning cannot be considered ecologically sustainable under current management and implementation systems.

Current prescribed burning practices in the Eden RFA risk a significant decline in regional fauna diversity with no guaranteed benefit to wood production.

3.2.7 Guidelines/Rules/limits for Application of Practice

Maximum values should be set for the following (recommended percentages in parentheses):

- the gross area of dry sclerophyll forest subject to broad area prescribed burning at frequencies of less than once in 15 years (30%);

- the fraction of shrub and ground cover removed within prescribed burn areas (30%);
- the fraction of mid- and lower-slope forest subject to prescribed burning (10%);
- the fraction of gully and wet sclerophyll forest subject to prescribed burning (5%).

3.2.8 Linkage to Indicators and Targets

Indicator species and guilds

Habitat complexity (Catling and Burt 1995)

Small mammal abundance

Understorey cover

Shrub bird abundance and species richness (Smith *et. al.* 1994)

CWR species richness and abundance

Gross area prescribed burnt by forest type

Percentage of ground cover burnt within gross burn area.

Extent and connectivity

Long periods of consistent fire monitoring and mapping are essential to provide the information necessary for modelling the effects of prescribed burning. Existing information does not provide a suitable foundation for quantitative scientific assessment of prescribed burning effects on timber yield and biodiversity at a regional scale. Likely relative impacts can be estimated from proposed gross burn areas using forest type and topography as a surrogate for fauna habitat type and assuming fire regimes specified in management plans.

3.3 B23,24 IMPACT OF HARVESTING WITH AND WITHOUT HABITAT TREE RETENTION ON FAUNA VALUES

3.3.1 Statement of Practice and Value

This assessment considers the effect of habitat tree retention in harvesting areas on fauna values.

3.3.2 Nature of Practice

The principal effect of harvesting is the conversion of mature, uneven-aged and old-growth forests to regrowth. This causes an initial decline in fauna diversity followed by gradual recovery as species recolonize regrowth forest when it reaches a suitable seral stage. The degree of recovery depends on many factors including the intensity of harvest, the interval between harvesting, and extent and spatial pattern of retained unlogged mature forest. Species which depend on old-growth components such as tree hollows and uneven-aged or old-growth forest structure are not expected to recover within normal harvesting rotations unless their habitat components are specifically retained during harvesting operations. This can be achieved by moderating harvesting intensity and by leaving habitat trees (large trees with hollows).

Approximately 90% of arboreal mammals, 60% of bats, 20% of birds and 12% of reptiles in forests of eastern Australia depend on large old tree with hollows for shelter or nesting. These species may be eliminated from logged forest unless their tree hollow requirements are taken into account. Loss of trees with hollows is the most significant cause of biodiversity reduction associated with timber production in the forests of eastern Australia (Smith 1997).

Current practice aims to protect hollow-dependent species by retention and recruitment of habitat trees within logged forest. Conservation Protocols call for the retention of 10 habitat trees and 10 recruitment trees (trees retained to develop future hollows) per two hectares of forest scattered throughout the net logging area. The 1995 Eden EIS determination specifies that 6 habitat trees per hectare be maintained in area of good habitat value for hollow-dependent fauna. Conservation Protocols call for retention of 8 habitat trees per hectare where greater glider abundance exceeds 1 animal per hectare.

Large dead trees with hollows are retained and allowed to collapse naturally in areas outside the net harvesting area.

3.3.3 Mechanism of Impact

Most trees do not develop hollows suitable for use by hollow-dependent vertebrate fauna until they are in excess of 80 cm dbh and approximately 120 years of age. As timber harvesting rotations are less than 100 years trees with hollows are expected to be eliminated from harvested areas over the long term unless trees with hollows (habitat trees) are specifically retained and recruited (recruitment trees).

The effectiveness of habitat tree retention as a mechanism for protecting of hollow-dependent fauna in logged forest depends on many factors including the density of habitat trees, the spacing of habitat trees, and the ability of hollow-dependent fauna to survive in regrowth forest surrounding retained habitat trees. Hollow-dependent species which are highly mobile (e.g. birds and bats) and forage in regrowth as well as uneven-aged and old-growth forest, are most easily accommodated by retention of habitat trees. Other more sedentary and territorial species such as greater gliders and to a lessor extent yellow-bellied gliders which require mature forest structure for foraging in addition to tree hollows cannot be accommodated by habitat tree retention alone. These species require either long harvesting rotations (100 or more years) coupled with retention of unlogged mature forest refuge areas to sustain viable populations while the logged forest grows to maturity, or reduced harvesting intensity (partial logging), which retains a significant proportion (e.g. >33%) of unlogged mature forest within logging coupes.

The species considered to be most sensitive to harvesting is the greater glider because it occurs at moderate to high densities, is territorial and evenly spaced throughout the forest, requires large hollows, utilizes multiple hollows, and requires relatively mature forest for foraging. A number of studies have shown that the magnitude of decline in abundance of greater gliders after harvesting is approximately proportional to logging intensity but with a decline to zero or near zero density when retained tree cover is less than 5% to 33%.

The maintenance of large trees with hollows in logged forests is also essential to provide a source of large hollow logs for small mammals, reptiles and birds of the forest floor which depend on fallen timber to provide shelter and refuge.

3.3.4 Currently Applied Amelioration Measures

There are two broad approaches to amelioration of harvesting impacts on hollow-dependent fauna within logging coupes:

- retention and recruitment of habitat trees (trees with hollows) in logging coupes;
- retention of a proportion of mature and old-growth trees within coupes by low-intensity or partial logging.

The minimum density and spacing of habitat trees retained under current Conservation Protocols is likely to satisfy the requirements of hollow-dependent fauna in moderate- to low-productivity habitats provided that hollows are reasonably well spaced throughout the logged forest (Smith 1993). This density may be below current levels of tree hollow usage in high quality unlogged forests but should be sufficient to maintain hollow-dependent fauna in regrowth forest if allowance is made for a reduction in abundance of hollow-dependent fauna such as greater gliders after logging.

It is essential that retained habitat trees be evenly or well spaced throughout the forest in order to be effective for territorial species such as arboreal mammals. Grouping of 5 retained habitat trees into a single cluster effectively reduces habitat tree density from 5 per hectare to 1 per hectare. This is below the minimum requirement for arboreal mammals and can be expected to cause a significant decline in arboreal mammal species richness and abundance.

Partial logging has not been adopted as a formal ameliorative measure for protection of old-growth components in logging coupes but occurs by default in some mixed-species forests with a high proportion of unmerchantable stems.

There are currently no specific protection measures for large fallen timber on the forest floor other than a general requirement to take reasonable measures to protect ground habitat. It is unlikely that the minimum density and spacing of habitat trees required under existing protocols will be sufficient to ensure adequate recruitment of large fallen trees with hollows over the long term, particularly in forest subject to prescribed and post-logging burning. The full impact of current practice on ground logs is not likely to become evident for one or more harvesting rotations. Initial harvesting of uneven-aged and old-growth forest may provide a temporary increase in large log debris on the forest floor. However, this beneficial effect is not likely to persist beyond the second rotation.

3.3.5 Scientific Commentary

Many studies have shown that the abundance of hollow-dependent fauna is lower in sites which have been logged or culled to remove large dead trees than in unlogged or lightly logged control sites (Smith and Lindenmayer 1988; Gibbons and Lindenmayer 1995). The magnitude of variation is greatest for arboreal mammals but differences have also be reported for hollow-dependent birds and bats (Smith *et al.* 1995). Fine tuning of these associations is required to determine variations in minimum habitat tree density and spacing for particular species, forest types and situations.

Some studies have found a correlation between small mammal diversity and ground cover complexity including the abundance of large fallen timber but more comprehensive studies of large log dynamics and fauna dependence are required as a matter of urgency.

3.3.6 Importance to Eden RFA

The Eden region is characterized by extreme regional and topographic variation in the density of arboreal mammals and other hollow-dependent fauna. Approximately 63% of arboreal mammals are thought to occur in 9% of the forested area (Braithwaite 1984), mainly in high-elevation wet sclerophyll forests and low elevation moist gullies and lower slopes. This variation provides scope for compartmental and regional scale variation in habitat tree retention, with decreased retention in low quality habitats (e.g. down to 2 habitat trees per hectare in some areas of silvertop ash) and topographic locations (mainly ridges and exposed slopes) and increased protection in high quality habitats (mixed species and wet sclerophyll forests) and locations (mainly gullies and protected lower slopes).

There is currently no requirement to retain recruitment habitat trees in regrowth forests in the Eden region where current habitat tree densities fall below minimums specified in Conservation Protocols. Consequently it is likely that substantial areas of production forest in the Eden region are unconstrained by the requirements for habitat tree protection.

Retained habitat trees can double as seed trees to facilitate regeneration after logging and they also provide regeneration insurance in the not unlikely event in the Eden region that regrowth forests are killed by wildfire.

3.3.7 Potential Innovations in Practice

There is scope for more flexibility in levels of habitat tree retention in the Eden region to better balance conservation and timber needs at the regional scale. Some areas of forest could be designated for higher levels of tree retention and other areas for lower levels of retention without altering the current overall average of 30% tree cover retention after harvesting. However, no reduction in current minimum habitat tree retention levels should be considered without prior mapping of existing habitat tree densities and the completion of surveys and research which aim to measure current levels of habitat tree use by hollow-dependent fauna. Consideration should be given to recruitment of habitat trees in some regrowth forests which are currently excluded from mandatory habitat tree recruitment where they fall within strategically important planning zones such as wildlife corridors and special habitat management areas for threatened fauna (e.g. yellow-bellied glider, glossy black cockatoo) identified in the Response to Disturbance Project.

Conservation protocols should be developed to ensure greater protection and maintenance of large fallen tree (log) cover on the forest floor, at least in a spatial context if not on a coupe basis. For example ecological processes which maintain recruitment of large fallen timber could be mandatory in a minimum 30% of the forest at a compartment or compartment block scale, through use of partial logging.

A minimum proportion of the harvestable forest estate should be set aside for partial logging (>40% retention of large and old-growth stems) because this is the only area of logged forest which is likely to sustain an uneven-aged structure and a near-normal density of habitat trees and fallen trees over the long term.

3.3.8 Assessment Statement

The removal of large trees with hollows (habitat trees) and large hollow ground logs (fallen habitat trees) by timber harvesting has no equivalent in nature. Wildfire may cause the death of large trees with hollows but in nature these are left standing and continue to provide hollows and large fallen logs until a new generation of old-growth stems has developed. Wildfire has been shown to cause a temporal shortage of habitat trees in moist mountain ash forests in Victoria due to abnormally rapid decay rates but this effect is not expected in the drier forests of the Eden region except at a small and insignificant scale.

Intensive harvesting with no habitat tree retention is not ecologically sustainable at the scale of the logging coupe and is likely to cause a reduction in fauna abundance and species richness in the order 90% for arboreal mammals, and 15- 20% for all mammals and birds, approaching levels of decline expected in mixed hardwood plantations.

Intensive harvesting with habitat tree retention is likely to cause a reduction in arboreal mammal abundance of about 50% and species richness of up to 20% in logged areas depending on the extent and spatial arrangement of unlogged mature forest refuge areas and adherence to proposed 100-year logging rotations.

3.3.9 Guidelines/Rules for Application of Practice

Minimum requirements by forest type could be set for the following practices (suggested percentages in parentheses):

- moderate to low-intensity harvesting (>40% large tree basal area retention, 40% of loggable area by region);
- moderate to high-intensity harvesting with habitat trees (current practice, 40% of loggable area by region);
- high-intensity harvesting with no habitat trees (20% of loggable area by region confined primarily to low quality arboreal mammal habitat, areas with no existing habitat trees, and not more than 25% of the net loggable area within a compartment).

The following broad planning rules are suggested for implementation of variable-intensity harvesting of the type indicated in Figure 1:

- low- to medium-intensity logging should be located in the most productive and biodiverse sites and adjacent to filter strips in the majority (66%) of compartments to provide a broader wildlife corridor and refuge area;
- approximately one third of low and medium-intensity harvesting areas should be retained on ridge tops and slopes to cater for dry forest species, particularly hollow-dependent bats and birds and fallen-log-dependent ground mammals and reptiles which prefer dry forest types;
- high-intensity harvesting areas with no habitat trees should be located primarily in areas with no existing habitat trees, areas subject to high wildfire frequency which are likely to require harvest on short rotation, and areas of low arboreal mammal diversity;
- the area of forest subject to high-intensity harvesting with no habitat trees should not exceed the area of forest subject to low-intensity harvesting.

3.3.10 Linkage to Indicators and Targets

The potential magnitude of current harvesting impacts on fauna abundance and species richness cannot be modelled, other than in a theoretical context, without detailed information on percentage tree cover in regrowth forests. There is a clear need to measure and map levels of tree retention in logged compartments as a pre-requisite to ecologically sustainable forest management planning.

Recommended Measures

- habitat tree spacing and density
- large fallen log density
- stocking of medium and large trees by diameter class (harvesting intensity)
- mature and old-growth tree cover (harvesting intensity)
- greater glider abundance

Eden Biodiversity Indicators

Extent of Forest Type: forests should be classified and mapped into zones of different harvesting intensity by forest type. The density of retained, evenly dispersed habitat trees and large fallen logs should be measured in each zone (by field surveys of representative forest units stratified by logging history, topographic position and forest type) to give an indication of the percentage forest cover with zero habitat trees, zero to 5 habitat trees, 5- 6 habitat trees and > 6 habitat trees per hectare. Retained habitat trees which are closer together than 25 m should be considered clustered and counted together as one habitat tree for the purpose of assessment and classification, except in unlogged or low-intensity logged forest with more than 10 habitat trees per hectare.

Extent of Connectivity: the spatial effectiveness of forest in each of the above habitat tree density classes should be measured and quantified using a measure of the evenness of retained habitat trees (determined by nearest neighbour analysis) within zones of different habitat tree density, including unlogged corridors and retained forest in as well as logged forest.

Representative Species and Populations: measure and monitor the density or relative abundance of hollow-dependent fauna (e.g. indicator species such as the greater glider, the glossy black cockatoo and at least one hollow-dependent bat species) within mapped zones of different habitat tree density within representative forest types.

3.4 B22, 23, 24 IMPACT OF HARVESTING INTENSITY (LOW, MEDIUM AND HIGH) ON FAUNA VALUES

3.4.1 Statement of Practice and Value

This assessment considers the effect of variation in harvesting on fauna values.

3.4.2 Nature of Practice

Harvesting intensity in the Eden region has varied in space and time according to the type and condition of forests and the availability of markets for different sizes and types of wood product. The following four types of harvesting of increasing intensity can be recognized in the region:

1. low-intensity (selective) harvesting of the type which prevailed prior to the 1960s;
2. moderate-intensity harvesting in forests with a high cover of unmerchantable species;
3. high-intensity harvesting with habitat and seed tree retention;
4. high-intensity harvesting with little or no tree retention which prevailed in the 1970s.

Wood production forests were selectively (low intensity) harvested to supply low volumes of sleepers and sawlogs until integrated harvesting for export pulpwood and sawlogs commenced in 1969. The annual volume of wood harvested then increased by a factor of 10 to accommodate the export woodchip market. Intensive harvesting during the 1970s was carried out in large coupes and sometimes left few or no trees remaining standing after logging.

Current integrated harvesting involves felling of all merchantable stems for sawlog and pulpwood except those retained as habitat trees, food trees and seed trees. Regeneration is natural, from retained seed trees. On average about 30% of the basal area of regrowth forest consists of trees retained during the initial logging cycle (SFNSW 1994). High harvesting intensity occurs when all trees except habitat trees and seed trees are felled and moderate harvesting intensity occurs where forests have a high proportion of unmerchantable stems and tree species. Ironbarks, woollybutt, rough barked apple are retained because their red wood is unmerchantable as woodchip. Because harvesting at Eden is economically sustainable down to about 20 m^3 per hectare some very low-intensity (selective) harvesting occurs under the banner of integrated harvesting (SFNSW interview).

By 1994, the wet and dry sclerophyll forests of the study area consisted of two structural types, uniform regrowth forests resulting from high-intensity integrated logging and clearfelling (75000 ha) and fire (2500 ha) and multiaged forests resulting from selective logging and wildfire (118000 ha in state forest and 40000 in reserves). The Eden EIS proposes to harvest the remaining 118000 ha of multiaged forest by the year 2012. This will leave a period from 2013 to 2030 when no sawlog yield is possible from these forests unless special innovations are introduced such as increased retention of potential sawlogs in the current cycle and modification of mills to take smaller diameter logs.

Pulpwood yield will be provided by thinning of existing regrowth from 2013. Regrowth will be thinned after approximately 30 years when harvested trees reach a size suitable for commercial sale. Use of thinning machines compacts slash and removes any naturally occurring forest understorey in a similar manner to fire. Final sawlog harvest is not proposed until after approximately 100 years. However, harvesting of trees retained to provide future sawlogs may occur at any time before this period. Regrowth forests are predicted to yield from 3-3.5 m^3/ha/yr from ages 30 -120 (Eden EIS page 3-136).

Forest with an old-growth structure is comparatively rare in the study area, comprising approximately 3% of State forest and 9% of conservation areas based on a conservative (social) definition of old-growth (forest dominated by mature and over-mature growth phases which have been subject to negligible unnatural disturbance). This area may be at least twice as large under ecological definitions of old-growth based on the relative predominance of senescent growth forms in the forest canopy.

3.4.3 Mechanism of Impact

The principal effect of intensive harvesting is the conversion of mature, uneven-aged and old-growth forests to regrowth. This causes an initial decline in fauna diversity followed by gradual recovery as species recolonize regrowth forest when it reaches as suitable seral stage. The degree of recovery depends on many factors including the intensity of initial harvesting, the interval between harvests, and extent and spatial pattern of retained unlogged mature forest.

Species which depend on old-growth components such as tree hollows and uneven-aged or old-growth forest structure are not expected to recover within normal harvesting rotations unless their habitat components are specifically retained during harvesting operations. This can be achieved by reducing harvesting intensity or by leaving habitat trees and key food trees.

Approximately 90% of arboreal mammals, 60% of bats, 20% of birds and 12% of reptiles in forests of eastern Australia depend on tree hollows for shelter or nesting. Most of these species can be protected over the long term by retention and recruitment of habitat trees. However, some arboreal mammal species which require mature and old-growth forest structure for foraging in addition to tree hollows cannot be accommodated by habitat tree retention alone. These species also require either long harvesting rotations (80 or more years) coupled with retention of unlogged mature forest refuge areas to sustain viable populations while the logged forest grows to maturity, or reduced harvesting intensity (partial logging) which retains a proportion (>33%) of unlogged mature forest within logging coupes.

The species considered to be most sensitive to harvesting is the greater glider because it occurs at moderate to high densities (>1 per hectare), requires large hollows, utilizes multiple hollows, and requires relatively mature forest for foraging. A number of studies have shown that the magnitude of decline in abundance of greater gliders after harvesting is approximately proportional to logging intensity with a decline to zero or near zero density in the short term when retained tree cover is less than 5% to 33%.

Comparisons of forest fauna diversity between logged and unlogged forests suggest that there is a broad correlation between harvesting intensity (% canopy removal) and biodiversity decline within logged forests. The average decline in species richness of all forest birds and mammals within logged areas is expected to be negligible under low-intensity (>70% canopy retention) selection logging regimes, approximately 11-20% under moderate-intensity logging regimes with a canopy retention of 33%-70% , and 20%-28% under intensive harvesting regimes which retain approximately 0%-25 % tree cover. This general trend can be attributed to a combination of factors including the effects of burning, reduction in forest structural complexity, simplification of ground cover, culling and reduction in abundance of large old trees with hollows, and reduction in the area of retained unlogged forest (required to support fauna populations while regrowth forests mature).

3.4.4 Currently Applied Amelioration Measures

Partial logging has not been adopted as a formal ameliorative measure for protection of old-growth fauna and habitat components in logging coupes but occurs by default in some mixed species forests with a high proportion of unmerchantable stems or with food trees of threatened fauna. Conservation Protocols call for retention of *Allocasuarinas* with more than 30 cones crushed by glossy black cockatoos beneath the crown, retention of at least four winter-flowering eucalypt species per two hectares where they occur (these may be synonymous with habitat trees if they have hollows), retention of mature *Banksia* and retention of all yellow-bellied glider food trees with V notches.

3.4.5 Scientific Commentary

A number of studies have shown that the short-term decline in arboreal mammal abundance in logged forests is approximately proportional to the percentage removal of large stems. The long-term effects of harvesting at moderate to low-intensity have been estimated by comparison of fauna diversity in forests which were lightly to moderately selectively logged in the distant past with unlogged controls. The long-term effects of intensive harvesting have not been estimated with certainty, because this is a comparatively recent practice which has not been monitored over a complete harvesting cycle, and which continues to expand its overall extent and pattern of impact. Some key unknowns include:

- the capacity of retained habitat and recruitment trees to persist in the face of wildfire, prescribed burning and post logging burning;
- the rate and effect of decline in the supply of large ground logs;
- the adequacy of retained unlogged forest (filter strips etc) to sustain populations of mature-forest-dependent arboreal mammals and birds while regrowth forest matures; and

- the confounding effects of intensive harvesting, prescribed burning, grazing, thinning, wildfire and predation by feral animals.

3.4.6 Importance to Eden RFA

The Eden region is characterized by extreme regional and topographic variation in the density of arboreal mammals, and greater gliders in particular. Approximately 63% of arboreal mammals are thought to occur in 9% of the forested area (Braithwaite 1984), mainly in high-elevation wet sclerophyll forests and low-elevation moist gullies and lower slopes. This variation provides scope for compartmental and regional scale variation in logging intensity, with increased harvesting intensity in low quality habitats (silvertop ash) and topographic locations (mainly ridges and exposed slopes) and decreased harvesting intensity in high quality habitats (mixed species dry sclerophyll forests and wet sclerophyll forests) and locations (mainly gullies and protected lower slopes).

3.4.7 Potential Innovations in Practice

There is scope for more flexibility in harvesting intensity in the Eden region to better balance conservation and timber needs. Some areas of forest could be designated for higher levels of tree retention and other areas for lower levels of retention without altering the current overall average of 30% tree cover retention after harvesting. A higher proportion and more strategic location of low-intensity harvesting is desirable as a precautionary measure to ensure survival of mature forest fauna populations within the logged estate. This can only be achieved by a combination of compartmental and regional scale planning.

Conservation Protocols should be developed which specify the pattern and level of overall canopy and large tree retention required under partial logging operations to achieve conservation goals. It is for example considered desirable from a silvicultural point of view to allow trees to regenerate in small patches or even-aged cohorts in order to minimize suppression by retained overwood trees. This requirement is to a degree inconsistent with fauna conservation goals which seek to maintain some forest with an uneven-aged structure and to maintain evenly spaced habitat trees at a density of up to six trees per hectare to accommodate the requirements of highly territorial hollow-dependent fauna. This dilemma could be accommodated by a spatial arrangement of small gap (50-70 m diameter) felling with permanent retention of habitat trees in an unlogged or selectively logged matrix around the periphery of gaps in order to satisfy a minimum density of 5-6 habitat trees per hectare with as even a spacing as possible (Fig. 1). Under this arrangement any large fallen logs or head logs and butt logs created during felling could be pushed into retained habitat tree matrix for permanent protection. Post-logging burning would need to be confined to individual fires in the centre of gaps isolated by fire breaks from the surrounding unlogged and selectively-logged matrix.

As the confounding effects of thinning on fauna and fauna habitat are virtually unknown, it is recommended that this be a priority area for further research.

3.4.8 Assessment Statement

Biodiversity decline in logged forests is likely to be proportional to harvesting intensity.

- Intensive harvesting with no habitat tree retention is not ecologically sustainable at the scale of the logging coupe and is likely to cause an overall reduction in mammal and bird abundance and species richness in the order of 20%-30%, approaching declines expected in mixed hardwood plantations.
- Moderate-intensity harvesting (33%-70% tree cover retention) is likely to cause a reduction in the order of 10%-20% in the abundance of fauna but may not affect species richness at the scale of the logging coupe. However, precise minimum levels of retained cover necessary to retain sensitive and mature-forest-dependent species after logging are not known.
- Low-intensity or selective logging(<30% large tree cover retention) is not likely to reduce fauna species richness but may cause of some decline in fauna abundance at the coupe level .

The regional impact and sustainability of harvesting is largely determined by the scale and pattern of harvesting at different intensities. Current integrated harvesting which includes a mixture of moderate-intensity harvesting and intensive harvesting with habitat trees relies on retention of reserves and unlogged forest to sustain a full complement of fauna species at the regional scale.

Current practice is causing a decline in fauna abundance at a regional scale which is expected to continue as additional areas of uneven-aged forest are harvested (Lunney 1987). This practice cannot be considered ecologically sustainable in a precautionary sense within the logged forest estate because there is a risk that declines in species abundance will eventually progress to regional loss of sensitive species over the long term. This risk could be reduced by more extensive and strategic application of moderate and low-intensity harvesting practices and by expansion of the unlogged forest network (see cell interaction B17,18 and 21).

3.4.9 Guidelines/Rules for Application of Practice

Harvesting intensity can be varied in isolation, or in combination with harvesting rotation time and harvesting pattern to reduce the threat to fauna which prefer mature, uneven-aged and old-growth forest.

Minimum percentage areas by forest type should be set for harvesting at the following range of intensities (suggested percentages in parentheses):

- no harvesting (25% of loggable area by region including filter and protection strips);
- low-intensity harvesting (>70% large tree (>50 cm dbh) basal area retention, 15% of loggable area by region);
- moderate-intensity harvesting (> 33% large tree basal area retention, 20% of loggable area by region);
- high-intensity harvesting with habitat and food trees (current practice, 20% of loggable area by region);
- high-intensity harvesting with no habitat trees (20% of loggable area by region confined to low quality arboreal mammal habitat and not more than 25% of the net loggable area within a compartment).

The actual location of extent of forests logged at different intensities at the compartment scale will depend on a number of factors including existing forest structure and the percentage of unlogged forest retained in or adjacent to the compartment. The following broad planning rules are suggested for location of variable-intensity harvesting zones:

- unharvested areas should be located predominantly in gullies, and areas of high biodiversity in good condition (66% of sites) with the balance in ridges and slopes;
- low-intensity logging should be located adjacent to filter strips in the majority of compartments to provide a broader wildlife corridor and refuge area;
- low-intensity harvesting should be located in the most biodiverse habitats within the compartment in a majority of compartments with the balance on ridges and slopes;
- moderate-intensity harvesting should generally be located between high-intensity and low-intensity harvesting;
- high-intensity harvesting areas with no habitat trees should be located in areas with no existing habitat trees, or areas subject to high wildfire frequency which are likely to require harvest on short rotation;
- high-intensity harvesting with no habitat trees should not be located on more than 30% of ridge tops;
- the number of different harvesting treatments within a compartment should range from one to four depending on forest structure and uniformity but the overall average should exceed two;
- different treatments within compartments should occupy approximately equal areas;
- the area of forest subject to high-intensity harvesting with no habitat trees should not exceed the area of forest subject to low-intensity harvesting.

