Towards Ecologically Sustainable Forest Management in Western Australia

A Review of Draft Jarrah Silviculture Guideline 1/02

Panel Report Part 2 for the Conservation Commission of Western Australia

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Executive Summary

The purpose of this report is to provide technical advice to the Conservation Commission of Western Australia to assist in informing the public on how the draft jarrah silvicultural guideline provides for:

- Regeneration adequacy (of jarrah and marri)
- Salinity constraints
- Habitat and biodiversity conservation.

The Panel was also asked to identify where the guideline may not adequately provide for these values and to advise on research and monitoring programs to support the New Forest Management Plan. We have also commented on some issues related to but outside the terms of reference that we believe may be of assistance to the Conservation Commission of Western Australia.

In formulating its recommendations, the Panel was acutely aware of changing community values and expectations with respect to forest management, the State Government embracing ecologically sustainable forest management (ESFM) through recent amendments to the Conservation and Land Management Act, and the changed forest policies. The high level of reservation in the forest region, including remaining old growth forest, has improved the conservation status of forest ecosystems. The Panel is also aware of the social, economic and environmental benefits to the State of a viable and ecologically sustainable native forest timber industry. Through the development and implementation of the New Forest Management Plan, Western Australia is well placed to provide to the world, an exemplar of ecologically sustainable forest management.

The draft jarrah silviculture guideline ("*Silvicultural Practice in the Jarrah Forest: Silvicultural Guideline 1/02*"; DCLM undated) is detailed and technically sound with respect to providing for regeneration adequacy of commercial tree species. It incorporates many of the latest research findings of the impacts of timber harvesting on jarrah forest ecosystems, though much of the research is yet to be published in scientific journals. However, it should incorporate several key findings that have important implications for habitat and biodiversity conservation. There are many recommendations in the body of this report that aim to assist in this regard, but the key recommendations of the Panel are:

- A new framework for a fully integrated planning process to deliver ESFM is needed. It should emphasise forest ecosystem management, identify the various levels and components of planning and demonstrate how these are aligned and cross-linked, including linkages with policies, codes of practice, prescriptions and other documents such as silviculture guides.

- The forest biodiversity conservation objectives proposed in this report could be used as a basis for developing silvicultural strategies to manage for habitat and biodiversity values and for aligning forest planning processes.

- Existing manuals and codes of practice with respect to soil conservation should be reviewed and upgraded. Clear objectives and strategies are required in the jarrah silviculture guideline to reduce soil damage during logging operations, or it should refer to other appropriate documentation. The drier the soil conditions under which operations proceed the lower is the risk of soil damage. Techniques such as the use of a global positioning system to locate logs and to plan extraction to minimise the network of snig tracks should be investigated.

- Alternative techniques for establishing jarrah and marri regeneration that minimise impact on the soil and on understorey species should be investigated.

- Operational-scale trials to examine the effectiveness of varying stream buffer widths on water quality and stream ecology should be implemented across a range of forest landscapes including the high and intermediate rainfall zones.

- Structural goals need to be developed at various spatial scales to obtain a well dispersed arrangement of different seral stages and habitat types in forests available for timber harvesting. This will provide habitat diversity and facilitate post-logging recolonisation.

- The retention, distribution and ongoing availability of mature forests is important for the long term protection and conservation of fauna that depend upon this habitat element. Mature forest is an important structural stage that needs to be adequately represented across the forest region. Options for how this might be achieved in forests available for timber harvesting are presented in this report.

- An ongoing program of targeted forest research and monitoring, jointly funded by government and industry, is fundamental to continuous improvement and to achieving ESFM.

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1. Introduction

This is the second report of an expert technical Panel established to a) advise the Department of Conservation & Land Management (DCLM) on monitoring of the jarrah silvicultural trial as required under Ministerial Condition 11 (Part 1) and to b) advise the Conservation Commission of Western Australia in relation to the draft jarrah silviculture guideline ("*Silvicultural Practice in the Jarrah Forest: Silvicultural Guideline 1/02*"; DCLM undated) and research and monitoring priorities to support the New Forest Management Plan (Part 2).

1.1 Scope and Terms of Reference – Panel Report Part 2

With respect to Part 2 of its deliberations, the Panel, comprising Dr Neil Burrows (Chair), Dr Per Christensen, Dr Steve Hopper, John Ruprecht and Dr Joanna Young, was specifically asked to;

"Prepare a review to address recommendation 3.4 (Jarrah Silviculture) from the Ferguson et al. (2001) report Calculating Sustained Yield for the Forest Management Plan (2004-2013) – A Preliminary Review.

The review is to focus on three key elements of the silvicultural guidelines proposed for the next plan period relating to;

- *regeneration adequacy,*
- *salinity constraints, and*
- *habitat and biodiversity conservation.*

The review should also indicate monitoring and research priorities and funding needed in the next plan period.

The aim of the review is to inform the public in relation to silvicultural guidelines and practices that provide for these three forest values.

In advising the Chair of the Conservation Commission, the Panel should note;

- *the text leading to Ferguson et al. recommendation 3.4 (pages 36 and 37),*
- *operational, safety and economic considerations in design and implementation of silvicultural systems.*

In preparing a written report for the Chair of the Conservation Commission, the Panel was given the following instructions:

"*1. The Panel is to provide technical advice to the Conservation Commission to assist in informing the public on how the revised jarrah silviculture guideline provides for;*

- *regeneration adequacy,*
- *salinity constraints, and*
- *habitat and biodiversity conservation.*

The Panel is also to identify areas where the new guidelines may not provide adequately for these values.

2. *Provide advice on jarrah forest research and monitoring priorities to support the New Forest Management Plan, in part based on a summary of relevant research and monitoring programs currently undertaken by DCLM.*
3. *The report is also to include a summary of relevant research and monitoring programs and projects undertaken by the DCLM. Advice is to be provided on priorities and funding needed for the next plan period."*

Detailed background to these issues is provided in this Panel's Part 1 report (Burrows *et al.* 2001) to the A/Executive Director, DCLM, so will only be summarised here. In preparing advice on research and monitoring needed to support the New Forest Management Plan, it should be noted that while a discussion paper was available (Conservation Commission of Western Australia 2002), the New Forest Management Plan was not available at the time of preparing this report.

Emphasis and coverage of the draft jarrah silviculture guideline.
The Panel understands that the brief for the revision of the silvicultural guidelines required a revision of a specific set of existing guidelines (J. Bradshaw pers. comm.). According to Bradshaw (2002);
"*The guidelines were prepared primarily to provide guidance to operations staff to achieve their task of timber harvesting in a way that satisfied the requirements of future timber production so far as was possible within the limitations imposed by the protection of other values according to recognised objectives. To that extent other values take precedent over timber production. They are intended to cover the silvicultural practices to be employed on the areas identified for timber production*".
Bradshaw (2002) acknowledges that the draft jarrah silviculture guideline provides objectives and strategies for other (non-wood) values as a framework, but these are not dealt with in the guideline. Bradshaw pointed out that the guideline is part of the Environmental Management System (EMS - apparently in preparation), which includes guidance on a broader range of activities including environmental issues.

These limitations, the scope and purpose of the guideline, and the extent to which habitat and biodiversity conservation issues are covered elsewhere is not explicit in the guideline itself, nor does it make adequate reference to other documentation within the EMS framework. The issue of the forest management planning process, the level of integration and the consistency of planning documents that make up the EMS is discussed further in this report

With respect to the draft jarrah silviculture guideline, the first ten pages deals with objectives and silvicultural strategies for water and biodiversity, as well as other values including wood products, raising the expectation that all of these values would be dealt with in some detail in the guideline. For these reasons, and given the importance of silvicultural treatments to ESFM, including water, habitat and biodiversity values, the Panel has reviewed the guideline with the expectation that it would address these issues in some detail.

1.2 Context

The Ministerial Conditions
The Department of Conservation and Land Management (DCLM) is required to report publicly to the Environmental Protection Authority (EPA) on compliance and progress with respect to seventeen Ministerial Conditions attached to the current Forest Management Plan (1994-2003). It is intended that a final public report should help verify environmental performance with regard to implementation of this plan. This plan signalled a shift from the selective removal of commercial trees in jarrah forest to the creation of gaps up to a maximum of 10 hectares. This treatment was intended to facilitate the release and development of jarrah and marri regeneration present beneath the forest canopy. In 1992 the EPA accepted the silvicultural rationale for gap creation but it stated (EPA Bulletin 652 1992) that adoption of the silvicultural guidelines proposed for broadscale use should be contingent on monitoring of environmental impacts on a range of sites. This was embodied in the Ministerial Condition 11.1, which was to ensure that information from monitoring was available for an evaluation of the environmental impacts of this more intensive treatment prior to the drafting of the New Forest Management Plan for 2003-2012.

There are five additional environmental conditions that are related to the jarrah silvicultural systems adopted after 1992:

- Ministerial condition 3: Precautionary approach and adaptive management
- Ministerial condition 12: Phased logging
- Ministerial condition 14: *Banksia grandis* reduction
- Ministerial condition 16: High salt risk catchments.
- Ministerial condition 17: Forest Monitoring and Research Committee.

Ferguson *et al.* (2001) Recommendations

The DCLM and the Conservation Commission have the responsibility for implementing several key recommendations made by Ferguson *et al.* (2001), especially those requiring attention during the development and drafting of the New Forest Management Plan. Ferguson *et al.* (2001) clearly identified that the current jarrah silvicultural systems including gap creation, cutting to shelterwood and thinning required review, acknowledging that changes to the silvicultural systems could impact on the calculation of sustained yield. They also recognised public concern about three elements of the silvicultural systems, namely:

- Regeneration adequacy,
- Salinity constraints, and
- Habitat and biodiversity conservation.

As well as advising that the DCLM complete its responses to the Ministerial Conditions, Ferguson *et al.* (2001) recommended the following:

Recommendation 3.4, Jarrah Silviculture
(1). The Conservation Commission should, as a matter of urgency, and following the completion of the DCLM reports on the Ministerial Conditions, prepare a review of the silvicultural guidelines with respect to regeneration adequacy, salinity constraints, and habitat considerations to inform decision in the current revision of the Plan.
(2) The review should also indicate monitoring and research priorities and funding needed in the next Plan period.

It is emphasised that in this report, we review the draft jarrah silviculture guideline, "*Silvicultural Practice in the Jarrah Forest: Silvicultural Guideline 1/02*" (DCLM undated). A copy of our Part 1 report (Burrows *et al.* 2001) was made available to J. Bradshaw, the author of the draft silvicultural guideline (note: as his name does not appear on the document, we refer to it as DCLM (undated). A number of planning processes have run concurrently because of timing constraints associated with the development of the New Forest Management Plan.

Forest Conservation and Environmental Objectives

A major shortcoming that became evident during 1997 and was addressed by Codd (1999) was that environmental commitments, or objectives, were not clearly stated in the current Forest Management Plan (DCLM 1994). A clear statement of agreed commitments could have facilitated the DCLM's mid term reporting to the EPA as well as facilitating ongoing audit of progress with implementation. As a consequence of the Codd report (1999), the DCLM and the EPA agreed to a set of environmental commitments, which the EPA published in Bulletin 983, June 2000. The DCLM has reported to the EPA on implementation of the current Forest Management Plan (DCLM 1994) against these commitments in its annual progress and

compliance reports of 1998 and 1999. It is assumed that in the drafting of the final compliance report the DCLM will further address how the commitments have been met.

Ferguson *et al.* (2001) also recognised that clearly defined objectives for non-wood related products (including environmental values) were not evident with respect to south-west forests, making it difficult to adequately evaluate trade-offs between competing values. They made an obvious but critical observation that clearly defined non-wood product objectives are also essential to judge progress towards the achievement of Ecologically Sustainable Forest Management (ESFM). This sentiment was reflected in their Recommendations 3.12 (Structural Goals), 4.1 (Whole of Forest) and 4.2 (Fire Management).

Ecologically Sustainable Forest Management (ESFM)

The Western Australian Regional Forest Agreement bound all parties to a commitment to practice ecologically sustainable forest management (ESFM) within a framework based on the Montreal Criteria and Indicators. However, the absence of a clear, agreed working definition of ESFM and of clear biodiversity conservation objectives has lead to a wide range of interpretations and views about ESFM, which has hindered the development of a shared vision. A report published by the joint Commonwealth and Western Australian Regional Forest Agreement Steering Committee (CRA 1998) attempted to provide some guidance in this respect and it was at least very clear that:

"*The strategy for conserving biodiversity relies not just on a CAR reserve system, but also on the application of ecologically sustainable forest management across all tenures*".

