1 Background

1.1 INTRODUCTION

The competing demands of conservation and industry on our forests have been an area of debate and controversy for more than two decades. The National Forest Policy Statement (Commonwealth of Australia 1992), agreed by the Commonwealth, State and Territory governments in 1992, provides the framework for a long-term solution to this issue.

The NFPS sets out the process for undertaking joint Commonwealth and State Comprehensive Regional Assessments (CRAs) of natural, cultural, economic, and social values of Australia's forests. These assessments will form the basis for the negotiation of Regional Forest Agreements (RFAs) between the Commonwealth and State governments. A joint regional assessment of national estate values in the Southern Forest Region in 1990 by the Australian Heritage Commission (AHC) and the Department of Conservation and Land Management (CALM) provided a model for the approach to later CRAs under the NFPS.

Regional Forest Agreements will encompass:
- the establishment and management of a forest reserve system which is comprehensive, adequate and representative;
- ecologically sustainable management of the forest estate; and
- the development of an efficient, internationally-competitive timber industry.

RFAs are agreements between the States/Territories and the Commonwealth and recognise the range of economic and environmental obligations which each government has regarding the long term management and protection of forest values in specific regions. RFAs are intended to provide stability through the establishment of a sustainable resource base for industry, while at the same time ensuring the protection of Australia's biodiversity, old growth and wilderness through a comprehensive, adequate and representative (CAR) reserve system and complementary off-reserve management.

A central aim in the RFA process is to recognise and consider the full range of forest values when making forest resource use decisions. This reflects the need to consider both benefits and costs when making policy or resource use decisions.

1.2 LEGISLATIVE AND POLICY FRAMEWORK FOR THE RFA PROCESS

There is a range of legislative obligations and policies at the Commonwealth and State levels that forms the framework for the RFA process. RFAs are intended to recognise and meet the legislative obligations and policies of both governments.

The National Forest Policy Statement (NFPS)

The NFPS defines the policies of State and Commonwealth governments in relation to the RFA process and its objectives. The NFPS sets out the vision of the Commonwealth and State governments for Australia's forests and forest industries based on the principles of ecologically sustainable forest management. The elements of that vision are described in the NFPS and comprise the following:

- forest conservation;
- wood production and industry development;
- integrated decision making and management;
- private native forests;
- plantations;
- water supply and catchment management;
- tourism and other economic and social opportunities;
- employment, workforce education and training; public awareness, education and involvement;
- research and development; and
- international responsibilities.

National reserve criteria (JANIS)

Following signing of the NFPS, an intergovernmental Technical Working Group on Reserve Criteria was established in 1993 to draft the national criteria required by the NFPS, under the Joint Australian and New Zealand Environment and Conservation Council (ANZECC)/Ministerial Council on Forestry, Fisheries and Aquaculture (MCFFA) NFPS Implementation Sub-committee (JANIS). The Technical Working Group comprised representatives from Commonwealth and State forestry, conservation and scientific agencies.

A report by JANIS, *Proposed Nationally Agreed Criteria for the Establishment of a Comprehensive, Adequate and Representative Reserve System for Forests in Australia*, was released in mid-1996 and public submissions were invited. Following consideration of these submissions by JANIS, the criteria were finalised and Ministers from ANZECC and MCFFA have now endorsed these criteria.

The National Reserve Criteria include provision for the protection of biodiversity, old growth and wilderness, as well as recognising the role of off-reserve management in meeting conservation objectives. Further details of the criteria are provided in the biodiversity, old growth and wilderness chapters of this report.

Commonwealth legislation

The Commonwealth's principal involvement in forest issues derives from the *Export Control Act 1982* which regulates the export of woodchips and unprocessed wood. In assessing applications for export licences under this Act, the relevant Minister is required to ensure that a range of Commonwealth legislative obligations is met. The major legislation includes:

- *Export Control Act 1982*;
- *Endangered Species Protection Act 1992*;
- *World Heritage Properties Conservation Act 1983*;
- *Australian Heritage Commission Act 1975*; and
- *Environment Protection (Impact of Proposals) Act 1974.*

Western Australian legislation

The NFPS recognises that State and Territory governments have constitutional responsibility for land use decisions and primary responsibility for forest management. To fulfil this responsibility the States and Territories have enacted legislation that allocates forest land tenures and specifies the administrative framework and policies within which public and private forests are managed. The major Western Australian legislation includes:

- *Conservation and Land Management Act 1984*;
- *Wildlife Conservation Act 1950*;
- *Mining Act 1978*; and
- mineral-based Agreement Acts.

A list of the Commonwealth and State legislation relevant to the RFA process is provided in Appendix 1.

Indigenous issues

The RFA process addresses indigenous issues in two distinct ways: consultation on the outcomes and process in general (as part of the wider consultation process); and on cultural heritage, through the national estate assessment.

As with all communities and stakeholder groups with an interest in the Western Australian RFA, Aboriginal communities in the region and appropriate representative bodies are already involved and will continue to be consulted throughout the RFA process.

The *Native Title Act 1993* recognises and protects native title rights and interests. In recognition of this Act:

- where any government action to implement an RFA could affect native title, the action will be taken in accordance with the *Native Title Act*; and
- an RFA is not intended to influence in any way native title claims that may arise.

1.3 THE RFA PROCESS IN WESTERN AUSTRALIA

Background

During 1995, the Commonwealth and the States of New South Wales, Victoria, Western Australia and Tasmania undertook a process of identifying Deferred (or Interim) Forest Areas in order to provide interim protection for forests that may be required for a CAR reserve system while RFAs are being completed.

A Deferred Forest Agreement (DFA) between the Commonwealth and Western Australia was signed in July 1996. At the same time, the Prime Minister and Premier also signed a Scoping Agreement setting out the administrative and operational arrangements for undertaking a CRA and developing the RFA for the South-West Forest Region, as well as committing both governments to establishing processes and timetables for the completion of the RFA.

The RFA process is managed by a Joint Commonwealth-Western Australian Steering Committee, supported by technical committees.

Stages in the RFA process

The major stages in the RFA process are outlined below.

1. Project planning
   —including an analysis of gaps in data, data evaluation and accreditation.
2. Filling of data gaps and developing agreed methodologies for the CRA.
3. Assessment phase
   —assessments undertaken for the South-West Forest Region CRA, which are described in this report, include:
   - timber production and other forest products;
   - tourism and recreation;
   - water resources;
   - mineral resources;
   - social values;
   - biodiversity;
   - old-growth forests;
   - wilderness;
   - national estate;
   - world heritage; and
   - ecologically sustainable forest management.

   The CRA provides a synthesis of the information on which the RFA can be developed and agreed between the Western Australian and Commonwealth governments. References to any technical papers relevant to the assessments are provided.
4. Integration and options development phase
   —during the integration phase, information from the assessments and public consultation will be brought together to identify and analyse issues that need to be addressed in the development of RFA options for public comment.
5. RFA options report
   —production and release for public comment. Opportunities for consultation with the community and stakeholder groups will be provided following the release of the options report. With this in mind, a series of workshops will be held in the south-west and in Perth over the next few months. The consultation process is designed to focus discussions on the issues that need to be addressed in the RFA. The first workshops will familiarise stakeholders with the information contained in the report. Any deficiencies identified in the data or methods at that stage will be taken into account in the development of the RFA. The options report will be released for public comment.
6. RFA finalisation
   —following conclusion of the public comment period and consideration of submissions, the Commonwealth and Western Australian governments will develop and negotiate the Regional Forest Agreement, which is scheduled to be completed in early 1998.

2 The South-West Forest Region

2.1 LOCATION

The South-West Forest RFA Region extends from near Gingin in the north-west to near Denmark in the south-east. The western boundary follows the foot of the Darling scarp and excludes the Swan coastal plain. The eastern boundary follows a line between Northam and Rocky Gully which approximates the gradation from tall forests to woodlands (see Map 1).

The region includes 30 shires and the major towns are Toodyay, Dwellingup, Boddington, Harvey, Collie, Donnybrook, Bridgetown, Nannup, Margaret River, Manjimup, Pemberton, Walpole and Denmark.

2.2 GEOLOGY, LANDFORMS AND SOILS

The south-west forests lie on the margin of the Great Plateau which is composed of ancient Precambrian granitic rocks, partially overlain by sediments. A weathered lateritic mantle overlays both the granitic and sedimentary rocks. Small areas of unconsolidated sediments, usually grey sands, occur in a variety of topographic positions.

In the south of the region, the Great Plateau slopes towards the Southern Ocean and forms part of the Ravensthorpe Ramp. Most of the plateau is of low relief with an elevation of 280 to 340 metres. Granitic monadnocks are sometimes exposed as emergent features above the plateau surface. Prominent examples are Mt Randall, Mt Cooke, Mt Chudalup and Mt Frankland. An area known as the Donnybrook Sunkland, which occurs between the Dunsborough and Darling faults, is a southern extension of the Perth basin.

Broad ridges of Tamala limestone are prominent features of the southern coastal zone. They rise to 100 metres and often act as barriers behind which estuaries such as Wilson Inlet and Broke Inlet have developed. Much of the south coast is characterised by small embayments with granitic headlands and steep limestone cliffs. These bays are less common on the west coast.

Eighteen major rivers drain the region. Most streams that arise in the region have a characteristic sequence of valley forms, from broad, flat and swampy headwaters through several stages of dissection to deep channels. The major rivers and streams are sluggish in their lower courses.

Jarrah-marri forest occurs primarily on the lateritic soil profile which consists of about 0.5 to one metre of gravelly sandy loam topsoil overlying a concretionary zone of ferruginous and aluminous horizons of ironstone gravels in a yellow-brown sandy loam matrix up to five metres thick. Beneath this, deep kaolinitic clay extends up to 30 metres to bedrock. Massive ironstone duricrust pavements are common just below the surface of lateritic soil near ridge tops and on some slopes.

Younger red earths and podzolic soils occur in the more dissected southern landscape. These soils support karri-marri forests or, where rainfall is insufficient, forests of yarri or jarrah. Sandy soils often develop downslope of laterite ridges. These sands generally support low woodlands of *Banksia* spp. or *Allocasuarina fraseriana*. Leached sands occurring in broad drainage lines support heath or sedge communities.

The relationship between soil and landform units and vegetation patterns in the region is described by Mattiske (1997 and in prep.).

2.3 CLIMATE

The climate of the south-west forests area is Mediterranean with warm dry summers, mild wet winters and occasional frosts.

Rainfall in the northern part of the region ranges from 635mm at the eastern margin to 1300mm about 10 kilometres east of the Darling scarp, reflecting the rain shadow effect of the escarpment. Average annual rainfall in the southern part of the region exceeds 1400mm in some areas, but there is a marked

declining gradient with distance from the coast. Seasonal summer drought for four to six months of the year is commonly experienced in the northern part of the region. Rainfall and strong winds caused by northern cyclonic conditions are often experienced during the autumn months. The seasonal drought is not as pronounced in the southern forests, where occasional summer rains are experienced.

Average maximum temperatures in the hottest month, February, are about 30ºC and average maximum and minimum temperatures in the coldest month, July, are about 15ºC and 5ºC, respectively.

Thunderstorms and lightning caused by strong convection activity associated with trough instability can be expected about three times per month from October to April (Gentilli 1989). This lightning activity coming in the drier months creates very high risks of forest fires. Strong winds associated with this period of instability add to the risk of fire ignition and intense fire behaviour in forests of the south-west.

Six climatic zones, related to rainfall and evaporation, were developed by Gentilli (1989). Mattiske (1997) concludes that there is a consistent relationship between these climatic zones and patterns of vegetation in the region.

2.4 VEGETATION

The vegetation of the south-west forests is influenced by its links to past events. The forest boundaries have moved considerably during geological history. Paleological evidence suggests that the vegetation once contained *Nothofagus, Araucaria, Agathis, Dacrydium* and *Podocarpus*, and that the forests were more similar to the temperate rainforests of modern-day Tasmania and New Zealand (Churchill 1961). The pollen record suggests that subsequent to the period of temperate conditions, there were periods of marked rainfall fluctuation.

Evolutionary and genetic studies of the living flora suggest that the region contains many relictual taxa. However, some groups appear to have undergone active recent speciation. It would appear that for woody genera, active speciation has been concentrated in the transitional rainfall zone, while the wetter areas have provided a refugium for the persistence of relictual taxa. For annuals and perennial herbs, on the other hand, the region has been a major centre of speciation (Hopper et al. 1992).

Jarrah-marri forest occurs uniformly on lateritic soils throughout the northern part of the region and also in the south where annual rainfall ranges from 900mm to 1100mm. The overstorey is dominated by jarrah and marri with minor occurrences of yarri, bullich and flooded gum. The most dominant small trees in the understorey are bull banksia *(B. grandis)* and sheoak *(Allocasuarina fraseriana)*. The sclerophyllous understorey vegetation superficially appears uniform. In reality it is a complex multi-dimensional continuum of species responding to a number of environmental variables (Havel 1989).

Karri forest occurs in the extreme south-west of the region within the 1100mm rainfall isohyet south of a line from Nannup to Denmark. Two main outliers occur, one on soils derived from coastal limestone at Karridale, the other on soils derived from weathered granite on the Porongorup Range north of Albany.