The following guidelines are suggested for implementation of innovative moderate-intensity harvesting by creation of small gaps in a matrix of unlogged or partially logged forest (Fig 2):

- location of gaps under moderate-intensity harvesting with gaps (Fig 1) should coincide with unstocked, regrowth and structurally uniform patches where possible;
- location of habitat trees and the unlogged matrix should coincide with old-growth and uneven age forest patches and patches dominated by food trees or unmerchantable species;
- partial logging of the matrix around gaps should be selective, removing a maximum 50% of stems > 50 cm dbh in a manner which

maintains an uneven-aged structure and protects the understorey as much as possible during logging.

3.4.10 Linkage to Indicators and Targets

Recommended Indicators

- percentage of logged forest in different harvesting intensity classes.
- stocking of medium and large trees by forest types and harvesting intensity class (harvesting intensity)
- mature and old-growth tree cover (harvesting intensity)

The Extent of Forest Type: record the percentage of forest in different logging intensity classes at compartmental, compartment group and regional scales. Define harvesting intensity classes in terms of percentage tree cover retained after logging, or proportion of stems by size class retained after logging, or an equivalent.

Extent of Connectivity: the spatial arrangement of forest in each harvesting intensity class should be measured and quantified using an index of connectivity. This could be based on parameters such as the proportion of forest in each class (e.g. high habitat-tree retention areas) located in narrow, intermediate and wide (>1 km) areas, the mean length of narrow retained areas, and the edge to area ratio of habitat in each class.

Representative Species and Populations: measure and monitor the relative abundance of fauna which prefer mature and uneven-aged forest (e.g. greater glider) in representative harvesting intensity zones by stratified random sampling.

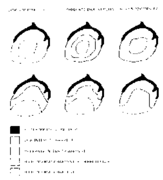

Figure 1 Some alternative spatial arrangements of different harvesting intensities at the compartment scale

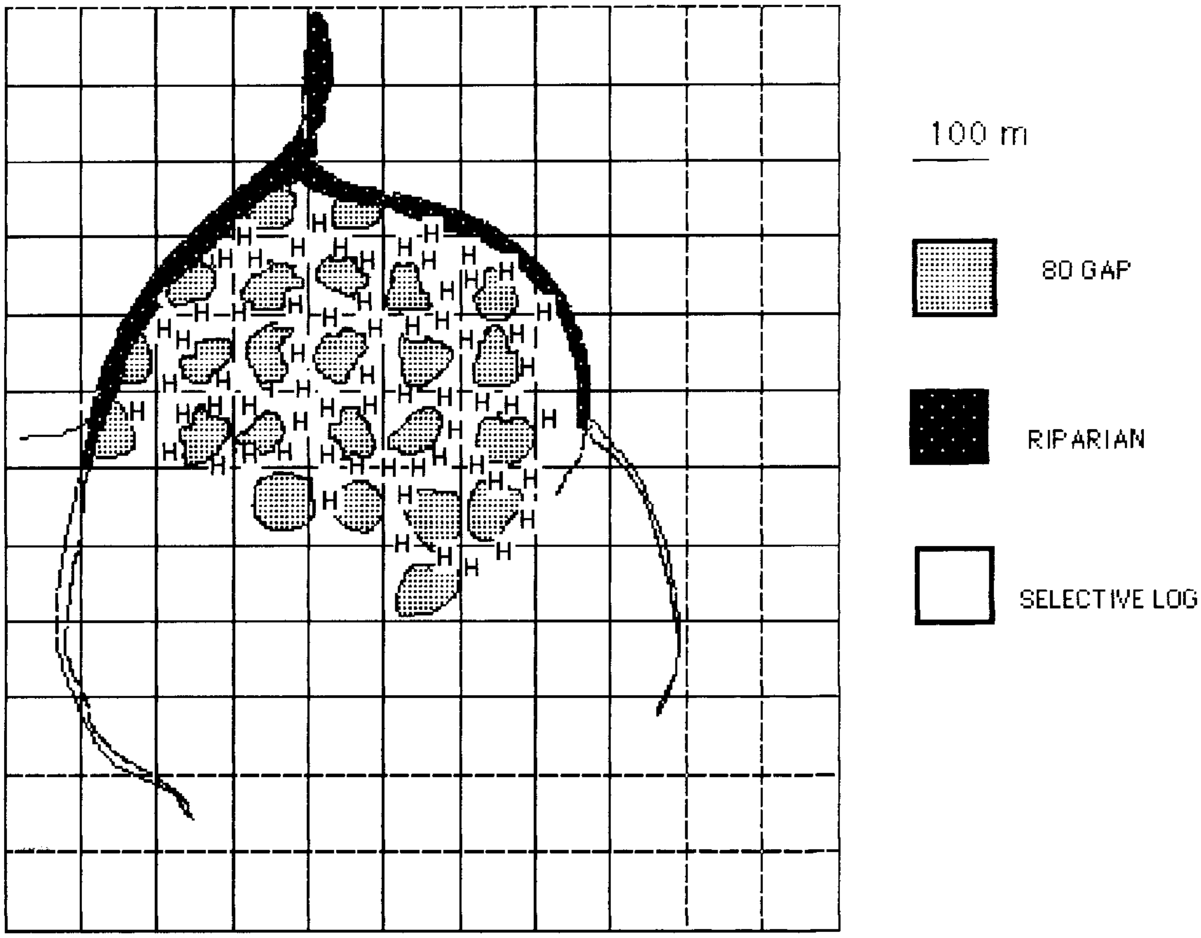

Figure 2 An example of high-intensity harvesting with small gap felling

3.5 B15,16 & 19 IMPACT OF HARVESTING PATTERN (COUPE LOCATION, STREAM PROTECTION PLANNING & WILDLIFE CORRIDORS) ON FAUNA VALUES

3.5.1 Statement of Practice and Value

This assessment considers the effect of coupe location and pattern in the context of retained unlogged corridors, filter strips and temporarily unlogged (alternate) coupes on fauna, particularly mature and old-growth forest dependent species.

3.5.2 Nature of Practice

Under the Eden Preferred Management Priority classification system approximately 29000 ha of forest will excluded from logging and similar amount will be subject to modified logging (eg 50% canopy retention) to protect scenic values within the broad logging estate.

Retained unlogged or partially logged forests include the following areas:

Unloggable Areas: harvesting is excluded from areas which are steep, rocky and uneconomic to harvest (4412 ha); areas which are dedicated as preserved native forest (10289 ha); and areas with cultural heritage significance (218 ha).

Wildlife Habitat Areas: areas which have been set aside for fauna and flora habitat protection (11298 ha);

Modified Harvesting Areas: harvesting is modified (approximately 50% canopy retention) in some areas of potentially harvestable forest including catchment protection areas (5511 ha), research areas (2200 ha) and visual resource areas (17103 ha).

Filter Strips: strips of retained vegetation of at least 20 m width each side of stream with a catchment area equal to or greater than 100ha).

Protection Strips: strips of retained vegetation 10m wide each side of drainage lines identified on harvesting plans.

Alternate Coupes: each compartment is subdivided into 2-5 coupes. Alternate coupes are harvested on the first cycle and remaining coupes 3-18 years later. Unharvested coupes act as temporary refuges for fauna.

Moratorium Areas: areas totally 89000 ha which provide temporary habitat protection for the long-footed potoroo, southern brown bandicoot, large forest owls, smoky mouse and koala until management plans and prescriptions have been revised.

3.5.3 Mechanism of Effect

Patches of unlogged forest are retained in filter strips along creeks and gullies and on steep rocky areas and temporarily unlogged coupes have a beneficial role in the maintenance of off-park biodiversity by:

- providing refuge habitat areas in which fauna populations can survive initial logging (and fire) disturbance and from which they can recolonize regrowth forest once it reaches suitable seral stage;
- providing a linear reserve system for populations of some fauna species which prefer mature forest;
- providing potential fauna dispersal corridors between reserves and disturbance patches.

The extent to which unlogged forest fulfils these roles depends largely on the location, pattern and extent of retained areas and the interval between harvesting in logged areas. In general the unlogged areas in Eden function more as temporary refuge habitat areas (role 1) than as reserves or corridors for mature-forest-dependent fauna for the following reasons:

- filter strips are generally too long and narrow to function as reserves for mature and uneven-aged forest-dependent-fauna over the long term;
- the majority of unlogged filters strips and wildlife habitat areas are located in gullies which are the best areas for fire and drought protection, particularly in the eastern portion of the Eden region;
- filter strips and retained wildlife habitat is poorly represented on ridge and slope habitats;
- there are no unlogged corridors in Eden designed specifically to link major national parks.

3.5.4 Scientific Commentary

Studies have shown that a wide range of mature forest fauna persist in retained corridors of 56 - 250 m in width in plantation and native forest, indicating that wildlife corridors are beneficial as refuges at least over the short term (Recher *et al.* 1987). Insufficient data are available to identify minimum corridor and unlogged reserve widths, lengths and areas necessary to sustain viable populations of all mature-forest-dependent fauna over the long term. Ecological theory predicts that the size and spatial configuration of the existing system is not sufficient to sustain populations of some mature forest fauna over the long term as an increasing percentage of mature and uneven-aged forest in the Eden region is logged.

3.5.5 Currently Applied Ameliorative Measures

Conservation Protocols include the following provisions for protection of significant unlogged patches of forest in NSW State Forests:

- old growth protection; harvesting is excluded from area identified as old growth;
- rainforest protection: harvesting is excluded from rainforest with less than a 30% crown cover of pyrophytic vegetation and a 20 m buffer;
- riparian buffers: at least 10 m wide on each side of all first order streams, 20 m each side of second order streams, 40 m wide on each side of at least 80% of all third and higher order streams;
- connection corridors: each 500 ha of State forest must include a minimum of two

unlogged connection corridors at least 40 m wide (connecting second order streams) AND/OR one unlogged connection corridor at least 80 m wide connecting third order streams;

- Wetlands, heaths and rocky areas: buffer zones of 20m will apply to these areas where they cover less than 0.5 ha and 40m where they occur over more than 0.5ha;

While there are some survey data which indicate that small home range fauna can persist in narrow riparian buffers and connection corridors, theoretical considerations predict that such areas are likely to be too narrow to maintain biodiversity over the long term, particularly where forests are intensively logged immediately adjacent to retained corridors and buffers. Fauna experts consulted during the Response to Disturbance Project have recommended that corridors and riparian buffers be expanded to 200 m for yellow-bellied gliders, 1 km along major rivers for owls, 240 m for fishing bats and golden tipped bats, and 1km (with low-intensity logging) between catchments for stuttering frogs.

There is no corridor system in the Eden region designed specifically to facilitate genetic exchange and dispersal of sedentary fauna between major unlogged reserves and national parks. This may be particularly important over the long term where reserves are small (<5000 ha), isolated by a matrix of logged and burnt forest and where resident fauna populations are at risk of complete removal by wildfire, prescribed burning, feral animals or other disturbance. A true corridor network connecting reserves would need to be substantial in width (approximately 2 km) and would need to encompass ridge, slope and gully topographies. Such a corridor could be low-intensity logged but should not be prescribed burnt at frequencies of more that 15 years.

3.5.6 Evidence of Importance at Eden

Unlogged gully corridors are of particular importance in the low-elevation, fire-prone forests in the eastern portion of the Eden region where the majority of arboreal mammals are concentrated in gullies. In this region unlogged forests have a role as both temporary refuges and reserves for mature forest depended species, particularly arboreal mammal species such as the yellow-bellied glider and possibly the squirrel glider and brush-tailed phascogale which are not well represented in regional reserves.

At high elevations where national park networks are more concentrated, unlogged forests need to function more as both temporary refuge areas and true dispersal and movement corridors for sedentary fauna rather than as permanent linear reserves. Corridor design in this area will need to be quite different, focusing on wider corridors which include ridges and slopes in addition to gullies. The precise location of corridors may also be dictated by the occurrence of remnant populations of CWR mammals such as bandicoots, potoroos and *Pseudomys*.

Unlogged forests are likely to provide the primary mechanism for off-park protection of mature-forest-dependent fauna such as greater gliders in the Eden region, particularly with a forecast gap in supply of advanced regrowth forests suitable for provision of sawlogs between the years 2013 and 2030. There is a major risk that, with current overcutting in the Eden region and emphasis on pulpwood as the major product, planned rotation lengths of 100 years will not be adhered to and many regrowth forests will be re-harvested before they reach mature age. This will increase dependence on the unlogged forest for off-park conservation.

3.5.7 Potential Innovations in Practice

The percentage of forest allocated to corridors, filter strips and unlogged areas sould be increased from the current 15% to a minimum of 25%;

The width of riparian strips should be increased from 40 m either side (80 m) to a minimum of 200 m on third and larger order streams by locating low-intensity (>70% canopy retention) harvesting zones adjacent to filter strips on at least one side of drainage lines;

The interval between alternate coupe logging should be extended to 40 years in a portion of the forest estate to reduce reliance on riparian corridors as temporal refuge areas;

Agreed minimum periods between logging of alternate coupes should be adhered to;

Connection corridors required under conservation protocols should be expanded to a minimum of 200 m width;

A new corridor network linking national parks and nature reserves by a corridor 2 km wide (which includes ridge top an gully vegetation) should be planned with some allowance for low-intensity harvesting on the outer 500 m of corridors;

Harvesting rates in uneven-aged forest should be slowed to prevent the occurrence of a gap in mature forest supply between 2013 and 2030 because of its adverse effect on the area of unlogged mature and uneven-aged forest available to act as a temporary refuge area (e.g. in alternate coupes) while regrowth forest matures;

Unlogged corridors along major rivers should be expanded to 1 km width with the outer 300 m either side being subject to low-intensity logging.

3.5.8 Assessment Statement

While the current wildlife corridor and spatial arrangement of unlogged forest in the Eden region undoubtedly has a beneficial effect on biodiversity in logged forest it cannot be considered sufficient to guarantee the sustainability of forest-dependent fauna in a precautionary sense. A precautionary approach to corridor and unlogged reserve design would include expanded riparian strips in low elevation eastern forest, wider connection corridors and a new system of wide wildlife corridors linking national parks to facilitate long-term movement, dispersal, recolonization and genetic exchange between populations in reserves isolated by a matrix of regrowth and prescribed burnt forests.

3.5.9 Guidelines/Rules/Limits for Application of Practice

Minimum specifications are required for the following (suggested precautionary levels in parentheses):

- the percentage of forest (by type) retained in the unlogged condition at the compartment scale (20%) and regional scales (30%);
- width of unlogged and low-intensity logged filter strips on third and higher-order streams acting as wildlife refuges and corridors (80 m unlogged and 120 m logged at low-intensity);
- width of corridors linking national parks (2km including 1 km logged at low-intensity);
- minimum interval between logging of alternate coupes (20 years);
- minimum interval between logging cycles adjacent to filter strips and corridors (80 years);

3.5.10 Linkage to Indicators and Targets

Extent of Corridors and Links: percentage and proportional area of unlogged forests in retained buffers and corridors;

Extent of Connectivity: mean width of retained unlogged buffers and corridors, and mean width of low-intensity logged buffers and corridors.

Representative Species and Populations: monitoring of corridor-dependent fauna (e.g. yellow-bellied glider, amphibians).

3.6 B18 IMPACT OF PREHARVEST FAUNA SURVEY

3.6.1 Statement of Practice and Value

This assessment considers the effects of pre-logging fauna surveys on protection and maintenance of fauna values.

3.6.2 Nature of Practice

Current SFNSW policy aims to have the same fauna species present on compartments after logging that were present before logging, prior to the end of each logging cycle (SFNSW interview).

To assist in meeting this goal pre-logging fauna surveys are carried out in compartments prior to logging (including thinning) which are more than 2 km distant from a previous survey record except in the case of tiger quoll and microchiropteran bat records when no surveys are carried out within 5 km of a known survey record.

Current pre-logging survey procedure is described in a draft SFNSW (1997) report Threatened Species Protocol, Pre-logging and Pre-roading Survey Design,. Surveys, generally include 2 nights spotlighting, pit trapping for giant burrowing frog and *Sminthopsis*, tree trapping for phascogales and squirrel gliders, call playback for owls, hair tube sampling for medium sized mammals, and 2 nights harp trapping. Only those threatened species whose potential habitat is present are targeted in surveys. The approximate cost of pre-logging surveys is $2000 per compartment if no threatened fauna populations are found, with additional costs for extension and follow up if species of special interest are detected.

3.6.3 Mechanism of Effect

Pre-logging surveys are essential to locate populations of threatened and sensitive species which require protection by application of specific protection measures described in the Conservation Protocols. At least 13 of the 35 threatened and potentially sensitive fauna in the Eden region listed under the Response to Disturbance Project require special protection measures such as the placement of unlogged buffers around nest and roost sites, predator control, protection from prescribed burns, and protection of food trees and key habitat components.

Fauna surveys must be adequate in type, scope and season to ensure that populations of any target species present are actually detected. Under current Conservation Protocols pre-logging survey methodologies must be approved by NPWS in consultation with SFNSW. Although current survey methods fall short of perfection they represent a reasonable compromise between cost and effectiveness.

Pre-logging surveys provide initial (pre-disturbance) data for long-term monitoring of logging impacts on biodiversity. It is essential that this pre-logging survey data be complemented and gradually replaced by post-logging survey data as the extent of forest available for logging approaches its limit (currently scheduled for the year 2013). Post-logging survey data is necessary to monitor and evaluate the effectiveness of threatened fauna protection prescriptions.

3.6.4 Importance in the Eden RFA

Continuation of current pre-logging survey programs is essential throughout the Eden region wherever previous fauna surveys have not been carried out or have not been adequate to detect populations of threatened fauna.The Eden region has been moderately well surveyed for owls and arboreal mammals but there have been relatively few comprehensive stratified surveys of other threatened fauna groups.

3.6.5 Scientific Commentary

There is no scientific data which can be used to test the adequacy of current pre-logging surveys (scope and methodology). Intuitively the proposed scope of pre-logging surveys appears adequate for detection of most species but this needs to be validated by research and long-term monitoring. This should be undertaken at more than 12 fixed surveys stations (6 unlogged and 6 logged) which are repeatedly monitored during different seasons and years to evaluate the effect of survey method on findings.

3.6.6 Currently Applied Ameliorative Measures

Not applicable.

3.6.7 Potential Innovations

Pre-logging surveys will have a limited lifespan under current policy. Once all areas of existing forest have been logged or thinned for the first time no further pre-logging survey will be required. Pre-logging surveys should be complemented by post-logging surveys using identical survey methodology. Initially, at least one post logging survey should be undertaken for every two pre-logging surveys. Eventually all pre-logging survey sites should be subject to post-logging surveys at intervals regular intervals (eg not less than every 10 years).

The pre-logging and pre-roading survey program should be expanded to include pre-and post burning surveys of all compartments subject to prescribed burning which have not been the subject of a previous fauna survey. Post-burning surveys should also be conducted after wildfire.

Pre- and post-disturbance surveys should measure and record habitat features in addition to fauna abundance, including stand structure, understorey cover, ground cover and the presence of key habitat elements (logs food trees). This information can then be correlated with fauna changes to provide a better understanding of the patterns and causes of biodiversity change after logging, fire and other disturbance.

Tiger Quoll and microchiropteran surveys should be undertaken at all survey sites. There appears to be little justification for exclusion of tiger quoll and microchiropteran bat surveys from sites within 5 km of a previous record rather than 2 km as for other species. These species can be surveyed at relatively low cost by scat searches, hair sampling and call recording.

All food trees and habitat components potentially required by threatened fauna (e.g. *Allocasuarina*, V-notch trees, *Acacias*) should be identified and mapped for protection on harvest plans on all logging and burning compartments which have not been the subject of pre-logging surveys (because they fall within 2 km of a previous survey site) as a precautionary measure.

The adequacy of current pre-logging surveys (scope and methodology) needs to be tested empirically by establishing a research/monitoring program to evaluate the effects of season and survey effort on detection of threatened fauna.

3.6.8 Assessment Statement

Pre-disturbance surveys, including pre-logging , pre-burning and pre-roading surveys, should be considered essential for ecologically sustainable forest management in the Eden region. Many threatened species protection measures and prescriptions outlined in the Conservation Protocols, including the location of protection buffer zones around nests and roosts and protection of food trees and plants, cannot be applied unless pre-logging or pre-burning surveys are undertaken to identify any populations of target species and their habitat components present in areas scheduled for logging, burning or other disturbance.

Current approaches to pre logging and pre-roading survey cannot be considered ecologically sustainable because they do not include pre-burning surveys and they do not occur in all compartments prior to disturbance.

The effectiveness of pre- and post-disturbance surveys will depend largely on how well they are carried out and how effective the methods are for detection of threatened fauna. Intuitively current pre-logging surveys appear to be adequate for most species but this needs to be established by long term research/monitoring surveys, by implementation of compliance audit programs, and by training and assessment of survey personnel.

3.6.9 Guidelines/ Rules/Limits for Application of Practice

Pre-logging and pre-roading surveys should be expanded to include pre-burning surveys for all prescribed burning activities.

Post-logging, post-roading, post-burning and post -wildfire surveys should be undertaken at all pre-logging, pre-roading and pre-burning sites as part of a monitoring program to evaluate the effectiveness of current amelioration measures.

The exact location of pre- and post-disturbance surveys within logging compartments should recorded and selected to facilitate long-term statistical analysis of the effects of forestry practice on fauna diversity.

3.6.10 Linkage to Indicators and Targets

Representative Sampling of Species by Extent and Distribution: Pre-and post-disturbance surveys will provide monitoring information which can be statistically analysed to evaluate the long term effects of forestry practices on biodiversity, including the spatial arrangement and intensity of harvesting and prescribed burning.

3.7 B45 FERAL ANIMAL CONTROL

3.7.1 Statement of Practice and Value

This assessment considers the effects of predator control on CWR (critical weight range) fauna.

3.7.2 Nature of Practice

Control programs for wild dogs, pigs, foxes, cats, goats and rabbits are implemented in State forests of the Eden region by Feral Animal Control Officers under supervision of the district foresters.

Wild dogs are controlled by hand baiting at bait stations after monitoring for the absence of non-target species such as tiger quolls and dingos. Two week pre-baiting period is used to confirm the absence of non-target species at baiting sites. Control officers claim to be able to distinguish dingo from wild dog (domestic dogs turned loose by pig hunters) sign at bait stations. Pigs are controlled by trapping, shooting and poisoning. Cat and fox control by baiting is being trialed. Rabbit control is being carried out by local 1080 baiting and warren ripping in conjunction with neighbouring landholders. Ground control is practiced rather than aerial baiting to prevent non-target mortality. Aerial baiting in Victoria has killed non-target quolls radio-collared for scientific research. The aim of the feral animal control program is to have viable dingo packs and no wild dogs, foxes and rabbits in State forest public tenure.

There are 2 full-time feral animal control officers in SFNSW in the Eden region. The feral animal control program is funded by pulpwood income. Revenue in the Eden district exceeded expenditure by approximately 50% in 1996 despite the additional cost of biodiversity conservation practices such as predator control and pre-logging surveys (SFNSW interview). No equivalent program is in operation in forests of north-eastern NSW. Control is not as effective in national parks due to lack of funds or lower priority.

Predation by foxes and cats has been responsible for more mammal and bird extinctions and declines than any other threatening process in the south-east forests. Species most susceptible to extinction and decline are those of small to medium body weight (critical weight range species) with low reproductive rates which rely on natural shrub and vegetation cover to provide shelter (rather than constructing burrows). Most of these species are listed on the NSW threatened species list and will be individually considered in the Response to Disturbance project. Cats are the greatest threat to smaller species of 10-90 gram animals such as the smoky mouse, and foxes are the greatest threat to species of 35 -5000 grams such as the long-footed potoroo (Smith and Quin 1996).

The mechanism of decline is not fully understood but current evidence indicates that the presence of rabbits, prescribed burning and grazing and the removal of dingos by baiting are the primary causes of increased predation. Rabbits elevate and sustain predator (fox and cat) densities above natural levels to the point where native mammals and birds with low reproductive rates are unable to recover from sustained high predation pressure. Prescribed burning and grazing reduces natural cover which provides shelter from predators, and removal of dingos reduces competition and allows fox and cat numbers to increase.

3.7.3 Importance in the Eden RFA

There have been more extinctions and more severe declines of CWR fauna in the Eden region than in State forests of north-eastern NSW. This difference can be attributed to the greater abundance and more widespread occurrence of rabbits, foxes and cats, which in turn can be attributed to more extensive burning, more open forest and a history of more intensive dingo baiting. Many CWR species in the region have been reduced to scattered populations which require urgent protection and management to prevent further regional extinctions.

Predation is likely to be a more significant threat to biodiversity in the Eden region than timber harvesting because it has effect both on and off-reserve. It remains unclear whether the effects of predation have stabilized or are continuing to cause range and population declines. The current distribution pattern of many CWR species suggests that they are now confined to moist isolated fire refuges with dense cover.

3.7.4 Scientific Commentary & Currently Applied Ameliorative Measures

Rapid recovery and expansion of remnant populations of CWR species in Western Australian forests after the application of broad-area fox and cat control programs has demonstrated the effectiveness and importance of predator control for reversing the decline of Australian CWR species. Similar results should be attainable in the Eden region but will require a greater intensity of control effort (due to effects on non-target fauna) and more stringent and effective rabbit control in addition to fox and cat baiting. Predator control measures are unlikely to be effective if implemented in a patchwork basis without concurrent rabbit control because foxes and cats have large litters and rapid population growth and recovery potential. For effective control it is essential that predator and rabbit control in national parks be increased particularly as the area of the national park estate expands.

3.7.5 Potential Innovations

- Increase levels of routine fox, cat and rabbit control in national parks;
- monitor the effectiveness of current control methods and intensify control effort if necessary;
- monitor the effectiveness of control methods for retaining and enhancing dingo populations and abandon wild dog baiting if it is found to impact on native dog populations;
- use boundary fencing as an alternative to dog baiting wherever possible;
- prevent prescribed burning within the predicted core habitats of CWR fauna (see results of Response to Disturbance project) and within a 2 km radius of known remnant CWR threatened species populations.

3.7.6 Assessment Statement

Predation by feral animals is one of the most serious threats to biodiversity in the Eden region because it has the potential to cause regional extinctions and declines both on and off-reserve.

Steps taken by SFNSW to ameliorate this threat represent a significant initiative and contrast with the relative lack of effort in other regions and tenures. The effectiveness of these initial measures requires urgent evaluation by monitoring as a foundation for possible expansion and integration across all tenures, especially national parks.