Although the Western Australian Regional Forest Agreement embraces the JANIS (1997) criteria for the establishment of a CAR reserve system, such criteria were not specified for non-conservation reserve tenures that were to be managed according to the principles of ESFM. The nationally agreed criteria for the establishment of a CAR reserve system for Australian forests identified the following objectives for biodiversity conservation (JANIS 1997);

- to maintain ecological processes and the dynamics of forest ecosystems in their landscape context,
- to maintain viable examples of forest ecosystems throughout their natural ranges,
- to maintain viable populations of native forest species throughout their natural ranges, and
- to maintain the genetic diversity of native species.

Consistent with ESFM, the Panel is of the view that these objectives are also relevant to forests not in the conservation reserve system, e.g. to forests that are also available for wood production. There will invariably be some trade-off with respect to the temporal and spatial extent to which these objectives are met in wood production forests and with respect to issues of the abundance of individual species at any point in time. Burrows *et al.* (2001) proposed a spatially hierarchical set of biodiversity conservation objectives for discussion; these have been developed further in this report.

The Conservation and Land Management Amendment Act 2000

Sections 19(1) and 19(2) of the CLM Act clearly embrace the concept of ecologically sustainable management of State forest, timber reserves and forest produce in Western Australia. Section 19(2) sets out five principles to guide the implementation of ESFM:

a) *That the decision-making process should effectively integrate both long-term and short-term economic, environmental, social and equitable considerations.*

b) *That if there are threats of serious or irreversible environmental damage, the lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.*
c) *That the present generation should ensure that the health, diversity and productivity of the environment is maintained or enhanced for the benefit of future generations.*
d) *That the conservation of biological diversity and ecological integrity should be a fundamental consideration in decision making.*
e) *That improved valuation, pricing and incentive mechanisms should be promoted.*

These principles underpin the recently released, "*A new forest management plan for Western Australia: Discussion paper*" (Conservation Commission of Western Australia 2002).

Embracing ESFM and the explicit requirements to ensure the maintenance of biological diversity and ecological processes represents a further development in forest management in Western Australia.

Planning documents, including silvicultural guidelines, need to reflect this. As discussed above, the Panel anticipated that the draft jarrah silviculture guideline would comprehensively address non-wood values such as salinity and biodiversity conservation, or refer to other relevant policy, planning and management documents that deal with these in some detail. That is, forest management, including State forests and timber reserves available for timber harvesting, should focus on ecosystem management and the protection of ecosystem integrity (biodiversity, health and productivity), of which silviculture for wood production is a component.

Other Relevant Processes

Significant public documents that provide background to the processes that have resulted in the DCLM giving high priority to reporting on implementation and impacts of the jarrah silvicultural systems are at Appendix 1 in Burrows *et al.* (2001) and will not be repeated here.

The commitments published in EPA Bulletin 983, June 2000 remain relevant with respect to evaluating the impacts of jarrah silviculture during the last decade and include:

- Identify and publish the values to be managed for in each forest area.
- Implement long term monitoring programs to identify and study significant management issues in (all types of) forest.
- Regulate the production of forest resources to levels that can be sustained indefinitely.
- Preserve the quality of potable water supplies from forests.
- Undertake research to improve the scientific basis for the protection of biodiversity.
- Retain an average of (at least) 3 large trees on every hectare harvested to provide habitat.
- Retain, and protect as far as possible, at least one suitable ground habitat, i.e. hollow log, per hectare.
- For those high salt risk second order catchments identified in fulfilment of Ministerial Condition 16, DCLM will reach agreement with the Water and Rivers Commission regarding the precautionary management and protection measures to be implemented. The objective of the measures will be to prevent saline discharge into these watercourses.

Research and Monitoring

The need for ongoing research and monitoring has long been recognised but resource constraints and priority setting processes have limited activity. Research priorities and the monitoring approach to be adopted for the period of the New Forest Management Plan must be agreed to and funds committed. The Panel recognises that major changes in the timber industry and significant

reductions in levels of harvest places further pressure on the availability of resources to carry out research and monitoring. However, the Panel is of the view that government and industry must co-operate to give these activities a high priority if Western Australia is to benefit from a sustainable forest industry. The Panel is also of the view that Western Australia is well placed to be world leader and an exemplar of ESFM.

The key results of research and monitoring of some environmental impacts of jarrah forest timber harvesting since the implementation of current Forest Management Plan (DCLM 1994) were summarised by Burrows *et al.* (2001) and provide a sound basis for improving jarrah forest management. In this report, we provide advice on forest research and monitoring that is likely to be needed to support the implementation of the New Forest Management Plan and ESFM. Given the level of uncertainty surrounding any management of natural ecosystems, and consistent with an adaptive management approach, we also suggest a number of operational trials that might be considered in designated Adaptive Management Areas during the period of the New Forest Management Plan. Although requested to do so, the Panel has not provided advice on funding necessary to accomplish this. We are of the view that this is best done by the relevant agencies.

1.3 Approach

In formulating advice to the Conservation Commission on how the draft jarrah silviculture guideline provides for regeneration adequacy, salinity constraints and habitat and biodiversity conservation, the Panel invited the author of the guideline (Mr Jack Bradshaw) to brief the Panel. During the briefing, the Panel had the opportunity to question and to seek clarification on a number of issues. Panel members individually and collectively reviewed the document in the context of shortcomings identified in the earlier guideline (see Burrows *et al.* 2001) and in the context of the shift to ESFM flagged by the CLM Act amendment and the recently released forest management discussion paper (Conservation Commission of Western Australia 2002). Collectively, the Panel identified strengths and weaknesses of the draft guideline in the context of the terms of reference and of ESFM. The Panel also visited the forest for two days in August 2001 with J. Bradshaw, DCLM and Forest Products Commission (FPC) staff.

In providing advice on the jarrah forest research and monitoring priorities to support the New Forest Management Plan, with particular reference to regeneration adequacy and methods of assessment, salinity constraints and habitat provision for the maintenance of biodiversity and ecological processes in jarrah forests, the Panel referred to recommendations made during other processes (e.g. Ferguson *et al.* 2001, Codd 1999 and Dell *et al.* 1999) and invited input from the broader Western Australian scientific community on the question of research priorities for sustainable forest management (see Appendix 2).

2. General Comments on the Draft Jarrah Silviculture Guideline

The draft jarrah silviculture guideline provides a high level of detail for meeting the silvicultural objectives of:

- Thinning to promote growth on retained trees.
- Removing the overstorey (creating gaps) to release and promote the development and growth of existing regeneration (seedlings, ground coppice and small saplings).
- Cutting to a shelterwood to establish jarrah regeneration where it does not exist in sufficient density. Seedlings will be encouraged to establish and develop into ground coppice by reducing the competition from the overstorey. A forest canopy is maintained

to provide a continuity of forest values until the ground coppice is developed and capable of responding to release following canopy removal.

Explicit in these objectives, the guideline focuses on managing and manipulating commercial overstorey tree species largely for the purpose of timber production. This is important because in forests available for timber production, regeneration and development of commercial tree species following logging is fundamental to ecologically sustainable forest management (ESFM). The guideline reflects current scientific knowledge with respect to regenerating and growing jarrah (and marri). We are of the view that a silviculture system with a broader ecological base is needed to deliver ESFM.

This raises a number of questions about the forest management planning process and the over all planning framework. What are the relationships between the various levels of policy, plans, guidelines, prescriptions and codes of practice? Where do the silvicultural guidelines sit in this framework? How well integrated and aligned are the various levels of planning? Is it the purpose of the silvicultural guideline to address and integrate non-wood values? If so, to what extent? Against what set of over-arching objectives are plans/guidelines being developed? If non-wood values are not dealt with in some detail in the silvicultural guideline, then where are they/should they be dealt with? It is the Panel's view that silvicultural practices can greatly change the forest structure temporally and spatially, resulting in a range of impacts on other values such as biodiversity and water, consequently silvicultural guidelines must address, or be closely integrated with, broader forest ecosystem management guidelines.

Managing forests for the dual purpose of timber production and non-timber values, such as biodiversity conservation, requires clearly defined forest conservation objectives. It is difficult to develop lower order prescriptions and guidelines in the absence of an over-arching forest management plan that provides a reference framework to guide the silvicultural objectives and practices. For example, timber production and biodiversity conservation, at the extremes, can be virtually mutually exclusive objectives, hence the need for clear definition of priority objectives and of acceptable trade-offs. Unfortunately, rather than being sequential, the production of the draft jarrah silvicultural guideline has preceded the development of higher order planning processes. Burrows *et al.* (2001) suggest a framework for setting biodiversity conservation objectives at various scales for forests. While this is reflected in the preamble to the draft jarrah silviculture guideline, the guideline does not appear to have been developed with these objectives in mind.

In essence, a silvicultural guideline is about the growing and harvesting of commercial tree species, which is the thrust of the draft jarrah silviculture guideline. A better, integrated planning approach is needed, one that emphasises forest ecosystem management, including the extraction and growing of timber as a disturbance event that must be managed to protect and maintain other non-wood values, consistent with ESFM. This will require a multi-disciplinary approach to developing guidelines for managing forests from which timber (or other products such as water) will be harvested, including but extending beyond silvicultural prescriptions focused on the management of overstorey species.

The preamble to the draft jarrah silviculture guideline defines management objectives and silvicultural strategies for water, biodiversity, wood products, visual and heritage values. However, with a few exceptions, the draft guideline does not deal with non-wood products other than at the broadest level. Exceptions include the incorporation of some of the important findings of the Kingston study (see Burrows *et al.* 2001), such as revised habitat tree retention (rates and selection criteria), the retention of hollow logs and balga (grass trees) and reference to increasing

the frequency of fox baiting. In essence, the draft jarrah silviculture guideline is a technical up-grading of the old guideline. As discussed above, it is our view that there needs to be a clearer statement of the purpose of the guideline and better integration of other forest management policy, planning, codes and manuals.

The Panel is of the view that a new conceptual framework may assist with delivering ESFM and with achieving better integration of forest management. For example, contemporary forest management models are appearing in the modern forest management literature, including the concept of ecological forestry (Hunter 1999) or ecosystem management (Vogt *et al* 1997), which focuses on maintaining the ecological integrity (biodiversity, health, productivity) of forest ecosystems. The central axiom of ecosystem management is that any manipulation of a forest ecosystem should emulate the known or inferred (from knowledge of ecological processes) natural disturbance patterns of the region prior to 'industrial' manipulation such as timber harvesting. Similarly, Attiwill and Fewings (2001) suggest that an understanding of the ecology of natural disturbances should form the basis for designing silvicultural systems. This is based on the assumption that the native species and communities have evolved under these natural disturbance regimes and will be better able to cope if human-induced disturbances emulate, or are within the natural range of variation of severity, spatial and temporal bounds (Hunter 1999).

This approach is also consistent with the precautionary principle. For example, small-scale removal of the overstorey of a mature karri forest, in a structural sense emulates some (not all) of the ecological impacts of a high intensity stand replacement fire. Thus, limited clearfelling in karri forest has an historical analogue in nature. However, substantial or total removal of the overstorey of a mature jarrah forest as a natural process has been the exception rather than the rule in recent evolutionary times. Mature jarrah is very resilient to even high intensity fire, therefore, disturbances such as logging that have the potential to create relatively large and contiguous tracts of regrowth forest, are unprecedented so could be expected to have some adverse impacts on biodiversity. If this is recognised, then appropriate measures can be taken to offset or minimise these impacts. Similarly, soil disturbance and compaction have no natural analogue so could be expected to have some negative consequences on forest soils that are highly weathered and low in fertility. Compacting or damaging the topsoil can physically impede root development hence plant growth and can further reduce moisture and nutrient availability. Measures can and should be taken to minimise these adverse impacts.

There are two issues of fundamental importance to biodiversity conservation in jarrah forests available for timber harvesting. The first is the adequate provision of 'legacy' habitat components, such as large hollow-bearing trees, hollow logs and patches of structurally mature forest. These habitat elements are not well provided for by regrowth forest and can take up to 140 years to develop following logging. The second issue is the development of whole-of-forest objectives for spatial heterogeneity of forest structures and age classes. To a large extent, this will be strongly influenced by historical cutting (or what already exists), but the new plan should address this for the future of the forests. On both accounts, our scientific knowledge is incomplete, so estimates will need to be based on existing knowledge, expert opinion and risk analysis. A high proportion of forest, including remaining old growth forest, is or will be in the formal reserve system. This needs to be taken into consideration when determining the amount and the pattern of retention of mature forest structures in forests available for timber production (see below).

Ecologically-based silviculture needs to recognise that other ecosystem elements (flora and fauna) are integral to, not incidental to or constraints to, silviculture and should be taken into account particularly in the early stages of planning for timber harvesting. For example, the final

jarrah silviculture guideline should make mention of standard pre-harvest threatened flora surveys and also predictions of fauna occurrence, or refer to other relevant documentation. Initial assessments of conservation, visual and heritage values are of critical importance and 'on ground' field staff have an important role to play in insuring values are not needlessly compromised. It is not just a matter of the convenience of having all of the silvicultural information in the one document; more importantly it is a matter of being seen to, and actually recognizing, that conservation of flora and fauna (and other values) are a component of modern silviculture. If not contained elsewhere, it is important that the detail of biodiversity management is contained in the silvicultural guidelines with the same prominence as the details of treatments aimed at regenerating and growing commercial tree species.