The distribution of karri within its main range is closely related to the presence of younger soils and topography (Bradshaw and Lush 1981). In the north-western parts of its range, in the Donnelly River valley, karri is typically found in incised valleys. Farther up-slope it occurs in mixture with marri, and on the ridges it disappears, being replaced by jarrah. Farther to the south, particularly in the catchment of the Warren River, where the landscape is more dissected and the rainfall is greater, karri extends from the valley bottom to the mid and upper slopes.

In the far south where the land was once subject to inundation by the sea, there are now widespread deposits of sandy soils, forming extensive seasonally inundated flats, supporting scrub and sedgeland communities. In this landscape karri occurs in the red earths that have developed around and below granitic outcrops. It is also found along the valleys of rivers which have dissected the sandy flats.

Extensive forests of karri and marri mixed with yellow tingle *(E. guiolfoylei)* and red tingle *(E. jacksonii)* occur on yellow and red duplex soils derived from the old land surface which outcrops along the south coast near Walpole and Denmark. Elsewhere, on weathered and less fertile soils within the 1100mm isohyet, jarrah or jarrah-marri forests predominate. Poorly drained sites and sands along the coast support a range of woodlands, heathlands and sedgelands. Small areas of yarri occur on the fresher soil where the rainfall is 900 to 1000mm. Areas of wandoo *(E. wandoo)* forest and woodlands occur on the clay soils in the north-eastern sector of the region where the rainfall is below 900mm (Christensen 1992).

The wide range of soils, together with climatic and topographic influences are reflected in the recognition of a high number of plant formations, association and vegetation complexes. Mattiske (1997) describes 30 vegetation classification and mapping systems carried out in the region. A comprehensive map of vegetation complexes developed by Mattiske (in prep.) for the Comprehensive Regional Assessment is described in detail in Chapter 12 of this report. More than 300 vegetation complexes are described within the region.

Bradshaw et al. (1997) published maps of 22 forest associations based predominantly on air photo interpretation of overstorey species. Bradshaw and Mattiske (1997) prepared a map of 30 forest ecosystems for the RFA region based on both overstorey and understorey composition. This mapping is described in Chapter 12 and shown in Map 12.

2.5 SIZE AND TENURE

The South-West Forest Region covers approximately 4.25 million hectares. Private land covers about 1.87 million hectares, or 44% of the region. The private land is mostly cleared and is used for a range of agricultural pursuits including dairy, beef cattle and sheep grazing, horticulture, viticulture, orchards and tree plantations.

Public land makes up about 2.38 million hectares, or 56% of the region. The public land is covered mostly by native forest and some tree plantations.

Conservation reserves (national parks, conservation parks, nature reserves and 5g reserves) as proposed in the 1994 Forest Management Plan occupy 31% of the public land or about 745 500 hectares. State forest occupies about 1 519 200 hectares, or 64% of the public land. Informal reserves within State forest occupy 314 900 hectares or 13% of the public land. The remaining public land as shown in Map 1 includes Commonwealth land, vacant Crown land and Crown reserves (see Table 2.1).

Table 2.1 Statement of land within the RFA region

Land category		Area	%
(A) CALM –	managed land		
	formal reserves	745 500	18
	informal reserves	314 900	7
	remaining State forest	1 204 300	28
	Total CALM managed	2 264 700	53
(B) Other public land			
	Commonwealth land	16 300	0.3
	vacant Crown land, pastoral lease, CALM misc. reserves	29 600	0.7
	Crown reserves	77 300	2
	Total other public land	123 200	3
(C)	Private property	1 868 500	44
Total area of RFA region		**4 256 400**	**100**

Notes:
1. Formal reserves include national parks, conservation parks and nature reserves including those proposed in Forest Management Plan (1994-2003).
2. Informal reserves include corridors on rivers, streams, travel routes, the Bibbulmun Walk Track and diverse ecotype zones.

2.6 POPULATION

The South-West Forest Region had an estimated population of 154 429 in the 1991 Census. The population of the 44 largest towns in the region was 127 316 in 1991 and 127 388 in 1996.

There are no cities within the RFA region, although the boundary includes part of the City of Armadale. The cities of Perth, Bunbury and Mandurah lie just outside the boundary of the RFA region. Collie is the largest township with a population of 7290. There are 11 towns with a population above 1000 people, including Augusta, Bridgetown, Boddington, Donnybrook, Harvey, Manjimup, Margaret River and Waroona and 22 smaller towns with a population between 100 and 1000 people.

2.7 REGIONAL ECONOMY

The South-West Forest Region supports a wide range of industries including agriculture, mining, mineral processing, manufacturing, hardwood and plantation timber milling, wood processing, recreation and tourism, and minor forest product industries such as finewood craft, beekeeping and floriculture.

Employment

The share of Western Australia's employment within the RFA area in 1996 was 19.2% compared to 18.5% in 1991. There are significant numbers of employees who work in the forest areas but who live outside the RFA region in coastal cities such as Bunbury, Mandurah or Perth. There are also workers who live outside the RFA region who work in industries whose raw materials and resources come from the RFA region. This includes bauxite refined at Kwinana, Wagerup and Pinjarra or timber processed in Bunbury and Perth. A summary of employment by sector for the RFA region is included in Chapter 11.

Output

The major industries in the RFA region contributed $8896 million to Western Australia's Gross State Product for 1995-96, compared to $6388 million in 1990-91. Agriculture, forestry and fishing contributed 10.4% of GSP, mining 14.4% and manufacturing 12%. Estimates have also been made of each industry group within and adjacent to the RFA area.

Trade

The value of exports from Western Australia of the mineral products produced in the RFA region in 1996/97 was $5.8 billion. The value of gold exported was $3.18 billion and alumina exports were valued at $1.7 billion.

Total exports from Western Australia in wood and wood-based products in 1996-97 was $123 million.

Agriculture, viticulture, tourism and other forest-related products also contributed siginifantly to the Western Australian economy and exports.

3 Multiple use forest management

3.1 LEGISLATION

The *Conservation and Land Management Act 1984* (the *CALM Act*) is the principal Act providing for multiple-use management of publicly-owned forested land in south-west Western Australia. Activities in these forest areas are also regulated by a range of other legislation.

CALM Act

The Act applies to State forest, timber reserves, national parks, conservation parks, nature reserves and any other landed vested in either the Lands and Forest Commission or the National Parks and Nature Conservation Authority.

On publicly-owned land the *CALM Act* stipulates only "necessary operations" shall take place in the absence of a management plan. For the preparation of a management plan the Act nominates the objectives for management of each tenure category thus providing increased levels of protection. The objectives for each tenure category are:

- State forest—conservation, recreation, timber production on a sustained yield basis, water catchment protection or other purpose prescribed by the regulations;
- national/conservation parks—fulfill the demand for recreation consistent with proper maintenance and protection of flora, fauna or cultural feature;
- nature reserve—maintain and restore the natural environment and to protect, care for and promote the study of flora and fauna and preserve any cultural feature.

Planning for multiple use of public land is achieved through the process set out in Part V of the *CALM Act*. Plans prepared under this part of the Act must comply with the management objectives set out in the Act, be for a maximum period of 10 years and be put out in draft form for public comment. The current plans for public land forests are the Forest Management Plan 1994-2003 and its precursors the Northern, Central and Southern Forest Region Management Plans published in 1987.

There is no legal requirement for planning forest management on private land unless it is enforced through conditions applied through formal approval of treatment of forest on protected catchments. A voluntary code of practice for timber plantations on private land provides guidelines on the contents of a management plan.

Forest Management Plan 1994-2003

In 1994, following public consideration of a draft, CALM published a 10-year plan for the south-west forests titled Forest Management Plan 1994-2003. This plan was designed to provide for multiple use of the forest within the framework of ecological sustainability. The plan incorporated the elements of two other documents published in draft form at the same time, the draft Nature Conservation Strategy and the joint CALM/Australian Heritage Commission study *National Estate Values in the Southern Forest Region of South-West Western Australia*.

The plan recognises the following key values required by the public from the forests:

- nature conservation;
- water;
- timber;
- recreation and tourism;
- community education and interpretation;
- natural and cultural heritage;
- minerals; and
- other products such as honey, wildflowers, seeds, grazing.

To provide for these values in an ecologically-sustainable way the plan enhances components of the following broad strategy:

- Establishment of a representative reserve system.
  Additions are proposed to the reserve system (tenures of national parks, conservation parks and nature reserves where disturbance to the forest is required to be minimal). This improves the representation of some vegetation complexes, incorporates representation of national estate values identified in the joint CALM/AHC study and protects a potential water storage site.
- The identification and protection through zoning of "special" areas within forest available for disturbing activities (tenures of State forest and timber reserve).
  Special areas include stream sides for water quality, nature conservation and recreation/tourism protection, rare ecotypes for nature conservation protection, travel routes and view-sheds for landscape protection, significant cultural sites and patches of mature forest distributed amongst regeneration for nature conservation. The plan improves protection of streams and includes new components of the biodiversity, such as ecotones, as protectable areas.
- Prescribing whole of forest structural goals for nature conservation and timber production.
- Prescribing a sustainable level of timber production.
- Setting priorities and procedures for the protection of the forests from pathogens, fire, weeds and pests.
- Developing and constantly updating codes of "best practice" for the implementation of strategies.

North, Central and Southern Forest Region Management Plans 1987

The North, Central and Southern Forest Region Management Plans were prepared according to the *CALM Act* and published in 1987. They covered the same south-west forest area as the Forest Management Plan 1994-2003. The provisions of the Forest Management Plan 1994-2003 replace the 1987 plan provisions for all State forest areas. However, the 1987 plans are current for all issues on State forest not covered by the 1994 plan (e.g. plantations) and any activity on national park, conservation park or nature reserves. The 1987 plans and the 1994 plan were assessed under the *Environmental Protection Act 1986* and are subject to Ministerial conditions.

Area plans

Area plans are produced within the framework of a regional plan where the issues in a particular area are too complex to deal with in sufficient detail in the regional plan. Typically these are the large national parks. Area plans in the south-west forests exist for: Lane Poole Reserve 1990-2000; Leeuwin-Naturaliste National Park 1989-1999; Shannon Park and D'Entrecasteaux National Park 1987-1997; Walpole-Nornalup National Park 1992-2002; Waroona Reservoir and Catchment area 1990-2000; Logue Brook Reservoir and Catchment area 1990-2000 and John Forrest National Park 1994-2004.

Other plans

Other lower level planning documents are produced such as:

- issue plans covering dieback protection; fire protection (Fire Control Working Plans for CALM districts); timber harvesting and regeneration (prepared for timber supply areas).
- operational plans covering matters such as feral animal control; noxious weed eradication; planting; road construction and maintenance.

Mining

The legislative framework covering the minerals industries can be divided into two sections:

- land access and the approvals processes that are required to be met prior to a project proceeding; and
- processes covering the operation of mining projects.

Land access

Access for mining on private land is governed by the *Mining Act 1978* which allows for the granting of mining tenements on private land after the consent of the owner has been attained. Tenements clearly specify the conditions under which the tenement holder must operate. On private land, owners have the rights to basic materials, such as sand and gravel, and do not require a *Mining Act* tenement for the removal and use of such material.

The approvals required to explore and mine on Crown land and conservation areas depend on the type of conservation area. Current Western Australian Government policy is that exploration within all national parks and class A nature reserves can proceed only with the agreement of the Minister for the Environment and the Minister for Mines. If an important mineral deposit is discovered, then mining is permissible only if both Houses of Parliament agree following an environmental assessment by the Environmental Protection Authority. Mineral exploration and mining in other conservation reserves requires the approval of the Minister for the Environment. Under the *Mining Act*, the concurrence of the Minister for the Environment must be obtained before mining can proceed on other categories of land managed by CALM. These categories include State forests, timber reserves and other nature and conservation parks. CALM, however, establishes the land-management conditions for conservation reserves and State forests and the conditions that may be required for access by miners.

Petroleum exploration and development in the South-West Forest Region are regulated by the *Petroleum Act 1967*, which provides the framework for these activities on land, islands and internal waters in Western Australia. The *Schedule of Onshore Petroleum Exploration and Production Requirements 1991* (which is an attachment to the *Petroleum Act*), covers environmental and safety restrictions related to petroleum exploration and production.

Standard conditions have been developed to cover mineral exploration and mining in the different types of conservation reserves, State forests and other environmentally sensitive areas. Tenements issued under the *Mining Act* also have conditions attached which draw attention of the licensee to the provisions of other Acts including the *Environmental Protection Act 1986*, the *CALM Act 1984*, the *Wildlife Conservation Act 1950*, the *Bushfires Act 1954*, the *Country Areas Water Supply Act 1947*, the *Aboriginal Heritage Act 1972*, the *Town Planning and Development Act 1928* and the *Aboriginal Affairs Planning Authority Act 1972*.

In developing a project, companies are required to meet requirements stipulated by a number of statutes covering project development, mine operation and post-mining rehabilitation. Such requirements have been introduced to ensure that the interests of all parties—the developer, community and government—are considered. Each tenement application and project proposal is assessed in terms of its location, site characteristics, land-use and the likely impacts or effects which the proposed activities (e.g. mineral exploration, project development, mining, ore treatment and processing, transport, storage and shipping) could have on the immediate and adjacent natural and modified environments.