3.7.7 Guidelines/ Rules/Limits for Application of Practice

Use maps showing the potential core habitat and occurrences of actual populations of threatened CWR species in the Eden region (as prepared for the Response to Disturbance project) to identify priority areas for predator control, rabbit control and cessation or minimal use of prescribed burning.

3.7.8 Linkage to Indicators and Targets

Suggested Indicators

- Density/species richness of CWR species populations;
- Fox, cat and rabbit density.

Extent of Habitat Type: record the area of forest by type which is subject to effective feral animal control practice; model and map the area of forest which acts as a refuge area for CWR species in terms of dense cover (low fire frequency) and low fox, cat, rabbit abundance.

Extent of connectivity: Develop an index of connectivity of CWR refuge areas.

Representative Sampling of Species by Extent and Distribution: model and predict the area of forest which supports foxes, cats and rabbits; model and predict the area of forest which supports a high diversity of CWR species.

3.8 B47 HABITAT AND FOOD TREE AND GROUNDCOVER PROTECTION

3.9 B48 SPECIES MANAGEMENT FOR FLORA AND FAUNA

EFFECT OF CONSERVATION PROTOCOLS: OVERVIEW

3.9.1 Statement of Practice and Value

This assessment considers the effectiveness of Conservation Protocols for protection and maintenance of threatened and sensitive fauna including species listed under the Eden Response to Disturbance Project.

3.9.2 Nature of Practice (harmful/ beneficial)

The Conservation Protocols (NPWS, SFNSW 1996) provide for the protection and maintenance of biodiversity off-reserve within the State forests estate.

The Conservation Protocols include provisions for the following:

- identification and protection of rainforest
- identification and protection of old-growth
- identification and protection of rare and non-commercial forest types
- identification and protection of wetlands, heaths, rocky outcrops, caves, tunnels and mines
- habitat tree retention
- significant food resource protection
- riparian buffer protection
- connection corridors designation
- burning mitigation
- grazing mitigation
- weed and feral animal mitigation
- pre-logging and pre-roading surveys
- ground habitat protection
- monitoring
- threatened fauna protection measures.

Most of these provisions (habitat trees, riparian buffers and corridors, retained rare and non-commercial areas, burning, feral animals and pre-logging surveys) have been evaluated in detail in preceding sections. The purpose of this evaluation is to provide an overview of the effectiveness of all protocols with particular reference to protocols which have not previously been considered.

Rainforest: current approaches aim to protect rainforest from disturbance by 20-40 m buffers. This prescription is probably sufficient to protect rainforest fauna but may be less than adequate to protect fauna which depend on rainforest margins as a refuge after wildfire. Wildfire is an important hazard in the Eden region and the distribution of rainforest is likely to be a good indication of the distribution and location of important wildfire refuge areas. For this reason it is recommended that the undisturbed buffer zone around rainforests in the Eden region be expanded to a minimum 100 m, particularly where rainforest patches are small (<10 ha).

Old-growth : current approaches to old-growth protection aim to identify and protect all remnant patches of forest which satisfy criteria for classification as old-growth . These areas will provide an important off-reserve network for protection of threatened and protected species which prefer mature and uneven-aged forest habitats. The effectiveness of this network will depend on its pattern and extent, which has yet to be determined. Once the final extent and pattern of old-growth has been mapped it is recommended that the boundaries of the area be rationalized (by inclusion of some areas of regrowth) to optimize its functional utility as a regional corridor, refuge and reserve network (see matrix B 15,16 &19, for more detail).

Habitat Trees: current prescriptions for habitat tree protection and recruitment should satisfy the requirements of hollow-dependent fauna which inhabit regrowth forests. Hollow-dependent species which prefer mature and uneven-aged forest are likely to require partial or moderate to low-intensity harvesting or substantial retention of unlogged habitat in conjunction with habitat tree retention in order to persist within logged compartments.

Food Resources: limited available evidence suggests that food tree species preferred by some threatened species (e.g. winter flowering eucalypts) will be adequately sustained under current harvesting and regeneration practice but this requires confirmation by post-logging monitoring. Identification and protection of some food trees and shrubs (e.g. *Acacias, Allocasuarinas*) relies on pre-logging and burning survey for adequate detection and protection. Current practice does not ensure that these resources are protected in all circumstances. There are currently no provisions for pre-burning surveys of factors which may effect the food and cover requirements of threatened fauna and no requirements for pre-logging surveys in all compartments. Consequently it is recommended that pre-logging and pre-burning habitat surveys be conducted in all compartments prior to disturbance. Where food plants of threatened fauna area present these could be protected automatically without the need for more expensive follow-up fauna surveys.

Riparian Buffers: riparian buffers were initially designed to protect aquatic habitats from siltation but they have an important additional role in providing refuge habitat for fauna affected by logging and fire in adjacent habitat. The width of riparian buffers is generally considered inadequate to provide a reserve system for many threatened fauna species within a matrix of logged and burnt regrowth forest. For this reason it is recommended that riparian buffers be considerably expanded (to >200 m) but with allowance for low-intensity partial logging in the outer portion of riparian buffers (see matrix B 15, 16 &19, for more detail).

Corridors: the Conservation Protocols require the designation of wildlife corridors of 40-80m wide to link drainage systems. Corridors of this width are generally considered inadequate to provide a reserve system for many threatened fauna species within a matrix of logged and burnt regrowth forest. For this reason it is recommended that wildlife corridors be considerably expanded (to >200 m) but with allowance for low-intensity partial logging in the outer portion of corridors. Wider corridors (2 km) which include both gully and ridge habitat are recommended to link major reserves such as national parks (see matrix B 15, 16 &19, for more detail).

Threatened Fauna Prescriptions: Conservation Protocols require the application of a wide range of specific amelioration measures for individual threatened species. These most frequently involve pre-logging surveys followed by protection of unlogged buffers around nest sites, roost sites and sensitive habitats. The Response to Disturbance Project has recommended extension of these amelioration measures for some species, generally to expand the diameter of unlogged buffers around known nest and roost sites and the width of unlogged or low-intensity logged riparian buffers (see Table 1).

3.9.3 Importance in the Eden RFA

Conservation Protocols provide a uniform approach to off-park fauna conservation in state forests throughout NSW. There is some scope for regional modification of these protocols to cater for regional variation in the type, scale and magnitude of threatening processes. In the Eden region two threatening processes, timber harvesting and predation by foxes and cats, appear to be more intense than elsewhere in NSW, and a third threatening process, prescribed burning, has the potential to have a greater future impact in the Eden region than elsewhere in NSW. This provides some justification for applying more rigorous ameliorative measures to retain unlogged buffers, and frequent fire exclusion areas such as those proposed in the draft Response to Disturbance project (Table 1).

3.9.4 Scientific Commentary

With the exception of requirements for habitat trees and to a lessor extent corridors and protection of the understorey from frequent burning, few quantitative scientific data are available to demonstrate the effectiveness of amelioration measures.

Most amelioration measures described in the Conservation Protocols are designed to protect the known essential habitat components (e.g. food plants, nest trees and shelter sites) and breeding sites of threatened and sensitive fauna populations. In most cases loss of essential habitat components through logging, burning or clearing can reasonably be expected to result in the loss or reduction in abundance of fauna which depend on them. This has been well demonstrated in the case of tree-hollow-dependent fauna. Far less certain is the behavioural response of fauna populations to disturbance of breeding sites, and the width of unlogged buffers around nest and roost sites along streams necessary to maintain normal reproductive behaviour and performance after disturbance. The most expensive aspect of pre-disturbance survey is the location of nest, shelter and roost sites of resident threatened fauna populations which require protection by undisturbed buffers. Greater emphasis needs to be placed on post-logging surveys to maintain the effectiveness of protection buffers.

3.9.5 Currently Applied Ameliorative Measures

Current Protocols may be regarded as reasonable precautionary limits for the protection of the essential habitat components and nesting/breeding sites of most rare and threatened species populations in the Eden region. Because these limits are based largely on theoretical rather than empirical assessment of possible impacts it is essential that they be monitored and re-evaluated over time.

There is scope for re-evaluation of powerful and sooty owl prescriptions which require the protection of 300 ha of potential habitat (where available) within a 2 km radius where this results in excessive reservation. Early approaches to conservation of large owls assumed that mature, old-growth and uneven-aged forest was important for maintenance of prey abundance. Subsequent studies suggest that these owl populations can be sustained at lower densities in logged forest by prey species which favour regrowth forest (e.g. ringtail possums, sugar gliders).

3.9.6 Potential Innovations

Rainforest: It is recommended that the undisturbed buffer zone around rainforests in the Eden region be expanded to a minimum 100 m, particularly where rainforest patches are small (<10 ha), to protect fauna which depend on rainforest margins as a refuge after wildfire.

Threatened Fauna Prescriptions: It is recommended that the supplementary Conservation Protocols identified in the Response to Disturbance Project (see Table 1) be adopted in the Eden region.

There is a need for inclusion of a general measure for protection of rare and poorly known species in the Eden region. Populations of all fauna species classified as rare or poorly known (e.g. by the Response to Disturbance Project) should be protected from all forms of potential threatening disturbance (logging, burning, feral animals) by undisturbed buffers of not less than one home range diameter around the limit of each known population. These species should all be targeted in pre-logging, pre-burning and pre-roading surveys.

For Conservation Protocols to be effective it is essential the pre-disturbance be carried out prior to initiation of any activities which may trigger the application of one of more species-specific amelioration measures. As concluded in section 3.5.8 (matrix interaction cell B18) pre-disturbance surveys should be mandatory to ensure that any populations of threatened fauna present are actually detected prior to disturbance.

The cost-effectiveness of the pre-disturbance surveys should be improved by placing more emphasis of habitat survey and less emphasis on fauna survey wherever possible.

3.9.7 Assessment Statement

Conservation Protocols provide some precautionary assurance that rare and threatened fauna populations will be detected and their habitats protected from logging disturbance, but there is no guarantee of habitat and population protection from prescribed burning disturbance. The overall effectiveness of Conservation Protocols should be improved to reduce risk by adopting the following general innovations as outlined in this and previous fauna sections:

- carrying out pre-burning surveys in addition to pre-logging and pre-roading surveys;
- carrying out post-burning and post-logging surveys;
- conducting pre- and post-disturbance surveys in all logging compartments;
- application of wider undisturbed buffers around threatened species populations and habitats;
- application of wider corridors and riparian strips;
- retention of a higher proportion of low-intensity logged and moderately-logged forest.

TABLE 1 SUPPLEMENTARY CONSERVATION PROTOCOLS FOR PROTECTION OF THREATENED FAUNA IN LOGGED FORESTS OF THE EDEN REGION RECOMMENDED IN THE DRAFT RESPONSE TO DISTURBANCE PROJECT

Species	Protection Buffer	Prescribed Burn	Food Tree Protection	Predator Control	Forest Structure	Corridors
Glossy Black Cockatoo	nest (100 m)	> 15 years				
Yellow-tailed Black Cockatoo	nest (50m)					
Square-tailed Kite	nest (2000 ha)					
Olive Whistler		none				
Crested Shrike-tit		low scorch				
Pink Robin		none				
Red-browed Treecreeper		low scorch				
Regent Honeyeater			old ironbarks			
Swift Parrot			old ironbarks			
Turquoise Parrot				y		
Bush Stone Curlew				y		
Greater Glider					uneven-age	
Yellow-bellied Glider			v notch trees winter flowering		uneven-age	200 m gully
Koala					uneven-age	
Powerful Owl	nest 200 m roost 50 m					
Barking Owl						1 km major Riv.
Sooty Owl	roost 50 m nest 200 m					
Masked Owl	roost 50 m nest 200 m					
Smokey Mouse		>10 years		y		
Southern Brown Bandicoot		>10 years		y		
Long-nosed Bandicoot				y		
Long-nosed Potoroo		>15-20 years		y		
White-footed Dunnart		targeted				
Tiger Quoll						
Long-footed Potoroo	reserve m. a.					
Common Bent-wing Bat	roost 1000 m (>20 animals)					
Eastern Horseshoe Bat	roost 1000 m (>20 animals)					

3.9.8 REFERENCES & SOURCES

See Chapter 8

4. SOIL

C12 WILDFIRE - SOIL

4.1.1 Statement of Practice and Value

Practice: Wildfire

(see cell A12)

Value: Soil

Properties of the soil that have both conservation and commercial value include:

- soil nutrient and carbon cycles
- soil biological diversity and abundance
- maintaining soil profiles and minimizing erosion.

Preservation of these soil properties is essential under any form of land use in order to ensure sustainability.

4.1.2 Nature of the Practice

a) Mechanism of impact

Impacts of fire on soil properties need to be considered in terms of their temporal scale and cumulative effect from repeated fires. In some cases the longevity of the impact is not known.

Short-term impacts of fire on soil properties include:

- Loss of nutrients (e.g. N, P, S, K) from the litter layer, understorey and surface soil by volatilization, particulate transfer, erosion of surface soil and ash by wind and water, leaching of soluble compounds such as nitrates and cations (Walker *et al.* 1986)
- Heat transfer down the soil profile causes mortality of litter and soil organisms, soil seed bank and subterranean organs of plants, and transformations of soil chemical properties particularly from organic to inorganic forms.
- Water repellency in surface soils is induced by the deposition of hydrocarbons on soil particles that cause non-wettable surfaces to develop (Humphries and Craig 1981; Leitch *et al.* 1983). Hydrophobicity of soil increases the risk of erosion and reduces infiltration rates.
- Increases in soil nutrient availability in surface soils occur in the short term due to deposition of ash which has high concentrations of exchangeable cations and phosphorus (Grove *et al.* 1986), heat-stimulated mineralization of organic matter, nitrogen and phosphorus, mobilization of inorganic phosphorus (Raison *et al.* 1990), and increases in soil pH. These effects are likely to persist for less than one year (Raison 1979).
- There is a high risk of erosion of surface soil and ash after fire, but the degree and extent depend on post-fire conditions of rainfall and wind, and topography (Walker *et al.* 1986). Ash is light, highly erodible and has very high nutrient concentrations (up to 30 times that in litter) (Raison *et al.*1990).
- Wildfires can result in fresh parent material being exposed, an increase in physical weathering processes, and hence an increase in the concentration of nutrient elements in soil some soil types (Hough 1982).
- Release of the greenhouse gas CO_2 from the combustion of biomass and surface soil organic matter and post-fire increases in rates of mineralization and respiration of soil organic matter. Losses of standing biomass, litter layer and soil organic matter reduce the total terrestrial carbon storage.

Long-term impacts include:

- Reduced abundance and diversity of soil and litter organisms occurs due to mortality during fire and less favourable habitat conditions in the post-fire environment with restricted litter layers and understorey, higher surface soil temperatures and evaporation (Campbell and Tanton 1981). A decline in soil biological activity results in reduced rates of decomposition and mineralization processes, reduced food sources for birds and mycophagous mammals, adverse effects on soil structure and permeability leading to greater erodibility (Lee *et al.* 1981).

- Reductions in mycorrhizal fungi in the soil and litter layer have adverse effects on the ability of plants to take up nutrients, particularly phosphorus, and this will influence the growth and composition of regenerating vegetation.
- Changes in surface micro-climate including a greater range in temperature and higher radiation.
- Increased drying rates of surface litter and reduced inputs of litter cause a decline in rates of decomposition, which can be up to 20% (Birk and Bridges 1989).
- Long-term declines in nutrient pools and rates of cycling, including rates of mineralization and litterfall (Keith 1991).
- Removal of CO_2 from a sink in the vegetation and soil and release to the atmosphere.

b) Importance to Eden RFA area

Forest soils in the Eden region have poor to medium nutrient status and low organic matter content, with particularly low levels of nitrogen and phosphorus in sedimentary materials (Kelly and Turner 1978). Thus any depletion in the biologically active cycling fraction of the nutrient pool will significantly reduce nutrient availability for plant growth. Many of the soil types are highly erodible and steep slopes occur in the north and western areas.

Endemic taxa of soil invertebrates occur in the region; some taxa are considered vulnerable, and some taxa are at the edge of their geographical range. Many invertebrate fauna have restricted distributions and specific habitat requirements (Wells *et al*. 1983; Greenslade and Rosser 1984; Greenslade 1990; Rentz and John 1990).

c) Scientific commentary

It is difficult to determine the effect of wildfire on ecosystem nutrient budgets and whether inputs balance outputs. Large amounts of nutrients are lost during these fires, but it is very difficult to quantify (Harwood and Jackson 1975). Determining the balance between nutrient inputs and outputs has not been attempted in these forest types, and the return period of wildfires at a site is difficult to define. A useful approach, however, is to measure changes in flux rates that represent critical processes over time under conditions of different fire regimes. The problem with this approach is obtaining sites that are comparable and replicated with different fire histories.

The effect of burning on increasing rates of nitrification and hence the potential for leaching of nitrate greatly increases the risk of nitrogen losses from the system. A reduction in vegetation after wildfires limits the amount of nitrate uptake and hence there is greater potential for loss. Increases have been measured following fires in populations of nitrifying bacteria (Jones and Richards 1977) and in nitrate levels in streamwater (Mackay and Robinson 1987). However, nitrification only occurs at some sites; the factors controlling this process are poorly understood, and forest sites potentially at risk in the Eden region need to be identified.

Interactions between plant growth, mycorrhizal fungi, mycophagous mammals and nutrient cycling represent key ecological processes that benefit from appropriate fire regimes but can be deleteriously disturbed by inappropriate fire regimes. Defining these fire regimes remains a major research issue.

Significant erosion and sediment yield have been recorded after wildfires in montane forests (Brown 1972; Good 1973; Leitch *et al.* 1983). Soils can remain in a highly erodible condition for a long time after fire until the soils lose their hydrophobicity, and revegetation and accumulation of litter occur.

d) Gaps in knowledge

- Total potential loss of nutrients and carbon in fires of different intensities.
- An appropriate return time at a site for wildfire to use in estimates of nutrient budgets.
- Longevity of changes in soil properties, for example nutrient availability, water repellency, soil organism populations.
- Time for recovery of essential habitat components required by soil fauna.

e) Currently applied ameliorative measures

(see cell A12)

4.1.3 Potential Innovations

(see cell A12)

Erosion mitigation measures after a wildfire to restrict movement of surface material downslope and sediment deposition in water courses.

4.1.4 Assessment Statement

Fires have major impacts on soil physical, chemical and biological properties. The degree of impact and longevity depend very much on fire intensity. There is insufficient information at present to assess the long-term impact of repeated wildfires. However, it is suggested that the increase in frequency of wildfires since European settlement would mean that there is not enough time for soil properties to recover from the disturbance.

4.1.5 Guidelines / Rules / Limits for Application of the Practice

Guidelines could probably be developed that would predict the proportion of nutrients and carbon lost from biomass, litter and soil under varying conditions of fire behaviour.

4.2 C13 FUEL REDUCTION BURNING - SOIL

4.2.1 Statement of Practice and Value

Practice: fuel reduction burning

(see cell 13A)

Value: Soil

(see cell C12)

4.2.2 Nature of the Practice

a) Mechanism of impact

The mechanisms of the impact of fire on soil are the same as those described in cell C12. The differences to be considered for the impacts of fuel reduction burning are related to the fire regime. Lower intensity fires will mean that many impacts are not as great after a single fire, but the higher frequency of fires means that the cumulative impacts over time from repeated fires become important.

b) Importance to Eden RFA area

(see cell C12)

c) Scientific commentary

The key issue in assessing practices of prescribed burning is the long-term consequence of small but cumulative impacts of repeated fires.

Frequent fire has the potential to deplete nutrient pools and reduce rates of nutrient cycling if the inter-fire period is inadequate to allow replacement of nutrients. The effect of fire frequency and intensity on nitrogen budgets has been demonstrated for four eucalypt forests in Australia, which span a range from wet to dry sclerophyll forests (*E. marginata, E. diversicolor, E. obliqua* and *E. pauciflora*) (Hingston *et al.* 1979; Hingston *et al.* 1980; Baker and Attiwill 1985; Hingston *et al.* 1989, Keith 1991). Although these are not the main species occurring in the Eden region, they do cover similar forest ecosystem types. A model of N losses in fires of different intensities, rates of fuel accumulation in litter and understorey and rates of natural inputs of N, was used to derive the frequency and intensity of fires that would allow a balance between N inputs and outputs (Raison *et al.* 1993). For a fire intensity where 50% of the N in fuel is lost, an inter-fire period of 9 years is required, where 75% of N is lost then an inter-fire period of 15 - 18 years is required. In forests where there is great variability in the distribution of N-fixing shrubs, such as in the jarrah forest, it is difficult to estimate an overall N balance for the forest type. This balance in N fluxes is a critical factor in assessing the cumulative effects of fire regimes. Even small changes in fluxes of the biologically active fraction of the N pool can have a major impact on the N supply rates. Keith (1991) demonstrated that frequent low-intensity burning can deplete mineralizable pools of organic N and rates of cycling even though there were large reserves of organic N in the soil. Five fires during a 14 year period reduced rates of nitrogen mineralization by 50% and two fires during that time reduced rates by 35%.

Repeated reductions of the litter layer and combustion of surface soil organic matter are expected to have the effect of reducing organic matter levels in the long term. However, these changes have not been quantified. A high proportion of the nutrients taken up by vegetation is derived from direct recycling through decomposition of the litter layer and mineralization of surface soil organic matter. Disruption of this nutrient cycling pathway could, therefore, have detrimental effects on nutrient availability and forest productivity.

Repeated fires also influence the decomposer cycle in the soil by direct mortality of organisms and restricted microhabitats in the litter layer and woody debris. A decline in the abundance and diversity of collembola and earthworms has been found (Neumann and Tolhurst 1991; Collett *et al.* 1993). There is very little information about the responses to fire of individual species of soil fauna. Habitat simplification of the litter and surface soil organic layers and fragmentation of suitable habitats leads to a decline in diversity and abundance and changes in composition of soil fauna (Friend 1993; York 1994; Greenslade 1997). Recovery of soil faunal taxa after fire appears to be highly variable and unpredictable and depends very much on post-fire environmental conditions (Christensen and Abbott 1989). The adequacy of refugia to allow recolonization has been questioned (Neumann 1991). Any decrease in soil fauna will lead to reduced food sources for higher fauna and reduced rates of decomposition, and hence to a decline in soil nutrient availability. In an ecosystem with high soil and litter biological activity, rates of decomposition are rapid and this means that large fuel loads do not accumulate.

Although prescribed fires are of relatively low-intensity and bare mineral soil is not supposed to be exposed, significant increases in erosion and movement of nutrients can occur. Loss of nutrients, as indicated by increases in concentrations of Ca, Mg, K and P ions in run-off water have been recorded as more than 10-fold (Hall 1994) and 2-6-fold (Ronan 1986) in eucalypt forests.

Forest productivity and growth of individual species are closely related to soil nutrient availability. Changes in the long-term equilibrium of nutrient cycles in forest ecosystems will ultimately be reflected in nutrient supply rates for the growing vegetation. Decreased productivity associated with a decline in rates of nutrient cycling under a regime of frequent burning has been demonstrated in the *E. pauciflora* forest (Keith 1991).

Raison *et al.* (1990) concluded that the ecosystems most at risk of nutrient depletion due to repeated burning are those where growth is already limited by nutrient availability, in which a high proportion of the nutrient capital is in aboveground biomass and litter, where nutrient inputs are low, and are sites prone to erosion. These ecosystem properties are characteristic of much of the forest area in the Eden region.

d) Gaps in knowledge

There has been no assessment in the Eden region of forestry practices and fire on the processes of energy and nutrient cycling that maintain ecosystem function. The above form of assessment of nutrient flux rates needs to be done in forest types that are burnt on a regular basis, in order to determine the stability of nutrient cycling processes. Such assessments together with monitoring of long-term experimental sites with known fire histories are essential to develop a scientific basis for formulation of prescribed burning regimes.

There is limited research on the effects of fire regimes on soil phosphorus availability. Phosphorus is a key element limiting productivity in Australian forest soils and has been identified as particularly important in the Eden region by Florence (1964). Research on methodology to measure availability of P in soil and rates of cycling are required. Plant bioassays offer some potential for assessing the effects of fire on soil P-supplying capacity.

The functional role of soil fauna in forest ecosystems needs to be investigated (Richards *et al.* 1990). A research priority is to identify key taxa to define functional groups and then to determine those taxa that may be useful as indicators of soil biological activity. Centres of endemism of invertebrates is an important aspect of overall community biodiversity. Conservation of these taxa requires identifying and preserving their specific habitat requirements, such as decomposing logs, moss and deep litter and humus layers.

Development of sensitive indicators is required to detect changes in soil fertility and forest productivity. Indicators of soil fertility should include flux rates of the biologically cycling pools of nutrients and carbon that are both the most sensitive to change and the most critical for forest productivity.

e) Currently applied ameliorative measures

(see cell 13A)

4.2.3 Potential Innovations

(see cells C12 and 13A)

Greater control of conditions under which burning takes place is required, in particular to burn only when soil and lower litter layers are moist and to minimize fire intensity so that a layer of uncombusted material remains to protect the soil surface. Burning should be done at times when storms are not forecast to reduce the risk of erosion of ash.

Monitoring of soil processes in relation to prescribed burning should include soil organic matter and nutrient contents, the labile fractions of these pools, and their rates of turnover in processes such as mineralization, respiration, decomposition and solubilization.

4.2.4 Assessment Statement

The impact of prescribed burning regimes must be assessed in terms of sustainability of ecological processes, as well as the conservation of individual species. Maintenance of energy and nutrient cycles are key factors determining ecosystem sustainability.

4.2.5 Guidelines / rules / limits for application of practice

If nutrient balances, such as those described in Raison *et al.* (1993), were developed for forest types in the Eden region, it would be possible to set guidelines for a maximum frequency and intensity of a prescribed fire regime at a site that would allow an equilibrium between inputs and outputs of nutrients. The region would need to be zoned for different fire regimes, based on characteristics such as pools of carbon and nutrients in the standing biomass, litter layer and soil, rates of turnover between these pools, susceptibility to nutrient losses by erosion and leaching, and rates of nutrient inputs.