Similarly, measures to protect soils during and after timber harvesting operations need to be explicit. Soil conservation is fundamental to forest health, production and biodiversity, yet the draft jarrah silviculture guideline deals fleetingly with their protection and without specific reference to the "*Manual of Management Guidelines for Timber Harvesting in Western Australia*" (DCLM 1999a), which requires revision (see below).

There will be some difficulties in implementing some of the actions specified in the draft jarrah silviculture guideline. Although narrowly focused, the guideline is complex and those involved in tree marking and harvest planning must be adequately trained and accredited. For example knowledge of the vegetation complexes and their recognition on the ground is now required especially with respect to minimising dieback impacts. This is not an easy task. Many decisions are being left to professional judgement, e.g. areas requiring post-harvest monitoring of regeneration success in gaps, further underlining the importance of training. Industry must also acknowledge that there must be a commitment from contractors and in-forest staff to meet the objectives set by DCLM or there will be an ongoing gap between policy and practice and consequent loss of credibility.

The objectives as stated under post harvest silvicultural treatments in the draft jarrah silviculture guideline will not be met without an adequate level of resourcing, and audits must accurately inform the Conservation Commission if areas are not being adequately treated, hence failing to meet silvicultural objectives stated in the guideline. Jarrah gap creation should cease during the plan if funds are unavailable for adequate post harvest silvicultural treatments in specific forest types e.g. low quality forests or forests with a high proportion of culls to sawlogs, isolated areas, or areas with high percentage of marri. Section 3.7 of the guideline for eastern forest states, "*The final outcome is expected to be small groups of treated forest in a matrix of selectively cut forest with limited thinning in some areas*". A case for selection cutting in some areas could be justified. Some specific objectives for some different types of forest could be set and trialed during the plan with feedback so that the guideline can be kept relevant in the face of changing market conditions.

ESFM is fundamentally about protecting the ecological integrity (biodiversity, health and productivity) of forest ecosystems while providing products and services to the community in perpetuity. The DCLM requires a full time experienced silviculturalist and an experienced forest ecologist who jointly develop and improve silvicultural and other forest management guidelines. Silvicultural expertise is clearly lacking in the Forest Management Branch of DCLM and has been exacerbated by the formation of FPC. The involvement of FPC and industry is also necessary to ensure that components of the Environmental Management System are updated as required.

It should be noted that some topics in the guideline are comprehensively covered but in some areas further guidance should be given. Heritage and environmental protection are two such sections (see section 4 below). The Panel is aware that policies with respect to heritage issues are being prepared by DCLM.

3. Specific Comments on the Draft Jarrah Silviculture Guideline

3.1 Regeneration Adequacy

3.1.1. Strengths

The guideline utilises the best available knowledge of the regeneration requirements of jarrah and the role of marri is also acknowledged. The guideline is quite explicit at the operational level and forms a sound basis for the harvesting, regeneration and growing of jarrah. Priority for silvicultural treatments is also given.

The potential of different forms of regeneration is acknowledged and the role they may play in different forest types. Encouraging a role for coppice in areas where regeneration is proving difficult is positive and this initiative is also linked to less cull pushing and associated soil damage.

Contingency plans for regeneration failure are also included such as the planting of nursery-raised jarrah and marri. Regeneration of dieback sites is also mentioned; preference should be given to using dieback resistant strains of jarrah in all planting operations.

Specific guidance is given for the low productivity eastern zone forest and the importance of recognising different forest site types is being encouraged in harvest planning. Greater use of vegetation complexes (Mattiske & Havel 1998) is being endorsed, for example the boundary of different groups of vegetation complexes are to be clearly indicated on the harvest plan to assist tree markers in dieback areas. This recognises biophysical differences in various jarrah forest ecosystems and the need to adjust management practices accordingly.

The guideline also establishes uniformity of prescriptions with respect to harvesting in dieback areas in different regions.

The guideline is appropriate where the aim is to establish and release regeneration of good form in areas selectively logged in the past. Thinning is also given high priority.

3.1.2 Weaknesses

Although the guideline provides clear definitions of what is meant by thinning, gap creation, shelterwood harvesting and the associated regeneration objectives, selective harvesting is inadequately defined. No reference is made to areas referred to as "*extensively managed areas*" in previous guidelines. As some areas will be "*cut to culls*" or "*extensively managed*" in the next plan period it should be made clear the types of forest to be cut selectively and this type of harvesting recorded annually. The Panel believes that selective harvesting can be justified if it results in less short-term waste and options for future use of residues are retained. With the loss of marri chip-wood markets options should be retained for the future utilisation of trees that are currently inhibiting jarrah regeneration and growth. It may strengthen the guideline if the various silvicultural approaches to be adopted, dependent on residue markets, were explained.

With respect to the post-harvest monitoring of regeneration in gaps a clearer set of objectives and criteria should be provided for field staff. Statements such as, "*The purpose of this survey is to monitor success of regeneration coupes which appear to have been least successful*" are ambiguous and open to broad interpretation.

There are some uncertainties with regard to the regeneration in the eastern forests but it would seem that the best chance of seedling establishment is soon after logging disturbance, although seedlings will establish continuously with pulses of regeneration associated with summer/autumn fire particularly. Unpublished data from long term fire ecology plots in jarrah forests have shown that summer/autumn burning in unlogged forest increased the density and stocking of jarrah and marri seedlings compared with other fire treatments (N. Burrows pers. comm.). The uncertainties of establishing regeneration should be acknowledged in the guideline and regeneration results under different treatments and environmental conditions should be documented.

3.1.3 Recommendations

The establishment of regeneration by direct seeding: This is a new initiative presented in the guideline and should be trialed. Alcoa now favours direct seeding of jarrah over seedling planting as seedlings develop better form, they establish at stockings which favours good form, and root development is better than from planted stock. While it is recognised that rehabilitation following mining requires more intensive measures, such as heavy fertiliser applications etc., direct seeding may be justified in special situations.

Documentation and analysis of regeneration survey data: A better understanding of the interactions between regeneration failure (and success) and factors such as dieback, seed availability and climatic and edaphic factors is needed. Progress could be accelerated if regional regeneration survey data already collected were analysed and published. The methods of analysis needs further development and the Panel understands that DCLM has already initiated some work in this area.

Adequacy and timing of post harvest regeneration surveys: With respect to infilling understocked patches it is stated in the guideline that, "*It is important to attempt to identify the causes of poor regeneration so that steps can be taken to minimise these problems in the future*". There must be a specific commitment to ensure that this happens. It should also be noted that regeneration in areas cut to gaps and shelterwood during the current Forest Management Plan (DCLM 1994) should be assessed during the next five years to ensure that prescriptions are adapted in a timely way if problems are identified.

Overstorey species mix: An assessment of the standards and a basis for monitoring overstorey species mix (jarrah-to-marri ratio) following harvesting are required. Relying on pre-harvest surveys may be misleading, as in some cases jarrah (and marri) regeneration present prior to logging may be lost during harvesting and disturbance. We also recommended investigating ways of managing overstorey species composition associated with regeneration treatments to ensure that biodiversity and production objectives are met in future forests.

Stocking standards: The basis of the revised stocking standards in the guideline has not been adequately explained. We recommended that there be a mechanism to review and establish stocking standards for different forest types during the life of the New Forest Management Plan and following an analysis of survey data.

Review of seedling planting: Over the last 10 years nursery raised jarrah seedlings have been planted beneath jarrah in some shelterwood areas and there have also been a number of research

trials. The survival and success of such regeneration should be reviewed and findings published during the first half of the New Forest Management Plan period.

Alternative regeneration strategies: The role of summer/autumn fire coincident with a viable canopy-stored seed crop should be investigated as a mechanism for establishing an adequate pool of regeneration on some shelterwood cut sites.

3.1.4. Uncertainties and Research Needs

Competition control and seedbed preparation: These issues have the capacity to become sensitive as the trade-offs between tree establishment and growth and the maintenance of biodiversity values are considered further. There is evidence of changes in native plant species abundance/cover as a result of excessive disturbance to the topsoil (scarification) and mechanical control of understorey competition (Burrows *et al.* 2002). Jarrah seedling establishment is favoured by practices that reduce competition from other species. Further research is required into jarrah seedling establishment, and soil/site types that prove to be a problem should be defined. The importance of applying fertilizers to boost survival should also be assessed and environmental impacts, if any, assessed. Alternative techniques of establishing regeneration, including the use of fire rather than mechanical disturbance, should be trialed on some sites.

Monitoring of species mixes and dealing with marri dominance: On some sites, marri tends to dominate the regrowth. Where this occurs, there is some uncertainty about whether the imbalance should be corrected and if so, how. From a commercial wood production perspective, this is a problem that may be exacerbated if higher proportions of marri are left standing in the absence of a marri woodchip market. The effect of overstorey species mix on biodiversity is not well understood. As habitat trees, there is no species preference shown by birds or arboreal mammals, although marri tends to develop more hollows than jarrah (Whitford 2002), is usually a prolific flowerer and the fruits are an important food source for species such as cockatoos. Ways of manipulating species composition particularly in areas where a shift to marri is believed to be occurring should be researched. Ferguson *et al.* (2001) noted that early non-commercial crown release (a form of thinning) has the potential to improve jarrah dominance in these (jarrah-marri) stands but this has yet to be evaluated because there are few stands of suitable age available. We understand that operational trials are proposed and we endorse this. Thinning trials should be conducted to determine whether jarrah's dominance status could be improved on some southern forest site types.

Regeneration in the eastern jarrah forest: While the guideline recognises the past difficulties with establishing regeneration and recommends making maximum use of existing regeneration, further research may be required into understanding the flowering phenology, seed production and natural recruitment strategies of jarrah to increase the likelihood of successful seedling establishment. Ongoing work to ensure that post harvest burn prescriptions will give satisfactory results is also required. This issue could escalate given the potential for decreasing rainfall (hence productive capacity) across the south-west region (IOCI 2001).

Dieback: Although many aspects of dieback caused by *Phytophthora cinnamomi* have been well researched in the jarrah forest north of the Collie River, the rate of spread and impact of the pathogen on some other vegetation types is poorly understood. An area of uncertainty is whether the pathogen affects seedling establishment and survival on some sites under particular conditions. The ongoing production of jarrah may be compromised with impacts on the sustainability of the industry. The analysis of regional regeneration survey data may assist with assessing specific impacts of dieback on regeneration.

Use of vegetation complexes: Use of the Mattiske and Havel (1998) vegetation complexes is incorporated in the dieback section of the guideline. While there are benefits in developing this approach, there are also some constraints that need to be overcome. An important benefit is in recognising that the jarrah forest is not homogenous and that different management approaches may be required in different ecosystems (landform, soils, climate and vegetation). A constraint is that very few people are familiar with the vegetation complexes. This can be remedied by training in the recognition of key indicator species and the development of simple field keys that help in the identification of assemblages. The concept of linking vegetation complexes with ecological vegetation systems, fauna habitats, fire management and silviculture is a good one and should be progressed.

3.2 Salinity Constraints

3.2.1 Strengths

The guideline maintains the current measure for salinity mitigation as jointly agreed to by the DCLM and Water and Rivers Commission. The current measures for salinity mitigation are based on a major research program that was undertaken to determine the impacts of timber harvesting on stream salinity. There is no basis by way of new evidence for changing these measures.

3.2.2 Weaknesses

The salinity mitigation measures are not clearly defined in the draft jarrah silviculture guideline. The definitions of concepts such as 'salt sensitive' and 'high salt risk' areas are unclear in the document. There needs to be either a section on management practices to mitigate salinity impacts or a separate document that is specifically focused on the salinity issue.

The management objective for water does not include other water quality aspects such as turbidity, particularly adjacent to water supply reservoirs. The importance of maintaining water quality in forests within water supply catchments needs to be strongly emphasised.

Insufficient attention is given to aquatic biota in the Water and Biodiversity objectives. There needs to be a more explicit recognition of biodiversity values encompassing the structural composition and functional integrity of aquatic ecosystems.

There is inconsistency between management objectives as specified in the guideline and those expressed in the current Forest Management Plan (DCLM 1994).

The specific requirements for stream buffers are not referred to in the guideline. The planning, design and operational requirements for stream buffers are not explicit. Given the importance of stream buffers, the guideline must make it very clear that diligent placement and protection of the integrity of stream buffers is paramount if water quality and the riparian zone vegetation is to be protected during and after logging operations. If these details are provided elsewhere, then the guideline should refer to other relevant documents.