The major approval processes which a proponent needs to obtain before a project can proceed are stipulated under the following statutes:

- *Environmental Protection Act;*
- *Mining Act;*
- *Town Planning and Development Act;*
- *Land Act;*
- *Aboriginal Heritage Act;* and the
- *Aboriginal Affairs Planning Authority Act.*

The approval requirements for a given project may vary and not all approvals are required for all projects.

Legislative processes for the operation of mining projects

Once the necessary approvals have been obtained by the developer, the construction phase can begin and the mine can be brought into operation. As part of the environmental approval process, companies are required to submit an environmental management program (EMP) to the Department of Environmental Protection (DEP). This document specifies the management practices that will be adopted by the proponent to ensure that operations are maintained within acceptable environmental limits. The EMP requires approval by the Environmental Protection Authority prior to the start of project operations and on going monitoring of the project.

Mine operations must be carried out in accordance with the *Mining Act* and the *Mines Regulation Act 1946*, except for major mining developments which are carried out under State Agreement Acts.

As well as containing provisions covering the application, processing, approval and procedures for exploration and mining, the *Mining Act* contains provisions which cover the surrender of mining titles, conditions of access to public and private land, payment of royalties and settlement procedures for title disputes. The *Mines Regulation Act* covers occupational health and safety requirements for the mining sector.

State Agreement Acts

For large capital intensive projects involving the development of an extensive resource, the developer may choose to negotiate a State Agreement with the Government. The agreement must be ratified by Parliament and development proposals be approved before the project is brought into operation. Thereafter, the operations under the agreement are authorised by statute.

State Agreements bind both government and developer to specific responsibilities and set down the obligations of both parties throughout the life of a significant development project.

Western Australia has used State Agreements to foster its resource development. State Agreements are expressly intended to provide an additional level of security over the life of a major project and have played a significant role in the development of the State's mineral and energy resources. The agreements provide the maximum available certainty over land tenure (property rights) required for project development that can be granted under the relevant State law. A high degree of certainty regarding the constraints on the future operation and management of the project is assured because the agreement provisions can be changed only by mutual consent of the State and developer.

Benefits to the Government include a clear identification of developer and State obligations allowing the State to coordinate provisions of public infrastructure and facilities. Other benefits of State Agreement Acts are that they have the potential to increase the value-added component of minerals through further processing within Western Australia, as they commit developers to considering the establishment of secondary processing facilities, subject to commercial viability.

The main overall benefit to the developer of entering into a State Agreement is a reduction in sovereign risk. For example, a significant benefit to the developer is legislative protection, in that a State Agreement can override other government legislation (with the exception of the Environmental Protection Act and Commonwealth legislation). Other benefits include security of tenure and protection against any zoning action under any Act, regulations and by-laws which may adversely affect the operations of projects under the agreement.

On the other hand, State Agreements bind the developer to meet on-going requirements to ensure that the project is operated within social and environmentally acceptable levels and conditions.

The importance of State Agreements in the context of the Western Australian RFA has been recognised in the Scoping Agreement signed by the Prime Minister and Premier. Under clause 2 in the Preamble, it is stated that:

"The Commonwealth and Western Australia recognise that this agreement, and any RFA negotiated, cannot impose on a party any obligation that is inconsistent with a law of the Commonwealth or of Western Australia where that law is binding upon that party."

The Agreement Acts and statutes administered by the Department of Resources Development relevant to minerals projects operating within the RFA area are listed below.

Alumina/bauxite
- *Alumina Refinery (Worsley) Agreement Act 1973*;
- *Alumina Refinery (Wagerup) Agreement Act* and *Acts Amendment Act 1978*;
- *Alumina Refinery Agreement Act 1961*; and
- *Alumina Refinery (Pinjarra) Agreement Act 1969*.

Coal
- *Collie Coal (Griffin) Agreement Act 1979*; and
- *Collie Coal (Western Collieries) Agreement Act 1979*.

Mineral sands
- *Mineral Sands (Beenup) Agreement Act 1995*.

While a State Agreement clearly does not "freeze" the rights and obligations of the State and of companies for the duration of a project, with its explicit requirement for effective negotiation with the company over any proposed changes, it does represent a significant strengthening of property rights available to the company and a reduction in investment risk. This is likely to be a major reason why most companies contemplating major long-term investment in resource development in the State seek to establish such an agreement.

3.2 IMPLEMENTING MULTIPLE USE MANAGEMENT

Minerals

Mining and mineral processing is the most economically significant industry in the RFA area generating some $2.68 billion in revenue and more than 8000 jobs in 1995-96. The main minerals mined are bauxite in the northern jarrah forest, coal at Collie, gold at Boddington, mineral sands on the coastal plain southern coastal plain and tin-tantalum-lithium and spodumene-lithium at Greenbushes. These operations clear and rehabilitate approximately 600 hectares per annum.

As discussed previously, many of the mining operations are covered by State Agreement Acts. Such Acts require the companies to submit mining and rehabilitation plans. As an example, there are two significant committees involved in management of bauxite mining.

The Mining and Management Program Liaison Group (MMPLG) was set up as a result of the Ministerial conditions of 11 August 1995, for the production increase for the Wagerup alumina refinery. It is chaired by the Department of Resources Development and comprises representatives of State government agencies whose areas of responsibility are affected by Alcoa's mining operations. The agencies are CALM, Department of Minerals and Energy, Water and Rivers Commission, Water Corporation and Department of Environmental Protection. Alcoa and the MMPLG prepare and implement plans to manage the impacts of mining operations on the local community in consultation with the affected local government authorities. The MMPLG also reviews mining plans and manages issues relating to Alcoa's mining operations and coordinates environmental auditing of Alcoa's mining and management program.

The Mining Operations Group (MOG) undertakes liaison on operational issues with staff at Alcoa's three mine sites. The MOG comprises representatives from Alcoa and those government agencies with a direct interest in the day to day operations of the mines. These include CALM, Water and Rivers Commission, Water Corporation and the Department of Minerals and Energy. The primary task of MOG has been to evaluate Alcoa's advance forest clearing applications for the three mine sites. Clearing applications are evaluated according to forest management strategies that the MOG has developed from the five and 25-year mining plans.

Heritage

There is no stand-alone plan for natural heritage, for which a strategy is incorporated into the Forest Management Plan 1993-2004. This strategy is based on the 1992 Memorandum of Understanding between CALM and the Australian Heritage Commission that was developed following a joint CALM/AHC inventory of national estate values in the Southern Forest Region. The major element of protection for these values is their adequate representation in the reserve system. Planning to protect natural heritage values within areas disturbed for other uses is based on guidelines produced in the joint study and built into planning for those activities, particularly timber harvesting and road making. Planning and operational guidelines designed to minimise impacts on national estate values which are sensitive to timber production operations include ensuring that regeneration of the forest emulates the original structure, mix and relationship of forest types and care to avoid soil compaction, erosion and stream siltation. Where the location of cultural sites is known they are protected from disturbance activities that may affect the cultural values present.

Recreation and tourism

Most active recreational pursuits such as horse riding, mountain-bike riding and motor sports are facilitated in State forest. Recreation and tourism are typically excluded from nature reserves, unless there are special reasons such as a prior history of recreation. Draft area management plans include details of CALM's intentions and provide an opportunity for public comment. Once the plan has been approved there is some public consultation during the design and implementation phase. Sometimes plans showing proposed developments are displayed at recreation sites and comments invited. Proposed developments on harnessed water-supply catchments are submitted to the Water and Rivers Commission for endorsement. The intention to establish new sites or modify existing sites is advertised in local newspapers. Highlights are often reported in CALM's annual reports.

CALM's *Recreation and Tourism Strategy 1996-2000, People in CALM places* requires each recreation opportunity and each developed tourism site to be evaluated to determine its compatibility with CALM's

conservation objectives. Acceptable levels of environmental change that can be sustained within a given ecosystem need to be identified. Procedures followed are:

- evaluating recreation and tourism opportunities in terms of their compatibility with conservation and other management objectives—recreation sites are selected, designed and developed according to procedures in CALM's Recreation Operations Manual;
- establishing management guidelines that take into account conservation objectives;
- training CALM staff and tour operators;
- assessing and planning activities and facilities to minimise their impacts on nature conservation values;
- implementing new developments according to approved management plans; and
- identifying acceptable limits of environmental change that can be sustained in a given ecosystem and taking action when these levels are in danger of being exceeded.

Water

The main organisations involved are the Water and Rivers Commission (for long-term planning), Water Corporation (for existing and proposed water supplies) and CALM for CALM-managed lands. Close liaison is maintained between these organisations.

The Water and Rivers Commission aims to maximise the social, economic and environmental benefits to the community to ensure the availability and quality of water resources for present and future generations. The Commission allocates water resources, taking into account environmental and social aspects.

Regional water resource reviews and development plans are the primary means of providing guidance in the development of the State's water resources. These plans assess water supply and demand and identify possible environmental, social and cultural constraints. Plans are to be prepared for the 10 regions in the State; three had been prepared to 30 June 1996, including plans for the Bunbury-Collie region and Albany-Denmark region. A draft plan for the Busselton-Walpole region has been prepared. Water allocation management plans are the primary means of providing a framework for water allocation. The planning process involved provides for future needs to be considered. The plans provide public information and are subject to public participation.

The Water Corporation is required to act in accordance with prudent commercial principles and endeavour to make a profit, but considers potential effects on the natural environment of existing and proposed water supply developments. New developments are subject to EPA processes, including public participation when required.

CALM management plans set out requirements for catchment protection, water production and water quality maintenance where water is a management issue. The requirements of the Forest Management Plan 1994-2003 include:

- reserves of undisturbed vegetation to be retained on every river and stream on CALM land;
- restrictions on the proportion of forest which may be harvested in forest areas with saline ground-water tables;
- cooperative planning procedures with the Water Corporation to ensure potential water resource development sites are set aside for the future use and benefit of the community;
- continued work with the Water Corporation and other relevant agencies to reverse stream salinity by soundly-planned reforestation.

Timber production

The sustainable yield of products from the jarrah and karri forests was calculated based on a number of factors, including allowance for existing and proposed reserves and achieving forest structural goals.

On 16 August 1993, the Minister for the Environment made a determination of the annual sustainable timber resource available for allocation. The determination applies from 1 January 1994 until 31 December 2003. In summary, the Minister set an average annual harvest of 214 000m^3 of first grade karri saw logs and 203 000m^3 of other logs; 490 000m^3 of jarrah first and second grade saw logs and 559 000m^3 of marri logs. CALM contracts for the annual sale of log timber up to the allowable cut. Almost all of these sale contracts for sawlogs expire on 31 December 2003. Further details are provided in the Forest Management Plan 1994-2003.

Harvesting plans integrate multiple-use requirements such as:
- timber industry log requirements (size, quality, volume, haulage distance);
- visual resource management requirements;
- protection of research and inventory plots;
- dieback disease requirements;
- fire protection;
- regeneration requirements;
- heritage requirements;
- Aboriginal, archaeological, historical sites;
- catchment protection (salinity, sedimentation, siltation, turbidity);
- water production;
- honey production requirements (apiary sites);
- nature conservation requirements, including rare and endangered species;
- recreation and tourism;
- neighbours amenity requirements;
- public safety, including road safety;
- mining;
- public utilities including telephone, electricity; and
- education, interpretation of forest environments.

Harvesting plans aim to maintain productive capacity by various means such as harvesting mature and senescent, damaged or under-stocked forest and other forest growing at well below potential growth rates; thinning overstocked stands to promote growth on retained trees; and salvaging damaged or diseased trees that would otherwise be lost. Harvesting and regeneration plans aim to minimise the time between harvesting and regeneration and to rehabilitate areas as soon as practical to bring them back into production. Silviculture aims to retain the same species that were present before harvesting.

Nature conservation

The conservation objective in the Forest Management Plan 1994-2003 is:

"*To maintain biological diversity at the genetic, species and ecosystem level in the forest, with special emphasis on the protection and conservation of threatened, rare and uncommon taxa and communities.*"

Broad objectives include to:
- seek security of tenure for all forested areas considered to have value for nature and resource conservation, and oppose alienation of reserved land;
- establish a representative reserve system;
- incorporate measures that sustain biological diversity in forests managed for multiple purposes; and
- prepare wildlife management programs for selected taxa and identify, locate and seek to conserve threatened or endangered flora, fauna and communities in the forest.

Other products

Honey production

All apiary sites on pubic land are registered by CALM with an annual lease fee being imposed to cover administration and associated costs. Beekeeping is considered to be compatible with most other land uses in State forests, although site selection is critical and is coordinated so that factors such as the risk of dieback spread are considered. Apiary sites are positioned approximately three kilometres apart and each beekeeper is allowed to hold eight public land sites for every 100 hives owned. Beekeeping is allowed in national parks for those already licensed, however, a moratorium prohibits new sites being established until research on the impact of honeybees on flora is completed.

Wildflowers, blossom and seeds

Native flora and other vegetation declared as flora under the *Wildlife Conservation Act* are protected on all land within Western Australia. CALM regulates the bush picking sector of the floriculture industry and administers a licence system to ensure that harvesting from crown land does not pose a threat to flora conservation. Conditions are applied to all licences which specify quotas, permissible area, time frame and preferred access.