4.3 C14 POST-LOGGING BURNING - SOIL

4.3.1 Statement of Practice and Value

Practice: Post-logging burning

(see cell A14)

Value: Soil

(see cell C12)

4.3.2 Nature of Practice

a) Mechanism of impact

- Loss of nutrients and carbon in slash and surface soil occurs by volatilization, particulate transfer and increased rates of mineralization.
- High temperatures result in a high proportion of elements being lost, particularly phosphorus. For example, 1000 kg N ha^{-1} from biomass and 200 kg N ha^{-1} from surface soil can be lost (Walker *et al.* 1986), and 40% of the P in the biomass combusted can be lost (Raison *et al.* 1993).
- Induced hydrophobicity of soil results in a greater risk of erosion.
- Deposition of ash and heat-induced transformations of soil chemical properties, particularly phosphorus, result in short-term increases in nutrient availability (Romanya *et al.* 1994).
- The risk of erosion is high due to the exposed soil surface and light ash on the surface.
- Burning associated with clear cutting sometimes results in increased nitrification and hence increases the risk of leaching (Ellis *et al.* 1982; Richards and Charley 1983).
- High-intensity fires cause mortality of soil organisms and their abundance and diversity post-fire is restricted by altered environmental conditions and loss of suitable habitat. Reductions in mycorrhizal fungi are particularly important for establishing root systems and nutrient uptake of the regenerating vegetation.

b) Importance to Eden RFA area

(see cell C12)

c) Scientific commentary

A high proportion of nutrients is lost from the site due to post-logging fires. The amount of each nutrient lost depends on the intensity of the fire which determines the amount of debris that is combusted and at what temperature. Raison (1980, 1981) estimated that it would take 150 years for the phosphorus lost in a slash fire to be replaced at site burnt after harvesting a wet sclerophyll forest. The loss of N in a single slash burn can greatly exceed the amount of N removed in harvested biomass (Squire and Flinn 1981).

Calcium is also a critical element that is lost in high-intensity fires and particularly large amounts are lost due to the combustion of bark (Adams and Attiwill 1991). There is some evidence that such nutrient losses are detrimental to tree growth in the long term (Woods 1981; Balneaves 1990).

Major changes in the chemical forms and availability of nutrients, particularly phosphorus, have been measured in ashbed soils. However the longevity of such changes and the consequences for long-term availability of nutrients have not been established.

The interaction of N and P fluxes in maintaining stable cycling of nutrients. Increased soil P availability due to soil heating can stimulate the regeneration of N-fixing shrubs and so has positive effects on both N and P cycling. In contrast, if the availability of soil P is gradually depleted by repeated burning then this will have negative effects on the cycling of both P and N.

d) Gaps in knowledge

Nutrient balances need to be calculated to assess losses from harvesting and burning compared with natural rates of inputs.

The potential impact of soil disturbance and burning on the abundance and diversity of fungi is an important issue. Mycorrhizal fungi play a vital role in the recovery of regenerating vegetation , maintaining uptake of nutrients rather than potential loss from the soil, and contributing to long-term site productivity. Saprophytic fungi play a role in the processes of decomposition and mineralization and thus in the functioning of nutrient cycles.

e) Currently applied ameliorative measures

(see cell A14)

4.3.3 Potential Innovations

(see cell A14)

Some slash should be retained on the soil surface across the coupe to provide habitat, for example decaying logs, patches of deep litter and moss.

4.3.4 Assessment Statement

There is a high loss of nutrients and this needs to be assessed in terms of the nutrient balance. Soil fertility is a non-renewable resource of very high value, upon which growth of all plants relies. Any practice that causes long-term reduction in soil fertility will lead to a decline in productivity as well as other ecological processes.

4.3.5 Guidelines / rules / limits for application of practice

The practice of post-logging burning should be limited, both as a broad-area practice, and within the area of the coupe. Wet sclerophyll forest and areas near rainforest should be particularly restricted.

For areas where post-logging burning is going to be used, guidelines should be defined to control fire behaviour, protect remaining trees within the coupe and surrounding vegetation at the boundary, and specific habitats such as patches of understorey, litter, decaying logs and moss to assist recolonization and conserving biodiversity.

Fire behaviour could be controlled by setting limits of soil and litter moisture contents to reduce the impact of damage and desiccation of the whole coupe area. Practices should be defined to ensure that fires are adequately contained and extinguished so as to prevent re-ignition.

4.4 C17 HARVESTING - SITE EROSION HAZARD ASSESSMENT

4.4.1 Statement of Practice and Value

Site erosion hazard assessment offers a means to evaluate land as to its propensity to produce erosion. There is no standard system because erosion hazard encompasses multiple factors; climate, terrain, vegetation, ‘erodibility’, and management. There is the added problem that different types of erosion represent different processes.

There are three current erosion hazard assessment practices within the EMA related to site erosion hazard assessment.

NSW Soil Data System Erosion Hazard Class

DLWC has a current program of soil-landscape mapping across eastern NSW, including 1:100000 sheets within the EMA. As part of the mapping program site data collected by surveyors including an estimated ‘Erosion Hazard’. This latter attribute has 5 categorical classes (slight to extreme) based on climate, site geomorphic activity and existing land use (Abraham and Abraham 1992).

SEMGL Erosion Hazard Assessment

Specified in the SEMGL (DLWC) and based on the Universal Soil Loss Equation (USLE) as calculated by the SOILOSS program (version High School) (Rosewell 1994). This erosion hazard assessment is required for 'Protected Lands' managed by DLWC. Note that the SEMGL are guidelines and not legally enforceable.

Water Pollution Hazard Assessment

SFNSW applied for and obtained a Pollution Control Licence for logging operations from the Environmental Protection Agency (EPA) of NSW in 1992 under the Pollution Control Act of 1970. Within the current licence (1996), a water pollution hazard rating (WPHR) is developed for logging coupes and associated roads based on the Universal Soil Loss Equation (USLE) (SOILOSS Ver. 5.1). In addition, assessment of Percent Dispersible Soil (PDS) for the coupe is required as a basis for determining further logging prescriptions. The use of the WPHR and PDS can require laboratory analyses of soil samples (to determine particle size, dispersion percent or Emerson aggregate test, and organic matter percent) if there are no published data or default values are unacceptable. WPHR is based on USLE with a modified C factor to account for post-harvest disturbance by forest harvest type (eg. native forest integrated logging versus selective logging) and the vegetative recovery over a year.

4.4.2 Nature of Practice

Erosion hazard assessment is considered an essential facet of modern soil management and professional land management.

a) Mechanism of impact

The mechanism of impact differs slightly between the SEMGL and EPA Licence systems.

The SEMGL assumes that GHA maximum erosion hazard can be assessed by applying the USLE equation to a standard 10 m of snig track with the maximum slope of the GHA. Use of the USLE means that only sheet/rill erosion process can be estimated. There is no assumption as to whether soil loss calculated from this standard snig track remains within the GHA or is transported to the drainage system. These erosion hazard classes are calculated using USLE for L = 10 m, C = 0.45, P = 1. In essence, the SEMGL considers erosion as a long-term process.

The EPA Licence requires assessment of the likelihood that logging operations in a particular environment will cause water pollution rather than soil erosion *per se*. The EPA WPHR system also uses the USLE equation but assumes that it is applicable to any 20 m length of the GHA. In contrast to the SEMGL system, cover factors have been modified from 0.45 (representing a fresh, bare snig track) to reflect whole harvested compartment and recovery over a 12 month period as affected by harvesting intensity, type of machinery used, and whether there was any post-harvest burn. In addition to calculating the WPHR, the EPA licence requires the assessment of Percent Dispersible Soil (PDS) within the GHA. Both the WPHR and PDS > 10 assumes that any soil eroded or dispersed has the potential to be delivered to the streams. This also reflects a shorter-term focus of the WPHR system compared with the SEMGLs.

b) Evidence of importance at Eden

There have a number studies investigating the impact of forest operations on soil erosion in the EMA. The majority have been associated with either the Yambulla or Tantawangalo Research Catchments. There have also been erosion pin studies (within Catchment 5 at Yambulla), caesium isotope studies, and most recently rainfall simulator studies (CRC for Catchment Hydrology). Results have been variable due to different scales and different processes being assessed. The large area of coarse-grain granitic soil parent materials under forests does mean that soil erosion and deformation due to forest operations will remain an important impact in the EMA.

c) Scientific commentary

Erosion hazard assessment is a multi-factor concept that encompasses four general components:

- energy source
- terrain setting
- resistance force, and
- management factor.

The energy source can be wind, rain, flowing water (waves) and gravity. These factors can detach and transport soil/regolith material. In reference to rainfall, this energy has been called erosivity.

The terrain setting provides a 3D environment within which the energy is dissipated, modified or concentrated.

Resistance to the energy source is provided by vegetation and soil/regolith properties. In reference to soil properties, this resistance is referred to as the erodibility.

Management can modify all above three factors by affecting the energy source (e.g. windbreaks), the terrain (e.g. contour banks), and soil or vegetative resistance (e.g. hydro-mulching) in either a positive or negative manner.

It is important to note the difference between erosion hazard assessment and erosion models. Effective erosion hazard assessment methods should be inclusive of all erosion processes; wind, sheet, rill, gully, tunnel, stream bank, wave and mass movement. It is also important to differentiate between hazard potential and its probability of occurrence (vulnerability or risk). Erosion models encompass the four components discussed above but deal with a specific erosion process, e.g. sheet and rill erosion.

Research on soil erosion under forests in Australia has traditionally been done at catchment scales within forest hydrology programs. This affects the way erosion is measured. The hydrological approach emphasises sediment delivery to streams or water quality parameters (turbidity) whereas measurements of actual forest soil loss within compartments or coupes are still uncommon. There are a number of current projects that are aiming to measure forest soil erosion rates under various conditions and management treatments. These projects are using a variety of techniques including runoff plots, rainfall simulators, sediment traps, and caesium isotope measurement. Soil erosion is also covered in the hydrology and water quality sections.

Forest harvesting can significantly decrease soil saturated hydraulic because of loss of macropores with compaction (Rab 1994; Lacey *et al.* 1994; Justoff and Majid 1987; Justoff 1991). The largest changes occurred for log-landings and major snig tracks which makes runoff control from these structures critical to minimise post-harvest erosion rates.

While the use of the USLE in determining WPHR has the regulatory advantage of producing a quantitative assessment of soil loss, there are several important problems with this approach:

- The USLE predicts erosion due to sheet or rill processes on simple landforms but it does not predict sediment delivery to streams nor does it consider other erosion processes that can affect water pollution such as gullying, stream-bank erosion, or mass movement.
- Overseas research has shown that if standard erosion control systems are in place within a coupe then sediment delivery, due to overland flow within the coupe, is minor compared to sediment from a forest road system where it crosses the stream network (e.g. Reid and Dunne 1984; Swift 1988; Elliot *et al.* 1994).
- Soil erodibility term (K) in the USLE model is probably the most questionable of the five model factors. Its measurement scale is the finest of all the factors requiring sampling strategies to cope with spatial and soil depth variation. The component properties (organic matter, particle size, permeability and structure) were proposed based on analysis of the original USDA erosion plots (none of which were on forest soils). There have been numerous revised procedures for estimating erodibility for both agricultural soils (Loch and Rosewell 1992) and forest soils (Laffan *et al.* 1996). Forest soils offer particular difficulties of their heterogeneity; high gravel, root and organic matter content.

The only other forest agency in Australia that uses an erosion hazard assessment in its Code of Forest Practice is Tasmania. In this case, a categorical Soil Erodibility Class is derived based on geology, vegetation and local soil knowledge. This classification is then used to specify forest operation prescriptions. The Tasmanian code also assesses hazard due to mass movement and specific geomorphology such as karst (limestone/dolomite landscapes). Soil and geomorphological expertise is nurtured at the operational level and within the Forest Practices Board that also carries out an audit function.

British Columbia, Canada is similar to Tasmania in having a legislative Code of Forest Practice. BC Forests has developed a series of hazard assessment systems that cover mass movement (terrain stability), gully erosion and soil degradation (surface disturbance, compaction, surface erosion and mass wasting). These assessment are categorical, field based, point-scored systems.

Washington State USA has a Code of Forest Practice similar to that of British Columbia and a hazard assessment system based on watershed analysis. There is an explicit division on scale of assessment from reconnaissance down to local. There is also an important recognition of the difference between hazard potential and its probability of occurrence (vulnerability or risk). Washington watershed analysis distinguishes two main categories of hazard:

- Surface erosion
  - Hillslopes
  - Roads
- Mass wasting (landslides)

The section on roads is particularly useful as roads are currently not well assessed by any Australian system.

In conclusion, no Australian Code of Forest Practice fully deals with a comprehensive erosion hazard assessment system. The NSW system utilises the USLE and by doing so focuses on a single erosion process and ignores others. There is also no consistent approach to erosion hazard assessment across land uses in the EMA.

d) Currently applied ameliorative measures

Not relevant.

4.4.3 Potential Innovations

Regolith Stability Classification

Develop a simple categorical classification of regolith stability made at the Regional scale by local expertise and geological/soils data. Such a classification should have two components:

1. regolith cohesion
2. regolith sediment delivery potential.

This dichotomy reflects the dual interest of State agencies in both erosion hazard and water pollution hazard. Emphasis on the regolith has the following aims:

- To extend the concept of landsurface resistance to erosive forces from that meaningful for sheet and rill erosion (erodibility) to broader form that encompasses gully erosion and various forms of mass movement.
- To change the scale of initial determination of erosion resistance and potential sediment delivery from that of a soil sample (soil layer) to scales equivalent to that of landform pattern (Speight 1990).

The proposed regolith stability classification is based on concepts developed by Laffan *et al.* (1985); Turner *et al.* (1990) and Brown and Laffan (1993). The EPA, DLWC and SFNSW are currently investigating the application of such a regolith classification.

Effective use of the USLE model

The use of the USLE should be restricted to situations where its assumptions are valid. The current USLE model in SOILOSS is best applied to assess soil loss (not water pollution hazard) resulting from sheet and rill erosion on representative units of snig track such as intended in the SEMGL actual erosion risk (AEH) concept (CaLM 1993). For these conditions the assumptions of 1) a planar slope length and gradient (LS) factor area with no convergent or divergent flow lines, and 2) Hortonian overland flow, can be accepted.

Some of these limitations with the current use of the USLE model can be overcome by the following procedures:

- Determine what part of the GHA would display Hortonian overland flow and saturated overland for a 1 in 5 year rainfall event- this would require spatial prediction of certain soil hydraulic properties.
- Determining the LS factor for 3-D surfaces as shown by Moore and Wilson (1992). This would require use of terrain analysis of a digital elevation model (DEM) of the GHA.
- Continue development of the forest cover factor (EPA 1995) to account for contact and non-contact vegetation variability, its post-harvest recovery, and fire interactions.
- Calibrate and validate the system.

These procedures would allow the appropriate use of USLE over at least part of the GHA. The technology required to do this is becoming available on a routine basis which means that it is a medium-term solution. The remaining area of the GHA (if any) should not be subjected to hazard assessment based on SOILOSS.

Water pollution hazard assessment should be improved by developing a system that evaluates erosion and sediment delivery from forest roads associated with the logging operation. The

Washington State system (Washington Forest Practice Board 1992) provides a good model.

Measurement of the USLE K factor and Percent Dispersible Soil (PDS)

Investigate the possibility of replacing the current requirement of estimating or measuring K factor and PDS with the soil erodibility determination proposed by Laffan *et al.* (1996). This system has following advantages:

- It has been developed for forest soils
- Based on field and laboratory determinations of water-stable aggregation via wet-sieving and/or dispersion tests, soil strength, stoneyness, thickness of soil layers, permeability and drainage class
- The laboratory water-stable aggregate test can be done locally because it only requires sieves, an oven and a balance
- Incorporates the PDS concept of the EPA Licence into an erodibility measure.

Medium to Long Term Innovations

These options are proposed for investigation and development to operational practice within 1 to 5 years. They all utilise modern technology in the form of GIS, DEMs, terrain analysis, and remote sensing. They also have implications for organisational management, personnel and interdepartmental responsibilities.

The development of these options should be encouraged and supervised by an interdepartmental committee (including stakeholder representatives from conservation and industry) because they would have implications for EPA, SFNSW and DLWC. Any research requirements would be identified from such a committee.

■ Produce a new hazard assessment system which will enlarge the concept of 'erosion' from current emphasis on sheet and rill to encompass:

  - Mass movement (landslides)
  - Mass wasting (slumping)
  - Gully and channel erosion.

■ Develop a State-Federal joint venture (Geological Survey of NSW and AGSO) to produce a set of digital geophysical coverages across the EMA. These coverages would include magnetics and gamma-ray spectrophotometry (radiometric K, Th and U) at a 200 m spacing. These coverages would form the basis of a superior geological, geomorphological and quantitative soil property assessment across the EMA. The predominance of the Bega Batholith across the EMA also means that the radiometrics, in combination with terrain analysis approach outlined above, could be particularly useful in quantifying 'Regolith Stability' and erosion hazard at fine scales across the EMA. AGSO records show that the EMA has no current airborne radiometric data at all.

■ Adopt a long-term redirection towards the use of digital spatial prediction of erosion processes, hazard assessment and terrain analysis techniques. SFNSW already has major resources available in its GIS system and there have been, and will continue to be, important developments in spatial erosion modelling utilising terrain analysis concepts. These models have major advantages in forest systems where geology, contours and streamlines are often the main geographic data available. Harvest Plan Management System software in SFNSW already uses ARCVIEW to produce harvesting plan maps and it offers a framework for further development of spatial land properties.

■ Increase the emphasis on forest roads as a major source of sediment during and after logging operations.

■ Calibrate and monitor the system via selective research catchments, hillslope plots, rainfall simulation experiments etc. This provides the means to maintain and improve the system, upgrade the internal expertise, and provide critical quantitative data for process erosion models such as WEPP.

■ Develop a **Hierarchy of Scale** for assessment from State ➨ Region ➨ District ➨ watershed ➨ hillslope. Different scales are efficient for assessment of different erosion processes.

■ Similarly, a **Hierarchy of Expertise and Support** should be available for the hazard assessment. Responsibility should be generally decentralised to the District level where the harvesting plans are prepared. This will require training and encouragement for local terrain-soil expertise. However there should also be situations where it is necessary to call upon Regional or State specialists to confirm assessment of high hazard and required prescriptions. This is the approach used by Forestry Tasmania (Brown and Laffan 1995).

4.4.4 Assessment Statement

No Australian Code of Forest Practice fully deals with a comprehensive erosion hazard assessment system. The systems in NSW forests mostly utilise the USLE model and by doing so focus on a single erosion process and ignore others.

There is also no consistent approach to erosion hazard assessment across land uses in the EMA. By applying for a Pollution Control Licence, SFNSW placed itself under a detailed, legally binding, regulatory environment that the other land uses do not face. Neither National Parks or agriculture tenures use a systematic erosion hazard assessment even though the main soil erosion and sediment producing activities are associated with agricultural and urban/coastal development in the EMA.

Much would be gained form a uniform, across-tenure approach to erosion hazard assessment (similar to approach used for fire management) instead of the current emphasis on SFNSW practices.

4.4.5 Guidelines/Rules/Limits for application of Practice

Critical slope limits

Both the SEMGL and EPA Licence approaches limit forestry operations using slope and buffer zones around drainage lines/depressions. Maximum slope limit is currently 30° but this can decrease with increasing erosion hazard or WPHR class.

The 30° slope limit due to erosion hazard is purely arbitrary; based on prior experience and calculations, using the ULSE model and assuming certain ‘unacceptable’ soil loss values. Therefore to claim the limit should be 25° rather than 30° is also an arbitrary decision if based on erosion hazard alone.

Increasing slope does effect the degree of deep soil disturbance (see C24/25 below).

The use of slope is actually a simplification of a critical terrain property that can be termed ‘sediment transport capacity’. In the USLE model (and its revised versions), Moore and Wilson (1992 and 1994) have shown that the LS factor can be related to ‘stream power’ and the sediment transport capacity. In complex terrain the LS factor can be derived as a function of **slope** (S) and **specific contributing area** (Ac) at any point on the landsurface. These terrain attributes can be derived for any DEM. Thus the use of slope alone is not a good critical limit if the aim is to link the limit to erosion processes. The use of a critical LS limit would require DEMs and terrain analysis for its calculation but it would be more meaningful for forested landscapes than slope alone.

What a critical LS value should be for forestry operations is unknown. However there have been studies which have developed critical limits for various erosion processes (sheet/rill, gully and mass movement) that use both slope and specific contributing area attributes (Moore *et al.* 1988; Costantini *et al.* 1993; Dietrich *et al.* 1992 and 1993; Prosser and Abernethy 1996). All of these models require site-specific soils/regolith data to be predictive. <u>This would be a profitable area for further research in the EMA</u>.

Critical stream buffer widths

This topic is discussed in more detail in the Hydrology sections [D_].

Critical area generating overland flow

A missing limit to the application of erosion hazard assessment systems is determining the upper boundary for the valid application of the implied erosion process. For example, USLE predicts sheet/rill erosion but this process occurs only if there is overland flow of water (runoff). In applying the USLE model to forests (such as in the EPA WPHR system) it is assumed that all the forested landscape produces overland flow. This is a questionable assumption for forest soils. In fact, this interacts with critical slope concept in that there could areas > 30° that do not have overland flow so that used of the USLE to calculate soil loss is invalid. However, it is important to note that while sheet/rill and gully erosion require overland flow, mass movement does not.

The other important point concerning overland flow generation is that it is a function of both soil hydraulic properties (which can be considered constant) and rainfall intensity, which is a dynamic attribute.

Linkage to Indicators and Targets (When known and where appropriate)

The Montreal Indicator 4.1(a) specifies;

'Area and per cent of forest land (including plantation) with significant soil erosion'.

The proposed interim indicator to the Montreal Implementation Group has been:

'Area and per cent of forest land systematically assessed for soil erosion hazard, and for which site-varying scientifically based measures to protect soil and water values are implemented.'

4.5 C24 HARVESTING AT HIGH-INTENSITY WITH NO RETENTION

4.5.1 Statement of Practice and Value

Harvesting of native eucalypts at high intensity, with or without habitat retention, utilise various heavy tracked or rubber-tyred machinery moving across the GHA. Harvesting practices result in various degrees of soil disturbance related to:

- Tree felling, de-limbing and de-heading.
- Mechanical transfer of the tree boles to the log dump producing a generally upslope confluence of snig tracks with consequently increasing degrees of traffic.
- Mechanical stockpiling, debarking and loading the logs onto road transport.
- Removal of logs from the site.
- Redistribution of bark on the site.
- Post-harvest soil/site amelioration or soil conservation works such as ripping or cross-bank construction.
- Post-harvest fire (see C14).

4.5.2 Nature of the Practice

a) Mechanism of impact

This practice impacts to the soil via:

- soil disturbance (removal of litter layer, exposure of mineral soil, soil displacement etc.),
- soil traffic and compaction by track/tyred machinery and partially suspended snigged-logs,
- potential for accelerated soil sheet/rill/gully erosion and sediment delivery to streams can occur with the exposure of mineral soil and possible compaction increasing runoff via decreased infiltration and hydraulic conductivity,
- removal of a transpiring forest canopy can also potentially increase the flux of soil water towards and into the drainage system which may accelerate gully and stream bank erosion processes,
- removal of nutrients from the site via wood harvest,
- loss of nutrients in the eroded soil particles,
- nutrient loss during post-harvest fire (see C14), and
- redistribution of nutrients on the site during erosion, slash movement and fire.

b) Evidence of importance at Eden RFA area (scale and/or intensity)

The intensive nature of integrated harvesting in the EMA can produced significant areas of disturbed and deformed soils. These impacts have been quantified by Lacey *et al.* (1994) for 3 soil types within the EMA.

There is no conclusive evidence linking varying degree of site disturbance to changes in long-term forest productivity in the EMA.

c) Scientific commentary (Key reference)

There is evidence of a direct relationship between soil compaction, due to forest operations, and subsequent change in forest productivity from work outside the EMA. However the relationship is better established for young trees in forests or for seedlings grown in glasshouses (Williamson 1990; Rab 1994). Retrospective surveys conducted to establish long-term effects are few, but available evidence suggests potential for long-term effects in East Gippsland (Rab *et al.* 1992). While there is increasing data quantifying significant changes in soil compaction due to forest operations, it is still difficult to relate these impacts to actual changes in long-term forest productivity. There are also indications that the impact on forest productivity varies with forest type. For example, no significant difference was found in the growth of 5-year-old slash pine (*Pinus elliottii*) planted on a site harvested in wet, saturated site conditions compared to a site harvested in dry soil conditions even though there was significant changes in compaction and rutting between sites (Tiarks 1990).

Soil moisture affects compaction, however the degree of soil volume change per unit of soil moisture varies between soils because of differences in texture and/or organic matter. This behaviour can be used distinguish two categories:

- moisture sensitive soils which have marked changes in compactibility with increasing moisture content- well graded, coarse-textured soils and fine textured, smectite clay soils
- moisture insensitive soils which have only minimal compactibility with increasing moisture content- poorly graded, coarse-textured soils and medium to fine texture soils with non-expanding clays (kaolin)

Such a categorisation requires some form of compaction test such as Murphy and Robertson (1984).

Yarding Method

Lacey (1993) summarised data on area of exposed mineral soil (AEMS) and area of deep disturbance (ADD) and showed that yarding method influenced disturbance more than any other single factor. A ranking of yarding methods in relation to the degree of disturbance would be ground > cable > aerial, and within cable yarding methods the corresponding ranking would be jammer > grapple > highlead > skyline. Within ground yarding methods, rubber-tyred skidders produced more disturbance than tracked machines. Recent studies in Malaysia (Justoff 1991) and USA work (Aust and Lea 1992) confirm these conclusions. New harvesting technologies have potential for further minimising soil disturbance via 'walk-over' technology (e.g. excavator logging)

Logging Intensity

There appears to be no consistent, strong relationship between area disturbed and timber volume extracted on a per area basis (Williamson 1990; Lacey 1993). Neither does varying forest harvesting intensity (clearfelling versus selective logging) appear to produce significant differences in soil disturbance (Lacey 1993).

Slope

For ground-based harvesting, AEMS may decrease with increasing slope while ADD can increase (Murphy 1984) because steep slopes tend to reduce total soil disturbance in ground skidding operations by restricting machine activities to ridge crests and snig tracks (Lacey 1993). On slopes > 40% (22°) ADD can triple in comparison to lower slope disturbance (Garrison and Rummel 1951).

Vehicle Traffic and Compaction

Most of the literature shows that soil compaction will occur within first several machine passes (Rab 1992; Lacey 1993) with only marginal change with subsequent travel. This is particularly the case with rubber-tyred vehicles compared to tracked vehicles (Justoff 1991). However unlike compaction, changes such as reduction in pore-size distribution, decreased air diffusivity and saturated hydraulic conductivity do still occur with increasing number of passes (Lenhard 1986 and Hildebrand 1989; Justoff 1991).

Machine differences in static ground pressures do not equate to similar differences in dynamic contact pressures. Emphasis should be to minimise dynamic contract pressures through such systems as rubber-belted tractors, lower pressure tyres, forwarder load designs and advanced (hydraulic) transmissions with slippage control (Wasterlund 1989).