Research into the relationship between stream buffers and aquatic ecology has found that stream salinity is a major determinant. Studies by Borg *et al.* (1998a and 1998b) found that changes to mean annual sediment concentrations and turbidity in the southern forests were only significant with no stream buffer. Growns and Davis (1991) showed that logging without buffers may cause changes to the composition of the macro invertebrate community of a stream for at least 8 years. These changes were considered to be due to the increase in stream salinity. More comprehensive investigations by Trayler and Davis (1998) found substantial changes to the invertebrate community of a karri forest clear-felled without buffers 5 years after logging. Sedimentation was

not an important factor in the invertebrate community changes. However salinity was considered a possible factor in the substantial changes to the invertebrate community.

The research on stream buffers and stream salinity has already been incorporated into the management responses with the protection measures to prevent saline discharges incorporating a permanent 50 m stream buffer on either side of the stream. However given that the research has shown that salinity changes can have substantial change on invertebrate communities it would be prudent to also include the intermediate rainfall zone (the high salt hazard zone) in any evaluation of stream buffers.

Roads are recognised as a major source of turbidity and the guideline should stress the importance of well-constructed and well-engineered roads for protecting water quality. The "*Manual of Management Guidelines for Timber Harvesting in Western Australia*" (DCLM 1999a) provides roading information and should be referred to in the guideline.

Application of chemicals such as fertiliser, pesticides and herbicides needs to be undertaken in such a manner as to ensure it does not affect water quality.

Prescribed burning for silvicultural reasons needs to take into account the potential impact on water quality, particularly where burns associated with timber harvesting are high intensity and burn stream buffer/riparian vegetation and humus layers to expose the soil.

3.2.3 Recommendations

Adaptive management: Review the need to change stream buffer prescriptions based on the results of research currently under way and on the results of monitoring. As a minimum standard, maintain current salinity and water quality guidelines with respect to retention of stream buffers and leaf area index (basal area) unless there are sound scientific reasons for change.

Stream zone protection: Consistent with adaptive management, strong consideration should be given to the recommendation in 3.3.4 below, which recommends the retention of mature forest habitat zones incorporated into stream zones. A representative sample of these should be monitored to assess their added effectiveness with respect to protecting water quality and stream ecology.

Research and Monitoring: The DCLM catchment study currently under way in the northern jarrah forest intermediate rainfall zone (IRZ) should continue and be expanded to incorporate aquatic biota. Water quality should be monitored at selected gauging sites within and downstream from areas of forest subject to logging. Automated gauging could measure flow-weighted and event-related salinity, turbidity and nutrients. From a water supply viewpoint, water quality should remain within guidelines for potable water while, from an ecological viewpoint, criteria for salinity, turbidity and nutrients should be developed as recommended in the ANZECC guidelines and account for known tolerance of local fauna. Monitoring of water quality would be a way of measuring the adequacy of logging and buffer prescriptions.

Biomonitoring has been shown to provide much more useful information about ecological condition of ecosystems than chemical monitoring. There is a range of methods for monitoring biological health of aquatic communities. The recent development of AusRivAS models, as the result of the national Monitoring River Health Initiative, provides a cost-effective method, with standardised methodology, for measuring the ecological health of streams. Monitoring ecological condition provides another measure of the adequacy of buffer prescriptions.

Monitoring should also occur with respect to compliance with buffer prescriptions. Existing evidence from the south-west and elsewhere suggests that the current buffer prescriptions are likely to be adequate to protect the water quality and ecology of most forest streams. However, it should be acknowledged that this has not been thoroughly tested. Where problems do occur, and the Panel understands that this is infrequent, they appear to be mostly the result of non-compliance with prescriptions. The extent of compliance with prescriptions should be audited. The prescription (in the guideline or other documentation) may also need to be better defined to account for some of the confusion in definition of buffer extent. Additional training may also reduce the risk of non-compliance.

3.2.4 Uncertainties and Research Needs

The major uncertainty remains the appropriate width of stream buffers. A recent review of the buffer prescriptions by Water and Rivers Commission identified some major changes. These recommended changes to the buffer width prescription for different stream types need to be evaluated. The Panel understands that operational-scale trials to examine the effectiveness of varying stream buffer widths on water quality and stream ecology are proposed in the draft New Forest Management Plan and endorses this action.

3.3 Habitat and Biodiversity Conservation

The importance of having clearly defined forest biodiversity conservation objectives, including for forests available for timber harvesting, has been emphasised above and elsewhere. The following objectives are a further development of those proposed by Burrows *et al.* (2001) and are presented here to assist with the evaluation of the extent to which the draft jarrah silviculture guideline accommodates biodiversity and habitat values.

Biodiversity is recognised as comprising of species diversity, genetic diversity and habitat diversity. The objectives proposed below largely focus on species and habitat diversity. Genetic diversity is implicit in species diversity and habitat diversity is represented by structural diversity and diversity of ecosystems, such as the vegetation assemblages of Mattiske and Havel (1998). Structural diversity, as well as being a coarse surrogate for biodiversity, is an important objective in its own right.

3.3.1. Proposed Biodiversity Conservation Objectives

At the whole-of-forest scale:

To maintain biological diversity and ecological process in ecosystems within the forest region. A CAR reserve system is an important strategy for achieving this.

At the landscape scale: A definition of a landscape:

"A mosaic where the mix of local ecosystems and landforms is repeated in a similar form over a kilometres-wide area. Several attributes, including geology, soil types, vegetation types, local flora and fauna, climate and natural disturbance regimes tend to be similar and repeated across the whole area" (adapted from Forman 1995). Scale is usually tens of thousands of hectares.

Forest landscape units (FLUs), derived from vegetation complexes, have been recently described and mapped by Mattiske and Havel (2002). The Mattiske and Havel (1998 and 2002) maps are based on climate, landform, soils and extensive quadrat-based sampling of vegetation so represent the most comprehensive, refined and biologically meaningful descriptors of forest ecosystems currently available.

Landscape scale conservation objectives: Take all reasonable measures to:

- *Maintain viable populations of native species throughout their natural range.*
- *Ensure a diverse representation of forest structures, habitat elements and seral stages through time and space.*
- *Protect ecologically sensitive communities and niches such as riparian zones, aquatic ecosystems, wetlands, granite outcrops and other non-forested complexes.*
- *Ensure maintenance of water quality.*

At the forest management unit scale: A definition of a forest management unit:
A spatial or administrative element within a landscape. It could be a (sub) catchment or an administrative management unit such as a forest block. It could contain a representation of landforms and ecosystems (or vegetation assemblages) common to the landscape unit. Scale is usually several thousand hectares.

Forest management unit scale conservation objectives: To take all reasonable measures to:
- *Ensure that no species declines to irretrievably low levels or to levels such that they are classified as threatened or vulnerable.*
- *Ensure that the capacity of the forest management unit to provide its natural range of habitat elements is not permanently compromised due to management activities.*
- *Ensure that an adequate proportion of the forest management unit retains mature or old growth overstorey structural characteristics or is within close proximity of a reserve that contains mature or old growth characteristics.*
- *Prevent soil damage and rehabilitate damaged areas such as landings.*
- *Prevent the introduction and spread of dieback due to management activities.*
- *Prevent the introduction and spread of weeds and other aliens such as foxes and rabbits.*

At the forest patch scale: A definition of a patch:
A discrete area of forest to which a single silvicultural treatment has been applied including a gap, an area cut to shelterwood or thinned. Scale may vary from a few hectares to several hundred hectares.

Forest patch scale conservation objectives: To take all reasonable measures to:
- *Ensure that the capacity of the patch to provide its natural range of habitat elements is not permanently compromised due to management activity.*
- *Retain adequate habitat trees and potential habitat trees and other critical habitat elements.*
- *Prevent soil erosion.*
- *Maintain the productive capacity of the soil by minimising soil damage (compaction, profile-mixing, and puddling).*

Threatened species and communities:
- *Conserve all populations of threatened species and communities.*

3.3.2 Strengths

The draft jarrah forest silviculture guideline has incorporated a number of significant recent findings from the Kingston Project and Burrows *et al.* (2001) including:

a) A revision of the guideline for habitat tree selection and retention in logged areas. The new guideline requires the retention of both primary (6 trees ha^{-1}) and potential (6-8 trees ha^{-1}) habitat trees and provides details on how to improve the selection and pattern of retention of these trees based on research findings of habitat use by arboreal fauna (Whitford 2001, 2002).

This has resulted in a doubling of the number of primary habitat trees to be retained and is a significant advance.

b) Protection and retention of balga (grass trees), which are important habitat for the threatened Western Ringtail Possum (WRP) *Pseudocheirus occidentalis* and other fauna, including some small mammals, reptiles and bats.
c) Advance burning to protect riparian vegetation and habitats from high intensity fires associated with post-logging (silvicultural) burns.
d) Post-logging intensification of fox control, especially where Western Ringtail Possums, or other vulnerable fauna, are known or thought to occur.
e) Retention and protection of adequate hollow logs as habitat.
f) Somewhat clearer guidelines with respect to the removal/reduction of understorey vegetation and non-commercial trees that may compete with jarrah and marri regeneration.

3.3.3. Weaknesses

It is the Panel's view that the guideline does not adequately address a number of key issues raised in the Burrows *et al.* (2001) Part 1 Report. As discussed above, the extent to which these issues should be addressed in the guideline, or elsewhere, is unclear to the Panel. Key issues include:

a) Soil disturbance and damage: The issue of soil conservation is addressed in other documents and the guideline should refer to these. Given the importance of soil to ESFM, the Panel is of the view that documentation pertaining to soil damage including the "*Code of practice for timber harvesting in Western Australia*" (the Code) (DCLM 1999b) and the "*Manual of Management Guidelines for Timber Harvesting in Western Australia*" (the Manual) (DCLM 1999a) require updating and expansion. The documentation (and practice) should deal with means of reducing soil damage as well as disturbance/damage assessment procedures, target standards and rehabilitation procedures. Forest officers in charge of timber harvesting and contractors should be well trained in aspects of soil conservation. Soil damage/disturbance originates from essentially two activities. The first is by way of collateral damage associated with machine activity during the felling and extraction of timber. Burrows *et al.* (2001) made several recommendations directed at reducing soil damage including avoiding wet soils, or winter logging, smart design and layout of snig tracks and landings to minimise machine traffic and disturbance and the evaluation of machinery with lower ground pressures.

The second activity that leads to soil damage/disturbance is the silvicultural practice of mechanically disturbing the soil to improve conditions for jarrah and marri seedling establishment, sometimes at the expense of the distribution and abundance of other non-commercial understorey and mid-canopy species. Attempting to enhance the regeneration and growth of jarrah and marri by mechanical soil disturbance to both reduce competition and to create a receptive seedbed is a form of disturbance that does not emulate, or is not analogous to in scale and intensity, any natural disturbance regimes or recruitment processes in jarrah forests. On some sites at least, the result in the short term is a reduction in the abundance of native understorey vegetation, a proliferation of short-lived weeds (Burrows *et al.* 2002) and a simplification of the structure of the lower strata (hence, habitat simplification). The extent to which this constitutes a problem for biodiversity in the medium to long term is unknown. Monitoring (FORESTCHECK) should provide better data on this. A record of how many hectares are so treated annually in different forest types may be informative.

Soil damage/compaction is most acute on and around log landings. The current practice of ripping and re-vegetation aims to rehabilitate landings. It is important that local species are used in the revegetation. The guideline lists species for landing rehabilitation that do not

naturally occur, or are likely to be off-site. For example, *Allocasuarina humilis* is listed for "western jarrah forests", but this could be well outside the naturally occurring range of the species, depending on the definition of "western jarrah forests". Species chosen for the rehabilitation must be aligned to their geographic range and to site conditions.

b) Silvicultural treatments; removal/reduction of competition: The draft jarrah silviculture guideline is more prescriptive than the earlier guideline, but the removal or reduction of 'competition', or other native understorey species, remains a concern. The basis of the concern is that understorey vegetation, including 'non-crop' tree species such as *Banksia* sp. *Allocasurina* sp., *Xylomelum occidentale*, and *Persoonia* sp., and non-commercial (culls) jarrah and marri, are important elements of the biodiversity in their own right because they provide structural diversity and in some cases become important habitat elements in young regrowth forests. It is recognised that species such as *Banksia grandis* and *Allocasuarina fraseriana* can form (unnaturally) dense thickets in response to previous logging/disturbance, hence restricting the establishment, regeneration and growth of jarrah and marri. As recommended by Burrows *et al.* (2001), clear and consistent definitions of what constitutes unacceptable competition (likely to prevent the establishment of regeneration) and how this should be treated are needed. The practice of reducing/removing competition to favour the establishment and growth of commercial tree species, on some sites, highlights the conflict between timber production and biodiversity. Decisions about what value takes precedence must be guided by higher order settings of values and principles that determine acceptable trade-offs. Sustained yield of wood cannot be maximised without the relative abundance of other species being affected.

c) Structural goals: Setting structural goals at various scales is important for both timber production and biodiversity conservation, the latter encompassing not only species and genetic diversity, but also habitat and ecosystem diversity. That is, structural goals are important in their own right (structural and habitat diversity is part of biodiversity) and as a surrogate, or coarse filter for the conservation of species diversity. The theory of maintaining a range of forest structures, age classes or successional stages as a surrogate for sustaining conditions for maintaining biodiversity has emerged largely from the boreal forests of the northern hemisphere. Following stand replacement disturbances such as fire or logging, some forests develop through a classic successional pathway with respect to the composition and structure of the overstorey and the understorey. For forest types that have a legacy of being even-aged at some scale, and which follow a post-disturbance successional pathway, setting structural goals is difficult enough, but achievable and desirable as each stage of development offers variety with respect to habitat and biodiversity.