Grazing

The Forest Management Plan foreshadows the phasing out of sheep and cattle grazing in native forest areas over the next 30 years. The minor advantage of reduced fire hazard from grazing is considered to be offset by the degradation of nature conservation values.

Forest Management Plan 1994–2003

The manipulation of forest stands to achieve a forest structure and composition consistent with nominated management objectives is the science of silviculture.

The Forest Management Plan 1994-2003 sets the silvicultural policy for CALM-managed land. At the whole of forest level it defines four disturbance classes for the jarrah forest and specifies a structural goal for each. For the karri forest, it sets a goal for the percentage representation of the mature/senescent, immature, juvenile and establishment stages of stand development. (See below for each species.)

Within these whole of forest structural goals silvicultural policy is based on the stand condition and its interaction with the ecological characteristics of the forest.

Jarrah

Structural goals have been set for each of four categories of disturbance recognised in the jarrah forest. These categories range from minimal disturbance (e.g. conservation reserves) to high disturbance (e.g. forest areas subject to mining). Forest available for timber harvesting is predominantly within the moderate disturbance category where the structural goal for the term of the plan is to convert no more than 1% of the forest to the establishment phase each year. In time, this will provide for about 40% of the forest in this disturbance category to be dominated by trees in the mature and senescent stages of development, about 40% by immature, about 15% by juvenile and about 5% by establishment stages of development.

Timber harvesting operations in the jarrah forest may be linked to a variety of silvicultural objectives. Where there is a predominance of vigorously-growing trees, the stand is thinned. Where this is not the case, stands are harvested with the object of promoting regeneration. This is achieved either by harvesting in a way that will release existing lignotubers to grow unimpeded into saplings; or, where there are insufficient lignotubers as determined by pre-harvesting surveys, by harvesting to create a shelterwood under which seedlings can establish. Within a particular area of forest the proportion that is harvested to each of these objectives, and the degree of intermixing, vary according to the existing stand structure and condition.

In many areas the desired silvicultural objective is largely achieved by the harvesting operation itself. A proportion of the remainder is completed by silvicultural-tending operations one or two years after harvesting. In forest types that are regarded as marginal for long-term production harvesting may be done by selective cutting.

Marri occurs together with jarrah in varying proportions throughout the main jarrah forest range, and is more abundant in the southern forests. Relationships between forest composition and site characteristics have been described by Havel (1975) and Strelein (1988). Western Australian blackbutt occurs in association with jarrah and marri on moist sites throughout the jarrah forest, while wandoo is generally confined to the lower rainfall eastern forests and along the Darling scarp. Both these species have been harvested on a significant scale in the past, but constitute only a small proportion of the timber removed in current jarrah forest harvesting operations. Existing silvicultural prescriptions cater adequately for the requirements of Western Australian blackbutt, and a specific prescription has been prepared for treemarking and regeneration of wandoo (CALM 1989a).

Karri

The overall silvicultural goal for the karri forest is to maintain a sequence of age classes which ensures that about 40% of the forest consists of trees in mature and senescent stages of development (CALM 1994). In order to achieve this goal, management in forests subject to timber harvesting seeks to maintain the preceding stages of development in sufficient proportions to sustain the mature and senescent stages in perpetuity. Silvicultural strategies vary according to the structure and age of the existing forest.

Patches of even-aged and vigorously-growing karri forest that are greater than two hectares in area are identified for thinning. Once these patches have attained a top height of 30 metres and are old enough to yield saleable products they are thinned to an appropriate density by commercial harvesting.

Mature forests and forests of mixed structure created by past logging activities are harvested using a clearfelling system. Logging slash is burnt at high intensity in autumn to create a receptive seedbed and to remove fuel that would otherwise be a hazard for the regenerating stand. Regeneration following harvesting is achieved within the following year or two by means of seed trees retained temporarily on the site, by planting with nursery-raised karri seedlings, or by broadcast seeding. The seed tree method is used wherever possible in order to use on-site seed and minimise the cost of regeneration operations. Planting is used when the seed crop is inadequate. Broadcast seeding is employed only to a limited extent because of the high cost of karri seed, and the inconsistent results obtained using this technique. Regeneration surveys are conducted to ensure the stocking meets success targets.

Marri occurs in association with karri and may be the more abundant species on some sites, particularly in lower rainfall areas on the margins of the karri forest range. Marri regenerates readily from seed and ground coppice following fire or logging disturbance, and no silvicultural intervention is normally required to maintain the marri component of mixed karri/marri stands.

Fire management

Fire is a naturally-occurring disturbance factor in south-west ecosystems, to which most of the flora and fauna are generally well adapted. The bushfire hazard in the south-west of Western Australia is as potentially severe as anywhere in Australia and although fire is a natural and necessary element, it can also be an agent of death and destruction for human assets and values.

CALM is responsible for all fire management on State forest, timber reserves, national parks, conservation parks and nature reserves. Although other government departments are responsible for other Crown land tenures, fire management is often effected through interagency agreements with CALM. Fire management on private land is the responsibility of the landowner but local government and the Bush Fires Board have a role in controlling and coordinating their efforts.

Fire management strategies employed in the south-west forests include the use of prescribed fire, fire detection, direct fire suppression, public education and law enforcement.

Prescribed fire

The controlled application of fire in Western Australia's native forests serves three important functions:
- to assist in achieving rapid regeneration of the forest following harvesting—different fire intensities are required to achieve the different silvicultural objectives;
- to provide strategic protection to life, property and forest values (including established regeneration) from damaging high intensity wildfire through the use of fuel reduction burns; and
- to maintain and enhance fire-adapted flora communities and fauna habitats and recycle nutrients within the forest ecosystem.

Fires are generally categorised as being of low (litter fires of less than 350 kW/m), moderate (understorey vegetation fires of 350-2000 kW/m) or high intensity (defoliating canopy fires of more than 2000 kW/m).

Silvicultural use
Low, moderate and high intensity prescribed fire is an important silvicultural tool in south-west forests.

Low intensity fire is used to remove the flash fuels from jarrah harvesting debris and "burn back" the above-ground stem of the lignotubers without damaging the below-ground component of the lignotuber. This will stimulate the lignotuber to form a dynamic shoot that will progress to the sapling and pole stages.

Moderate intensity fire is used to establish regeneration in jarrah forest through natural seed fall from retained trees and subsequent germination and development of seedlings on the resulting ash bed.

High intensity fire is used in karri forest to remove most of the harvesting debris, create an ashbed and induce seedfall from the seed trees if they have been retained. Removing harvesting debris reduces the future fire hazard as well as the potential for lower-bole damage to developing regeneration in later prescribed burning.

Fire is excluded from regenerated stands until such time as future crop trees can withstand a low intensity fire. This may be 10 to 15 years in jarrah and 15 to 20 years in karri. CALM (1997c) provides a more detailed discussion of the silvicultural application of fire in the jarrah forest.

Fuel reduction burning
The most effective means of minimising the damaging effects of wildfires is to reduce available fuel levels with prescribed fire. Low intensity fire is used to maintain low fuel buffers adjacent to areas with high life and property values such as townsites, plantations and farming communities. A network of low fuel areas is also maintained within large forest blocks to stop the run of high intensity fires. In the drier forest the buffers are designed with an acceptable loss of about 2000 to 4000 hectares, whereas in the karri forest it is 1500 to 2000 hectares.

Wildlife management
Prescribed fire is used for particular wildlife management purposes. For example it is incorporated into the Perup Nature Reserve fire plan to regenerate heartleaf poison thickets used by woylies and tammar wallabies for cover. Fire is also excluded from some areas in order to maintain habitat for particular species.

Fire planning

The integration of the use of prescribed fire with the detection, suppression and education strategies occurs in the planning phase. The principal planning tool is a risk evaluation system called the Wildfire Threat Analysis (WTA). The WTA provides a framework for evaluating the values at risk, the risk of an ignition occurring, the suppression response available and the headfire behaviour potential. All of these factors are mapped and overlain to provide the planner with the information needed to integrate and optimise the fire management strategy.

CALM regions and districts maintain master burning plans that are updated each year and from which an annual burning plan is produced. The annual burning plan is discussed with local government and Bush Fires Board officers to allow integration of private land fire management with that for public land. Districts also prepare an annual fire control working plan that sets out their resource levels, fire detection requirements and standing orders.

Where an area management plan exists, such as that for Walpole-Nornalup National Park, specific fire management requirements to meet the objectives for the area will be set out over and above the broad strategic fire requirements.

Weeds, pests and diseases management

Threats include:
- fungal diseases such as dieback due to Phytophthora cinnamomi, wood rots, stem and branch cankers, leaf spots;
- insect pests include jarrah leaf miner, gumleaf skeletoniser and bullseye borer;
- feral animals; and
- invasive weeds.

Feral animals

CALM's fox control program "Western Shield" is in place in the forest area. Control measures for pigs, goats, rabbits and cats also occur in various areas, under annual programs in CALM regions and districts. Some eradication programs occur on private property and the Agriculture Protection Board targets feral animals of economic importance on other Crown land.

The priorities for feral animal control on forested lands managed by CALM are:
- Priority 1—protection of rare and vulnerable animals, especially where risk of native species extinction exists;
- Priority 2—the progressive eradication of feral animals from selected offshore islands;
- Priority 3—protection of other important habitats and high value ecosystems subject to significant environmental degradation;
- Priority 4—control of feral animals adjacent to private property, around areas subject to regular public use, in harnessed catchments and in disease risk areas;
- Priority 5—remainder of CALM lands.

Feral animal control is covered in CALM management plans. Draft management plans include details of CALM's intentions and provide an opportunity for public comment. Once the plan has been approved there is typically little public consultation during the implementation phase. Highlights are often reported in CALM's annual reports.

Disease control

Over the past 25 years a detailed dieback control strategy has been developed and implemented in south-west forests. This involves policy, research, planning (including disease location and impact mapping), community education, liaison, field management, silviculture, control of access and monitoring. The principal research and operational findings are that:

- the fungus spreads in contaminated soil carried as a result of human activities;
- spread can be reduced if stringent hygiene is practised;
- the forest has markedly varying degrees of susceptibility to the disease; and
- the high density of *Banksia grandis*, which is highly susceptible to the fungus, is a major factor contributing to disease spread and intensification.

Disease control is usually covered as a topic in CALM management plans. Draft management plans include details of CALM's intentions and provide an opportunity for public comment.

Weeds

Numerous weeds are present on CALM land, including weeds declared under the provisions of the *Agriculture and Related Resources Protection Act*, e.g. blackberries, and other weeds such as veldt grass. CALM's objective is to prevent the accidental introduction of weeds, control declared weeds and control non-declared "environmental" weeds on its lands.

Each CALM district is required to survey and record the location and extent of weed infestations. A weed control plan is then developed at a regional and district level in liaison with the Agriculture Protection Board (APB) and implemented within the constraints of funds available. Resource limitations preclude the treatment of all known weed infestations.

The priorities for forest weed control are:

- Priority 1—areas of highest value from a conservation, recreation, production or protection aspect;
- Priority 2—small new infestations, particularly in headwaters of streams;
- Priority 3—large infestations adjacent to private property and likely to affect it;
- Priority 4—remainder of CALM land.

Weed control is usually standard practice when establishing tree plantations.

Insect control

There are three insects currently of concern in Western Australia's native forests: jarrah leafminer, gumleaf skeletoniser and bullseye borer. Despite extensive research into jarrah leafminer by CSIRO and CALM, no practical control measures have been found. A similar situation exists for gumleaf skeletoniser and the bullseye borer. Control of insect attack in native vegetation is usually not practical except in small areas such as some parks, and no formal planning is undertaken. Insect control is often practised if required when establishing tree crops on cleared land. One insect not present in native forests but of concern for pine plantations is sirex wood wasp.

Codes, manuals and guidelines

CALM has a range of codes, manuals and guidelines to control the implementation of management practices. The most significant are:

Timber Harvesting in Western Australia (1996)

This document currently includes the Code of Harvesting Practice and the Manual of Harvesting Specifications. The Code of Harvesting Practice was subsequently issued separately in 1997 following revisions of the occupational health and safety section. The code sets out broad requirements for felling, extraction, roading, loading and delivery, environmental protection, recording and safety. The manual on the other hand is more specific in setting responsibilities and standards in planning, roading, silviculture, coupe management, environmental protection, log specification and administration.

There is no legislative requirement for the provisions in either document, however, both documents are included as schedules to harvesting contracts so that their provisions become enforceable through the contract.

Code of Practice for Timber Plantations in Western Australia (1997)

This document is a joint production by CALM and the Western Australian chapter of the Australian Forest Growers and is intended to apply to private and public plantations. It provides guidelines on all aspects of plantation establishment and management. CALM is committed to compliance with the code, but its adoption is voluntary for private property owners.

Silviculture guidelines

Guidelines have been produced for silvicultural practices for all species. Guidelines or manuals also exist for many other activities that promote or protect multiple use management in forests. These include fire management, recreation operations, apiary management and wildflower harvesting.