Soil Strength Measurement

Soil bulk density is a direct measure of soil compaction but has been found inadequate as an indicator of soil strength (Lacey 1993). Alternative measures are cone penetration index and shear strength (Lacey *et al.* 1994) but they have the disadvantage of being very sensitive to moisture content and are unreliable on soils with high gravel content.

Both soil compaction tests and soil strength measurements display the importance of understanding soil moisture temporal and spatial variation in determining the impact of forest operations on different soils (Lacey *et al.* 1994).

Rates of Soil Recovery from Compaction

For soils containing non-expansive clay, the period for recovery from compaction can be from 5 to 50 years (Lacey 1993). Amelioration of log-landings by ripping may not be effective if soil strength has reached high values (Lacey *et al.* 1994). However, ripping remains the most efficient means rehabilitating compacted soils as long as it is done at the correct soil moisture. Optimum workability for most soil occurs near their plastic limit (Dexter

1988). At or near this moisture content ploughing or ripping will produce the maximum shattering of clods without smearing (too wet) or pulverising (too dry) the soil.

Changes in soil nutrient levels

Nutrients in the soil can be decreased by the influence of fire, by erosion, by leaching beyond the root zone or by removal in forest products. In addition to losses, spatial redistribution of nutrients on the landscape can occur during harvesting operations when surface soil and litter on the forest floor are moved by the use of machines. Irregular redistribution of nutrients happens also when harvesting slash (specially the bark) does not get uniformly distributed on the harvested coupe. The practice of windrowing will result in the maximum redistribution of nutrients and organic matter with least uniformity in the pattern of distribution. Both nutrient losses and irregular redistribution of soil nutrients will affect adversely the productivity on a site.

Huge amounts of slash are left on or around the site after harvesting. For the three forest types in Eden woodchip area, Turner and Lambert (1986) estimated 406 to 458 t ha^{-1} of total aboveground biomass out of which about 100 t ha^{-1} were removed in the harvest leaving 300 to 350 t of slash (about 75% to 80% of the standing biomass). More than 50% of the woody biomass remained on the site. In the mixed-species eucalypt forest at Maramingo in East Gippsland, Hopmans *et al.* (1993) measured about 244 t ha^{-1} of debris (out of the total aboveground biomass of 344.1 t ha^{-1}, 100 t ha^{-1} of wood was removed). Harwood and Jackson (1975) estimated logging slash of 630 t ha^{-1} in a mixed eucalypt forest with rainforest understorey in Tasmania. Jones (1978) recorded an average of about 500 t ha^{-1} of fuels in 14 slash disposal fires in W.A. These values are probably towards the higher end of the range of slash left on the coupe following clearcut harvest; the values usually lie between 200 and 400 t ha^{-1}.

A number of practices given below lead to nutrient losses. Hopmans *et al.* (1993) estimated that total loss of nutrients in harvest and slash burning as in kg ha^{-1}: N, 241; S, 21; P, 11; K, 95 (23% of available); and Ca, 283 (26% of the available). The combined losses of nutrients from harvesting and burning of logging residues were estimated at 50-70% of the amounts in the aboveground biomass. On slash burning 180 kg of N would have been lost. They suggested that high-intensity burning of logging residues in the mixed forests of eastern Victoria should be avoided wherever it is possible.

<u>Nutrients removed with the removal of wood from the site</u>

This will include any removal of wood during final harvest or thinnings. The amount of nutrient removal in wood will depend on; a) the amount of wood removed, b) whether the bark removal happens on the site or ‘off’ the site, and c) the concentration of nutrients in the vegetation components removed. Bark is usually many times higher in nutrient concentrations than the wood, and thus the amount of bark removed will affect the nutrient status of a site in a significant way.

Timber intensive harvesting involves four operations that can seriously affect losses of nutrients via erosion and leaching into nearby streams. These operations are road construction, felling, skidding and yarding, and site preparation prior to re-establishment.

[Post-logging nutrients lost during slash burn are discussed in C14.]

<u>Nutrients lost during site preparation</u>

Following logging the site may remain unoccupied by vegetation for considerable period. During this time an excessive amount of nutrients may be released on mineralisation of soil organic matter. The amount of soil water will also be excessive so that leaching of nutrients can result in their loss. Any soil cultivation as a site preparation measure, for example, for plantation establishment may also result in increased mineralisation rates and thus loss of nutrients. In a review of eight studies in USA forests, Neary (1977) concluded that well-planned and managed logging operations produce only relatively small increases in nutrient output in stream flow. Under these conditions losses of nitrogen and phosphorus would not be expected to exceed 10 kg ha^{-1} yr^{-1} and 0.5 kg ha^{-1} yr^{-1}, respectively. Extreme losses will occur only when all vegetative growth is suppressed for a long time (three or more years) after clearfelling.

d) Currently applied ameliorative measures (where applicable)

- Redistribution of bark from log landings to the GHA via snig tracks
- Cross-bank construction on all snig tracks
- Ripping log landings and replacing stockpiled topsoil if dump is not to be reused.

4.5.3 Potential Innovations in Practice

Timber extraction infrastructure

In harvesting native forests, compaction is likely to occur even with a minimum number of machine passes. If amelioration is difficult (or at least uneconomical), in the short-term the option left is to design an optimal snig-track network and log landings to specific engineering grades. This system then becomes a part of the infrastructure of the managed coupe, just as the access roads, with emphasis placed on engineering soil conversion works to minimise off-site effects of this infrastructure (Rab 1992; Lacey 1993; Lacey *et al.* 1994).

Site classification

The criteria for quantifying soil disturbance have improved. However, the relationship of type and degree of disturbance with subsequent forest productivity or off-site impact (water quality or erosion rates) is still poorly understood and thus an obstacle to interpreting the disturbance data.

Lacey (1993) points out the need for a more standardised classification of forest soil disturbance which covers both the source (e.g. tree-felling, snigging, log loading) and degree (categorical classes or depth of soil impacted) of disturbance.

Two general classes of forest soil disturbance have been recognised (Murphy 1984): 1) area of exposed mineral soil (AEMS), 2) area of deep disturbance (ADD) and these remain the only categorisation that can be used across the international literature.

There are several approaches to site classification for soil compaction hazard. Murphy and Robertson (1984) showed that relationships between soil compaction and soil moisture (compaction curves) could be determined for major soil landscapes and used to rank soils as to their compaction hazard. This is preferable to the more simplistic seasonal operation classification (‘wet’ or ‘dry’ weather classes).

The B.C. Ministry of Forests (Canada) (Anon. 1995) has developed a field survey approach to rank forest operation areas as to their potential soil degradation hazard. Five major soil-degrading processes were recognised.

- Soil compaction and puddling
- Soil displacement
- Forest floor displacement
- Surface soil erosion
- Mass wasting (not mass movement)

The compaction hazard classification is based on:

- soil coarse fragments and soil texture classes
- soil moisture regime

The soil displacement hazard is based on:

- slope gradient; increasing slope increases the hazard
- slope complexity; 2 or more of gullies per 100 m of contour by increasing slope class increases the hazard
- substrate conditions; a substrate type versus soil depth table presents a series of ‘unfavourable subsoils and substrates’ by depth classes, with the hazard increasing with decreasing soil depth.

Both of these hazard classifications can be potentially modelled using the quantitative terrain modelling approach (Gessler *et al.* 1995) discussed above in reference to erosion modelling.

‘Decompaction’

One option available after harvesting plantations (and native forest harvesting to a lesser extent) is to deliberately ‘decompact’ a significant proportion of the harvested area by pushing over the trees or stumps. This emulates natural forest soil disturbance processes of windthrowing and produces a micro-topography with pit-mounds. This practice has only limited application because of increased site disturbance and erosion hazard.

Another approach available for plantation and certain native forest sites is to cultivate (rip or blade plough) prior to harvesting (Pennington and Ellis 1997). Cultivation is a standard practice in establishing plantations. However the increasingly common practice of slash retention with chopper-rolling in pine plantations makes ripping or blade ploughing less efficient.

Organic matter management

Organic matter conservation practices such as chopper-rolling or slash layering in forwarder thinning operations of plantations (McMahon and Evanson 1994) can diminish soil compaction hazard.

Harvesting operations can significantly reduce soil organic matter levels (Rab 1994), an effect which has implications for increasing compaction hazard as well as affecting future productivity. Therefore practices that retain non-commercial biomass without impeding access or traffic should be encouraged. Current practices include dispersal of bark-wood-leaf residues. Tops (leaves and twigs) should be left on the site. Whole-tree harvest or thinning can cause higher nutrient losses.

Extraction of wood from a site should be maximised and every attempt should be made to reduce the amount of woody slash after harvesting.

Broadcast burning of slash should be undertaken only under special conditions where the amount and nature of logging residues make their alternative disposal difficult. Slash burning should be completely avoided when harvesting plantations. Alternative methods of slash management should be considered.

4.5.4 Assessment Statement

Soil disturbance during harvesting should be minimised to avoid adverse effects such as erosion and compaction. But there is a catch; effective regeneration of many eucalypt species (including *E. sieberi*) requires disturbance of the litter and surface soil layer to initiate seed germination. So there has to be an 'optimum' degree of soil disturbance for sustainable forest management. What this optimum level of disturbance should be is unknown.

No specific measures are required to offset the losses of nutrients as long as leaf, branch and bark materials are retained on site. Any measures to reduce erosion losses will contribute to a decrease in nutrient losses.

4.5.5 Guidelines/Rules/Limits for application of Practice

Possible choices are;

- Minimise the area of the GHA receiving harvesting traffic.
- Limit the area of the GHA with >10% increase in bulk density of any horizon of the surface (0-30 cm) soil.

4.5.6 Linkage to Indicators and Targets (When known and where appropriate)

Two Montreal Indicators are relevant to this practice. They are:

- 4.1(d) Area and per cent of forest land with significantly diminished soil organic matter and/or changes in other soil chemical properties.
- 4.1(e) Area and per cent of forest land with significant compaction or change in soil physical properties resulting from human activities.

The respective interim indicators proposed to the Montreal Implementation Group are:

- 4.1(d) The total quantity of organic carbon in the forest floor (< 25 mm diameter components) and the surface 30 cm of soil.
- 4.1(e) Proportion of harvested area with > 10% bulk density of any horizon of the surface (0-30 cm) soil.

4.6 C27 INTENSIVE STAND MANAGEMENT - FERTILISING

4.6.1 Statement of Practice and Value

This practice refers to increasing the timber yield by intensively managing forest stands. In stands where optimum levels of productivity are limited by deficiency of a nutrient, intensified stand management will include measures to remove that deficiency by small inputs of fertiliser. Low but optimum inputs will can be aimed at causing either no or only small changes in other forest values (biodiversity of flora and fauna, water).

4.6.2 Nature of the Practice

If practiced carefully, only beneficial effects are expected.

a) Mechanism of impact

Removing any site nutrient deficiency will increase plant growth. If the input is low, any effect on the soil properties is expected to be low. Under these conditions the effect on the soil fauna and soil flora will also be small, and probably beneficial. The main problem can arise from the method of application of fertiliser, which if carried out wrongly can result in nutrient losses to waterways, affecting their nutrient concentrations with associated adverse effects on river ecology.

b) Evidence of importance at Eden RFA area

Some information on the possibility of increasing stand productivity when fertiliser is applied at the time of first commercial thinning of regrowth stands is available and can be considered to be valid for EMA.

c) Scientific commentary (Key reference)

Application of fertilisers often results in increased forest productivity and in some cases may be essential for healthy forest growth. Adverse environmental effects due to application of fertiliser can occur but these can be minimised by careful assessment of the need to apply fertiliser, the choice of fertiliser materials and the methods of application.

A wide range of fertiliser materials is now available, thus allowing specific choices to be made to meet operational requirements. The key factors that influence the application of fertiliser are the species and its stage of growth, topography, soil type, time of year, weather conditions and the presence of competing vegetation. The potential impact on water quality by drift, leaching or run-off during aerial applications can be minimised by 1) selecting carefully flight paths to avoid waterways and waterway buffer strips, and 2) selecting granulated dust free fertilisers. Manual or other ground-based methods of application of fertiliser are more easily controlled to prevent adverse effects.

It has been recognised that occurrence of nutrient deficiencies and variations in forest productivity can be broadly related to the geological substrate and variations in soil development. This has led to the development of a ‘Technical Soil Classification’ for *Pinus* plantations in Australia (Turvey 1987, Turner *et al.* 1990) and assessment of its ability to form a basis for assesssing crop yield (Turvey *et al.* 1990). In New South Wales part of this system has been used to develop a database in which the exotic plantations can be stratified into units according to geological mapping units (Knott and Ryan 1990; Ryan and Knott 1991). This method provides a good framework for extrapolation of research findings to broadacre forestry on a site specific basis.

4.6.3 Potential Innovations in Practice

Low inputs of fertiliser should be considered in these forests. In order to attain maximum gains from the fertiliser it will be better to apply it after thinning or early spacing (management of overstorey). Phosphorus (P) is usually the most deficient element for plant growth in these systems. Therefore an application of P <50 kg/ha as superphosphate is expected to provide maximum benefit. P will increase nitrogen (N) fixation by understorey leguminous plants and will thus enhance the cycling of both N and P. Thus management of both understorey and overstorey strata is an essential component of this practice. A site-specific fertiliser application will ensure that its effects on soils, waterways, flora and fauna are minimised.

4.6.4 Assessment Statement

There are two aspects requiring assessment: the economic considerations and the environmental effects. Increased timber yield would require evaluation in terms of the cost of applying fertiliser. Any change in values relating to flora and fauna populations and soil and water should be included in this assessment. No information is available presently to assess these effects in the Eden area. These impacts can be assessed by initiating field trials on representative sites where long-term timber yield and other values are monitored. If it is applied following thinning operations, helicopter or ground applications should be considered with special care to avoid drainage line and creeks. Digital Elevation Models (DEMs) and/or maps can be used to optimise the technique of fertiliser application by minimising losses and effects on watercourses.

4.6.5 Guidelines/Rules/Limits for application of Practice

Fertiliser application should be limited to areas of intensive silvicultural activity such as plantations and productive native regrowth stands that are scheduled for thinning or spacing (see F25 and F26).

Application should be planned to match site-specific requirements such as nutrient limitations, understorey competition, stream-side buffers and terrain.

4.7 C31 WET WEATHER SNIG TRACK AND SOIL MANAGEMENT

4.7.1 Statement of Practice and Value

SFNSW FPC (Forest Practice Code)

Wet weather controls apply to all aspects of timber harvesting operations on an all year round basis. They are designed to prevent excessive soil disturbance, minimise water turbidity and avoid undue damage to roads and tracks during periods of wet weather.

- Automatic closures without notification
- Notified closures (partial or total)

Automatic closures will apply without prior notification generally when it is physically raining and/or water is running in table drains or wheel ruts of natural surface roads and snig tracks or timber extraction tracks within timber harvesting areas as a direct result of rain or snowfall.

EPA Pollution Control Licence (SFNSW)

Where runoff occurs from a road surface, haulage may not occur unless the road is a gravel or sealed road

Extraction tracks and snig tracks must not be used where:

- There is runoff from the track surface or,
- There is a likelihood of significant rutting leading to turbid runoff from the track surface.

Logging operations by wheeled loaders and trackscavators must cease where there is runoff from the log dump surface.

SEMGL (DLWC/SFNSW) 'Protected Lands'

During wet conditions, roads/snig tracks should not be used for log extraction in the following circumstances:

- where there is run-off from the road/snig track surface; or
- where significant damage to the road/snig track surface (including rilling and rutting) is likely to occur.

4.7.2 Nature of the Practice

This practice is positive.

a) Mechanism of impact

Overland flow of water within the GHA or associated roads is the main mechanism for detaching and transporting sediment to the drainage network. Traffic on wet soils can also produce deformation via puddling and compaction. This can alter soil macropore structure and limit subsequent water infiltration and hydraulic conductivity.

Soil strength is also highly dependent upon soil moisture. Avoiding traffic on wet soils diminishes the hazard of soil compaction as the result of forest operations.

b) Evidence of importance at Eden RFA area (scale and/or intensity)

Suspended sediment draining from unsealed roads is probably one of the most important sources of sediment across the whole EMA, across all tenures. Comparing all tenures, agricultural lands (unsealed roads and cultivated lands) would be the predominant source of sediments during wet conditions.

Harvesting operations have been in the past classified into 'wet' versus 'dry' weather sites although the uncertainty of tenure and availability of coupes has disrupted this planning procedure in recent years.

c) Scientific commentary

Elliot *et al.* (1994), reviewing forest soil erosion, summarised that roads are the dominant source of sediment in Eastern US forests (Swift 1988), and a major source of sediment in Western Forests (Reid, 1981; Reid and Dunne 1984). It is estimated 50% to 90% of sediment in a forest comes from roads. Landslides are the other major contributor to sediment.

In reference to the effect of USA EPA Best Management Practices (BMPs) on forest water quality, Binkley and MacDonald (1994) pointed out that in most cases, BMPs have been developed that can minimise degradation of water quality to within generally acceptable limits. However, it is important to note that extreme storm events, such as those with a recurrence interval in excess of 50 years, can degrade water quality and stream habitat in both managed and unmanaged forests, despite the careful application of BMPs.

d) Currently applied ameliorative measures (where applicable)

The current applied ameliorative measures consist of: 1) stopping any traffic after a critical level of soil-moisture or overland flow is reached within snig tracks, and 2) ensuring adequate track/road drainage structures are present to facilitate soil drainage and access as soon as conditions permit.

Of course, these measures only apply within State Forests. Shire roads are closed during flood events but otherwise traffic is not controlled during wet weather. Restricted budgets also mean that Bega Shire is maximising the distance between drainage structures (culverts etc.) on unsealed roads.

Road maintenance programs also interact with amelioration post-wet conditions.

4.7.3 Potential Innovations in Practice

The potential exists to develop quantitative, spatial soil-water models based upon DEMs, terrain analysis, and a simple 1 or 2 dimensional soil-water-balance model. Interfacing this model with local meteorological data would allow more site-specific definition of soil-water limitations to forest operations. This approach is complementary with that proposed for erosion modeling (section C17 c)).

4.7.4 Assessment Statement

This practice is probably one of the most critical to the impact of forest operations on water quality. Within State Forests the EPA Licence and Forest Code of Practice specifies detailed practices. However, it is essential that wet weather soil management be viewed on a total catchment basis across all tenures. From this perspective there still are major deficiencies with other tenures, especially agricultural and private forest land.

4.7.5 Guidelines/Rules/Limits for application of Practice

Forest operations should cease when it is physically raining and/or water is running in table drains or wheel ruts of natural surface roads and snig tracks or timber extraction tracks within timber harvesting areas as a direct result of rain or snowfall.

Operations should not recommence until rain and/or runoff has ceased.

4.7.6 Linkage to Indicators and Targets (When known and where appropriate)

This practice has a direct link to Erosion Hazard Assessment (section C17).

4.8 C32 SNIG TRACK CLOSURE - DRAINAGE AND EROSION MITIGATION

4.8.1 Statement of Practice and Value

Current practices in State Forests are specified by the EPA Pollution Control Licence and practices for 'Protected Lands' are specified in the SEMGL.

EPA Pollution Control Licence (SFNSW) Schedule 4

<u>Drainage of Extraction Tracks and Snig Tracks</u>

- Sections of extraction tracks and snig tracks must be progressively drained at the completion of logging operations around each section of track, using one of the following techniques, or a combination thereof:

  a) existing ground cover must be retained as far as practicable. Where this prevents concentrated water flow in excess of the minimum filter strip widths, constructed drainage is not required; or

  b) slash and logging debris must be retained as far as practicable. Where retained slash will prevent concentrated water flow in excess of the distances specified for filter strips and no post logging burning is planned, constructed drainage is not required; or,

  c) outfall drainage must be used as far as practicable. Where outfall drainage will prevent concentrated flow in excess of the distances in Table 4, constructed drainage is not required.

- Where the techniques in condition 97 of this schedule are not practicable, constructed drainage must be provided in accordance with condition 99 of this schedule.

- The maximum spacing of extraction track and snig track drainage structures must be designed to limit erosion of the track surface in accordance with Table 4:

TABLE 2: MAXIMUM SPACING OF EXTRACTION/SNIG TRACK DRAINAGE STRUCTURES (M)

Track Grade (Degrees)	Water Pollution Hazard Category		
	1	2	3
5	200	150	100
10	150	100	60
15	80	60	40
20	60	40	25
25	40	30	20
30	30	25	15
35	25	20	10

Table 4 may be interpolated to derive site-specific maximum spacings.

- Where drainage of a section of track in accordance with conditions 97 or 98 would preclude the use of the track for other, ongoing operations, the drainage of the track may be delayed until those other operations are complete.

Snig track and extraction track drainage structures must be designed to:

d) have sufficient capacity to convey the peak flow from 1:2 year storm event; and

e) divert water onto stable surfaces; and

f) minimise the unchecked flow of water directly into watercourses and drainage lines or onto roads and log dumps; and

g) divert water at a velocity which minimises damage to the structure.

- Drainage structures to be used on snig tracks, and the techniques to be used to achieve the outcomes required in condition 101 of this schedule must be specified in the harvesting plan.
- Where a storm event which exceeds the design criteria of track drainage structures occurs within 12 months of the completion of operations, the structures must be assessed and repaired if necessary.
- Windrows on snig tracks and extraction tracks must be dealt with in accordance with condition 67 of this schedule.
- Where a post logging burn is planned, flammable materials must not be used in track drainage structures.
- Where crossbanks are used they must be constructed to a minimum unconsolidated effective bank height of 35 cm, or a consolidated effective bank height of 25 cm, unless otherwise calculated in accordance with condition 10lLa) of this schedule.
- Crossbanks must not be constructed of bark.
- Drainage must be effected as soon as practicable at the completion of operations on each extraction track or snig track, and in any event within two days, unless soil conditions preclude construction of effective drains or would lead to increased soil erosion. Instances where the drainage is not effected within two days of the completion of logging operations must be documented on the supervising forest officer’s copy of the harvesting plan, including the reasons why.
- The number of snig tracks or extraction tracks open at any open time must be kept to a minimum.
- Drainage must be effected if the use of an extraction track or snig track is to be temporarily discontinued in accordance with Table 5:

TABLE 3: DRAINAGE OF EXTRACTION TRACKS AND SNIG TRACKS AT TEMPORARY CESSATION OF OPERATIONS

Water Pollution Hazard Category	Monthly Rainfall Erosivity Rating	Number of Days
1	N/A	10
2	>900	5
	<900	8
3	>900	3
	<900	5

- Snigging and timber extraction must occur in an uphill manner unless downhill snigging maintains or decreases the potential for water pollution, or unless physical constraints preclude uphill extraction.
- Where downhill extraction or snigging is proposed, one of the following techniques or a combination thereof must be used:

h) downhill snig tracks must enter the log dump from the side or below;

i) a drainage structure must be in place immediately before a snig track enters the log dump, at the end of each day’s operation.

Cross bank drainage (SEMGL) -Tenure: -SFNSW/Protected Lands

Cross banks should be constructed to a height of approximately 50 cm, unconsolidated and spaced according to Table 7.

Cross banks should divert water onto stable vegetated surfaces. They should not divert water directly onto other tracks or roads. The exits of these banks should allow water to drain readily from the roads.

Where a temporary cessation of operations will occur, temporary cross banks should be installed.

TABLE 4. CROSSBANK SPACING

Slope	Maximum bank spacing (m)
< 5°	As specified
≥ 5 - < 10°	60
≥ 10 - <15°	40
≥ 15 - < 20°	30
≥ 20 - 25°	20

Post-logging drainage (SEMGL) tenure: SFNSW/Protected Lands

Where the logging operation has ceased (even if it is planned to use the road at any time in the future) the road should be drained as soon as practicable by re-establishing effective cross fall drainage or by cross banks (either peaked or broad based) unless otherwise specified. The channels of these cross-banks should be constructed with a minimum gradient to ensure the effective removal of water from the road/track.

Wet weather closure –

Practices discussed in C30 apply.

4.8.2 Nature of the Practice

Beneficial. A limitation is that cross banks can only go in after operations using that track have ceased.

a) Mechanism of impact

Snig tracks offer an ideal surface for erosion to occur. Exposure of soil, decreased infiltration rates due to traffic and compaction ans downhill flow directions all maximise the potential to produce overland flow after rainfall and thus affect detachment and entrainment of sediment. The main way to alleviate this problem is to minimise the slope length and decrease sediment transport velocities by constructing cross-banks across the snig tracks at various intervals downslope. The aim is not to 'dam' the track but to slow the velocity of overland flow and redirect it off the track onto areas with greater cover and lower disturbance. This process should allow the majority of any entrained sediment to be deposited within the GHA.

b) Evidence of importance at Eden RFA area (scale and/or intensity)

This practice has been one of the key foundations to the SEMGL (and its predecessor SEMC). It is a key area for training machine operators by SFNSW and DLWC staff.

c) Scientific commentary (Key reference)

The preliminary results from large rainfall simulation experiments at three harvested forest sites in the EMA (Croke *et al.* 1997; Croke and Mockler 1997; Croke 1997) have produced the following results;

- Runoff from snig tracks was consistently higher than the GHA across all soil types, all rainfall intensities, and all age classes.
- Snig tracks produced about 7 times more surface water than the GHA on recently logged sites but this decreased to 2 times with increasing duration of recovery.
- Snig track runoff had the highest sediment concentrations for each storm event across all soil types and consequently produced the highest sediment yields.
- The percentage sediment deposited at each cross-bank ranged from 40% to 100% across all soil types and rainfall intensities.
- Cross-banks were found to be very effective measures of reducing sediment delivery to the GHA across all soil types and rainfall intensities.
- Much of the sediment eroded from highly disturbed areas such as snig tracks is deposited prior to reaching the bottom of the hillslope.
- Curvilinear relationships between cover and runoff on both snig track and GHA declined with increasing rainfall intensity, whereas relationships between cover and erosion

remain consistent even under extreme rainfall events.

- A cover density of 50%-60% appears to represent a critical value in reducing surface runoff across the range of sites.

d) Currently applied ameliorative measures (where applicable)

Not applicable.

4.8.3 Potential Innovations in Practice

The current EPA Licence schedules for SFNSW are very detailed. Only minor innovations are presented.

Cover on snig tracks may be increased by adding slash, mulch etc. as cross banks are being constructed. Seeding the track may be warranted in certain situations.

A ‘corduroy’ of small limbs/boles across the track between cross banks would further decrease runoff velocities. This is another form of cover.

4.8.4 Assessment Statement

Current practices within SFNSW are adequate. The situation outside State Forests and Protected Lands is not regulated nor monitored.

Operator training, assessment and auditing is crucial to implementing and improving this practice.

4.8.5 Guidelines/Rules/Limits for application of Practice

See EPA Licence Schedule 97 to 112 above.