Prior to 1829 the jarrah and jarrah/marri forests most likely existed as a predominantly uneven-aged forests with a mature overstorey, even at the finer scale. This was largely because of the resistance of the mature overstorey to synchronous and widespread destruction by natural forces such as fire and the fact that jarrah and marri do not depend upon infrequent, single pulse recruitment. Seedlings will establish continuously and relatively frequently following fire or other disturbances that do not partially or totally remove the overstorey. Jarrah and marri, unlike karri, can persist as ground coppice on the forest floor (beneath the canopy) for many decades developing an extensive root system and starch reserves to enable it to develop through to the next stage when there is an opening in the canopy. In forests not available for timber harvesting, these processes will continue, provided fire is managed appropriately. However, determining structural goals for jarrah/marri forests that are available for timber harvesting is more complex if the need to do so is to satisfy biodiversity conservation objectives. Timber harvesting since European settlement has altered

the age (size) class distribution of trees in much of the forest and contemporary silviculture (gap and shelterwood cutting) will eventually result in more areas/patches of even-aged regrowth forest. Therefore, at a coarser scale, the structure of the jarrah forest is more diverse now than in the past, largely as a result of decades of timber harvesting.

In theory, the enhanced structural diversity resulting from decades of timber harvesting could promote habitat diversity, hence biodiversity. Thus, a structural goal may be to obtain a well dispersed mosaic of forests at different seral stages after logging. At the appropriate scale, this should facilitate rapid recolonisation once a seral stage provides habitat features necessary to support a particular species (a sink), and there is a nearby source population. It is our view that the need to ensure an adequate proportion and distribution of structurally mature forest that contains a preponderance of large trees is important. This structural type, or seral stage, may take at least 140 years to develop following logging and is important habitat for arboreal mammals, some hollow dependent birds and probably some arthropods.

Clearly, adequate ongoing representation of mature forest with hollow-bearing trees is critical to structural diversity and to biodiversity conservation. It is consistent with the proposed objectives (above) and with the principles of ESFM. How much should be retained, where it should be retained and how structural goals are to be met into the future will require further discussion and analysis. Not only is the modelling quite complex, but each iteration will impact upon the area of forest available for timber production (hence sustained yield calculations). Over-riding this is the fact that the existing forest structure is a legacy of post-settlement activity, which will limit future options, at least for the life of the New Forest Management Plan. The process will involve analysis of the trade-offs with timber production and other values. In considering the level of retention of mature forest patches within forests available for timber harvesting, and consistent with the objectives proposed above, the Panel accepts that there will be reductions in the abundance of some species over some time period. However, consistent with the proposed objectives, the Panel considers that, at the forest management unit scale (see above), and therefore at higher scales, all reasonable measures should be taken to ensure that no species declines to irretrievably low levels as a result of management activities.

Contemporary jarrah forest silviculture has the capacity to create even-aged patches of regrowth, particularly in areas cut to gap, which, over time, could apply to considerable areas of forest available for timber harvesting. Areas currently cut to shelterwood may be cut to gap some time in the future when the regeneration beneath the shelterwood is adequate. The Panel acknowledges that varying harvesting rotations can assist in the meeting of structural goals without withdrawing forest from harvest. For example, it has been proposed to manage large areas of jarrah forest on a 220 year rotation, however it should be recognised that these forests may not necessarily provide the mature forest structure and old growth characteristics (structural complexity, hollows etc.) necessary for elements of the biota. Ongoing timber harvesting operations are planned for most of these areas (DCLM 2000). For example, after the initial cut to shelterwood, seed trees may be removed after 20 years, with thinning operations at 40, 70, 150 and 170 years post the initial cut to shelterwood. Gaps are created once more at 220 years. If the physical/mechanical reduction of competition within stands continues, together with the associated burning of debris to minimise risk of wildfires, then this could result in sustained impacts on many other animal and plant species if there are not local refugia. Retained areas of mature relatively undisturbed forest in such areas can take on local significance for the maintenance of biodiversity.

The retention of habitat trees, potential habitat trees and culls provide important refugia for some fauna, but it is unlikely to constitute an uneven-aged forest and it does not (structurally) constitute a mature forest. Therefore, current jarrah silvicultural prescriptions have the potential to create a spatial and temporal scale of even-aged regrowth forests, and a degree of functional homogeneity. Research and monitoring to date suggest that this is unlikely to adversely affect the majority of organisms but the suite of species that require mature forest structures could be disadvantaged if these are not provided for at appropriate temporal and spatial scales (see Burrows *et al.* 2001). It should also be acknowledged that little is known about the impacts of frequency of disturbance on soil microbes and invertebrates.

d) Retention of mature forest habitat refuges: The need for clearly defined structural goals is critically linked to issues of long term continuity of mature forest patches that provide refugia for key faunal elements within forests available for timber harvesting. While it may be argued that the substantial existing and proposed forest reserve system adequately provides for forest with old growth characteristics, there is a need to ensure the availability of mature stands with hollow bearing trees, as well as large hollow logs, on a local scale in or near forests available for timber harvesting. We are of the view that this is consistent with principles of ESFM and with the proposed forest conservation objectives at section 3.3 above. However, we also recognise that this will not be straightforward given the proportion of forest, including old growth forest, which is in the reserve system and the existing structural state of the forest after more than 150 years of timber harvesting and other activities. The spatial distribution of reserves is uneven with much greater reservation in the southern forests.

Long-term availability of mature forest patches is an important biodiversity conservation issue that will also have ramifications for timber harvest levels (as discussed above). This issue was discussed by Burrows *et al.* (2001) and was referred to by Christensen (1997) in his Regional Forest Agreement report to Environment Australia. Ensuring the ongoing availability of mature forest habitats at various spatial scales relates directly to the proposed forest biodiversity conservation objectives outlined at section 3.3.1 above.

As discussed above, timber harvesting since European settlement has altered the structure and size/age class distribution of trees in much of the jarrah forest. Generally, this has resulted in an increase in the number of younger, smaller trees, a reduction in the number of larger, older hollow-bearing trees, a reduction in the area extent of pre-settlement mature forest structures and changes in age/size class distributions. For example, the limited data available for the jarrah forest (e.g. Stoate 1939, Stoate 1940, Abbott and Loneragan 1986) show that virgin (uncut) jarrah forest usually contained about 30-45 trees (jarrah and marri) per hectare in the larger size classes (>65 cm diameter at breast height over bark - dbhob), compared with comparable forests that have been selection cut (about 19 trees per ha), gap cut (about 5 trees per hectare) and shelterwood cut (about 9 trees per hectare). No doubt there is variation around these figures across the range of the jarrah forest, but they serve to make the point that there has been a reduction in the number of large trees and mature forest structures over more than 150 years of timber harvesting in the jarrah forest. At the whole-of-forest level, this may not be a major concern given the extensive level of forest reservation. However, in the interests of ESFM, and consistent with the proposed forest conservation objectives at section 3.3.1, the key questions are:

- What are the biodiversity implications of this in forests available for timber harvesting?
- What are the appropriate spatial and temporal scales of retention of mature forest refuges to achieve the objectives specified at section 3.3.1?

- What are the impacts of this on timber production and on other components of ESFM including cultural, social and economic factors?

The Kingston Project (Burrows *et al.* 1994), which examined the impacts of timber harvesting on a jarrah forest ecosystem, revealed that most plants and animal populations were not significantly affected by logging (in the short to medium term). However, the project showed that logging had adverse impacts, at least in the short to medium term and at the local scale, on some bird species and arboreal mammals such as the Western Ringtail Possum and the Common Brushtail Possum (Burrows *et al.* 2001 and Adrian Wayne, *pers. comm.*). While the Common Brushtail Possum population appears to have recovered, Western Ringtail Possums and some bird species are still in a recovery phase (G. Liddelow, reporting on FORESTCHECK 2002; personal communication). The study also revealed that the temporary exclusion areas (TEAs or buffers) significantly buffered the impacts of logging operations on the fauna, including arboreal mammals and some species of birds at the broader scale and have contributed significantly to the relatively rapid recovery of birds, which is the rationale for the TEAs. Retaining habitat trees, logs and other elements in logged patches was also important supplementary habitat but this did not provide prime habitat or protection for some species, nor did it provide prime sources for recolonisation. It will be important to retain patches of mature forest to provide refugia for some species, including arboreals mammals and some birds, and sources for recolonisation as surrounding regrowth forest matures. The quality of habitat provided by regrowth forests (with retained habitat trees) at various stages of post-logging development for fauna that prefer a mature forest structure and that require hollows is not well understood. Current research and monitoring will provide better information on this over the next 4-5 years. Until this information is available, retention of these habitat elements at appropriate temporal and spatial scales is particularly important for threatened taxa, such as the Western Ringtail Possum, and also for other species whose habitat may be vulnerable to logging (see proposed conservation objectives at 3.3.1 above).

The Panel agreed that there are a number of ways of achieving structural diversity and retention of mature forest habitats at the forest management unit scale. Two approaches are presented below for consideration. The fact that we are putting forward different approaches underlines the point that in most cases where ecological management is being practised there is no path of certainty. What is being suggested is based on the best available knowledge at the present. In recognition of this we suggest that rather than doing the same thing everywhere all of the time, and consistent with adaptive management, that each of these options, and perhaps other practical options that may emerge from further discussion, be trialed and carefully monitored (see below). In addition, we recommend further ongoing research into other species that may have mature forest habitat requirements.

Option A: In response to the findings of the Kingston Project, Burrows *et al.* (2001) recommended, "*retaining mature (or old growth) patches of about 200 ha (minimum) in a matrix of regrowth forest on a forest block, preferably continuous or connected (eg, creek lines), should be considered until better information is available*".

Aside from structural goals (important in their own right – as discussed above) this is a particularly important consideration where threatened or taxa vulnerable to logging are known or thought to occur. Until better information is available it is prudent to take a precautionary approach consistent with landscape and forest management unit scale conservation objectives proposed at section 3.3.1. We recognise the shortcomings of being too prescriptive while not having access to other sources of data to properly evaluate the impacts of our recommendations on other values, particularly socio-economic values. On the other hand, we also recognise that

making vague recommendations are unlikely to be particularly helpful to the Conservation Commission or to further discussion on the issue. Bearing this in mind, we have attempted to be more definitive in our views with respect to retention of mature forest in areas available for timber harvesting, but suggest that the issue will require further discussion and analysis. The suggested area of retention by Burrows *et al* (2001) (minimum 200 ha) is based on limited data, namely the home range data for the Western Ringtail Possum (about 2-2.5 ha per animal) and limited data on viable population estimates for medium sized mammals (50-200 individuals).

Mature forest is characterised here as forest (as opposed to non-forested ecosystems) that meets the JANIS (1997) definition of old growth, or forest that has a mature overstorey (height and cover) and has a preponderance of trees in the larger diameter classes (for example, more than 15 trees per hectare >65 cm dbhob).

The retention rate is not based on a definitive understanding of the dynamics of metapopulations, but is a preliminary estimate by scientists who have studied in detail, the birds and arboreal mammals on the Kingston Project. In this study area (of some 11,000 ha with a history of mostly light selection cutting) about 30% of the area was logged during the study (of which about 50% cut to gap, 50% cut to shelterwood) with the remainder existing as either (largely) unlogged (in this cycle) temporary exclusion areas (TEAs), informal reserves (stream and road) or non-forest ecosystems. In order to maintain viable populations of arboreal mammals, including the threatened Western Ringtail Possum, scientists recommend retaining at least 20-30% of the unlogged (in this cycle) forest (including TEAs and informal reserves), which equates to about 14-21% of the total forest area (at this study site) (A. Wayne, personal communication). This should be retained at least until the recently logged and regenerated forest had recovered to a state where it provided good quality habitat for these animals. Space-for-time monitoring through FORESTCHECK and current detailed studies of the ecology and biology of the Western Ringtail Possum and the Common Brushtail Possum, should provide a better basis for managing metapopulations of arboreal fauna. The proposed levels of retention of mature forest habitats appropriate to the various scale objectives set at section 3.3.1 should be revised following the findings of this research and monitoring.