3.3 FOREST RESEARCH

CALM's Science and Information Division (SID) undertakes forest research on public land. Its role is "to provide up-to-date and scientifically-sound information to uphold effective conservation and land management in Western Australia". SID consists of three research groups:

- Bio-resources group—concerned with the inventory of systematic, biological and ecological information on the biota and documentation of the landscape characteristics and ecological communities of the State;
- Bio-conservation group—focuses on the processes which are diminishing or degrading the State's bio-resources and how these processes can be managed effectively so the resources are conserved;
- Sustainable Resources group—researches the management and use of species from which natural products are derived, including plantations.

The groups interact extensively and work with staff in other parts of CALM. There is also considerable interaction with scientists in the CSIRO and universities and with scientists in other government departments and authorities.

Bio-resources and Bio-conservation

Current research areas include:

- development of the departmental monitoring program;
- development of guidelines for monitoring Australia's wetlands of international importance;
- community conservation of the Walpole-Nornalup National Park;
- community conservation of the Lake Muir complex;
- conservation biology of locally-endemic eucalypts;
- radio tracking of translocated noisy scrub-bird;
- conservation biology of rare and threatened flora;
- seed biology, seed bank dynamics and long-term germ plasm storage of Western Australia's flora, particularly rare flora;
- control and ecology of the red fox in Western Australia;
- the development of micro-satellite probes to investigate the social organisation of foxes;
- quenda translocation methods;
- factors affecting establishment in the numbat reintroduction program;
- recovery plan for the chuditch;
- population surveys, conservation status and area-based wildlife management programs;
- ecology and conservation of Western Australian pythons;
- conservation biology of vulnerable frogs;
- control and management of *Phytophthora megasperma* in national parks and nature reserves;
- effects of three fire regimes on ground-dwelling invertebrates in the jarrah forest;
- effects of spring and autumn prescribed burns on small vertebrates in the jarrah forest;
- control of jarrah leafminer;
- effects of fire and logging on jarrah forest vegetation;
- fire danger and fire behaviour in south-west forests;
- jarrah growth on dieback sites;
- biological and chemical control of *Armillaria* in karri regrowth stands;
- monitoring of gumleaf skeletoniser attack on jarrah;
- effects of logging and fire on birds of the jarrah forest;
- *Phytophthora cinnamomi* impact in the northern jarrah forest;

- effect of logging and burning on fauna hollows in jarrah and marri;
- dieback-resistant jarrah;
- fire technique for germinating brown boronia;
- fire history and impact of *Phytophthora* in jarrah forests;

Recent projects (1992-1995) include:
- long-term data on diversity and composition of small vertebrate and invertebrate communities in mallee and woodlands in south-west;
- data on resilience to disturbance in relation to climate, fire, drought, etc. in determining structure and composition of faunal communities;
- recovery plans for woylie, tammar, Purdie's donkey orchid;
- research plan for ground parrot;
- wildlife management program for rare and threatened flora in metropolitan area, Albany districts, other southern districts;
- development of a fire response database;
- *Phytophthora* spp. research, including control with phosphonate;
- other forest diseases research;
- susceptibility of *Pinus radiata* to *P. cinnamomi*;
- bullseye borer research;
- fire behaviour and fire impact model for jarrah forests;
- site hazard rating for impact of *P. cinnamomi* in northern jarrah forest;
- jarrah leafminer studies;
- effects of different fire regimes on jarrah forest understorey;
- age to first flowering after fire and month of peak flowering of jarrah forest species.

Sustainable Resources

Silviculture

Silvicultural research conducted since the 1930s has contributed to a substantial body of knowledge about the regeneration, development and management of karri forest stands. This research has been reviewed in detail by Breidahl and Hewett (1995), and current developments have been described by McCaw and Rayner (1995). Detailed silvicultural specifications are available for all harvesting and regeneration operations carried out in karri forest (CALM 1990a, 1992a, 1995b, 1997a, b)

There is a long history of silvicultural research in the jarrah forest dating back to the early years of organised forest management in the 1920s. Abbott and Loneragan (1986) reviewed a large body of published and unpublished research on the ecology and silviculture of jarrah, and Stoneman et al. (1989) discussed the silviculture of jarrah and the application of silvicultural systems to meet various land use objectives. Detailed silvicultural specifications are available for all harvesting operations carried out in jarrah forest (CALM 1989a, b, c, 1995a, 1997c, d)

Current Sustainable Resources research projects include:
- increasing productivity of karri regrowth stands by thinning and fertilising;
- spacing effects on development and form of regrowth karri;
- regeneration of jarrah in southern jarrah forest;
- improving seedling nursery techniques;
- seed orchard management for the supply of superior *Eucalyptus* globulus seed;
- development of vegetative multiplication techniques for *E. globulus* clonal forestry;
- pine tree breeding;
- *E. globulus* tree breeding;
- marri family provenance trial (including kino-free marri);
- inoculation of *Pinus radiata* seedlings with different mycorrhizal fungi;
- performance of *E. globulus*, planted on farms, in relation to soil and site attributes;
- determining the cause of death of *E. globulus* grown on shallow soils on the Darling plateau;
- prediction of silvicultural requirements (ripping, mounding, fertilisation) for specific sites before trees are planted;
- early rotation nutrition of *Pinus radiata* on ex-pasture land on the south coast of Western Australia;
- pine timber belts.

Recent research projects (1992-1995) include:
- evaluation of the success of in-fill planting of karri seedlings;
- compared growth performance of seedlings raised using a variety of nursery techniques;
- thinning/fertiliser experiment in karri regrowth;
- study of factors affecting emergence, mortality and growth of jarrah from seed in the northern jarrah forest;
- thinning and fertilising of jarrah pole stands;
- development of computer program to help set commercial wildflower picking quotas;
- permanent plots to provide data on effects of legumes, season of germination and ash on survival and growth of brown boronia.;
- study on herbicides used for thinning jarrah and marri;
- whole-farm planning to determine optimum placement of pine plantation on farms;
- modified blue gum planting designs to minimise salt damage and drought deaths;
- soil survey and land evaluation systems for different tree crops on farms;
- fertiliser response trials for *E. globulus*.

Other organisations such as CSIRO, Alcoa of Australia Ltd and universities have undertaken some research in related topics. Many research projects are currently taking place at an international, national and State level. These will help understanding of the relative importance of greenhouse gases and particular sources and sinks. Of particular interest has been the work conducted by the Climate Impact Group of the CSIRO on the regional implications of the greenhouse effect for Western Australia. CSIRO Forestry Group staff based at Floreat conducted some research on nutrient cycles and carbon flows in jarrah and karri forest in the 1970s, 1980s and 1990s.

3.4 MONITORING, REVIEW AND REPORTING

Major reviews of management systems of CALM and other agencies occur at irregular and often long intervals, frequently during restructuring exercises, e.g. the amalgamation of the Forests Department, National Parks Authority and part of the Fisheries and Wildlife Department to form CALM in 1985. Minor reviews occur much more frequently. Some sections of CALM, including the CALM Corporate Executive, have annual seminars, which present an opportunity to consider performance and discuss possible changes. Some of CALM's manuals and guidelines are reviewed fairly regularly and revised every few years. The timber harvesting manual has been kept reasonably up to date, in recent years.

Continuous improvement

While there is no specific policy within CALM to have continuous improvement there is a corporate efficiency and effectiveness objective. Numerous improvements have been introduced in recent years and many are documented in CALM's annual reports. For example, in the 1996-97 report (CALM 1997e) there was information on:
- developments in the State salinity strategy;
- extensions to the Western Shield feral animal control program;
- introduction of a new Threatened Species Scientific Committee to provide advice on flora and fauna requiring special protection;
- revision of the priority flora list (includes declared rare flora);
- trials of aerial fire-fighting techniques;
- distribution of information on CALM programs through the Internet;
- trials of techniques for use of the dieback-inhibiting chemical, phosphite;
- amendments to the gazetted list of specially protected fauna; and
- preparation of interim recovery plans for taxa classified as critically endangered.

4 Timber production and the timber industry

4.1 FOREST TYPES, EXTENT AND MERCHANTABILITY

Two major tall forest formations are recognised for timber production within the south-west. These are the dry sclerophyll jarrah (*E. marginata*) and wet sclerophyll karri (*E. diversicolor*) forests. Several commercially-important timber species occur in mixture within these forest formations, including marri (*Corymbia calophylla*)—which occurs throughout each—wandoo (*E. wandoo*), Western Australian blackbutt (*E. patens*) and Western Australian sheoak (*Allocasuarina fraseriana*). Minor quantities of powderbark wandoo (*E. accedens*), bullich (*E. megacarpa*) and yellow tingle (*E. guilfoylei*) have also been harvested from State forests.

Of the total area of approximately 2.45 million hectares of public native forest managed by CALM, timber harvesting is permitted only on a portion of the multiple-use forests within State forest and timber reserves. The net area of each forest type in which timber harvesting is permitted is calculated by deducting from the total area of each forest type those areas within formal and informal reserves.

Under the current forest management plan (CALM 1994) the net area available for harvest is shown in Table 4.1. The legislative and policy basis for timber production planning is detailed in Chapter 3.

Table 4.1 Area of different forest types available for harvest

Forest type	Area
Jarrah/marri	1 111 000 hectares
Wandoo	50 000 hectares
Karri/ marri	94 000 hectares

A range of log grades is produced with size and quality specifications differing between grades and species depending on the major end use processing (CALM 1996). The hardwood industry is undergoing a major shift from producing structural grades to decorative grades and secondary processing which in turn changes the log grade requirements and specifications.

Log processing is primarily divided into solid wood processing and residue processing.

Solid wood processing

Western Australia's hardwood species are suitable for a range of solid wood products which includes veneers, furniture, panelling, mouldings, flooring, joinery, plywood, laminated veneer lumber, other laminated products and structural grades. Lower grade material from local hardwood species is suitable for uses such as lower specification structural timber and sleepers. Round timbers are also sold as building poles, transmission poles, bridge and jetty timbers and fencing.

Residue wood processing

Mill residues and forest residues suitable for a range of products are produced from harvesting and processing solid wood. These residue materials are suitable for pulp and paper, reconstituted wood panels such as particleboard and MDF, charcoal, activated carbon and firewood.

The proportion that each log grade comprises of the total annual harvest is discussed further in the following section.

4.2 SUSTAINABLE YIELD FOR THE JARRAH AND KARRI FORESTS

Approach

The level of sustainable yield has been determined by setting forest structural goals and ensuring that the annual harvest level does not exceed the gross bole increment of the species (CALM 1994). Because definitions of what constitutes a sawlog will change over time as milling technology and other factors change, the gross bole volume (GBV) is used to provide an estimate of the maximum resource available over time. The supply of logs of current sawlog specifications is then analysed. Chiplogs and residue logs are generated as a consequence of the sawlog harvesting and essential silvicultural operations such as thinning.

The potential to increase wood yields through the application of silvicultural research on stand density, nutrition and spacing practices has been recognised for a number of decades. The historical development of silvicultural practices in the jarrah and karri forests is documented in Stoneman et al. (1989) and Christensen (1992) respectively. Silvicultural practices have been progressively adapted and their impact on timber yield has been incorporated in the regular revisions of the calculation of sustainable yield. Consequently, the sustainable yield levels adopted in the current management plan incorporate many of the economically-viable resource enhancement practices. There is therefore limited capacity to increase forest productivity beyond the projected yield levels.

Level of harvest

The annual sustainable timber resource to be made available for allocation during the period 1 January 1994 to 31 December 2003 was determined by the Minister for the Environment on 16 August 1993 (Minson 1993). This is summarised in Table 4.2.

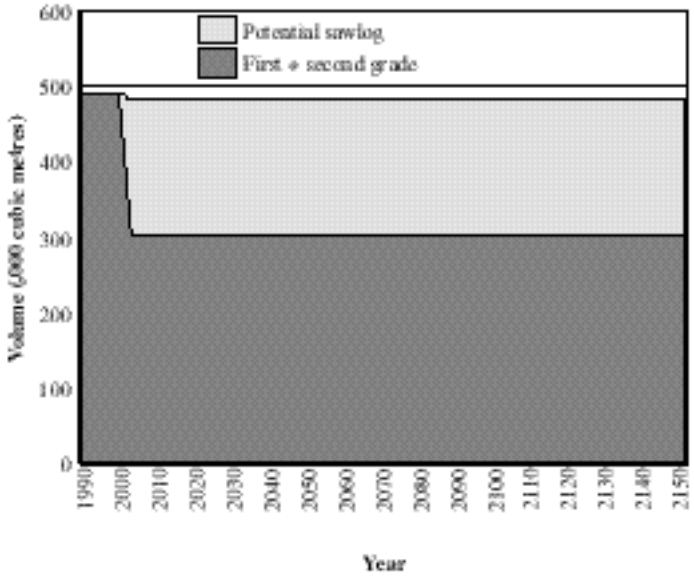
Table 4.2 Annual timber allocation available, January 1994-December 2003

Species	Sustainable yield Gross bole volume m^3/annum	Log product yields (current specifications) m^3/annum		
		First grade sawlogs	First and second grade sawlogs	Other logs
Jarrah	1 360 000		490 000	870 000
Karri	417 000	214 000		203 000
Marri	559 000			

Note: Forest residue material (derived from branchwood and dead trees) may be harvested in addition to gross bole volume.