4.8.6 Linkage to Indicators and Targets (When known and where appropriate)

Not considered appropriate.

4.9 C34 PLANTATION ESTABLISHMENT

4.9.1 Statement of Practice and Value

SFNSW FPC Part 3 Tenure: SFNSW

- Soil stability should be protected by measures which regulate site disturbance.
- Soil, water catchment, cultural and landscape values should be protected by careful construction and maintenance of roads and tracks and regulation of their use.
- Whenever possible, and consistent with the requirement for rapid reestablishment of ground cover, mechanical clearing and cultivation operations should be scheduled for the drier seasons of the year, to minimise the chance of soil compaction and puddling, and to maximise soil fracturing during cultivation.
- Mechanical operations must cease when the soil is saturated or when surface runoff is occurring.
- Where clearing for plantations is required, it should be carried out using techniques that optimise the retention of ground cover and minimise the potential for soil movement, consistent with the requirements for effective tree establishment.
- Where practicable, approved low-ground impact machinery should be used for plantation clearing and cultivation.
- Where stacking or windrowing of heavy debris is required, rakes rather than blades should be used to minimise soil movement. Windrows and stacks must not be pushed into drainage feature protection areas and must be physically separated from them.
- Line cultivation should be carried at a gradient sufficient to avoid ponding as well as excessive water velocities and erosion.
- Disposal areas for road drainage water must not be cultivated or disturbed.
- Where maximum soil protection is required, and consistent with requirements for effective tree establishment, preference should be given to strip or spot methods of cultivation and weed control, rather than broadcast methods.

EPA Pollution Control Licence (SFNSW)

Schedule 4 specifies a number practices pertaining to the delineation and management of filter strips adjacent to drainage features in native and softwood plantations. These will not be discussed in this section.

4.9.2 Nature of the Practice

a) Mechanism of impact

Plantation establishment in the EMA is similar to other forms of agricultural cultivation, especially forms of minimum tillage. There are usually the following process affecting soil values:

- Construction of access roads
- Delineating and managing filter strips adjacent to drainage features
- Stock-piling and burning large woody debris (windrowing) if required
- Cultivation along the contour of planting rows usually by
  - winged blade ploughing
  - ripping, or
  - mounding
- Weed control along planting lines
- Hand or machine planting of seedlings
- Fertilisation

Therefore the mechanism of impact on soils is varied. Soil disturbance, erosion and mechanical traffic processes are similar to those discussed in sections C24/25 and C30/C31 although the relative intensities are different.

b) Evidence of importance at Eden RFA area

There are extensive areas of pine plantations and small but increasing areas of eucalypt plantation in the EMA. Most of this area is on the tablelands although parts of the old private Kapunda plantation are in the Towamba valley. The establishment of the Kapunda plantations in 1988 produced some highly significant erosion events (Prosser and Soufi 1997).

c) Scientific commentary

The Prosser and Soufi (1997) Kapunda study showed that a combination of intensive cultivation (blade ploughing of the whole compartment) and highly erodible soils, coinciding with a period of intensive storms of 2-year recurrence interval, produced major gully erosion. Such establishment practices (especially the ploughing) were not then and are not now current in the SFNSW pine plantations. However, Prosser and Soufi (1997) state that there is a window of opportunity of approximately one year during which an extreme storm event can cause massive erosion, this is relevant to all pine plantation establishment, public or private.

For SFNSW, establishment of new plantation area has meant the purchase of ex-agricultural land or development of joint-venture operations with private landowners. This has meant that the post-1980s plantation establish techniques have changed significantly from those used pre-1980 to convert ex-native forest. Soil properties of ex-agricultural lands that affect plantation establishment included:

- Existing erosion/land degradation (scald areas, gullies, saline seeps etc.)
- Higher bulk densities due to grazing pressures and removal of trees
- Changed soil chemical regimes due to fertilisation and use of legumes (N fixation)
- Different weed control problems due to imported pasture grasses/crops/weeds and soil nutrient regime.

d) Currently applied ameliorative measures

Not applicable.

4.9.3 Potential Innovations in the Practice

- Develop a large scale soil/site evaluation system based on intensive soil survey and sampling of newly purchased land or new age classes prior to establishment. These data are then used as part of a soil management plan for that particular unit of plantation covering erosion hazard and mitigation, trafficability, fertiliser requirements, buffer strip management etc.
- There is potential to utilise the developing technologies from ‘precision agriculture’ to varying ripping depth or fertiliser requirement at time of application by real-time reference to GIS spatial soil/site data.
- Excavator based spot cultivators (Hall 1997) can be used in terrain unsuitable for blade-ploughing or ripping (e.g. rocky soils or steeper terrain) for site preparation. This would minimise site disturbance but would require hand planting.

4.9.4 Assessment Statement

Plantation establishment is a critical time when there is minimal vegetative cover and variable soil disturbance. The aim of establishment should be to maximise seedling establishment and early growth with the minimum amount of site disturbance. For ex-agricultural land these practices have become increasing mechanised so there becomes an increasing need to minimise ground traffic at establishment. This degree of intensive management means that obtaining detailed soils information as an integral part of site establishment can be justified to develop site-specific soil management strategies.

4.9.5 Guidelines/Rules/Limits for application of Practice

- Site classification and/or soil survey as an integral process of evaluating any land proposed for native/softwood plantation development. This would address areas to be planted, areas reserved, buffer/filter areas, and erosion hazard assessment.
- A soil management plan developed for areas of plantation establishment – based on data collected during site classification/ soil survey.

4.9.6 Linkage to Indicators and Targets (When known and where appropriate)

There should be a specific target for plantation establish/development (State Forest, joint venture, and private) in EMA as part of the RFA and 2020 National Plantation Strategy.

4.10 C35 PLANTATION HARVESTING

4.10.1 Statement of Practice and Value

SFNSW FCP (Part 3) Tenure: (SFNSW)

Slash spreading on extraction tracks

Processors and harvesters should distribute slash (limbs/branches) across extraction track

Wet soil conditions

- ■ Along road verges, rutting should not exceed 150 mm below the natural surface over any 10 m section of track
- ■ Within 30 m of a designated dump, and on major extraction tracks, rutting should not exceed 250 mm below the natural surface over any 10 m section of track
- ■ Within compartments, rutting should not exceed 100 mm below the natural surface over any 10 m section of track
- ■ Cable yarding can continue during wet conditions providing there is no movement of machinery on landings.

EPA Pollution Control Licence (SFNSW)

Schedule 4 details practices for operations within buffer and filter strips for native species and softwood plantations. These practices will not be detailed in this section.

4.10.2 Nature of the Practice

a) Mechanism of impact

In general these are similar to those detailed in C23/24.

The main difference from hardwood practices (C23/24) is the increasing use of mechanical harvesters that can ‘walk-over’ the terrain. These harvesters/processors can de-limb and stack the logs while forwarders collect these logs and bring them to a log dump. Therefore plantation operations allow for more traffic across the compartment but there is usually less exposure of mineral soil or development of defined snig tracks.

b) Evidence of importance at Eden RFA area (scale and/or intensity)

There are large areas of SFNSW pine plantation in the EMA that will be coming onto a sustained harvesting cycling in the next few years.

c) Scientific commentary (Key reference)

Lacey *et al.* (1994) found that in comparing the impact of harvesting operations between native hardwood (EMA) and pine plantations (Bathurst region), the intensity of soil disturbance was lower with plantations but the frequency of disturbance was higher. The most significant results from the pine plantation investigations was that even low levels of visible soil disturbance on winter harvested sites may be associated with substantial soil physical property change by compaction. What this soil physical property change means as far productivity of the subsequent crop is still being investigated (six-year post-harvest measurements will be made this year). These long-term monitoring trials are rare and difficult to do due the time factor, spatial variation, and confounding effects due to site amelioration practices prior to replanting.

There is a lot of research confirming the advantages of retaining and comminuting (if possible) organic matter (slash and A horizons) on sites. Modern harvesting machinery facilitates this. There is an increasing use of ‘chopper-rollers’ as part of the post-harvest site preparation to mulch residual slash. The use of such machinery requires relatively ‘clean’ sites and gentle topography.

On steeper terrain it can be economical to use cable-logging technology. These systems have the advantages of minimising soil disturbance and soil deformation by eliminating machinery traffic within the GHA (Lacey 1992).

d) Currently applied ameliorative measures (where applicable)

Site amelioration prior to replanting usually consists of some form ploughing or ripping along the proposed planting lines. Unfortunately, the introduction of slash retention or chopper-rolling has made ploughing less effective due the multiple obstacles. Currently this could be overcome only by ploughing deeper with more brute force.

4.10.3 Potential Innovations in the Practice

Development of new harvesting machinery is being driven by the twin goals of greater economic efficiency and reduced environmental impact. There are several innovations towards low dynamic ground pressure ‘walk-over’ systems including ones that have articulated legs rather than treads.

Site preparation has seen the introduction of excavator-based drills which can walk-over slash and auger planting holes. This further minimises soil exposure prior to replanting and can facilitate site amelioration into more difficult terrain.

With the level of sophistication now in plantation operations it is possible to develop detailed soil management packages. One key to minimising soil physical degradation due to harvesting is to be able to predict soil moisture across complex terrain. From this point it would be possible to predict soil strength, estimate soil compaction hazard and optimise timing of operations.

4.10.4 Assessment Statement

Plantation economics have strongly influenced effective plantation harvesting machinery, which has been designed to minimise soil disturbance and soil deformation. However there is still a great deal of traffic across plantation GHAs and the impact of the inevitable soil physical change upon subsequent plantation growth is still poorly understood.

4.10.5 Guidelines/Rules/Limits for application of Practice

- Maximise the use of ‘walk-over’ harvesting and site preparation machinery/technologies
- Retain harvesting slash and promote chopper-rolling practices
- Site preparation needs to ameliorate degraded soil while minimising soil disturbance
- Regulate operations on soil moisture regimes both in timing (summer versus winter) and process (cease operations when soil runoff becomes observable or rutting becomes significant).

4.10.6 Linkage to Indicators and Targets

None appropriate.

5. WATER

5.1 D 1 LAND USE ALLOCATION

5.1.1 Statement of Practice and Value

Planning authorities and economic trends can affect the use of land. There is a potential for grassland in the region to be converted to a forest cover by plantation establishment.

5.1.2 Nature of the Practice

Neutral; it depends on the outcomes of land use changes.

a) Mechanism of Impact

Areas of private land which could be used for plantation purposes have a potential impact for water yield decline in the local region especially where grassland is converted to forest. Areas of steep slope and/or erosive soils can influence stream flow quality in the local region due to roading and site preparation activities. In some areas the land use change could be beneficial in terms of increased soil protection.

b) Evidence of Importance for the Eden RFA

Local advice is that further plantation development is proposed in the Bombala area and that plantations could be established in the Bega area if dairy farming economics become marginal.

c) Scientific Commentary

Dargaval *et al.* (1995) and others have reviewed the scientific evidence which supports this assessment. Compared to rainfed grassland, a tree cover has the potential to reduce streamflow yield by up to 50%.

d) Risk Assessment

At a sub-regional level unless adequate planning and good practice systems are employed there is a moderate risk of declines in streamflow.

5.1.3 Potential Innovations

Local Government/State Government should require an EIS for proposals aimed at substantially changing land use in a region. Ultimately Codes of Practice should be developed for all land uses.

5.1.4 Assessment Statement

A review is needed to examine at the sub regional level the implications for water yield of converting grassland to forest. If not currently the case, legal structures should be developed which allow the SEMGL and other Codes of Practice to be applied to plantations on private land.

5.2 D 12 WILDFIRE AND WILDFIRE SUPPRESSION - WATER

5.2.1 Statement of Practice and Value

Wildfire can result in changes in forest stand structure and age. Wildfire suppression involves the use of bulldozers to provide access for fire suppression. See also 4.1, 4.2 and 4.3.

5.2.2 Nature of the Practice

Negative for wildfire and beneficial for suppression.

a) Mechanisms of Impact

- Water yield changes may occur where large areas of old growth have been converted to regrowth.
- Water quality may be reduced where rainfall intensity, steep slopes and hydrophobicity cause sheet flow by movement of ash and burnt surface soil layers.
- Water quality can be reduced due to fire trails and roads built for fire suppression activities.

5.2.3 Evidence of Importance of Eden

Evidence from the Yambulla experiments is that severe wildfire caused a significant increase in suspended solids concentrations and relatively minor increases in dissolved solids. Changes occurred during stormflow and had largely disappeared after five years. These changes were probably muted due to the drought conditions which prevailed in the post-fire period (Harper and Lacey 1997).

Scientific Commentary: The impact of fire on water quality depends on fire intensity, post fire climate and soil characteristics. In mixed species forests growing on duplex soils long periods of drought can result in high post fire soil hydrophobicity. If severe thunderstorms follow immediately after fire, severe sheet erosion can result. On the other hand, periods of low-intensity rain after fire can reduce the hydrophobicity. Along with a recovery in ground cover the risk of severe sheet erosion reduces with time. In the wetter forests growing on gradational soils where there is less litter accumulation, the impacts of wildfire on water quality can be quite minor even after heavy post-fire rain.

For the Eden areas there is no evidence as yet that fire induced regrowth can result in major long-term water yield changes. This is probably due to the fire resistant nature of much of the forest where large areas of regrowth are rare due to the recovery of the crowns of the original forests. However there are further opportunities to detect changes, for example analysis of the Rutherfords Creek long-term stream flow data.

The impacts of fire suppression activities are the same as these discussed in the cells dealing with road construction and can be largely reduced by rehabilitation works such as the installation of cross drains etc.

5.2.4 Risk Assessment

Given the duplex soils and variable rainfall of the Eden area the hazard to water quality of uncontrolled intense wild fire is high, although reduced somewhat for turbidity by the coarse nature of the soils derived from the Bega Batholith. The risk of occurrence is high due to the high incidence of drought and electrical storm activity.

Careful fuel reduction burning which leaves riparian strips intact and leaves a residual ground cover can reduce the hazard but as discussed in other cells this practice affects bio-diversity values.

5.2.5 Assessment Statement

Wild fire and fire suppression can result in water quality degrade and the risk of wild fire to water values can be reduced by sensitive fuel reduction burning.

The potential impact of the suppression measures can be reduced by appropriate fire trail construction and rehabilitation practices.

5.2.6 Guidelines Rules/Limits/ For Application of Practice

The suggestion in sections 2.6.5, 3.1.4 and 3.2.9 will benefit water values.

5.3 D - 7, 8 STREAM CROSSING DESIGN AND CONSTRUCTION IMPACTS ON WATER

5.3.1 Statement of Practice and Value

Within all forests, roads are needed for management access and in forests used for timber production roads need to be able to carry large vehicles. Roads need to cross streams and drainage lines using bridges, culverts and fords. This requires considerable soil excavation and placement. There is a potential for soil to enter streams causing bed load accretion and to increase suspended solids.

5.3.2 Nature of the Practice

Potentially negative unless precautions are in place.

a) Mechanism of impact.

Lack of foresight in design details and, if relevant, construction control can cause:

- Road wash outs due to lack of culvert capacity and protection of road surface and batters.
- Road formation drainage from the crossing approach can directly enter streams by channelised flows if silt traps and diversion structures are not developed.
- Erosion of culvert and bridge abutments.
- Unnecessary deposition of earth into streams because of the type of machinery used, e.g. use of a bulldozer compared to an excavator.
- The use of logs, or log fills, as culverts at stream crossings. Inevitably about 20 – 30

years later they will decay causing fill erosion and crossing collapse into the stream channel.

- Poor location of borrow pits and gravel pits.
- Long stretches of road in a cutting above stream crossings.

b) Evidence of Importance at Eden

There is no direct experimental evidence but comment from Department of Land and Water Conservation staff is that shire roads tend to dispose of drainage directly to streams.

However the importance of good road design is stressed in the world literature and there is a general consensus that roads are the main cause of water quality degrade in forested catchments and that much of the degrade occurs at stream crossings (Dargavel *et al*. 1995). This conclusion is supported by research quoted in 4.4.2 and 4.8.1 of this document. Although regional water quality may not be an issue in terms of State Forests (Eden EIS), effects of roads on local water quality should not be discounted.

c) Scientific Commentary

Dargavel et al 1995 summarise the scientific literature concerning roads and water quality.

Smith and O'Shaughnessy (1997) characterised the source and fate of sediment flows from roads and showed that channelised flows from road drainage outlets travel on average 25 m with 20 per cent of flows being greater than 40 m. They also presented for consideration a number of ameliorative measures.

The NSW Standard Erosion Mitigation Guidelines, the draft of Part 4 of the State Forests Forest Practices Code dealing with Road and Trail Construction Use and Maintenance recognise much of the mechanisms described in 2(a) but the ameliorative measures are presented as recommendations i.e. "shoulds" not "musts".

However Schedule 4 of the Pollution Control License for the Southern Region replaces the "should" in the draft code and the SEMGL with "musts". This change is supported.

d) Risk Assessment

Currently stream crossing structures are planned to carry the 1:5 year flood and resist damage from the 1:10 year flood. This seems a modest target. Given the variable nature of rainfall in the district and the fact that most bed load and sediment generation and movement occurs in the larger storms it is recommended that a detailed assessment be undertaken of the benefits of having structures designed to pass the 1:10 flood and resist damage from the 1:20 year flood. A review of the literature shows that the 1:5 year standard has been adopted by VicRoads Victoria in 1994 for rural roads and also by the Australian Road Research Board Limited in 1993 for unsealed roads. However it is probable that road stability rather than offsite impacts were the prime determinant in the 1:5 year standard.

5.3.3 Potential Innovations

a) Ensure that logs from formation clearing are placed precisely on the ground without gaps rather than loosely heaped at the top of batter slopes. This material provides an excellent silt trap.

b) Direct culvert outflows away from streams using logs cleared from the formation.

c) Use material from the formation for silt trap construction.

d) Use high quality non-dispersive rock between the last protective humps/culverts to reduce finer generation at the stream crossing.

e) Where possible have the road on a reverse grade for say 20 - 30 m either side of a stream crossing.

f) Ensure that culverts and cross banks are placed either side of a stream crossing such that the length of road draining into the stream invert is minimised subject to the provision of an adequate filter strip.

g) Ensure that cross banks are armoured with rock in order to increase their resistance to traffic damage.

h) Have a minimum distance in place of, say 40 m, for the location of borrow pits and gravel pits in relation to streams.

i) Make the use of excavators compulsory in stream crossing construction.

j) Ensure that good practice codes for stream crossing apply across all land tenures.

k) Actively research the development of cross-drain structures which have low maintenance and low impact characteristics to trap and divert road drainage before stream crossings.

l) The width of filter and buffer strips which receive road drainage must be evaluated on a separate basis to that used in coupe protection measures. Roads can represent a permanent sediment source.

5.3.4 Assessment Statement

The measures contained in the draft code for road and fire trail design and construction management are excellent and would be strengthened by the innovations outlined in Section 3. A maintenance plan will need to ensure that the measures adopted continue to function.

5.3.5 Guidelines/Rules/Limits for Application of Practice

For roads in general, filter strips for drainage lines and streams should be a minimum of 40 m in width and the distance should be measured from the edge of the saturated zone.

5.4 D 9 ROAD AND CROSSING USE, MAINTENANCE AND CLOSURE, WATER QUALITY

5.4.1 Statement of Practice and Value

These notes must be read in conjunction with 5.2 to avoid repetition. The detailed requirements of the State Forests and DLWC Guidelines and Prescriptions and the Pollution Control licence are sound. Road use maintenance and management policies have a potential to greatly improve water quality.

5.4.2 Nature of Practice

Beneficial if followed, negative if ignored.

The Eden EIS over a three year period estimated that the following roading actions would take place:

- construction of 10.5 km of primary road access
- construction of 128 km of secondary road access
- maintenance of 650 km of forest roads.

On the basis of an approximate formation width of 7 m and a pavement width of 5 m this will require the clearing of 97 ha of formation and the maintenance of 325 ha of pavement. As well, on the basis of a cross drain or culvert located every 60 m this amounts to periodically checking about 1000 culverts and their associated sumps and outflow protection devices.

Given that roads with low use can generate 60 to 100 tons of total sediment per ha per annum, the need to have in place adequate drainage structure is clear.

a) Mechanisms of Impact

- The direct placement of earth into streams during construction and maintenance.
- The continual entry to streams of erosion products from fill and batter slopes and the road pavement due to lack of or poor maintenance of protective structures, especially flow-spreading devices below drainage outlets.
- Failure of culverts and cross drains due to lack of maintenance, thus increasing the likelihood of pollutant entry to streams.
- Over topping and destruction of roads at drainage crossings due to lack of culvert maintenance and protection of the road from overtopping.
- Blockage of road culverts and failure of cross drains causing excessive flows down roads.
- Failure of bridge members, especially decking, causing road pavement entry to streams.
- Failure to protect table drain bases causing the excessive production of erosion products.
- Vehicle travel on wet roads causing destruction of the pavement and transport of sediment.
- Dusting of roads during dry periods causing subsequent sediment transport during rain.
- Lack of grading maintenance causing loss of road profile (crown) and the development of longitudinal channelised drainage flows.
- Disturbance of silt trap areas causing trapped silt to be mobilised.
- Failure to install temporary drainage during road construction.
- Particularly for Shire (Council) roads, lack of prescriptions and staff training for those involved in forest road maintenance.

b) Evidence of Importance at Eden

DL and WC staff report that the standard of road construction and in particular maintenance is excellent for State Forest managed roads, requires improvement for Council-maintained roads and is unknown for private roads.

c) Scientific Commentary

The general scientific literature points out that while roads can produce sediment during construction prior to the stabilisation of the formation and the pavement surface, they also represent a permanent source of sediment particularly if the road is regularly used. The Eden EIS provides an excellent review of the rate of sediment production from roads and its eventual fate. Although the total sediment loads from the roading system are small when viewed in a regional sense, deposition of sediment into drainage lines and first-order streams must be regarded as significant if it occurs regularly into what where previously undisturbed streams. O'Shaughnessy and Jayasuriya (1991) noted that it took over 10 years for the influence of the construction of four road crossings on a first-order stream to cease affecting sedimentation rates into a weir stilling pond. When developing a maintenance program it is essential that road use be taken into account. Leslie and Dunn (1984) reported that heavily used roads can have sediment production rates ten times higher than lightly used roads and that sediment production rates during rain increased by up to eight times during truck passage.

The need for drainage line and stream protection is provided by research (Dargavel *et al.* 1995) showing that fish feeding and breeding habitat and macro-invertebrate habitat can be adversely affected by sedimentation. As noted previously, habitat can be affected for long periods in low energy streams such as first-order forest streams where most of the flow is base flow.

d) Risk Assessment

Roads represent a high hazard to streams and drainage line in terms of their potential to threaten water quality and habitat. Within State Forests the risk of this occurring is low to medium providing current levels of maintenance continue. For Shire roads located in private and public tenure and for private roads in private tenure the risk is higher due to perceived lower levels of maintenance.

5.4.3 Potential Innovations

These innovations aim at improving the current situation and particularly for the State Forest tenure represent a fine tuning of the current system.

- For Shire roads develop training and protocols which prohibit the practice of placing spoil into or near streams and drainage lines.
- During road construction ensure that fuel tanks are not, as in the current Code, at least 10 m from streams but 50 m.
- By preventative maintenance and protocols ensure that the mechanisms described in (a) do not take effect.
- Allow batters, verges and table drains to stabilise by vegetative growth and then maintain them by slashing, not grading.
- Avoid smoothing cut batters but leave them rough to encourage the development of a vegetative cover.

5.4.4 Assessment Statement

In general subject to the innovations described in (5.6.3) the practices employed in the Eden RFA area are of a high standard and the main aim of land management authorities should be to improve the standards applied by other road managers and within other land tenures. As in the rest of Australia there is a large gap between stream protection levels on public land and private land.

5.4.5 Guidelines/Rules/Limits for Application of Practice

Modify condition 85 of the Pollution Control licence to prohibit use of all roads during wet weather (except sealed roads) if runoff is directly entering a stream or drainage line. Other wet weather restrictions relating to road damage are at the discretion of the road owner (manager).

5.5 D 11 FIRE TRAIL IMPACTS ON WATER QUALITY

5.5.1 Statement of Practice and Value

This cell should be read in conjunction with the other cells dealing with roads. Fire trails are constructed and maintained to provide access for fire prevention and suppression activities. Stream and drainage line crossings are needed and can affect water quality values.

5.5.2 Nature of Practice

Potentially negative.

a) Mechanisms of Impact

The potential impact on streams of trail construction would be the same as the potential impact of roads with the proviso that the degree of formation clearing is likely to be less. However with fire trails there can be increased use of causeway crossings. As fire trails can be on steeper grades than roads, failure to drain road approaches has a greater potential to cause water quality degrade.

The long-term impact of fire trails varies according to the level of maintenance of drainage structures. Although departmental use can be light, legal or illegal recreational use can destroy the drainage infrastructure particularly as such use can occur regardless of weather conditions. Because fire trails are often located in remote areas, damaged infrastructure may remain in a defective state for long periods. As fire trails are located on both non-commercial and commercial forests budgetary allowances for maintenance can be low in the non-commercial forests.

As fire trails often rely on an outsloped formation for drainage, damage to the pavement from heavy use can readily result in long runs of longitudinal ruts which can drain directly into drainage lines and streams.

b) Evidence of Importance at Eden

There is no direct evidence. Appendix 9 of the Eden EIS outlines an extensive program of fuel reduction burning which requires the establishment of fire trails and fuel breaks. It can be assumed that an extensive fire trail network is present on all tenures of forest land.

c) Scientific Commentary

Dargavel *et al.* (1995) summarise the scientific literature concerning roads and water quality.

Smith and O'Shaughnessy (1997) characterised the source and fate of sediment flows from roads and showed that channelised flows from road drainage outlets travel on average 25 m with 20 per cent of flows being greater than 40 m. They also presented for consideration a number of ameliorative measures which are outlined in the other cells dealing with roads.

Both the NSW Standard Erosion Mitigation Guidelines and the draft of Part 4 of the State Forests Forest Practices Code dealing with Road and Trail Construction Use and Maintenance recognise many of the mechanisms described in 5.7.2 but the ameliorative measures are presented as recommendations i.e. 'shoulds' not 'musts'.

However Schedule 4 of the Pollution Control License for the Southern Region replaces the 'shoulds' in the draft code and the SEMGL with 'musts'.

d) Risk Assessment

Given the steep grades which can apply to fire trails and their often remote location there is a moderate to high risk that damaged sections of trail could be a hazard to water quality.

5.5.3 Potential Innovations

Ensure that cross drains, spoon drains etc. have sufficient capacity to cope with irregular maintenance periods and are sufficiently armoured to withstand vehicle use at times of heavy rain. Ensure that detailed records are kept of fire trail location and conditions. Review on a regular basis the adequacy on the network and where a trail becomes redundant ensure that it is rehabited.