Under this option, it is suggested that retained habitats be added to the stream reserves and buffers. Riparian systems provide the best quality habitat and this may act as source areas for species displaying 'source-sink' population dynamics. Riparian systems also provide a high level of landscape connectivity, which is important for those species that form metapopulations. This approach also provides additional protection to streams both in terms of water quality and stream ecology and is manageable in the field. In landscapes not well dissected by streams and rivers, such as on some broad plateaux, then as a general rule, mature forest patches should be retained such that the boundary to boundary distance between them and the intervening regrowth forest is not greater than the dispersal capacity of threatened fauna or vulnerable species such as Western Ringtail Possums. The spatial distribution of mature forest refuges should also consider the proximity of formal reserves and the circumstances of discrete sub-populations of species that form metapopulations.

While we have provided some specific suggestions, further thought and discussion needs to be given to the area and spatial arrangement of mature forest refuges taking into consideration the formal and informal reserve system, current knowledge of the distribution, population dynamics and dispersal capacity of fauna that depend on mature forests, and of the implications for timber supply.

Option B: Regrowth forest is suitable habitat for the majority of forest fauna. A small minority of species require the presence of mature forest elements such as mature trees and large logs. To cater for these species there is a need to ensure that mature forest elements remain present across the forest in all major forest types.

There is in existence an extensive system of formal and informal reserves, but there are still large areas, especially in the north, that are comparatively distant from any reserves. In the future, these areas could become "*oceans of regrowth forest*" of varying ages separating "*continents*" of reserved forest. In the interests of ESFM, we need to ensure that there are "*islands*" with mature forest elements, within the larger "*oceans*". This is to ensure that those species that have a requirement for mature forest elements are able to continue to inhabit suitable areas across the entire forest, including the regrowth.

To cater for this requirement it is suggested that in areas of production forest that are 'remote' with respect to reserves, say more than 5km from any area of reserve of not less than 200ha, then provision is made to ensure that there is a continuing availability of mature forest elements. These 'remote' areas of production forest will already have varying percentages of informal reserves, protected non-forest areas, road, river and stream zones. Where these reservations, including formal and informal reserves, total less than 20% of any forest management unit or similar scale (as defined under the forest biodiversity conservation objectives proposed above), it is suggested that further additions of forest with mature overstorey structural characteristics be considered. These additions should comply with the following:

a. Additions together with other formal and informal reserves should total no less than 20% of the area of any forest management unit or similar scale.
b. Additions may be heavily selection thinned providing that there is retention of no less than 10-15% canopy of mature and over mature trees. Retained trees may include species other than jarrah, e.g. marri (*Corymbia calophylla*), flooded gum (*Eucalyptus rudis*), bullich (*E. megacarpa*) or *Melaleuca* sp.
c. Additions should, wherever possible, adjoin existing stream reserves or surround permanent or semi-permanent swamps, granite outcrops, areas of woodland, treeless flats and other non-forest types with high biodiversity value.

The aim should be to retain continuity of mature forest elements in a pattern across the regrowth forest to complement and form a link with the areas of formal reserves.

3.3.4. Recommendations

Soil conservation:

A change to 'dry' soil only logging will produce the greatest improvements in soil conservation and probably at the least cost to forest managers. Further research may be needed to develop an operational definition of 'dry' soil.

The manual (DCLM 1999a) and the code of practice (DCLM 1999b) should be revised and referred to in the final jarrah silviculture guideline. A revision should be based on best available knowledge, best practice and should at least clearly define a) the importance of protecting soil b) what constitutes soil damage c) acceptable physical and area limits to soil damage d) measures to be taken to minimise soil damage, e) rehabilitation techniques and f) the audit of rehabilitation measures.

Improve the frequency and standard of training in soil disturbance identification, assessment, management and rehabilitation.

Emphasise management to minimise soil damage rather than focus on thresholds. Encourage a softer approach to log extraction.

Improve attention to targeted rehabilitation of soil damage based on a systematic evaluation of damage of logged areas. Improve audit of rehabilitation measures.

Consider the development of global positioning systems (GPS) for locating logs and planning snig track design (see below).

Understorey vegetation conservation: Alternative techniques for establishing jarrah and marri regeneration that do not cause significant changes to the understorey composition should be trialed over the life of the New Forest Management Plan. These include use of fire under conditions conducive to the continuous establishment and growth of tree species over time in preference to soil scarification and physical reduction of understorey competition to create a pulse of regeneration in a short time.

Structural goals: The current Forest Management Plan (DCLM 1994) attempts to set structural goals for the forest. The extent to which these goals were met, the temporal and spatial appropriateness of these goals and the need to re-visit goals relevant to the New Forest Management Plan should be progressed. Structural goals should then determine the pattern of timber harvesting over the life of the plan. Ensuring an ongoing availability of mature forest structures in forests available for timber harvesting is critical for habitat diversity and species diversity objectives (see recommendation below). How much should be retained and where will require further discussion and spatial analysis. This should involve analysis of the trade-offs with timber production and other values.

Mature forest habitat refuges: Consistent with ESFM and with the forest conservation objectives proposed in section 3.3.1 above, mature forest habitat refuges should be retained at the forest management unit scale in forests available for timber harvesting in addition to habitat trees retained in logged and regenerated forests. These should be incorporated into the stream reserves or as viable strips linking stream reserves. The area and distribution of mature forest habitat refuges needs further discussion and analysis incorporating the latest biological knowledge, the proximity and extent of mature forest in reserves and the impacts of retention on timber supply and other components of ESFM such as socio-economic factors. Consistent with adaptive management, a range of options should be trialed over the life of the New Forest Management Plan.

Silviculturalist and Forest Ecologist: In addition to silvicultural expertise, the Forest Management Branch of DCLM should consider employing a forest ecologist to assist with the development, implementation and compliance of silvicultural guidelines, codes of practice, manuals and policies with respect to ESFM, with the interpretation and incorporation of research findings and with training.

4. Additional Comments

4.1 Purpose of Silvicultural Guidelines

Where silvicultural guidelines (and other guidelines, codes, etc.) fit in relation to the broader planning framework, how they integrate and align with other planning processes and their purpose with respect to broader forest management objectives, needs to be explicit. In reviewing the draft jarrah silviculture guideline the Panel took the view that, with respect to regeneration

adequacy, salinity constraints, habitat and biodiversity conservation, this guideline was the primary operational mechanism for managing these values in forests available for timber harvesting. There may well be other viewpoints. Some clarity may be provided and unanimity reached by a clear elucidation of the forest planning framework describing the purpose of each plan (guideline/code of practice etc.), where it fits in the framework and the alignments and linkages within the planning process.

The Panel notes that silvicultural guidelines are, "*designed to provide guidance to officers of the Department of Conservation and Land Management and the Forest Products Commission for the application of tree marking and silvicultural treatment*" (DCLM 2002). The draft jarrah silviculture guideline communicates what is to be done in the field. It is therefore important that agreed specific conservation objectives be stated clearly at the beginning of the document including the overriding objective that application of the ESFM system should deliver outcomes that mean the risks of environmental damage as a result of timber harvesting will be minimised. The document must remain focused on giving specific guidance to tree markers and staff responsible for ongoing protection of the ecological integrity of the forest. Definitions used in all DCLM documents must be agreed and then adopted universally. Definitions used in the draft jarrah silviculture guideline differ from those adopted in the new forest management plan discussion paper (Conservation Commission of Western Australia 2002). The objectives should also be complementary or consistent between key documents such as the New Forest Management Plan and the various silvicultural guidelines.

There may be merit in developing a comprehensive forest management manual that brings together relevant policies, practices, prescriptions, guidelines etc. In addition to enabling a consistent and logical management framework to be developed, one that facilitated integration and consistency between policies, prescriptions and activities, there may be other benefits, as noted by Bradshaw (2002);

- It would provide a 'one-stop' reference source of all information relevant to forest management in WA.
- Its preparation would provide an opportunity to resolve contradictions and trade-offs before policies promulgated.
- It would provide for an equal weighting of all values.
- It would provide the background philosophy to all aspects of management

Bradshaw (2002) also noted some disadvantages to this approach, most of which relate to logistical issues of preparing and updating such a document. However, if it was prepared and distributed largely in electronic format, via web sites, then many of these problems could be overcome.

4.2 Operational Safety and Economic Considerations

With regard to operation health and safety, the risks posed by selection logging systems in jarrah are generally acknowledged as not being as great as they have been for the logging of mature karri or mixed species stands in the south. Monitoring of accidents and ongoing exploration and evaluation of safety procedures and equipment is expected to continue, involving all relevant in-forest workers.

The Panel is aware that economic considerations can affect choice and implementation of harvesting prescriptions. Once large areas of marginal or low quality forest are scheduled for harvesting the costs of all necessary operations should be reviewed relative to the income to be

derived from the harvesting. The importance of residues and low quality logs being marketed from forests already of degraded log qualities should become evident from such an exercise.

The importance of residue markets must be stressed or the objective of ensuring regeneration, particularly in areas with high proportions of standing culls to sawlogs, may not be met. As mentioned above it is important that records are kept of areas essentially "cut to culls". At a later date greater uptake of residues may justify such sites being revisited to ensure regeneration. The effects of any long-term loss of marri residue markets may have to be evaluated during the life of the New Forest Management Plan. The costs of ensuring regeneration may have to be shared by different parties.

The Panel notes that the draft jarrah silviculture guideline for the eastern zone forests now prescribes that the trees to be retained should "*contain a sawlog only if there is not other suitable seed trees available*". It is understood that the intent of maximising sawlog removal in the first pass is to minimise incentive to return in the short term. This will allow for a longer period of recruitment of regeneration over several fire events as discussed above.

In considering how proposed conservation objectives may be met by the modification of silvicultural prescriptions the Panel has been aware that during the next plan period the native timber industry will contract due to greater reservation and the reduction of sustained yields, which will be calculated allowing for some level of uncertainty as outlined in Ferguson *et al* (2001). Recognising that the sustained yield has been dramatically reduced over the last 5 years, that further dramatic decrease in allowable cut could threatening the viability of the industry and that substantial areas of forest are/will be represented in the conservation reserve system, the Panel has attempted to provide advice that will ensure an ecologically and economically sustainable native forest timber industry. In many areas existing and proposed informal and formal reserves should mean that no additional forest will need to be withheld from logging but in some areas of the central and northern forest with a history of repeated logging and major disturbance it would be prudent to ensure mature forest is retained in patches across the landscape.

4.3 Cultural Heritage and Environmental Protection

Although the Panel was not asked to address the issues of cultural heritage and environmental protection these issues are inadequately dealt with in the draft jarrah silviculture guideline. The Panel is aware that the DCLM is developing policy documents for a range of cultural heritage issues. It may not be appropriate to include detail in the silvicultural guidelines themselves but DCLM must ensure that the policies and subsequent codes of practice are sufficient and give relevant practical guidance. The Ministerial Advisory Group on Karri and Tingle Management (Ferguson *et al.* 1999) concluded, "*a field guide on the Code of Practice concerning cultural heritage should be developed*". The Panel understands that such a document is being developed by DCLM.

Implementation of guidelines developed with respect to principles of ESFM highlights the need for DCLM to review the codes of practice relevant to jarrah forest harvesting and consider the production of guides for industry personnel such as contractors, otherwise the probability of objectives being met will decrease.

4.4 Informing the Public.

As stated previously the primary focus of the jarrah silvicultural guideline is on jarrah regeneration and treatments, which should enhance the growth of future crop trees. This is of particular relevance as the protection of the remaining old-growth jarrah forest means that all

future sawlog harvesting will occur in areas that have been largely selection cut in the past, often repeatedly. In addition to informing the public on how the guideline will accommodate wood and non-wood values, information should be provided about the risks associated with aspects of forest management. There will be some trade-offs with other values. These need to be identified and the public informed or consulted. For example, while many species will be unaffected, there will be temporary reductions in the abundance of some species for varying time periods after logging. The proposed forest conservation objectives need to be developed in consultation with the broader community. On some sites, jarrah regeneration to the standards required by the guideline may only occur following intrusive measures to reduce competition, which will have an impact on some understorey species. Such an approach may be justifiable but the Conservation Commission and the DCLM have the responsibility of ensuring that other values are not adversely affected in the long term and the conservation objectives are met.

4.5 Summary Remarks

The Panel recommends that the following be considered during the period of the New Forest Management Plan.