Figure 4.1 shows the long-term wood flow of grade 1 and 2 jarrah sawlogs associated with the annual sustainable GBV of 1.36 million cubic metres. The long-term non-declining level of sawlog supply based on current specifications, harvesting practices and conversion technologies is approximately 300 000m^3 per annum. However, with the future adoption of whole tree bole logging methods and the further refinement of sawing technologies to enable lower grade logs to be sawn, it is anticipated that the sustainable supply of sawlogs could range between 410 000 and 480 000m^3 per annum.

Figure 4.1 Sustained jarrah sawlog supply (developed for 1994 Forest Management Plan)



This jarrah yield strategy incorporates a number of key assumptions, including:

- adjustment of stand yields to accommodate the effects of disease or degradation;
- commercial and non-commercial thinnings were scheduled for regrowth jarrah stands; and
- a nominal 150 to 200 year rotation length.

Figure 4.2 Sustained karri sawlog supply (developed for 1994 Forest Management Plan)

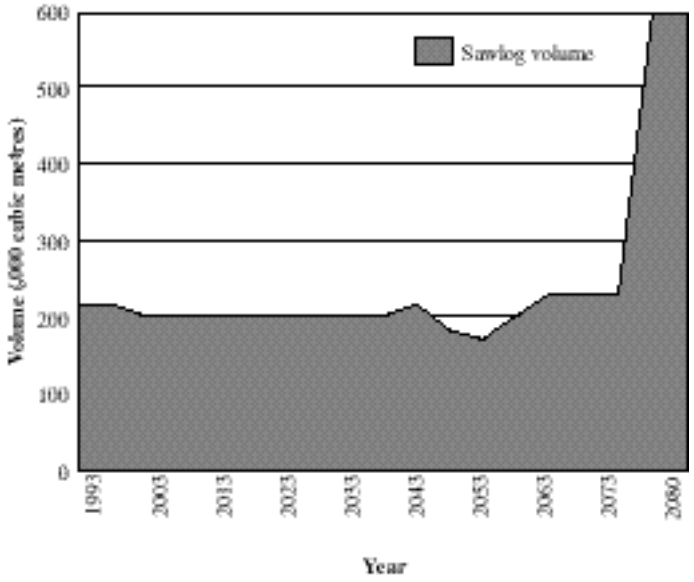


Figure 4.2 shows the long-term supply of karri sawlogs. Over time, an increasing proportion of the sawlog supply will come from thinning or harvesting regrowth stands. The substantial increase in sawlog availability after 2070 coincides with the harvesting of regrowth stands regenerated from the 1970s. Further background is provided in CALM (1992b). The key assumptions used when scheduling the yield include:

- portions of the regrowth estate would be grown on to biological rotation lengths exceeding 250 years and the remainder would be managed on a nominal rotation length of 100 years;
- regrowth stands would be thinned during the rotation, with the timing, frequency and intensity of thinning varying across site qualities; and
- no fertiliser would be applied.

Map 3 shows the relative significance of forest areas to the sustainable sawlog supply during the next 40 years. The various codes depict the contribution of the areas to the scheduled woodflow and were derived on the basis of species, site potential, silvicultural history, timber inventory and disease status.

4.3 INDEPENDENT APPRAISAL OF SUSTAINABLE YIELD

Calculating a sustainable yield for forests involves a sequential process in which data and information are integrated from a variety of information systems in order to develop a schedule of future harvesting. In 1993, the Meagher Committee (Meagher et al. 1993) evaluated the level of sustainable harvest from the jarrah and karri forests. This examination of CALM systems and results incorporated an expert review of the jarrah inventory system and the associated timber estimation procedures by the Australian National University (ANU). The methodology used by CALM was found to be "appropriate and essentially correct" and the importance of monitoring and updating area and volume data was emphasised (Turner and Wood 1993).

A further appraisal of the systems and methodology for each species was conducted for the RFA. This review by ANU and the Commonwealth Government aimed to determine the reliability of the yield forecasts for use in the RFA process. It involved a detailed assessment of the methods of area calculation, inventory, growth and yield prediction, and the scheduling systems.

The results indicate that the datasets, models, systems and methodologies used by CALM to assess sustainable yields from the karri and jarrah forests are appropriate, internally consistent and contain adequate safeguards on data quality through the use of competent staff for their collection and analysis, and the incorporation of monitoring procedures throughout the system. Areas of forest are accurately mapped to a refined level using the modern technologies of large-scale aerial photography, global positioning systems and a geographic information system (GIS). (CALM was the first forestry organisation in Australia to introduce a GIS.) The jarrah inventory procedure is an innovative world-acclaimed system, delivers data within the design error bounds and is acceptably monitored and updated. Estimates of the karri forest resource derive from an inventory completed in 1984 and although the data are updated through a sophisticated tracking and feedback system, a new inventory should be under consideration. Growth data are collected from remeasurements of more than 1000 plots and growth models developed for the estimation of future growth of regrowth stands appear to deliver reliable forecasts under current management strategies. Computerised systems are used to investigate a large number of future (100 to 200 years) scenarios in order to produce recommendations of sustainable yield from the two forest types. The interpretation of these scenarios requires experience and comprehensive understanding of the forests. To assist in this, the management feasibility of these scenarios is checked through a new computerised tool which translates the strategic solutions into maps of the future forest condition.

The reviewers' conclusion is that the systems and procedures developed by CALM staff for estimating sustainable yields from the jarrah and karri forests of the South-West Forest Region are adequate and appropriate and certainly rank among the best in Australia in terms of comprehensiveness of the data base, monitoring arrangements and growth modelling. The complex computerised systems and production of scenarios for estimating future yields are largely the result of the efforts of a dedicated few and the Department needs to ensure that the skill base is disseminated through documentation, training and transparency of decision procedures.

4.4 STRUCTURE AND MANAGEMENT

Overall size and production levels

The timber industry in Western Australia is concentrated in the south-west of the State. Industry activity ranges from the production of tree seedlings, growing, tending and managing the forest estate, harvesting, through to sawn timber conversion and secondary processing to provide a wide variety of wood-based products.

The annual turnover of the combined hardwood and softwood sectors is estimated to exceed $850 million and the industry employs more than 20 000 people either directly or indirectly. The hardwood sector is the larger and more geographically dispersed component of the industry. In 1996-97 the hardwood industry grew more than 22 million seedlings, planted more than 20 000 hectares of hardwood plantation on cleared farmland, harvested or tended more than 24 000 hectares of forest and converted more than 1.5 million cubic metres of roundwood (Table 4.3) into various wood products (CALM 1997e).

Table 4.3 Hardwood log production from Crown land and private property, 1996-97

	Crown land		Private property		Total	
	(m^3)	(tonnes)	(m^3)	(tonnes)	(m^3)	(tonnes)
Sawlog timber [1]						
Jarrah	466 757	613 065	4 234	5 566	470 991	618 631
Karri	190 429	235 532	1 536	1 904	191 965	237 436
Marri	7 232	8 969	1 412	1 751	8 644	10 720
Blackbutt	2 232	2 916	53	66	2 285	2 982
Wandoo	521	685	59	73	580	758
Sheoak	2 676	2 676	199	199	2 875	2 875
Other	5	6	12	15	17	21
Total native	669 852	863 849	7 505	9 574	677 357	873 423
Globulus	473	563	819	974	1 292	1 537
Mallet	0	0	0	0	0	0
Muellerana	72	85	0	0	72	85
Total plantation	545	648	819	974	1 364	1 622
Total sawlogs	670 397	864 497	8 324	10 548	678 721	875 045
Non-sawlog material						
Native hardwood						
Chiplogs	610 188	746 777	57 526	70 479	667 711	817 256
Industrial wood	3 294	4 085	1 725	2 139	5 019	6 224
Firewood	44 472	46 178	860	900	45 332	47 078
Charcoal logs	89 775	94 008	668	668	90 443	94 676
Other [2]	16 338	19 761	1 135	1385	17 473	21 146
Sub-total native	764 067	910 809	61 914	75 571	825 978	986 380
Plantation hardwood						
Chiplogs	6 729	7 873	36 051	42179	42 780	50 052
Industrial wood	0	0	0	0	0	0
Other [2]	1 196	1 228	0	0	1 196	1 228
Sub-total plantation	7 925	9 101	36 051	42179	43 976	51 280
Total non-sawlog material	771 992	919 910	97 965	117 750	869 954	1 037 660
Total log timber	**1 442 389**	**1 784 407**	**106 289**	**128 298**	**1 548 675**	**1 912 705**

Source:CALM (1997)

Notes:

1. Sawlog timber from all sources including veneer, but not including chiplogs, particleboard, industrial wood, firewood, fencing material, poles, piles and minor forest products.
2. Includes poles, bridge timbers, burls, chopping logs, mining timbers, pegging logs and fencing material.

Most of the native forest resource is publicly-owned and managed by CALM. The department is therefore the largest supplier of hardwood logs to the timber industry, supplying more than 90% of Western Australia's annual log production. The supply of hardwood sawlogs and chiplogs from public (Crown) land has remained fairly constant over the past decade (see Figures 4.3 and 4.4).

Although about 350 000 hectares of native forest occur on private property within the south-west (see Table 12.3), it is managed for a variety of purposes and provides only a minor component of annual log production (Figures 4.3 and 4.4). In contrast, substantial areas of hardwood plantations (mostly *Eucalyptus globulus*) have been established on private property during the past five to 10 years. These plantations have been developed by CALM, Bunnings Treefarms (a division of Bunnings Forest Products) and a number of small private companies and will make an increasingly important contribution to the chiplog supply in future years. More than 40 000 hectares of the 62 620 hectares of hardwood plantations established up to 1996 in Western Australia are located in the south-west (Shea and Hewett 1997). With the addition of another 20 000 hectares planted in 1997, the total area planted to *E. globulus* now exceeds 80 000 hectares.

Figure 4.3 Total hardwood sawlog production 1985-97 (,000 cubic metres) public and private forest estates

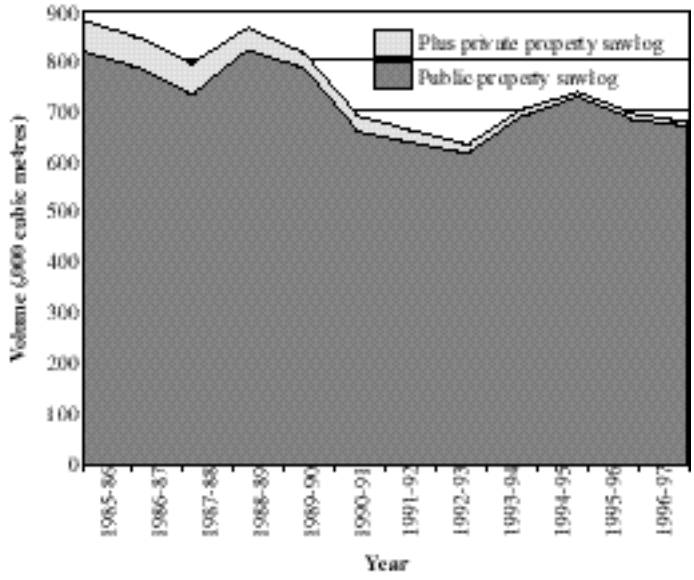
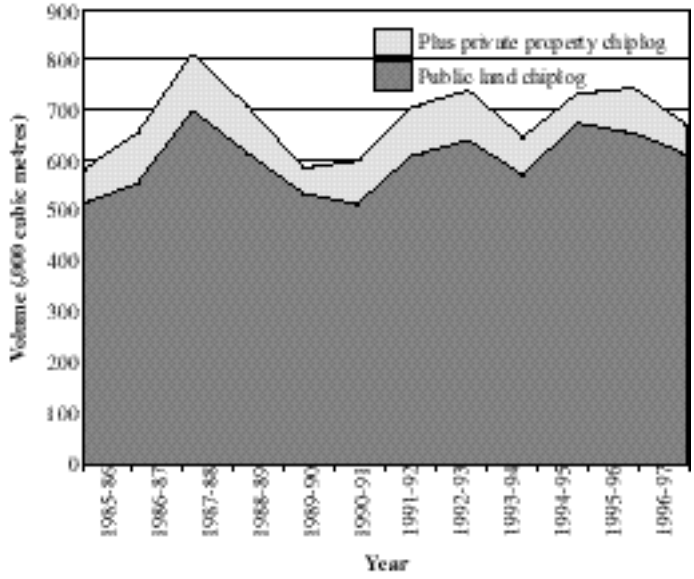


Figure 4.4 Total hardwood chiplog production 1985-97 (,000 cubic metres) public and private forest estates



Forest growing and management sector

The forest growing and management sector provides more than 500 direct jobs in nursery production, field management, research and administration of the public forest estate. CALM's management responsibility includes the implementation of legislation relevant to harvesting operations on public land to ensure that operations have minimum environmental impact, to provide guidelines regarding conduct, practices and log specifications and to ensure safety standards are maintained.

CALM regulates the supply of native forest logs from Crown land to sawmills by offering legally binding contracts of sale. The log allocation system aims to provide equity, security of access to the resource and maintenance of a free market environment by regularly letting tenders for a range of log products. Another objective of the log allocation system is to assist in the development of small mills which contribute to rural economies, create market competition and process a large proportion of second-grade logs (CALM 1987).