5.5.4 Assessment Statement

Fire trails can present a high hazard to water values. The adoption of regular maintenance and controls on use can keep the risk of hazardous incidents at a low to moderate level.

5.6 D 19 FILTER AND BUFFER STRIP MANAGEMENT

Statement of Practice and Value

The Standard Erosion Mitigation Guidelines and the Pollution Control Licence contain requirements for the width and location of filter and buffer strips aimed at protecting streams, drainage lines and drainage depressions from the entry of sediment and suspended solids.

5.6.2 Implications for Practices

Beneficial if implemented soundly.

a) Mechanism of Impact

In general logging coupes do not have the same potential to cause long-term degrade in water as do roads. Harvesting is generally a once-off operation which in the Southern Region will occur every 30 years where thinning will take place and about every 80 years where thinning will not be feasible. For example Grayson *et al.* (1993) showed that a forest harvesting operation in a Victorian mountain ash forest conducted according to high quality environmental standards which included a minimum 20 m wide filter strip bordering any saturated stream zone (and without any stream crossings) resulted in barely detectable changes in base flow and storm flow water quality. However the upper soil horizons had a good aggregate structure and high infiltration capacity.

Hairsine (1997) considered that 6 m buffers were able, for a range of flows, to trap 90% of incoming sediment. However this level of sediment trapping was greatly reduced if sediment flows formed or followed preferred pathways. Croke (1997) reported that runoff and sediment production rates from snig tracks immediately after harvesting were about seven times that of the general harvested area. However these runoff and sediment production rates dropped to about the same as the general harvested area in about two to five years as a vegetative cover developed. Mechanisms of impact on a filter or buffer strip can be summed up as:

- Direct snig track drainage via channelised flows through a buffer.
- Creation of channels for flows due to machinery entry into buffers.
- Snig track flows exceeding the infiltration characteristics of a buffer due to (mainly) lack of snig track cross drains.

b) Evidence of Importance at Eden.

Much of the data cited in (a) has been derived in the Eden situation. Occurrences of road drainage entering a drainage line protection strip have been noted, as have eroded channels from snig track drainage outlets (Orrego pers. com.).

c) Further Scientific Commentary (also see (a) above)

Dignan *et al.* (1996) have extensively reviewed the literature relating to buffer function and design and in the context of this note only a few highlights can be mentioned. They point out that buffer strips, by slowing flow velocities, cause heavier material to drop out of suspension. However fine colloidal material is removed by infiltration into the soil mantle. The ability of a buffer to carry out this function depends on the incoming flow rate, surface soil infiltration capacity and the saturated hydraulic capacity of the soil below the surface and the width of the buffer. However, buffers deal much less effectively with channelized flows. It is therefore important that flows into buffers be dispersed using artificial structures or by the placement of slash and non-merchantable material.

As noted elsewhere in this document, buffer requirements for road drainage are more demanding due to the permanent nature of roads and the likelihood of higher flow volumes. Smith and O'Shaughnessy (1997) examined sediment pathways below drainage outlets in the ash-type forests of the Victorian Central Highlands. One hundred and five sites were examined. Of these 73% showed channelized flows. Of 109 sites examined for flow length, the average flow sediment path was 25 m long with 17% of flows between 0-10 m long, and 20% of flows greater than 40 m. Recommendations for road filter strips are given in 5.4.5.

While Hairsine (1997) reported that 6 m buffers were effective in catching sediment from snig tracks in a once-off harvesting operation he pointed out that this situation would not apply where there was flow convergence or long term silt deposition. He also pointed out that it was essential for buffers to be located outside actual or potential areas of saturation as these areas do not provide an effective buffer.

d) Risk Assessment

According to the Eden EIS about 5000 ha of forest will be harvested annually. Thus assuming a runoff/sediment production decay rate of five years, about 25000 ha of harvested land is capable of providing above normal inputs of sediment to streams and drainage lines. However the risk is low to medium if the appropriate Codes of Practice are implemented.

5.6.3 Potential Innovations

These aim at protecting all waterways and drainage lines from the result of coupe activities. The principle is that all waterways should be protected. High sediment loads in the upper part of a drainage system eventually affect the whole system.

- Increase the minimum protection strip width to 10 m thus providing an additional level of security against accidental machine entry.
- Ensure that any buffer or filter strip width is measured from the edge of the saturated zone. Allowance must be made for its increase during rain.
- Apply filter strips to all streams and drainage lines at the levels prescribed in Table 1 Schedule 4 of the Pollution Control Licence for catchment areas greater than 100 ha and 40 ha.
- Prohibit machine entry (apart from approved crossings) into buffer and filter strips. Allow stand-off selective harvesting of trees in buffer strips and for drainage lines only in the area outside an inner 10 m.
- Before a coupe is signed off the supervisor should ensure that measures are in place to prevent channelisation in buffers and filters due to flow from snig tracks and other drainage.

5.6.4 Assessment Statement

With the adoption of the recommendations in 5.8.3 and subject to appropriate on ground surveillance it can be concluded for State Forests that the filter and buffer strip system will usually protect streams and drainage lines from abnormal amounts of sediment entry. The situation for private land is less certain and should be reviewed.

5.7 D 22, D 23, D 24 HARVESTING, REGENERATION AND WATER YIELD

5.7.1 Statement of Practice and Value

Forest harvesting and regeneration can change the structure and age of a forest. Evapotranspiration characteristics can be changed leading to increases or decreases in streamflow.

5.7.2 Nature of Practice

Neutral. Depends on water use priorities.

a) Mechanism of Impact

This should be read in conjunction with the EIS analysis. A long-term research program in the ash type forests (*E. regnans, E. delegatensis*) of the Melbourne Water catchments has shown that catchments with a fire-induced regrowth cover can have streamflows up to 50% less than catchments with an old-growth forest cover. This effect has been demonstrated at a catchment level and verified by process studies.

This effect occurs after wildfire and forest harvesting both of which can convert an older forest into a regrowth stand. The fundamental reason for this effect is related to the reduced leaf area index of older forests and the canopy structure of the understory and overstory.

It has been shown that long rotations and/or thinning regimes can improve catchment streamflows compared to conventional rotations (Dargaval *et al*. 1995).

No such effect has been detected after wildfire in the drier, more fire-resistant mixed-species forests in the Melbourne Water catchments due presumably to the fact that most of the trees in a mixed-species forest are of mixed age, survive wild fire and grow back their original crowns apart from areas where very intense fire has killed the original stand. In those pockets dense patches of regeneration can occur. Bridges (pers. comm.) considers that this mechanism applies in most of the forests of the Eden RFA.

However there is a strong body of opinion particularly in the conservation movement that the ash-type water yield changes after forest harvesting and regeneration also occur in the wetter mixed species forest of the region (e.g. in the *E.fastigata* forests) and there is a particular concern about impacts on low flow regimes.

b) Evidence of Importance at Eden

Cornish (1997) reports that after varying levels of forest harvesting and regeneration in the dry forests of the Yambulla experimental catchments and the moister forests of the Tantawangalo experimental catchments both peak flows and total flows increased. Unfortunately the published analysis to date does not go beyond the late 1980s and the results of a subsequent ten years of data collection are not yet available. However it is understood that the results of analysis of recent Tantawangalo streamflow data are about to be published. When available this will be an important publication. It is equally important that the Yambulla data is similarly analysed and the results published. Roberts (pers comm.) states that research in the *E. sieberi* forests indicates that the physiological relationships between sapwood area, leaf area and transpiration that operate in these forests appear to be the same as those in the E. regnans forest.

Cornish (*loc. cit*.) has presented some very useful analysis of streamflow trends in the 48000 ha Wallagaraugh catchment where integrated logging since 1972 had by 1996 covered 50% of the catchment.

Analysis has shown that no effect on streamflow was detectable until 16% of the catchment had been logged. By the period 1983 - 1989 when 25% of the catchment had been harvested streamflows had increased to more than 50% above the long-term average. As further logging continued catchment streamflows declined but were still some 20% above the long-term average. Cornish speculates that this decline was due to an increasing water use by the regrowth from earlier logging.

Because of concerns of irrigators in the catchment of the Bemboka River about the potential impacts of logging in the State Forests of the upper catchment Gutteridge Haskins and Davey Pty Ltd undertook in 1996/1997 a study of the impacts on streamflow of a number of scenarios using a modification of the Boughton model.

One scenario (Scenario 1), which was considered more realistic, assumed that water yields during the 30 or so years following logging of a mature forest would decline only slightly before a recovery to pre-logging levels. The other scenario (Scenario 2) (the ash-type effect) assumed an annual streamflow decline reaching 50% at the point of maximum water use by the stand.

Monthly and annual streamflows for these two scenarios were modelled for more than 50 years taking into account via a spreadsheet the changing mosaic of forest ages in the catchment. The assumed moderate increase in forest water use for scenario 1 had only a negligible effect on monthly streamflows while for scenario 2 summer monthly flows at the catchment outlet were reduced by up to 15% and in the upper sub catchments by up to 50%.

However the study pointed out that several factors could reduce this hypothetical impact.

- Current Eden silvicultural systems can result in a retained crown cover of 30% in the harvested area of a coupe.
- As much of the 1950 fire regrowth in reserves and State Forest ages water yields could increase.
- Stand thinning could result in water yield increases.
- Some of the forest in the region is of mixed age.

The study also pointed out that for the Bemboka catchment most of the hypothetical effects on streamflow were due overwhelmingly to harvesting and regeneration which had occurred prior to 1996. Due to the Interim decision process only 11% of the catchment will be available for future timber production.

c) Scientific commentary

See a) and b).

d) Risk Assessment

Until the results of the Tantawangalo and Yambulla catchment studies are evaluated risk is difficult to determine.

Any risk would apply to catchments subject to high consumptive demands, mainly the irrigation demands for the Bega River and its tributaries. Any impacts of forestry operations need to be considered along with future environmental flow requirements which it is understood are being considered for NSW river systems.

5.7.3 Potential Innovations

Any sub-catchment, where for environmental or consumptive reasons water yield may need to be enhanced or maintained, could be subject to long rotations, exclusion of harvesting and/or thinning regimes. Cornish (1997) has provided the ESFM team for Project 4 an algorithm which enables the assessment of various forest age water yield relationships on a catchment basis. As research data become available the algorithm could be modified.

5.7.4 Assessment Statement

When the results of research by the Co-operative Research Centre for Catchment Hydrology become available along with the results of analysis of more recent Yambulla and Tantawangalo data it is recommended that they be reviewed so as to provide a basis for evaluating forest change and long-term stream flow yields. In the context of the Eden RFA area, streamflow changes are likely to be important only in a sub-regional context and where there are concerns about potential streamflow changes these can only be meaningfully evaluated in a catchment or sub-catchment context. The current emphasis on retaining coupe crown cover, the extension of National Park areas and the emphasis on the protection of riparian vegetation are likely to ameliorate any water yield effects.

5.7.5 References

See Chapter 8

6. TIMBER PRODUCTION

6.1 INTRODUCTION

This chapter of the assessment deals with timber production values. The assessment is approached from the socio-economic viewpoint. It therefore includes aspects of both stand productivity and the economics of production.

6.2 F3 – FOREST MANAGEMENT PLANNING

6.2.1 Practice and Impact

Long term (strategic) and medium term (tactical) planning has a predominant effect on the extent of forest available for timber production and the economics of forest production.

6.2.2 Nature of Practice

Mechanism of Impact

Longer term (10-15 year, strategic level) and medium (1-3 year, tactical level) forest management planning determines the extent and location of timber production areas and leads to the allocation of forestry practices to specific areas of the forest. Forestry planning can begin when the extent of the available forest is established by higher-level land use planning and the overall goals and production targets for the forest's multiple outputs are known.

The allocation of practices to specific areas is constrained by the multiple management objectives for the forested areas. In the case of the Eden RFA area these include a significant contribution to off-reserve flora and fauna conservation and in come cases, to water values. The outputs of the planning process are the simultaneous determination of a number of medium term plans that allocate practices in space and time (e.g. timber production, road construction and management, fauna / flora management, fire protection, regeneration). The plans are a primary factor in determining the overall operating economics of the forest.

Importance to Eden

The development and application of strategic and tactical plans is important to the effective management of all forest areas. It is expected to become an area of increased importance under the Eden RFA with the identification of specific requirements for off-reserve management for species protection. The cross tenure identification of conservation requirements and reserve allocation should provide a good basis for development of these plans.

Scientific Commentary

The fields of strategic and tactical forest management planning are undergoing rapid development with considerable effort being expended in recent years in Australia and overseas.

However, the problems to be confronted in forestry planning at these levels are very large because of:

- the very high cost of collecting forest information means that information is always imprecise,
- the high rate of change in the state of the forest over time in response to season, fire, logging and other impacts means that information become obsolete quickly, and
- the multiple and conflicting demands for forest outputs demands, which prevent the application of analytical approaches.

Planners have therefore identified two important requirements for effective planning.

1. the ability to develop and present relevant planning information. This includes good representations of the current (and past) states of the forest, and an ability to predict likely future states, presuming

particular management actions. Improved models of habitat and timber production are examples of key supporting technologies.

2. a planning process that captures the inputs of all relevant stakeholders in the planning outcome. This is substantially a social and political process. For public agencies dealing with large regional forest estates, this has proven a significant task.

6.2.3 Potential Innovations

Considerable innovations in technique are being developed during the RFA process in NSW which is itself designed to achieve a planning framework for ongoing forest management (e.g. Regional Forest Forums for consultation, FRAMES for timber prediction, Response to Disturbance for species population and habitat requirements). The landscape-level resource modeling approach (e.g. Towamba pilot study) provides a basis for further development of a planning support framework that can allow effective stakeholder assessment of the multiple outputs from the forest under alternative conditions.

6.2.4 Assessment Statement

Current forest management plans for the Eden region are now out of date. The major elements of a regional-scale strategic forest management plan for the Eden Area should be a major outcome of the Eden RFA. However, there is likely to be a need to internalise the processes developed during the CRA and ensure their ongoing development.

Processes that support shorter-term tactical planning for major forestry operations such as road construction and maintenance, burning and harvesting also require development and relinking to the new strategic frameworks developed during the CRA.

6.2.5 Guidelines / Rules / Limits

An Eden Strategic Forest Management Plan should be completed within one year of the finalisation of the Eden RFA. The plan should include transparent provisions for its ongoing re-evaluation and revision.

Tactical plans (a rolling time horizon of three years is suggested) for major operations such as harvesting, road management, hazard reduction burning and habitat maintenance should also be revisited and processes linked to the framework provided by the strategic plan..

6.3 F12 WILDFIRE - TIMBER YIELD

6.3.1 Practice and Impact

Practice: Wildfire

(see cell A12)

■ Value: Timber yield

Characteristics of the forest that determine timber yield include:

Rates of productivity

Wood quality

Age class distribution of stands across the region.

6.3.2 Nature of the impact

a) Mechanism of impact

Wildfires have a pronounced effect on the forest resources and timber yields in the Eden ESFM area. Tree mortality or severe damage, temporary growth loss and increased defects are the main physical damage or loss to timber yield which are caused by high-intensity wildfires. The factors which directly influence the severity and physical effects of high-intensity wildfires and capacity for regeneration are:

forest ecosystems

- biological protective mechanisms e.g. bark thickness, bark texture (i.e. smooth, stringy, paper bark etc.), dormant bud strands;
- stand age and hence diameter and thickness of bark;
- canopy height above ground hence susceptibility to crown scorch; and,
- likely availability, in the crowns of the trees, of seeds which might permit regeneration.

fire intensity

- heat generation;
- duration of burning- residence time;
- amount of fuel consumed; and,
- height of flames and hence extent of crown scorch.

Tree mortality can be viewed in timber yield terms as the end of a spectrum of degree of wildfire damage. Death of trees influences the age class distribution both of trees within a stand and of the stands within the forest estate. The unpredictable nature of wildfire occurrence, intensity and extent makes it difficult to plan the supply of timber.

Productivity of trees can suffer a temporary set-back through damage of the crown and/or bole i.e. volume increments may be reduced for two years after high-intensity fires. Productivity may be increased in the short-term due to improved soil nutrient availability, if this factor outweighs that of damage. In the long-term, however, there is potential to reduce rates of nutrient cycling, leading to decreased productivity.

Losses in timber yield due to additional defect often increase with tree growth after fires. The defects include occlusion of dead wood, secondary damage by insects and wood decay, deformed stems and persistent epicormic shoots.

b) Importance to Eden RFA region

Fire is the major threat to timber yield in the Eden region and the current fire management policy in production forests aims to minimize losses in production. Fires across much of the region in the past have resulted in even-aged stands of regeneration and mixed-aged stands with a high proportion of degrade wood. The resulting age class distribution of stands means that only a small proportion (approximately 10%) of the timber resource can be used for sawlogs, and the remainder is used for woodchips. Hence the impact of wildfire is a major determinant of the supply of the timber resource in terms of quantity and quality in the region (SFNSW 1991).

While the objective of reducing risk of wildfires is often emphasised when discussing fire/fuel management, both State Forests and National Parks and Wildfire Service of NSW have statutory responsibilities for fire management. These are derived from:

Rural Fires Act 1997- State of New South Wales legislation requires planning and coordination of all rural fire prevention and control including hazard reduction.

Forestry Act 1916- the emphasis on fire management is directed to protection of production timber resources.

National Parks and Wildlife Act 1974- the Act requires the National Parks and Wildlife Service to prepare plans of management for national parks, nature reserves and other land managed by the Act. A reserve fire management plan is required for each bush fire-prone reserve.

Other regulatory conditions that can have an impact on the fire management practices are:

Environmental Planning and Assessment Act 1979

Clean Water Act (1970)

Clean Air Act (1961)

Soil Conservation Act (1938)

Wilderness Act (1979)

Threatened Species Conservation Act (1995)

Native Vegetation Conservation Act (Proposed)

From this legislation it is evident that both agencies have dual responsibilities for protection of life and property from wildfires and for protection of timber, conservation and environmental values.

The fire season in the Eden area generally commences on 1 September and continues until March. Dry winters and springs which are frequent in the area, can bring the fire season forward. Major wildfire events in the area usually occur when there are very high temperatures for up to four days in succession followed by severe thunder-storms with minimal rainfall. The winds are from the north-west to west. Prolonged drought is another factor of affecting the extent and frequency of wildfires in the Eden area. The area has a wildfire frequency of once in 3-12 years (Walker 1981), although most sites would require 4 to 7 years between fires to accumulate sufficient fuel (Gould 1996) to support a high-intensity fire.

The long-term average of the area burnt annually by wildfires (over 100 ha in size) in the Eden Forest Management Area between 1967 and 1990 was 7362 ha. During this period there were four fire seasons in which the total area burnt was over 10000 ha, i.e. 1968-69, 1972-73, 1980-81 and 1982-83 (Source: Eden Management Area EIS Appendix 9-13).

There is one published account of observations after a moderately intense wildfire (fire intensity <3000 kW m^{-1}) in dry sclerophyll forest of silvertop ash (*Eucalyptus sieberi*) and stringybark species (*E. agglomerata* and *E. muellerana*). In the area severely burnt, all living leaf tissue was consumed or scorched and 15 to 20 percent of the trees were either killed during the fire or died in the drought conditions which followed (Mackay and Cornish 1982).

The Timbillica fire which occured in November 1980 is a good example of the devastation of forest resources by wildfire. Within a period of less than 8 hours the fire burnt 27000 ha of State forest, 17500 ha of Nature Reserves and 1000 ha of private property. The wildfire burnt 13000 ha of regrowth forest. Estimated fire intensity was 90000 kW m^{-1} and the fire totally consumed living trees up to 15 cm diameter, most of the large logs and all organic matter in the surface soil (Review of fuel management program: Eden Management Area (Unpublished consultant report 1994). The only practical action to prevent an ecological and economic disaster like the Timbillica fire is to modify the litter and slash fuel by prescription burns.

Changes in fire management practices in forests may be made when new information and technologies become available, and in response to changing community attitudes (Williams and Gill 1995). The changes in fire management practices in the Eden Forest Management Area (FMA) for dry sclerophyll forest are documented by Bridges and Dobbyns (1991). From 1969 fuel reduction burning was carried out in broad areas of old-growth forest, and regeneration of harvested areas did not depend on burning. As the area of multi-aged forest declined, the introduction of alternative logging coupes made the logistics and operation of fuel reduction burning difficult and sometimes impractical. From 1976 the heaps of debris on the perimeter of log dumps were burnt. These were sources of many escape fires, particularly causing problems on days of high fire danger. The major wildfire of 1980 (Timbillica fire) was caused by smouldering dumps (Cheney 1981) and led to many changes to the fire management polices in the Eden FMA. The changes attributed to this wildfire were:

- material left at log dumps was dispersed into the logged coupe rather than burnt on the dump;
- post-logging burning was introduced; and,
- a fire management policy with an associated fuel reduction program was developed.

These changes are the bases of the current fire management practices in the Eden forest management area, which aims to limit the loss of timber production by wildfire and to provide a high level of protection to life, property and other identified assets from wildfire.

c) Scientific commentary

Yield modelling is being used to predict future resources of sawlogs and pulpwood (SFNSW 1991). These models need to include:

- relationships with nutrient supply and trends in response to changes in nutrient cycles under specified fire regimes
- potential losses in different grades of timber due to defect due to fire damage
- potential losses in total yield due to tree mortality in wildfires and changes in the age distribution.

There are difficulties in assessing the actual yield of the stand compared with potential yield of the site, and as yet there is no adequate method for this assessment.

d) Gaps in knowledge

- Productivity is related to soil organic matter content and nutrient availability. There is some evidence of a decline in productivity under a regime of frequent fires (Keith 1991). However, the relative decline in productivity due to declines in carbon and nutrient cycling under different fire regimes has not been investigated.
- There is little information about the amount of cambial damage to trees under wildfire conditions, or more importantly, the long-term consequences of the invasion of fungi and termites to the degrade of wood.
- Guidelines are required to allow prediction of the sawlog and pulpwood yield from a stand with a known potential growth rate and history of disturbance.

e) Currently applied ameliorative measures

Fire suppression and protection of timber resources is a major objective of fire management, and this includes fuel reduction burning in young regrowth stands.

6.3.3 Potential Innovations

Potential improvements for the protection of timber resources and maintenance of supply include:

- Improvement of strategic fuel reduction burning surrounding young regrowth.
- Use of intensive management of selected stands, including thinning and fertilizing. These practices are being investigated as a means of increasing productivity which will be necessary to fill the gap in timber supply created by the discontinuous age class distribution of stands across the region.

State Forests and National Parks and Wildlife Service (NPWS) have statutory responsibilities for fire management on public lands in the Eden ESFM area. Both agencies use prescribed fire and use different fire regimes to protect property and control wildfires. Their fire management policies vary depending on their management objectives and legislative responsibilities. These different policies and fire management practices may not be optimum or *best practice* for fire management in the ESFM area. A code of practice for fire management on public land in the Eden ESFM should be developed to provide the basis for establishing and maintaining a consistent standard for fire management in the ESFM area. Fires impact on the whole range of the ESFM's diverse land and resources management activities by land management agencies. A standard code could be an integral component of a range of measures taken to ensure the protection of life, property and other assets from wildfires. Any plan, instruction, prescription or guidelines developed for fire management activities on public land in the Eden ESFM area should be of a consistent standard to meet ecological sustainable management objectives

There is considerable documentation of the dependence of the flora and fauna on the area on fire but knowledge of the effect of season, intensity and frequency of fire on each component of the ecosystem is limited (Gill *et al.* 1994; Shea *et al.* 1981; Williams and Gill 1995). Large-scale, systematic monitoring of the impact of the different fire management regimes (both wildfires and prescribed fires) in the ESFM area is needed.

6.3.4 Assessment Statement

To mitigate high-intensity wildfires so that damage to forest, environment and economic values are minimised the following have to be maintained or scaled up by the fire management agencies:

- appropriate fuel management programs to maintain forest fuels in fire-prone areas in a condition that will be effective in controlling or minimising the impact of wild fires;
- a road and fire trail network adequate for effective access for fire suppression and fuel management;
- equipment and resources for detection and suppression of wild fires;
- community education programs to allow the general public to become more aware of the need for care with fire and fuel management; and
- liaison with other agencies.

Both public land management agencies have statutory responsibilities for protection of life and property from wildfires and for protection of timber, conservation and environmental values in the ESFM area. The fire management strategies in the ESFM have been derived from existing information and data with no specific data on fire/fuel management link to ecologically sustainable forest management. This approach is acceptable given the short time frame of this study. However, most of the statements regarding the impact of wildfires and the use of prescribed fires are based on experience and anecdotal evidence rather than empirical data. It is essential to review the link between the effectiveness of prescribed fire and wildfire suppression, and also its impact on the forest biota, and to demonstrate the past success of fuel management programs. Monitoring of the effects or impact of fires (both wildfires and prescribed fires) on timber resources and bio-diversity was found to be limited across the ESFM area. The longer the delays in implementing monitoring programs, the less chance there will be in assessing the full impact of fire management practices in the ESFM.

6.4 F13 FUEL REDUCTION BURNING - TIMBER YIELD

6.4.1 Statement of Practice and Value

Practice: fuel reduction burning

(see cell A13)

Value: Timber yield

(see cell F12)

6.4.2 Nature of Practice

a) Mechanism of impact

Fuel management is an essential practice of fire management in the Eden ESFM area in particular because of the history of wildfire in the area and the risk to environmental and commercial values posed by future wildfire. The main debate in fuel management is the effect of prescribed burning on wildfire behaviour and control, and the ecological effects of wildfires and prescribed fires. The objectives of fuel management practices are to:

- reduce fire intensity to minimise damage;
- limit rate of spread to minimise fire spread; and
- reduce the chance of wildfires starting.

Impacts of prescribed burning on fire management practices are:

- prescribed burning reduces the degree of fire hazard
- intentional delays or reduction in fuel reduction burning increases the fire hazard
- delay in fuel reduction burning in young regrowth forest to reduce or prevent damage to young trees (< 10 cm diameter and > 12 m high) increases fire hazard in regrowth stands and thus buffer zones are required to protect regrowth stands
- long-term benefits of prescribed burning are that the risk of high-intensity wildfires is reduced
- rate of soil erosion will depend on the intensity of the fire, slope, vegetation, soil type, rainfall intensity after fire (storm surges)
- nutrient loss - cumulative losses from prescribed fires versus losses from high-intensity wild fires
- reduce frequency and extent of wildfires will reduce the potential extensive damage caused by high-intensity wildfire to:
    - timber values
    - flora / fauna,
    - soil (by erosion) and
    - life / property
    - the atmosphere: smoke affects tourism and built-up settlement areas.