- Agreed specific conservation objectives should be stated clearly at the beginning of the silvicultural guideline including the overriding objective that application of the principles of ESFM and of ecosystem management should deliver outcomes that reduce risks of environmental damage associated with timber harvesting.
- Monitoring of accidents and safety in logging operations is to be expected to continue involving all relevant in-forest workers.
- The costs of essential operations to ensure regeneration in the eastern country should be reviewed relative to the value of timber being extracted. This should be done in terms of site potential as well as in terms of current operations.
- The effects of any long-term loss of marri residue markets may have to be evaluated during the life of the New Forest Management Plan. The costs of ensuring regeneration in areas with high volumes of unmerchantable trees may have to be shared by different parties. The Panel understands that the FPC is investigating new markets for marri residue.
- With respect to heritage and environmental protection the DCLM must ensure that the codes of practice are appropriate and give relevant practical guidance.
- The public should be informed of risks and uncertainties, e.g. that adequate jarrah regeneration may only be established on some sites following the reduction/elimination of competition by native understorey species and that some species will decline for a period after logging.
- The public should be consulted over the proposed conservation objectives in forests available for timber harvesting, which seek to retain viable populations of all species at various scales, but which recognises that there will be some declines in the abundance of some species following logging.
- Audits of implementation of post harvest treatments in different forest types should be conducted to assist in ongoing evaluation of the guidelines.
- A case for selection cutting in some areas could be justified. Some specific objectives for some different types of forest could be set and trialed during the plan with feed back such that guidelines could be readily be kept relevant in face of changing market conditions.
- It should be a condition of the New Forest Management Plan that DCLM have a full time experienced silviculturalist to develop and improve silvicultural and other forest management guidelines in liaison with the Forest Products Commission.

5 Research and Monitoring

This section is in three parts. Firstly, we identify operational trials that should be implemented, monitored and the results used to adjust management prescriptions (adaptive management). Secondly, we present a prioritised list of specific forest research issues, and thirdly we briefly comment on the FORESTCHECK monitoring protocol.

5.1 Adaptive Management Areas (AMAs)

Adaptive management, although not necessarily termed as such, has been practiced by forest managers for many decades. At a recent Science Forum organised by Murdoch University, the Conservation Council of Western Australia and the Conservation Commission, adaptive management was defined and discussed by a number of scientists who advised on the importance of adaptive management as part of the cycle of continuous improvement. They also suggested that adaptive management was not simply changing management when and if new research information became available, but rather, it also involved careful monitoring, recording and analysis of management activities and outcomes and about trying different things to see what worked and what did not. It was about having systems in place to quickly evaluate the impacts of management and adjusting activities accordingly.

Considering the uncertainties and risks associated with natural resource management, including timber harvesting, we suggest some bolder management should be attempted in a few places across the forest to provide opportunities to learn by doing. Provided this kind of management is based on a reasonable hypothesis and is carefully monitored, it will soon become apparent that extremes of management transgress the bounds of ESFM. Such trials could be established in formally recognised Adaptive Management Areas (AMAs), as have been developed in some North American forests. Ecosystem management should not be perceived as a 'recipe book' approach and scientists and managers must understand that a set of management tools, or guidelines, cannot be universally transferred to all ecosystems (Vogt *et al.* 1997). AMAs also serve to develop tools for conducting adaptive management, for demonstrating adaptive management, engaging stakeholders in on-ground forest management, and for engendering an adaptive management culture within DCLM and FPC. Operational scale trials that could be conducted in AMAs across a range of forest landscape units are outlined below. These are broad topics only; the details could be further developed in consultation with scientists, forest managers and other key stakeholders.

5.2 Operational Trials

Alternative regeneration techniques: In some circumstances, current regeneration methods may have some undesirable impacts on soils and understorey vegetation in forests cut to shelterwood to establish jarrah and marri regeneration. The role of fire, coincident with heavy seed years, and the absence of mechanical disturbance, should be trialed on a range of sites. The hypothesis under test is that over time regeneration can be established using natural processes with little adverse impact.

Competition control to enhance regrowth: Examine the cost effectiveness of various levels and techniques of managing understorey competition, including no post-logging silvicultural treatments and intensive treatments on a range of sites. The hypothesis under test is at some point, understorey does not constitute competition worth spending resources on.

Low impact logging: Continue investigating techniques to minimise the physical and area extent of impacts of logging on soils by trialing GPS systems for mapping and locating logs and for planning extraction routes. This minimises searching for logs by the skidder driver and reduces

'lost logs'. The hypothesis under test is that knowledge of where the logs are will reduce traffic and soil damage.

Managing overstorey species mix: On sites where marri appears to be dominating the regrowth, disproportionately to its status prior to harvesting, early non-commercial crown release trails could be implemented to improve jarrah dominance in these stands.

Effectiveness of stream buffers: Monitor the effectiveness of varying the width of stream buffers on water quality and stream ecology across a range of forests types, including in the intermediate rainfall zone. The hypothesis under test is that there is a point at which increasing buffer width does not provide water quality benefits.

Retention of mature forest habitat refuges: Vary the amount and spatial distribution of retained mature forest habitat refuges. Trial varying the retention rates of 'habitat trees' within regrowth forest as well as varying the size and distribution of patches of mature forest within regrowth forest. The hypothesis being that retention of mature forest in areas available for logging is important for sustaining viable populations of some groups of fauna at the forest management unit scale.

Diverse fire regimes: Vary the frequency, season and intensity of fire based on biological indicators. The hypothesis being that fire diversity promotes biodiversity.

5.3 Forest Research Priorities

In order to assist with determining forest research priorities, the Panel sourced recent (post 1998) documents that make reference to research needs, including the Dell Working Group Report (1999), the Dieback Research Advisory Committee (1999), the Regional Forest Agreement for Western Australia and Ferguson *et al.* (2001). We also solicited the views of a range of Western Australian biological scientists external to DCLM (see Appendix 2). We then prioritised these projects according to the criteria in Appendix 1. Research topics were arranged within the framework adopted by the new forest management plan discussion paper (Conservation Commission of Western Australia 2002), which is based on the Montreal Process (Criterion and Indicators) framework for ESFM, recognising that some topics could fit equally well in more than one criterion. Social, cultural and economic criteria are outside the terms of reference of the Panel, so are not included.

The proposed research priorities are summarised in the Montreal Criteria and Indicators framework in Table 1 below.

Table 1: Summary of high priority forest research needed to underpin ESFM in Western Australian jarrah forests. See also Appendices 1 & 2

Montreal Criterion	Research topic	Outcomes
Criterion 1: Conservation of biological diversity	Biological survey.	Basis for CAR reserve system. Inventory of forest biodiversity. Relationships between biotic and abiotic elements. Metapopulation structures.
	Long term effects of fire and logging on forest ecosystems, especially taxa known or likely to be sensitive to disturbance (eg, geophytes, cockatoos, owls, bats, possums, aquatic ecosystems).	Management practices that are consistent with ESFM. Response predictions. Identification of focal species and bio-indicators of effects of forest management.
	Identification of fauna that depend on habitats provided by mature forests with old growth characteristics.	Adequate retention of mature forest habitats throughout the forest region. Congruent with ESFM.
	Impact and control of *Phytophthora cinnamomi* (P.c.) in forest ecosystems. P.c – fire interactions.	Identification and protection of high conservation areas that are susceptible to P.c. Minimal spread of P.c.
Criterion 2: Maintenance of productive capacity.	Regeneration and recruitment strategies of jarrah across its range. Seedling planting, P.c resistant strains of jarrah. Role of fire.	Reduced risk of regeneration failure. Alternative regeneration techniques that minimise impacts on other values.
	Growth rates and form of jarrah and marri across their range	Improved growth models Improved timber yields
	Managing jarrah-marri stands where marri is dominant	Maintaining appropriate species mix for timber production and biodiversity values.
Criterion 3 Maintenance of forest ecosystem health.	Long term monitoring of impacts of P.c. Effectiveness of hygiene measures. Rate of spread of P.c. Efficacy of phosphite applications. Restoration of high impact sites.	Improved growth models. Reduced impact of P.c. on wood and non-wood values. Increased timber yield.
Criterion 4 Conservation and maintenance of soil and water	Ongoing monitoring and research into impacts of logging on groundwater hydrology, salinity, water quality in IRZ. Effectiveness of stream buffers	Protection of water quality, riparian zones and aquatic ecosystems. Forest hydrology models, predictions of effects of climate change.
	Characterisation and impacts of various levels of soil damage and disturbance on plant growth	Soil conservation code of practice, increased productivity.

5.4. Forest Monitoring

Ministerial Condition 11.1 specifically refers to the need to monitor the environmental impacts of jarrah silvicultural prescriptions on a representative range of treated sites. Monitoring is also referred to in other Ministerial Conditions, the Regional Forest Agreement, and other processes (see Burrows *et al.* 2001).

Monitoring is of fundamental importance for ensuring that management activities actually produce the intended outcomes with respect to management objectives. It is also important for 'continuous quality improvement' or adaptive management, and for gaining public credibility and confidence that forests are being managed in an ecologically sustainable manner. An over-riding objective is to minimise adverse and permanent environmental changes that may be associated with management actions. For these reasons it is important that the New Forest Management Plan continues a commitment to forest monitoring.

Using the knowledge gained from the Kingston Project, and via a series of internal and external workshops, the Science Division of DCLM has developed FORESTCHECK, a framework devised in 1999 to quantify, record, interpret and report on the status of key forest organisms, communities, and processes in response to both forest management activities and natural variation. Phase 1 of FORESTCHECK commenced in spring 2001 with the installation of FORESTCHECK monitoring sites in jarrah forests near Manjimup. Further sites will be established across the range of jarrah forest available for logging in the coming years.

The Panel is aware of the extensive consultation and workshops with scientists that has underpinned the present draft of FORESTCHECK. The strategy advocated is one that targets a broad range of organisms for initial monitoring at relatively few sites in logged jarrah forest.
This approach is based on the premise that it is difficult to forecast which organisms are least resilient to timber harvesting and, therefore, it is best to document as wide a range of species as possible in the monitoring program.

The Panel is satisfied that FORESTCHECK is workable and implementable. At a recent national meeting of the Australian Forestry Council's Research Working Group 10 (Native Forest Management), which focused on forest monitoring as one of the meeting themes, FORESTCHECK was recognised as the only comprehensive and institutional forest monitoring protocol in Australia and was suggested as a model for other agencies to investigate. Burrows *et al.* (2001) suggested that it might be unnecessarily complex in that it requires gathering a considerable amount of detailed information at relatively few sites. Resource limitations will constrain the number of sites, or replications, at which this detail can be gathered. A limitation of this approach is that it sacrifices geographical replication in favour of taxonomic comprehensiveness. The Panel was concerned that such a strategy overlooked a fundamental biogeographical attribute of the less fragile components of the jarrah forest biota – a relatively high rate of geographical replacement of species across the landscape. Indeed, this is a pattern for which the whole south-west botanical province is world-renowned.

Consequently, the Panel considered that a more strategic approach to monitoring would be to target a smaller number of species, or guilds, and achieve greater geographical replication across the jarrah forest. They suggested that the choice of species should focus on a) threatened and listed taxa, and b) those whose life histories and reproductive biology suggest low resilience to the impacts of timber harvesting based on the best available biological knowledge (indicator species). While such a strategy has the advantage of focusing effort on taxa most vulnerable to timber harvesting, there is a risk that present biological knowledge is insufficient to identify some such taxa at risk. Therefore, the Panel recommended regular review of this strategy under an

adaptive management model so that the list of monitored taxa remains current in terms of those least resilient to timber harvesting.

The Panel recommended a 12 month trial operation of FORESTCHECK on several sites where both strategies (that proposed by FORESTCHECK and that proposed by the Panel) could be evaluated to compare and contrast the cost-effectiveness of the two techniques. The trail should aim to identify indicators species, to evaluate their usefulness and utility, and to recommend which of the two strategies is most informative, cost-effective and representative. The results of this trail should be reported to the Conservation Commission and to the EPA. The Panel notes that the trial is under way and a report should be available towards the end of 2002.

Under the current proposal, FORESTCHECK does not address the monitoring of water quality and stream ecology. During the preparation of the protocol, it was felt that the science was not sufficiently advanced to devise a reliable, inexpensive monitoring protocol for water quality. However, recent modelling has shown that bio-monitoring can provide more useful information about ecological condition of ecosystems than chemical monitoring. Monitoring ecological condition provides another measure of the adequacy of logging and buffer prescriptions.

5.5. Recommendations

Operational Trials: Where practical and feasible, and following consultation with key stakeholders, the operational trials above could be implemented in designated Adaptive Management Areas and monitored over the life of the plan.

Research: There will always be a greater demand for knowledge than there will be resources to conduct the necessary research to gain the knowledge. The research issues listed in Table 1 are viewed as high priority strategic issues that need to be addressed to underpin the implementation of the New Forest Management Plan and to assist with ESFM planning and management during and beyond the life of the plan. The Panel suggests that the Science Division of DCLM prepare a cost estimate of this research over the life of the New Forest Management Plan. Both government and industry must provide adequate levels of scientific research funding. Partnerships and collaborations involving agencies such as DCLM, Water and Rivers Commission, WA Museum, CSIRO and local universities will result in the most cost-effective research programs.