Hardwood log pricing varies with log quality, the costs of production and markets. A base price structure exists for all log types—species and grades—which is adjusted annually using an appropriate market-based index. The price of log timber purchased under contracts of sale is based on royalties, costs of production (including harvesting and log transport costs), a requirement for return on investment and to promote value-adding (CALM 1992b).

Harvesting

CALM is responsible for all log harvesting and haulage operations on public land under contracts made between CALM and private companies. Harvesting operators undertake tree felling within the silvicultural objectives specified by CALM and require a thorough knowledge of hardwood log specifications to achieve maximum use from each fallen tree. Contractors are responsible for loading and transporting logs from the landing to mills under operational guidelines defined by CALM, which consider a range of environmental factors such as the dieback status in jarrah forests. Contractors may also be required to stack logs into stockpiles at either the forest landing or the mill.

Sawmilling

The present structure of the hardwood sawmilling industry ranges from large sawmills to single operators using portable mills for commercial craft and hobby purposes. There are more than 70 sawmilling companies in operation, managing 107 registered sawmills (see Map 2 for location of mills and wood processing plants). The industry is dominated by a small number of quite large companies which operate a number of mills. The sawmills are involved in a range of processing activities from predominantly high value kiln-dried and appearance-grade products (including furniture and mouldings) for both domestic and export markets, to green structural timber.

Manufacturing and further processing

Most sawn hardwood timber is processed to the dry-dressed stage and then to veneers, decking, flooring and speciality products such as joinery products, parquetry flooring, laminated beams, laminated benchwood, square dressed timber and wall panelling.

Jarrah is the traditional native timber used in furniture manufacturing in Western Australia, but marri and karri are gaining niche markets because of their attractive grains and structural properties. Extensive gum veins in marri makes the timber difficult to use, but a proportion of marri with acceptable levels of gum veins produces excellent furniture and flooring timber.

Residues and export woodchips

Wood residue material is generated either in the forest as a consequence of sawlog harvesting and silvicultural operations such as thinning, or in the sawmill as a by-product of the conversion of sawlogs. The major market for residue material is presently as export woodchips, to be used ultimately in the production of paper-based products.

There are two major hardwood chipping facilities operating in the south-west. Diamond Mill near Manjimup, which is owned and operated by Bunnings Forest Products, is the State's largest hardwood chipping plant. It processes approximately 700 000m^3 of residue logs each year, of which about 75% are marri and 25% are karri logs. The Whittakers chipping facility at Greenbushes Mill processes mainly sawmill waste, while small portable chippers for log residues and thinning material are also in operation.

Jarrah residues

A major market for lower quality jarrah logs and mill residues is the production of high quality charcoal which, in turn, is used as a reducing agent in the production of silicon metal by SIMCOA Operations Pty Ltd at Kemerton. Under the *Silicon (Kemerton) Agreement Act 1987* the State, through CALM, is required to supply up to 150 000 tonnes of dry jarrah charlogs, or the equivalent of dry jarrah and green jarrah charlogs, of fuelwood quality per year. SIMCOA also produces charcoal from sawmill residue provided by Bunnings Forest Products and Whittakers. Jarrah is a superior charcoal source for silicon production due to the fixed carbon content of between 90 and 95% and the low ash content.

Another significant market for jarrah residues is the domestic firewood industry, in which both commercial and private operators consume a total of more than 45 000 tonnes each year.

Wood panel products, pulp and paper

Wood panel products are composed of wood or other ligno-cellulosic material reduced to fibres or particles which are reconstituted or engineered using binding substances into medium density fibreboard (MDF), particleboard and plywood.

A range of panel products is manufactured in the south-west including:
- flooring material from particleboard;
- architraves, skirtings and furniture from MDF; and
- furniture, construction and marine timbers from plywood.

Hardwood fibres have in the past made up a smaller component of these products, with plantation softwood logs being the preferred fibre source.

In 1996, Bunnings Forest Products concluded an investigation which found that the establishment of a bleached chemi-thermo-mechanical pulp mill in the south-west was not viable at the time. This was due to the high parity price for woodchips on the export market and the relatively high cost of power generation. There is a recycling paper mill at Spearwood which produces packaging-grade paper products and another smaller plant at Canning Vale which produces tissue products from recycled printing and writing-grade paper.

4.5 TRADE IN WOOD AND WOOD PRODUCTS

Exports

Table 4.4 summarises the combined exports of hardwood and softwood products from Western Australia over the five years to 1996-97. Nearly all of these exports were sourced from the RFA area. Since 1995-96, Western Australia has been a net exporter of sawnwood. Most of the sawnwood exports are hardwood, suggesting almost 85% of sawn hardwood timber produced in Western Australia has been consumed locally. This trend is changing rapidly as sawmills and manufacturers focus on a high level of kiln-dried products to target eastern states and overseas markets. Woodchip exports have traditionally comprised around two thirds of the value of timber-based exports.

Table 4.4 Exports of wood and wood-based products from Western Australia, 1992-93 to 1996-97

	Volume unit	1992-93	1993-94	1994-95	1995-96	1996-97
Roundwood	m^3	63	158	204	433	6 629
Sawnwood						
Coniferous roughsawn	m^3	105	204	41	2	4 099
Coniferous dressed	m^3	12	25	601	618	1 018
Broadleaved roughsawn	m^3	8545	14 894	17 522	16 527	19 292
Broadleaved dressed	m^3	0	6	68	276	604
Total		8662	15 129	18 232	17 423	25 013
Railway sleepers	m^3	7941	2859	1912	748	699
Veneers	m^3	1	8	1	14	38
Plywood	m^3	49	98	99	149	127
Panel products						
Particleboard	m^3	18	22	0	46	36
Hardboard	m^3	0	100	0	2	0
Medium density fibreboard	m^3	552	0	52	0	1 181
Softboard and other	m^3	102	148	84	11	23
Total		672	270	136	59	1240
Paper and paperboard						
Printing and writing	tonnes	27	564	19	3	2
Household and sanitary	tonnes	19	152	893	424	74
Packaging and industrial	tonnes	8200	6547	13 293	27 559	32 608
Total		8246	7263	14 205	27 986	32 684
Wastepaper	tonnes	18 548	23 953	24 647	28 620	34 581
Pulpwood [1]						
Hardwood	tonnes	na	435 238	544 617	482 304	483 143
Softwood	tonnes	na			24 177	4 786
Total		na	435 238	544 617	506 481	487 929

	Value unit	1992-93	1993-94	1994-95	1995-96	1996-97
Roundwood	$A 000	44	120	504	359	3 404
Sawnwood						
Coniferous roughsawn	$A 000	28	73	483	3	784
Coniferous dressed	$A 000	18	13	411	218	537
Broadleaved roughsawn	$A 000	6155	11 528	13 459	14 184	15 942
Broadleaved dressed	$A 000	0	11	99	324	918
Total		6201	11 624	14 018	14 730	18 181
Railway sleepers	$A 000	3891	1543	976	433	479
Miscellaneous forest products	$A 000	685	3715	8871	7 775	7 538
Veneers	$A 000	8	29	6	103	148
Plywood	$A 000	66	47	69	256	70
Panels						
Particleboard	$A 000	6	7	0	21	43
Hardboard	$A 000	0	32	0	1	0
Medium density fibreboard	$A 000	231	0	77	0	395
Softboard and other	$A 000	25	102	27	7	15
Total		262	141	104	29	452
Paper and paperboard						
Newsprint	$A 000	0	10	0	0	0
Printing and writing	$A 000	36	337	68	29	30
Household and sanitary	$A 000	23	249	1326	610	137
Packaging and industrial	$A 000	3178	2275	6716	12 946	11 056
Total		3237	2871	8111	13 585	11 222
Wastepaper	$A 000	1920	2530	3942	4 837	4 700
Pulpwood						
Hardwood	$A 000	na	63 009	81 789	76 820	76 430
Softwood	$A 000	na			4 220	647
Total		na	63 009	81 789	81 041	77 077
Total	**$A 000**	**na**	**85 629**	**118 390**	**123 150**	**123 273**

Source: Australian Bureau of Statistics

Notes:

1. Pulpwood exports measured in bone dry units.

Imports

Western Australia is a net importer of veneer, plywood and panel products and is a large net importer of paper and paperboard products (Table 4.5). Imports of these products accounted for more than 60% of the total expenditure on imports of wood and wood-based products in 1996-97. Both paper mills in Western Australia rely mainly on recycled fibre.

Table 4.5 Imports of wood and wood-based products from Western Australia, 1992-93 to 1996-97

	Volume unit	1992-93	1993-94	1994-95	1995-96	1996-97
Roundwood	m^3	127	69	27	38	114
Sawnwood						
Coniferous roughsawn	m^3	7 893	6 587	5 521	5 742	4 346
Coniferous dressed	m^3	1 948	2 308	2 601	1 890	2 792
Broadleaved roughsawn	m^3	12 069	7 667	10 945	6 449	4 929
Broadleaved dressed	m^3	2 087	3 484	3 620	3 114	3 465
Total		23 997	20 046	22 687	17 195	15 532
Veneers	m^3	498	541	519	359	165
Plywood	m^3	4 921	4 086	3 634	6 172	5 615
Panel products						
Particleboard	m^3	345	262	732	97	4
Hardboard	m^3	407	1 072	1 198	880	311
Medium density fibreboard	m^3	1 582	1 378	1 926	2 125	3 016
Softboard and other	m^3	78	97	226	592	238
Total		2 412	2 809	4 082	3 694	3 569
Paper and paperboard						
Newsprint	tonnes	13 133	18 135	23 530	26 402	26 099
Printing and writing	tonnes	33 855	27 691	31 043	22 283	24 612
Household and sanitary	tonnes	1 413	1 266	1 215	750	409
Packaging and industrial	tonnes	2 591	3 032	3 088	3 550	4 303
Other industrial	tonnes	1 870	2 402	2 668	2 350	473
Total		52 863	52 526	61 544	55 334	55 8963
Wastepaper	tonnes	106	601	2125	327	0
Pulp	tonnes	7420	7811	8434	6658	5576
	Value unit	**1992-93**	**1993-94**	**1994-95**	**1995-96**	**1996-97**
Roundwood	$A 000	8	3	27	25	204
Sawnwood						
Coniferous roughsawn	$A 000	3 371	3 909	2 926	3 159	2 339
Coniferous dressed	$A 000	826	1 258	1 473	1 574	2 166
Broadleaved roughsawn	$A 000	6 787	5 219	7 682	4 673	3 566
Broadleaved dressed	$A 000	1 228	2 893	3 260	2 641	2 718
Total		12 213	13 280	15 342	12 046	10 783
Miscellaneous forest products	$A 000	10 134	12 804	14 719	14 549	12 815
Veneers	$A 000	424	587	536	608	235
Plywood	$A 000	2 903	3 228	2 730	2 985	3 120
Panels						
Particleboard	$A 000	79	141	204	56	3
Hardboard	$A 000	276	812	662	321	270
Medium density fibreboard	$A 000	958	1 025	1 580	1 389	1 538
Softboard and other	$A 000	12	48	84	37	50
Total		1 326	2 025	2 530	1 803	1 862
Paper and paperboard						
Newsprint	$A 000	9 071	12 657	16 069	27 763	20 780
Printing and writing	$A 000	35 886	34 559	35 943	38 701	33 730
Household and sanitary	$A 000	1 840	1 649	1 462	1 668	787
Packaging and industrial	$A 000	5 891	7 219	4 946	6 444	8 840
Other industrial	$A 000	3 968	4 531	5 154	4 749	2 102
Total		56 655	60 615	63 574	79 325	66 239
Paper manufacturers	$A 000	8 869	10 642	7 919	7 389	5 507
Wastepaper	$A 000	18	95	482	108	0
Pulp	$A 000	4 022	4 047	5 097	5 993	4 375
Total		**96 570**	**107 406**	**113 030**	**124 885**	**104 922**

Source: Australian Bureau of Statistics

During the past three years the value of exports has broadly been in balance with the value of imports. The value of sawn wood exports is now well in excess of the value of sawn wood imports. The value of pulpwood (woodchip) exports has slightly exceeded the value of paper and paperboard imports in recent years.

4.6 FUTURE RESOURCE AVAILABILITY

The quantity and quality of hardwood timber available in the future will be a key determinant of the industry structure during the RFA period.

Production from private native forest is considered likely to remain erratic and of very low volume relative to production from the public forests. Section 4.2 emphasised the long-term sustainability of the base resource available from public forest estate under the 1994 Forest Management Plan. The potential log grades available during the 20-year RFA period under the 1994 plan are summarised in Table 4.6.