The prescribed conditions under which fuel reduction burning is carried out mean that trees should not be killed, but there are effects on timber yield due to damage.

- About 10 % of trees are butt damaged by low-intensity fires in young regrowth (Cheney *et al.* 1992). This will have a cumulative effect with repeated burning.
- Cumulative damage occurs in mature forests due to repeated burning.
- Increased mortality of trees occurs with repeated damage. Mortality of smaller trees can occur with repeated damage.
- Damage to timber quality occurs as a result of bark and cambial damage that increases the potential for invasion by fungi and termites.

b) Importance to Eden RFA area

Fuel management is an integral part of the current fire management in the ESFM and involves a number of prescribed burning practices:

- strategic burning (to provide a high level of protection of life, property and identified assets- 3 to 5 year burning cycle)
- broad-area burning (to provide a mosaic of fire fuel with an average load about 5 to 6 t ha^{-1} over a broad area- 5 to 7 year burning cycle)
- post-logging burning (reduce the weight of logging slash- burnt during an 18 month period following logging)
- burning for management of flora and fauna (to provide specific fire for ecological management - the burning cycle depends on specific requirements); and
- fuel management in regrowth forest (to keep the fine fuels weights in regrowth stands at an average level to minimise wildfire damage-commence prescribed fire in regrowth stands when dominant and co-dominant trees diameters > 10 cm (Cheney *et al.* 1992) followed by 5 to 7 year burning cycle).
- These burning practices represent a range of different frequencies, intensities and seasons of burning. They reduce fuels below different thresholds, use different ignition sources, cover different areas and affect different percentages of the gross areas of forest burnt (Williams and Gill 1995).

c) Scientific commentary

The relationship between fuel load, rate of spread and fire intensity has been the primary argument used to support fuel reduction practices in eucalypt forest in Australia for more than 30 years. The rate of spread is directly proportional to fuel load; it is argued that reducing the fuel load by half, halves the rate of spread and reduces the intensity of the fire four-fold (McArthur 1962; Peet 1965).

Fuel load is the only fuel characteristic used in Australian fire danger rating systems to predict fire behaviour within a particular fuel type. Studies by McArthur (1962, 1967) and Peet (1965) in eucalypt forest fuels suggested that the amount of available fuel on the forest floor (i.e. the fuel consumed by the fire) was the most significant fuel variable affecting the behaviour of fires. Their experiments were conducted in dry eucalypt forest and the authors claimed that the rate of spread of the head fire (R) is directly proportional to the load of fine fuel (< 6 mm diameter) consumed (w) and is expressed as a simple linear relationship:

$$R = aw$$

where ‘a’ is a constant defined by McArthur (1962) and Peet (1965).

Fire intensity is defined as the rate of heat released per unit length of fire front (Byram 1959). It is expressed as ‘kilowatts per metre of fire front’ and is defined by the following equation:

$$I = HwR$$

where I = fire intensity (kW m^{-1}),

H = heat yield of the combustion of the fuel (kJ kg^{-1}),

w = load of available fuel (fuel consumed) (kg m^{-2}) and,

R = rate of forward spread of the fire front (m s^{-1})

Experience or anecdotal evidence rather than empirical data seem to be a major factor in assessing the effectiveness of fuel reduction burning as a fuel management technique. Case studies clearly show the operational effectiveness of fuel reduction on wildfire behaviour for 3 to 5 years (Underwood *et al.* 1985; Rawson *et al.* 1985; Lewis *et al.* 1994; Cheney 1996). Although expert opinion strongly supports prescribed burning to reduce the impact of wildfire (Lewis *et al.* 1994; Cheney 1996) public opinion is quite divided. Conservation groups point to apparent failures and are aware of the lack of solid scientific and statistical evidence to support a reduction in fire behaviour beyond 2-3 years after burning (Meredith 1996). It has even been argued that hazard reduction burning may actually enhance the propagation of wildfires by promoting shrub regeneration in areas which may otherwise have inherently few fire-prone characteristics (Anon. 1994).

A high proportion of the multi-age forest estate is affected by wood degrade. The effect of cumulative damage to trees by frequent, low-intensity fires is an impact of fuel reduction burning that has not been given much attention and should be investigated. There is very little quantitative information about the proportion of trees damaged in each fire and the cumulative effect from repeated fires. Trees retained during harvesting and then subject to post-logging burning and consequent fire-scarring are particularly susceptible to repeated prescribed burning and cumulative damage. Debris remaining on the ground from previous harvesting presents a major threat to regrowth. Even in low-intensity fires, large amounts of debris increase fire residence time and the number and size of smouldering piles of logs, and thus radiant heat damage to growing stems (Cheney *et al.* 1992).

d) Gaps in knowledge

Relationships need to be quantified between fire behaviour, degree of damage and increased potential for disease and termite attack, and long-term degrade of wood quality.

The cumulative effect of repeated fires in causing damage to trees needs to be assessed.

e) Currently applied ameliorative measures

Burning prescriptions should ensure that fires do not damage trees. However:

- prescribed fire intensities under a repeated regime has not been tested
- control of operational burns is not assessed

6.4.3 Potential Innovations

Operational burning should be controlled more strictly and fire behaviour monitored so that prescriptions are adhered to and fire intensity is minimized.

Post-fire assessment should include monitoring of the degree of damage to trees.

Considerations relevant to alternative fuel management practices are:

- prescribed burning regimes could be altered by varying the frequency, intensity or geographic location of burning operations;
- burning prescriptions and operational procedures might ensure that fuel management burning is excluded from:
  - rainforest areas
  - wildlife corridors
  - sensitive ecological communities
- prescribed burning prescriptions could be modified in response to specific management objectives for flora, fauna and biodiversity
- decreased frequency or extent of burning may pose unacceptable fire risk and endanger areas of adjoining land
- other fuel management techniques such as physical removal of fuel or some form of mulching / slashing are not considered to be operational or economically viable over large areas.

6.4.4 Assessment Statement

The main objective in the use of prescribed burning is to reduce the rate of spread and intensity of wildfire. The longer forests go without fuel reduction, the greater the fuel accumulation and greater the fire hazard. Fuel load is a component of fire intensity, so if fuel load is reduced, fire intensity is also reduced. Therefore, it is apparent that lower fuel weights will significantly reduce the number of days on which high-intensity fires can occur (Tolhurst *et al.* 1992; Williams and Gill 1995; Gould 1996; Raison *et al.* 1983) and improve the chance of wildfire control (Underwood *et al.* 1985).

Repeated damage to trees will lower the yield in terms of productivity and wood quality.

6.4.5 Guidelines / Rules / Lmits for Application of Practice

Prescribed burning is an art based on science and the main use of prescribed fires is to reduce the rate of spread and intensity of wildfires. Despite the debate of the effectiveness and impact of prescribed burning it is an efficient tool for reducing small-diameter fuels at or near the ground level. All prescribed burning should be done in accord with a prescription which defines not only the desired outcomes, but also the fire behaviour (rate of spread, flame height and fire intensity) and the specific weather and fuel conditions required to produce that fire behaviour and those outcomes. If burning is carried out when weather and fuel parameters fall with certain range or *window* a satisfactory outcome will result. Unanticipated stem damage, threats to forest biota, impacts on soil and water and smoke from both wildfires and prescribed fires are unsatisfactory.

Guidelines could probably be developed that would predict the proportion of damage due to fires of different intensities and frequencies, and the consequences in terms of reduced in wood quality.

6.4.6 Linkage to Indicators and Targets

Monitor degree of damage.

6.5 F22 – LOW INTENSITY HARVEST

6.5.1 Practice and Impact

Two lower-intensity silvicultural practices are proposed that permit limited timber production while minimising impacts on forest habitat and other values.

Type A1 Light Selective Logging

Description: The approach requires single tree selection and maintains uneven aged-structure. Canopy removal is suggested as 10% initially.

Type A2 Medium Selective Logging

Description: The approach requires individual tree selection and maintains uneven-aged structure. Canopy removal is suggested as 30% initially, but could be higher in selected areas.

6.5.2 Nature of Practice

This approach is proposed for areas where retention of a significant crown and under-story component is required for habitat or other reasons. Patterns of tree and under-story retention might be designed to conserve a number of habitat attributes and/or to ensure rapid recovery of wildlife following harvest.

Mechanism of Impact

Impacts are expected to be low and consist of some disturbance to the understory and to soil. The primary impact on timber values would be felt in the high cost of planning and harvesting and a very low timber yield per hectare.

A1 Light Selective

Site disturbance expected to be low and may even require some extension for regeneration reasons. Use of medium-sized tracked skidding is envisaged.

A2 Medium Selective

The final degree of site disturbance is expected to be moderate, and may even require extension for regeneration reasons. Use of medium-sized tracked skidders is envisaged.

Importance to Eden

Informal versions of this technique were applied through the operations of millers and sleeper-cutters prior to the introduction of integrated harvesting.

Scientific Commentary

- There is a good ability to manage floristic composition and stand structure.
- Regeneration of timber species particularly sensitive to competition may be difficult in moist forest types, and development of techniques will be required. Post-logging burning would generally not be possible.
- Care and attention is needed to minimise understory disturbance during harvesting.
- The technique would be likely to have high operational costs.

6.5.3 Potential Innovations

Use of mechanised equipment for felling and tree handling may minimise understory disturbance.

6.5.4 Assessment Statement

The practices should be applied in areas where a high level of habitat preservation is required. With development, the practice might usefully be extended to areas where timber harvesting is currently excluded because of a precautionary approach to wildlife preservation.

6.5.5 Guidelines / Rules / Limits

Applicable to areas where high habitat functionality is desired.

6.6 F23 – HARVEST WITH MODERATE HABITAT RETENTION

6.6.1 Practice and Impact

Three practices are proposed: group selection, patch cutting, and clearfalling with retention. These are designed to supply moderate to high timber productivity and satisfactory habitat for selected species.

Type B1 Group Selection (<75 m gap diameter)

Description: Small group cutting (following Australian Group Selection). Proposed groups 2-3 tree height in diameter. Number and arrangement of groups can be varied and experimentation is required. Thinning of the stand on a selection basis beyond the group edge may be a useful variation facilitating regeneration in some circumstances. An initial prescription could be to zone 10 – 20% of the coupe area for this treatment in any one cutting cycle, with 10 – 20 years between cutting cycles. These are interim prescription and require experimental and field validation.

Type B2 Patch Cutting (1 – 2 ha)

Description: Integrated harvesting in patches (1.5-3.0 ha). Contribution of mature trees to habitat addressed by adjusting eventual margin of adjoining patch. Frequency and arrangement of patches can be varied. Thinning by individual tree selection beyond the patch margin may be a useful variation. An initial prescription could be to zone 15% – 20 % of the coupe area for this treatment in any one cutting cycle, with 10 – 20 years between cutting cycles. Patches might be limited to 80% - 90% of the zone identified for this prescription over the rotation, to allow for clumps or small stands on patch margins to be retained in longer term for habitat. Recruitment of older stems in the next rotation would come from existing patch areas. Logging techniques based on use of excavators might be developed, with longer-distance extraction by skidder or dozer on a few well-selected trails.

Type B3 Harvest with seed tree, habitat and advanced growth retention.

This practice encompasses the integrated harvesting system currently applied at Eden. It generally involves 20%-30% canopy retention.

6.6.2 Nature of Practice

Type B1 Group Selection (<75 m diameter)

Suited more to moist and moist – dry transition zone forests or areas where structural diversity is necessary to maintain habitat attributes (nesting / browsing proximity).

More efficient and effective regeneration should be achieved as compared to individual tree selection methods, and longer-term timber productivity should be higher. Suppressed regeneration at margins of groups remains a difficulty and may require release in following cutting cycles. The technique allows ready manipulation of nesting and browsing habitat. It can be more difficult to use post-logging burning, and mechanical site disturbance may be required toward the wet sclerophyll end of the vegetation gradient. Inability to burn debris may increase fire risk to regeneration. The technique may be capable of development to involve excavators. Timber extraction could be by either skidder or dozer, with skidders preferred for longer-distance transport in favourable terrain.

Type B2 Patch Cutting (1 – 2 ha)

This approach would be more productive for timber values than group selection, while retaining a considerable degree of coupe-level structural diversity provided significant untreated areas are retained throughout all cycles.

Advantages / Disadvantages: Similar to group selection, but regeneration potential is improved with suppression losses from edge effects reduced. Post-logging fuel reduction may still be difficult, but techniques based on use of excavators for stacking debris are being developed. High management costs may still be anticipated.

Type B3 Harvest with Seed Tree, Habitat and Advanced Growth Retention (current system)

- Provides high current timber yield, while retaining a degree of habitat function.
- Post-logging burning more can be more efficient. There are significant production losses in the suppression of regeneration by overwood if retained stems are maintained in an even canopy cover.
- Long-term viability of habitat trees and their recruitment are issues where stems are retained on an individual basis.

Mechanism of Impact

These three practices present a range of expected regeneration efficiencies, influenced primarily by the standard of seedbed preparation and effectiveness of seeding and the degree of regeneration suppression from edge trees or overwood.

There are also important economic effects through increased forestry operational costs in these treatments with low timber yields.

Importance to Eden

The lower-intensity treatments have not yet been shown to be effective in the Eden forests. (see innovations section, below). The third approach is that currently applied.

6.6.3 Potential Innovations

Field techniques require development. The use of excavators for primary machine work within the group or patch offers possibilities to improve management of logging slash and control site disturbance.

6.6.4 Assessment Statement

The currently applied ‘clearfall with retention’ system offers a degree of habitat preservation and retention of advanced growth to preserve shorter-term sawlog production. Longer term productivity is reduced through over-wood suppression of regeneration.

The proposed group selection and patch cutting approaches offer greater opportunity for habitat manipulation and may retain a similar degree of timber productivity. However, they both require field evaluation.

6.6.5 Guidelines / Rules / Limits

- Practices are suitable for the full range of site types in the Eden region where both habitat function and timber production are required.
- Timber productivity declines with increased canopy retention.

- Habitat function related to hollows through time requires retention and recruitment of suitable trees.

6.7 F24 – HARVEST WITHOUT RETENTION

6.7.1 Practice and Impact

Type C1 Harvest with Minimal Tree Retention

Proposed for selected areas where habitat function is not required and site productivity is medium–high, with the aim of producing dynamic regrowth stands.

6.7.2 Nature of Practice

Mechanism of Impact

Impacts on timber yields from this practice are generally positive through maximised growth of regeneration.

The technique is also suited for application of cable-harvesting systems in areas of steep terrain and higher stocking where such systems would have lower environmental impact that ground-based skidding.

The visual impact of this type of operation is high and careful planning is required to conserve landscape values.

Importance to Eden

There are considerable areas of forest types in the Eden region that are suitable for even-aged management.

Scientific Commentary

Trees are retained only where necessary for seeding, in order to minimise suppression of regeneration.

6.7.3 Potential Innovations

When the practice is associated with high standards of post-logging site management, it can also allow significant improvement in the operational economics of subsequent operations (e.g. thinning).

6.7.4 Assessment Statement

Harvesting without retention is suitable for areas where a contribution to habitat is not required. Seed trees may be necessary to provide seed if post-logging burning is employed.

6.7.5 Guidelines / Rules / Limits

Suitable for application where habitat function related to tree hollows is not required.

6.8 F25 – THINNING

6.8.1 Practice and Impact

Type C2 Regrowth thinning

The practice involves the cutting, debarking and removal of smaller stems from regrowth stands. It involves the use of specialised equipment. Processing equipment is currently mounted on an excavator type-carrier. Pulpwood is extracted by rubber-tyred forwarder.

Thinning limits are based on a minimum economic tree size, stocking and terrain and ground conditions and haulage costs.

6.8.2 Nature of Practice

Mechanism of Impact

Thinning recovers material that would otherwise die through competition and be lost and can promote the diameter growth of residual stems thus reducing rotation length.

Importance to Eden

There are areas of regeneration originating from wildfire and logging that are suitable for thinning.

Scientific Commentary

Thinning can improve the economics of managing selected stands. It can boost early availability of sawlogs. Pulpwood from regrowth thinning has desirable properties.

However, it can damage residual trees and future losses from stem rot are unknown. There are cost penalties associated with thinning at small tree size when silvicultural advantages might be greatest.

6.8.3 Potential Innovations

Thinning of stands in Victoria growing on sites of high quality and that had received prior spacing, have shown significantly reduced thinning costs and increased sawlog growth rates. This suggests that the practice might be more effective when applied in combination with early spacing.

6.8.4 Assessment Statement

Thinning can be of significant benefit in producing an early financial yield to the forest owner, and when targeted to responsive stands can increase sawlog growth rates and reduce rotation length.

6.8.5 Guidelines / Rules / Limits

Thinning should be targeted to stands with higher site production potential where growth responses will be greatest.

Thinning cannot be carried out economically with current or foreseen technologies on steeper sites - we suggest limit of approximately 15 – 20 degrees.

Thinning cannot be carried out when the size of stems is too small. The mean size of those removed should be at least 0.20 m3.

6.9 F26 – SPACING

6.9.1 Practice and Impact

Type C3 Regrowth spacing

Spacing involves the removal of competing trees at an early age when the stems in question are too small to utilise. The practice requires careful timing to minimise operational costs while securing a high growth response. It is applicable to densely stocked fire regeneration and sites with higher growth potential.

6.9.2 Nature of Practice

Mechanism of Impact

Spacing can have a significant impact on site productivity by concentrating growth and utilisation of site resources on those stems that will ultimately by utilised as thinnings or sawlogs.

The technique may cause a small reduction in site water use, where the spacing removes a large proportion of stems, but this effect may be short lived as remaining stems increase their transpiration.

Importance to Eden

The extent of suitable sites in the Eden RFA area is unknown. The technique is most applicable in treating dense fire regeneration.

Scientific Commentary

The effectiveness of the technique in improving stand growth has been demonstrated in several studies in East Gippsland. Spacing is widely used in plantation forestry to encourage early growth of crop trees.

Two forms of implementation are in use:

- mechanical removal (usually with a clearing saw when stems are 2 – 5 cm in diameter), and
- stem injection of a herbicide (usually glyphosate).

There can be problems with coppice or understory competition, especially where mechanical removal (e.g. clearing saw) techniques are used.

6.9.3 Potential Innovations

Current spacing techniques are in the early stages of adoption in eucalypt forestry. There is a need for knowledge that will allow better prediction of operational costs and growth response for a given set of site and stand conditions.

6.9.4 Assessment Statement

6.9.5 Guidelines / Rules / Limits

Spacing should be applied only to heavily stocked stands on sites with a high productive potential where vigorous response is anticipated.

Stem injection may be favoured over cutting techniques because of lower cost, reduced coppice and feasibility of application at later ages when quality of retained stems is more assured.

6.10 F27 – FERTILISING

6.10.1 Practice and Impact

Type C4 Regrowth fertilising

This practice involves the application of fertiliser to regrowth stands at the time of thinning or later in stand age to boost sawlog growth rates.

6.10.2 Nature of Practice

Mechanism of Impact

Fertiliser has been shown to have a positive impact on growth rates in some trials.

Importance to Eden

The practice is not currently practiced in the Eden forests.

Scientific Commentary

Research has established that it is applicable to sites with some nutrient deficiency but with moderate to good soil water availability. Can be applied in combination with thinning / spacing.

6.10.3 Potential Innovations

Further knowledge of the relationship between growth response and site and stand characteristics is needed to effectively target stands where economic response would be greatest.

6.10.4 Assessment Statement

Fertiliser application can boost growth in stands with good soil water availability.

6.10.5 Guidelines / Rules / Limits

Should be restricted to stands with high economic growth potential.

6.11 F35- PLANTATION ESTABLISHMENT

6.12 F 36 – PLANTATION HARVESTING

6.12.1 Practice and Impact

The establishment and subsequent harvesting of plantations increases timber yield from a region.

6.12.2 Nature of Practice

Mechanism of Impact

Establishment and harvesting of plantations has a direct positive impact on regional timber yield.

Importance to Eden

Eden has significant areas of *Pinus radiata* plantation and small areas of eucalypt plantation.

Scientific Commentary

Establishment costs for eucalypt plantations in Australia are often higher than in a number of competing countries. It is therefore essential, where plantations are established primarily for wood production, that high growth rates are achieved to ensure economic viability. This requires care at the establishment stage to ensure that sites of adequate potential for the chosen species are selected for planting. It also requires that effective silvicultural prescriptions be followed.

6.12.3 Potential Innovations

- Further development of site adapted prescriptions are required to ensure maximum growth
- Further work is also required in site selection to ensure that areas chosen have the potential to achieve growth rates that will allow the plantations to be economically viable.

6.12.4 Assessment Statement

Plantations can increase regional timber availability. Establishment on fertile, well-watered sites and good silvicultural practice may be essential for economically viable returns.

6.12.5 Guidelines / Rules / Limits

Establishment for commercial purposes should be planned for more fertile, well-watered sites.

7. GEOCHEMICAL

7.1 J-12 IMPACT OF WILDFIRE ON CARBON STORAGE

7.1.1 Statement of Practice and Value

An aim of forest management should be to maximise the storage of C in Eden forests, within the constraints resulting from the need to provide other values. Fire, whether controlled (prescribed) or uncontrolled can have a major impact on C stocks, both in the short and longer-term. Note that the aim of prescribed burning (which releases C to the atmosphere) is to reduce the risk of wildfires, so that it is the net effects of these two types of fire that is important. See cell J13 for further discussion.

7.1.2 Assessment of Impact

Mechanism

Wildfire can combust organic carbon contained in vegetation, litter and soil. The amount of C released (largely as CO_2) to the atmosphere increases with fire intensity and the area burnt. Further release of C by accelerated soil respiration can occur for many months after wildfire. In total the release of C can be very large, and can occur within a short time.

Growing forest fixes C from the atmosphere, and rates are generally greater in regenerating stands than in mature or senescent forest. Thus rates of net C fixation may be higher in the decades following wildfire (or harvesting of mature forest). If wildfire results in degradation of soil fertility as a result of erosion or gaseous nutrient losses (see cell ?) or creation of understocked or badly damaged growing stock (see cells ??) then the potential for stand C storage will be reduced in the long term. Thus wildfire can markedly increase the release of C to the atmosphere in the short term (more steady release) and also has the potential to lower storage in the longer term.

Importance at Eden

Wildfire has major impacts in the Eden forests (see cell F12) because of its frequent occurrence and the significant issue for managers of all land tenures.

Scientific commentary

The effects of wildfire on forest C storage at Eden have not been calculated, and considerable R&D would be required to conduct a thorough assessment. Effects on soil C storage are complex (see cell D12). Effects on litter C storage may be minor when averaged over space and time. Effects on biomass C stores can be considerable, and could be estimated from mensurational models that calculate the standing volume of wood for all forest tenures. As a first cut, the C storage in above-ground biomass could be used as an indicator of the effect of wildfire on total ecosystem C storage.

Current ameliorative measures

Considerable efforts are made to control the frequency and extent of wildfires. These are based on use of broadscale prescribed burning (especially in State Forest) to lower fuels and fire risk, preparation (fire breaks, equipment and training, planning), early detection and suppression activities. Despite these activities wildfires will continue to occur. The capacity to control wildfire, and the best strategy to achieve this are contentious issues that are discussed elsewhere (see cells F12).

7.1.3 Potential Innovations

These revolve around alternative strategies for reducing the intensity and area of wildfires. Issues are: public education and commitment, improved cross-tenure (and Victoria/NSW) planning and operations, improved skilling of those involved in all aspects of fire management, more strategic and effective proscribed burning programs (area may be reduced but effectiveness increased), and better detection and suppression capacity. These comments are generic to the critical need to control wildfires if diverse forest management objectives are to be achieved.

7.1.4 Linkage to Indicators and Targets

Relates in a direct way to the indicators and targets proposed for geochemical cycles. The effects of wildfire will be a major contribution to the consequences of forest management for C budgets. The other major impacts will arise from conversion of mature forest to regrowth (negative impact on C stocks), reduced rotation lengths (negative), plantation establishment (likely positive), and greater use of forest products for construction and furniture (positive).

7.2 J-13 IMPACTS OF FUEL REDUCTION BURNING ON CARBON STORAGE

(see also cells J12,)

7.2.1 Statement of Practice and Value

Fuel reduction burning, which is used to reduce future fire risk, causes a direct release of C to the atmosphere from combusted material. Two types of prescribed burning are used in the Eden forests – that to reduce logging slash, and more frequent lower-intensity fire applied over much larger areas, especially on State Forest land. The aim is to consume only litter and understorey vegetation (1-2m height) and not to damage the overstorey – in practice damage to the overstorey occurs and this is a major issue that forest management must address (see cells F12).

7.2.2 Nature of Practice

Mechanism of impact

The obvious and short-term impact results from release of C during combustion. Some would argue that low-intensity fire merely accelerates natural decomposition processes, and that over time fire causes no net increase in C release. There are several reasons why this may not be true:

- Repeated low-intensity fire has the potential to lower soil fertility (and hence rates of growth of the vegetation) by nutrient loss and erosion (see cells D13,D14). Thus C fixation rates may decline progressively over time.
- Repeated removal of the litter layer may reduce inputs of C into the soil, where it has the potential to be stabilized and stored in significant amounts.
- Small amounts of charcoal (inorganic C) are formed during combustion and this largely inert material can be stored in the soil.

Thus the net effects of prescribed burning, quite apart from its effect on wildfire impacts, are not easily predicted, and are unknown for the Eden forests. The most significant mechanisms are likely to be the interaction with wildfire, the potential effect on site productivity especially as induced by accelerated erosion, and damage to crop trees and effects on their future utilization (sawlogs versus pulpwood).

Importance at Eden

Prescribed burning is widely used at Eden (? ha burnt annually after logging; ? ha treated annually with low-intensity fire).

Scientific commentary (see also cell J12)

Any credible assessment of impacts in Eden forests will require significant R&D, and is not possible within the time-frame of the RFA. It should form part of on-going R&D for the region. It would be better to concentrate on ways of improving the quality (minimising damage whilst getting effective fuel reduction) and effectiveness (strategic coverage) of prescribed burning programs (see cell F13).

Current ameliorative measures

A prescribed burning guide has been developed for the regrowth forests. Managers for other reasons aim to confine fire intensity to low levels, which provides some benefits for maintaining C storage.

7.2.3 Potential innovations

These relate to more effective prescribed burning strategies and practices (see cells ?, ?). The strategic nature (as opposed to broadscale coverage) of prescribed burning needs to be improved, as does the quality. Collection of appropriate fuel and moisture information to guide scheduling, and more formal monitoring and reporting of both coverage and quality (scorch, tree damage, subsequent erosion) is required. If these issues are addressed, benefits for C budgets will also accrue.

7.2.4 Linkage to Indicators and Targets

See cell J12.

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