Monitoring: Monitoring in the jarrah forest is not only a legal requirement (current Ministerial Conditions) but is a key to achieving ESFM. A commitment to monitoring (FORESTCHECK or the revised version), must be a clearly stated strategy in the New Forest Management Plan. Monitoring the ecological condition of selected streams needs to be a component of FORESTCHECK, but this will require additional resources.

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Appendix 1

Criteria for Setting High Priority Forest Research Needs

1. Relevance
    - to ESFM and forest management goals?
    - to Montreal Process Criteria & Indicators of ESFM?
    - is there a demand for results/findings?

2. Strategic importance
    - alignment with government policy
    - consistent with agency priorities?
    - alignment with forest plan?
    - what is already known?
    - how critical are findings to decision making?
    - scope?

3. Contribution to risk management
    - urgency of knowledge?
    - consequence of not doing the research?
    - potential issues?
    - low level research?
    - irreversible environmental outcomes?
    - economically efficient silviculture?

4. Feasibility
    - can results be achieved in acceptable timeframe
    - is it of immediate, high concern?
    - utility of results?
    - speculative/theoretical?
    - quality research, high standards, teamwork?
    - budget/resources available?

5. Achieves applied outcomes
    - results?
    - innovativeness?
    - widely applicable?
    - improves efficiency or quality of management?

6. Collaborative/catalytic?
    - suitability of project for honours or PhD investigation
    - potential for collaboration

Appendix 2

A summary of forest research projects identified by committees and scientists external to DCLM since 1998

Criterion 1: Conservation of Biodiversity

Dell *et al.* (1999)

1.1. There is a need for a systematic biological survey of the south-west forest region, especially the eastern jarrah forest and of the Blackwood Plateau jarrah forest.

1.2. Ongoing research is required on the effects of different fire regimes on forest communities and associated non-forest communities, particularly in the southern forest areas.

1.3. While research-to-date has provided valuable information, ongoing research is required to determine potential bio-indicators of influences of forest management practices on biodiversity values (at the genetic, species and ecosystem levels). Soil physical, chemical and biological components, bio-indicators and carbon cycling are areas for special attention.

1.4. There is a need to undertake research into soil damage and disturbance associated with logging activities to provide a sound basis for codes of practice and for monitoring.

1.5. Virtually nothing is known about bacteria in forests, and their role in the maintenance of ecological processes. Baseline surveys followed by monitoring and research are needed to provide information that can eventually be used for forest management and conservation purposes. Impact of disturbance, especially timber harvesting, disease and fire, should then be evaluated.

1.6. Significant gaps exist in the current knowledge base on the biodiversity of fungi. In terms of abundance and species diversity, this group is known to be an important component of the forest's biodiversity. Some fungi are also known to play an important role in various forest functions. Baseline survey followed by research and monitoring in relation to silvicultural practices is needed to provide the information necessary for sustainable forest management and conservation.

1.7. There is a need to continue and further develop research programs to gather information about taxa that are likely to be sensitive to logging, viz threatened taxa, arboreals and other hollow dependent taxa, geophytes, obligate seeders and some rootstock species. It is recognised that considerable progress has been made with the Kingston Project.

1.8. Monitoring and research projects such as that being conducted at Kingston block are producing valuable information on the impacts of forest management and operations on fauna bio-diversity. However, monitoring of faunal bio-diversity should be conducted across a representative range of sites available for logging, as proposed by FORESTCHECK. The monitoring programs should be linked to Ministerial Conditions and Recommendation 2.4 of the RFA ESFM report.

1.9. A survey and monitoring program is needed (as proposed by FORESTCHECK) to define the biodiversity of key invertebrate groups. Effort should focus on groups, which may include Gondwanan relictual species, and groups important in key ecological processes such as litter breakdown, nutrient cycling, pollination and predation.

1.10. Initial indications suggest that Western Shield is resulting in significant recovery of a number of critical weight range species including the Woylie, Southern Brown Bandicoot, Chuditch and Brush-tail Possum. Previous research on some of these species provided useful information on their ecology and habitat requirements. However, significant recovery of their numbers may result in alterations to some ecological processes such as

soil nutrient cycling, grazing and predation. It is recommended that the DCLM consider where monitoring and research may be required in order to maintain sufficient knowledge for managing other conservation values.

1.11. Recommendation 4.3 of the RFA ESFM report states that the DCLM should collate and maintain a database on forest soils and carbon. This should be done in order to establish and quantify what links exist between soils, carbon cycling and changes due to dieback impacts and could be a component of FORESTCHECK.

1.12 High conservation areas that are susceptible to *Phytophthora cinnamomi* (dieback) need to be identified for priority protection.

Ric How, WA Museum

1.13 Understanding the biodiversity in forest ecosystems (biological/ecological survey). Specifically; evaluate alpha and beta diversity in forest types with different management histories.

1.14. Appraising management impacts on diversity at the regional level.

1.15. Correlates of diversity and key ecological processes

1.16. Insights into key elements in the trophic webs of forests under different management regimes.

1.17. Impact of management on focal species.

Alex George, Consultant Botanist

1.18. Distribution and diversity of non-vascular plants (fungi, cryptogams etc.)

Dr Mike Calver, Murdoch University

1.19. Population trends in (indicator) vertebrate species (lists 22 species).

1.20. Detailed studies of two cockatoos and three mammals.

1.21. Impact of feral bees.

Dr Dale Roberts, University of WA

1.22. Interactions between fire, logging, dieback & fox control.

1.23. Metapopulation structure and movement patterns in forest fauna.

Professor Jonathon Majer, Curtin University

1.24. Establishment, maintenance and study of benchmark (undisturbed) forest ecosystems.

1.25. Independent analysis of timber yield data.

Dr Mike Bamford, Consulting Zoologist

1.26. At the species level: Impacts of logging on focal species such as black cockatoos, rufous tree creeper etc.

1.27. At the assemblage level: Long term impact of fire regimes, of logging and of dieback.

Dr Andrew Storey

1.28. Presence and effectiveness of stream/river buffers wrt aquatic ecosystems.

1.29. Effects of fire regimes on water quality, sedimentation and effectiveness of buffers.

1.30. Forest thinning/logging and salinity.

Professor Harry Recher, Edith Cowen University

1.31. Better understanding of the forest biota (distribution & seasonal abundance), database of forest biodiversity.

1.32. Long-term studies of spatial and temporal abundance of selected flora and fauna.

1.33. Long-term fire effects.

1.34. Identifying attributes of old growth forest and any biota that may depend on these.

Dr Per Christensen, Consulting Ecologist

1.35. Distribution and habitat requirements of forest bats
1.36. RTB cockatoos – survey, nesting requirements, where they nest
1.37. Stream fauna –what have we got? How is it affected by logging and burning?
1.38. Effects of fire and logging on macro fungi.

Dr Joanna Young, Consulting Pathologist

1.39. Dieback: Recovery of threatened species and ecological communities that are known or are perceived to be threatened by *Phytophthora cinnamomi*.
1.40. Limit the spread of *P. cinnamomi*. into areas where it may threaten biodiversity
1.41. Collation of information on communities (& species) being impacted and rate of disease spread.
1.42. Definition of high value conservation areas for priority control of dieback.
1.43. Further development of phosphite control methods.

Criterion 2: Productive capacity of forest ecosystems

Dell *et al.* (1999)

2.1. There is an on-going need to investigate the methods of successful jarrah and marri regeneration under different site conditions and the reliance on lignotubers as compared with seedlings. In particular, consideration is required on whether the growth form of jarrah at different sites and at different stages of development provides a sustainable resource for longer-term forest production. The syndrome known as 'carrot topping' in jarrah requires specific investigation.
2.2. There is a need to carry out research on a range of forest types to determine appropriate regeneration standards the different types of logging regimes with respect to regeneration adequacy and sustainable production. Further validation of methods for assessing the adequacy of regeneration is needed.
2.3. Ongoing research is required into potential relationships between silvicultural treatments, nutrient cycling and disease occurrence.
2.4. There is a need to monitor the growth performance of dominant logging species after different types of disturbance under different site conditions.
2.5. There is a need to investigate ways of managing species composition associated with regeneration treatments to ensure biodiversity and production objectives are met in future forests.
2.6. There is a need to investigate factors affecting growth form, especially in jarrah regeneration.
2.7. The impacts of dieback and invertebrate pests on wood production are not well understood. Where relevant, this aspect should be included in future pest monitoring and research programs.

Ferguson *et al.* (2001)

2.8. New growth models reflecting a wider array of silviculture and sites.
2.9. Utilisation of timber from shorter rotations and consequent impacts on yield schedules.
2.10. Carrot topping in jarrah regen.
2.11. Silviculture for mixed jarrah-marri stands where marri is dominant.
2.12. Survey techniques in different forest types and analysis of regen. survey data.
2.13. Seedling planting - survival and development.

Criterion 3: Forest ecosystem health and vitality

Dell *et al.* (1999)

3.1. Monitoring and research information is urgently needed to improve our understanding of the epidemiology of *P. cinnamomi* in soil, rate of inoculum spread and related aspects necessary to manage the disease.

3.2. Integrated monitoring sites, such as proposed by FORESTCHECK, are needed to develop an understanding of the links between forest production operations, the effectiveness of hygiene measures, dieback impacts, forest management practices and the conservation of bio-diversity and ecological values.

3.3. Information is required to ascertain whether phosphite can reduce the rate of autonomous spread of *P. cinnamomi* in jarrah forests.

3.4. Research is needed to tests surfactants, frequency of application and any other factors that would improve the efficiency of phosphite or other chemicals in controlling disease in a range of plant species and plants of different ages in the jarrah forest. Some monitoring is currently taking place in non-forested areas, but districts have limited resources and priorities appear to not be clearly defined. Resources and a mechanism for determining monitoring priorities are required.

3.5. Information is needed to determine whether phosphite has any long-term deleterious effects on bio-diversity particularly phyto-toxic effects on native plant communities in areas where frequent applications of phosphite might be needed for conservation or operational purposes.

3.6. The survival of resistant strains of jarrah and other species, as these are developed by the DCLM and associated institutions, should be monitored. The information is critical for understanding how they perform in a variety of field situations.

3.7. There is a need for quantitative data to assess the interactions of different fire regimes on the spread and intensification of dieback diseases in the jarrah forest.

3.8. There is a need to identify and initiate further long-term monitoring and research on the impacts of *Phytophthora cinnamomi* on different areas, plant species and vegetation communities throughout the jarrah forest, especially in southern forest communities.

3.9. Key communities and species that may potentially be impacted by vegetation changes following the introduction of *P. cinnamomi* need to be identified. Impacts need to be predicted, monitored, understood and managed.

Dieback Research Advisory Committee (1999)

3.10. Phosphite research (control of spread, phytotoxicity, optimal application regimes, pathogen tolerance, interaction with fire).

3.11. Phosphite mode of action.

3.12. Variation in pathogenicity across sites

3.13. Improved hygiene measures

3.14. Database of dieback research

3.15. Long term ecological impacts

3.16. Plant species resistance to P.c.

3.17. Host physiology and disease.

3.18. Inoculum levels and disease impact

3.19. Restoration of high impact sites

Criterion 4: Soil and water resources

Dell *et al.* (1999)

4.1. Ongoing monitoring and research are needed in the IRZ to investigate the extent to which logging might result in changes to groundwater hydrology, salinity and other water quality/hydrological parameters.

4.2. Aquatic invertebrates should be monitored in relation to forest management practices and operations (FORESTCHECK), where there is the potential for changes in water quality and hydrology parameters. Plans to expand the Monitoring River Health Initiative into forest areas will help, but further monitoring is needed to develop an understanding of processes and impacts in lower order tributary streams.

4.3. Forest hydrology models are needed to predict likely hydrological changes at the regional level following logging under various climate regimes and seasonal influences, and to assess the potential impact on aquatic organisms.

Research & Information Needs:- Other

Dell et al. (1999)

1. There is a need for better warehousing, dissemination and management of scientific data and knowledge.
2. There is a further need to integrate research findings into the development of ecological sustainable forest management practices. The latter could be developed through greater integration of data and research planning. Further, the limitations of "retrospective" (or chronosequence/space-for-time) monitoring need to be understood and taken into account when designing programs.
3. In future, researchers should consider more process type studies and better integration of research and monitoring in different forest ecosystems with operations and management as a means of developing ecological sustainable forest management practices.
4. Ongoing monitoring of fauna and flora (threatened) species recovery plans is needed. The purpose of and priorities for monitoring need to be clearly defined.