Table 4.6 Current and potential hardwood harvest levels from Crown land (,000m³)

Species	Specification	Approximate volume harvested 1996-97	Forest Management Plan 1994-2003	Potential available 2004-2020
Karri	Sawlogs (1st grade)	152	214	200
	Other logs	190	203	203+
	Wood additional to gross bole	12	75	75
Jarrah	Sawlogs (1st and 2nd)	453	490	300+
	Other logs	47	870	up to 900
	Wood additional to gross bole	109	300	100
Marri	Sawlogs	7		70
	Other logs	453	559	490
Blackbutt	All	6		variable
Wandoo	All	0.9		2
Sheoak	All	2.7		variable
E. globulus	All	7		1000 rising to 4000

Several trends are relevant when interpreting the potential available resource shown in Table 4.6:

- The sustained availability of high-grade sawlogs will extend opportunities for value-adding applications in the solid wood processing sector.
- Changes to harvesting practices and conversion technologies can provide the capacity to improve use of high-grade logs and enhance the use of lower-grade jarrah logs. Such strategies would enable the provision of greater volumes of jarrah sawlog material after 2003.
- The potential level of marri sawlog harvest is higher than that which is currently used. Opportunities exist to strengthen the end uses and markets where this species performs best.
- Minor species such as blackbutt, wandoo and sheoak provide a valuable complement to jarrah and karri and given their limited availability it is important that they be used in applications where their maximum value is obtained.
- Native forest residue material should be considered in conjunction with the hardwood plantation and pine residue resources when generating future development options.

Hardwood plantation and pine resource

By the end of the 1997 planting season, more than 80 000 hectares of *Eucalyptus globulus* had been established in Western Australia. Most of the plantings have been established since the late 1980s with a general intent to manage the stands on short rotations to produce woodchips. Stands harvested in 1996-97 produced 42 780m^3 of chiplogs (Table 4.3). Preliminary woodflow forecasts by the Bureau of Resource Sciences (BRS) suggest that the volumes available from these plantations will increase from around the year 2000 (Table 4.7).

Table 4.7 Hardwood plantation yield forecast (,000 m³ per annum)

Period	1995-99	2000-04	2005-09	2010-14	2015-19	2020-2024
	223	1233	1507	2658	3407	5033

Source: Bureau of Resource Sciences (1997)

Because chiplog rotations are 10 to 12 years the supply forecasts beyond 2010 are necessarily speculative as the plantations to supply these volumes have yet to established. Although these forecasts incorporate the owners'plans to expand the forest estate, the actual rates achieved may be higher or lower than those shown in Table 4.7. Moreover, a significant proportion of the resource is already

committed under long-term contracts with overseas investors. A change in silvicultural practices, such as an increased emphasis on sawlog production, would also affect future woodflows.

The softwood estate in Western Australia comprises both public and private forests. The current production from these forests is summarised in Table 4.8.

Table 4.8 Pine log production from Crown land and private property, 1996-97

	Crown land		Private property		Total	
	(m^3)	(tonnes)	(m^3)	(tonnes)	(m^3)	(tonnes)
Pine saw and veneer logs	253 724	253 724	42 944	42 944	296 668	296 668
Industrial wood	327 430	337 460	106 146	106 373	433 576	443 833
Pine rounds	5798	5798	27 785	27 785	33 583	33 583
Total log timber	**585 952**	**596 982**	**176 875**	**177 102**	**763 827**	**774 084**

Source: CALM (1997e)

Notes:

1. Sawlog timber from all sources including veneer, but not including chiplogs, particleboard, industrial wood, firewood, fencing material, poles, piles and minor forest products.
2. Includes poles, bridge timbers, burls, chopping logs, mining timbers, pegging logs and fencing material.

The production of sawlog and industrial wood grades has steadily increased over the past decade as plantations mature (Figures 4.5 and 4.6). Sawlog supply is forecast to exceed 450 000m^3 per annum by 2005, with a commensurate increase in the future availability of industrial wood from these plantations.

Figure 4.5 Total softwood sawlog production 1985-97 (,000 cubic metres) public and private plantation estates

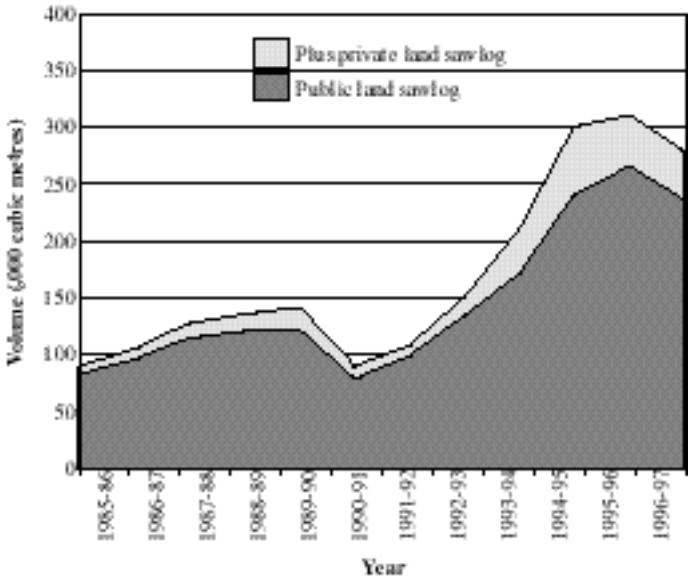
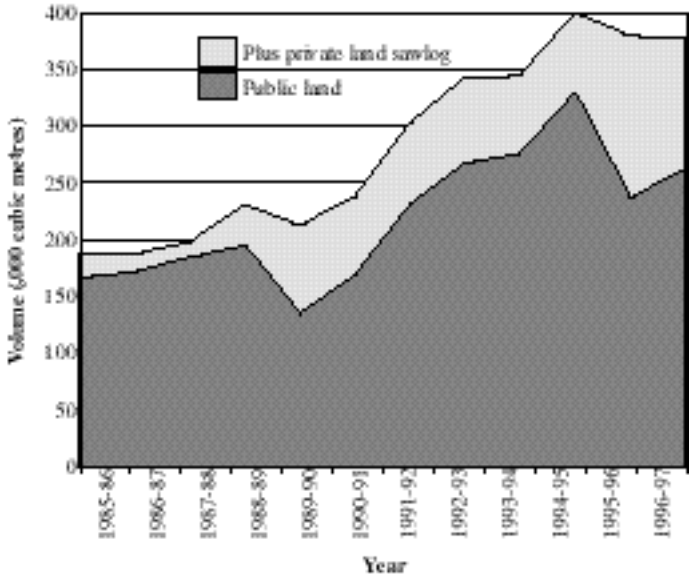


Figure 4.6 Total softwood industrial wood and pine rounds production 1985-97 (,000 cubic metres) public and private plantation estates



4.7 DEVELOPMENT OPPORTUNITIES

An objective of the National Forest Policy (Commonwealth of Australia 1992) and a desired outcome of the RFA process is the development of an internationally-competitive forest products sector. Western Australia's timber industry contributes significantly to the State economy and has undergone major structural adjustment over the past decade to enhance its competitiveness. Because any changes to future resource availability arising from the RFA may impact on the future development of the industry, a separate project was initiated to review the international competitiveness of the industry and to formulate possible scenarios for industry development through to the year 2020.

A consultant, the BIS Shrapnel Forest Group, was engaged to examine the future opportunities.

The first stage of the review examined the properties, potential products and availability of the Western Australian hardwood timber resource. An assessment of international markets for current and potential products was then undertaken. A number of market factors were identified as likely to influence the development opportunities of the Western Australian industry, including:

- reduced availability of tropical sawlogs from traditional producers in south-east Asia;
- a corresponding reduction in suitable veneer logs and hardwood supplies in major Asian markets;
- steady expansion in plantation capacity in south-east Asia;
- current excess capacity for the production of particleboard and medium density fibreboard (MDF) in the Pacific Rim area (although this excess is expected to be short lived due to strong growth in demand for these products in the region);
- a continued strong growth in demand for pulp and paper in the Asian region;
- the large number of pulp plants currently under construction in Indonesia, Korea, China, Thailand and Malaysia will probably contribute towards downward price pressure on both hardwood pulp and woodfree paper in the medium term; and
- possible softening in import woodchip prices in the Japanese market as import barriers to paper products are eased.

The competitiveness of the Western Australian industry relative to international cost structures was then investigated. The key factors influencing the industry's cost-competitiveness are discussed under separate headings.

Stability and security of wood supply

The ability to ensure continuity of supply from a sustainably-managed resource will be a key advantage in distinguishing Western Australian species from many competitors. The current sawlog contract system between CALM and individual sawmillers can guarantee supply for up to 10 years. Another approach has been to use State Agreement Acts to support the establishment of wood and other processing plants, using log timber made available by CALM. This approach has been used to assist the establishment of two softwood board plants and the large-scale charcoal-based metal manufacturing facility.

Wood costs

Western Australian sawlog prices appear competitive compared with suppliers from Malaysia, Indonesia and the United States and, to a lesser extent ,against suppliers from South America and Africa. This advantage over south-east Asian producers is expected to increase in coming years as supplies of tropical sawlogs decline further.

The delivered price for hardwood pulpwood (chiplogs) in Australia is higher than all other major pulp producing regions. The cost of pulpwood in Western Australia is largely driven by the high price of fibre paid by Japan. As trade barriers are reduced, and the Japanese pulp and paper producers are increasingly exposed to international market forces, it is probable that the price paid for pulp logs will decline, with a consequential flow on to Australian prices.

Energy

Although electricity prices in Western Australia are somewhat higher than in eastern Australia, they are comparable to levels in the United States, and are lower than those found in Brazil, Indonesia and Japan. Lower energy prices are expected to be achieved in the south-west from the following changes:

- removal of restrictions on customers with loads less than 5MW obtaining electricity from suppliers other than the Western Power Corporation;
- sale of the Dampier to Bunbury natural gas pipeline, and the building of a second pipeline to the south-west;
- allowing the development of alternative sources of supply of primary fuels; and
- encouraging the use by industry of co-generation opportunities.

Labour

Labour costs in Australia are lower than those of North America, Scandinavia and Japan, but higher than those of developing countries such as Chile, Brazil, Indonesia, and Thailand. However, typically higher productivity is also associated with the higher cost countries.

Other raw materials

Resin costs, which are a major component of wood-based panel costs, are believed to be comparatively high in Western Australia and are estimated to be 10 to 15% greater than in the United States. Some reduction could be achieved with economies of scale of production, given greater demand in Western Australia, however the costs of importing the raw materials are still likely to be high by international standards.

Capital costs

The costs of capital associated with individual companies or regions can vary widely, and depend on a range of factors. Prevailing interest rates have a strong influence on the rate at which finance can be obtained, and the expectations on returns for equity funding. At present interest rates in Australia are comparatively low. However, finance is not necessarily raised in the country where a plant is built, and in such cases will be further affected by changes in the exchange rate. Finance costs will also depend on a company's present mix of debt and equity.

Transportation

The cost of transport from Western Australia is high compared to other Australian states and overseas destinations. With larger export volumes, however, lower prices may be able to be negotiated.

Any reduction in port costs (which are high by international standards) should also lower freight costs. Some operators have already achieved competitive transportation costs by securing good back-loading rates to the eastern states with large volumes and low freight rates currently apply to woodchip shipments from Western Australia.

4.8 INDUSTRY DEVELOPMENT OPTIONS

The consultants, through meetings and workshops with industry, government agencies and specialists, then identified a series of probable development opportunities for the hardwood sectors.

Veneer products

Sliced veneer probably provides the best opportunity for the very best jarrah and karri logs. The natural colour and grain produce an attractive sliced veneer which maximises the use of the superior component of the resource. The comparatively low wood costs will ensure that sliced veneer produced in Western Australia will be able to compete favourably with other sources.

A plywood mill located in Western Australia would appear to be competitive against other hardwood plywood suppliers. The main advantage arises from the relatively low wood costs when compared to mills in Indonesia, Malaysia and Japan. Further confirmation is required of the veneer grade recoveries which can be achieved from the range of log grades and species. A Western Australian-based plant has the ability to combine softwood, plantation hardwood and native hardwoods and thereby make a range of panels suited to various end uses, by using the strengths of each of the species.

A similar set of advantages exists for laminated veneer lumber (LVL), with LVL manufactured from Western Australian native species able to provide both attractive appearance and strength. However, because the LVL market is considerably smaller than plywood, there will be fewer opportunities to concentrate on high-value niche markets, and because LVL can be manufactured from a range of log grades Western Australia's cost advantage may not be as strong.

Sawn timber

The focus for the hardwood sawmill industry is switching from essentially a domestic, structural focus to international markets for high-value solid-wood products. This trend is likely to be accelerated by increased competition from local pine for some structural markets. The hardwood timber resource is available in Western Australia and export opportunities will be created by declining supplies from traditional supply sources. The inherent wood qualities of both jarrah and karri allow use in a range of applications including flooring, furniture, joinery and other internal fixtures and fittings.

Considerable investment in drying and milling technology will be necessary to achieve international competitiveness. Technical research and development in new product areas will be necessary, as well as increased market development and promotion. Investment in drymill processing will be required if further efficient downstream remanufacturing is to be achieved.

Secondary processing

The increased availability of high-value sawnwood provides the opportunity to expand the secondary wood processing industry. This could include a combination of a number of manufacturing processes such as flooring, millwork and moulding, joinery, furniture and a variety of laminated wood products (including structural glue laminated beams, edge glued panels, and non-structural laminated products). It is believed there are excellent opportunities for Western Australian furniture manufacturers in the affluent markets of North America, Europe and Japan.

Efficient value adding will require appropriate drymill processing and investment in drying and secondary processing. Sawmilling companies or independent operators could provide the necessary specialist, intermediary manufacturing capabilities, supplying manufacturers of such products as furniture, joinery, cabinet fixtures and fittings.

While it is possible for an efficient secondary processing industry to develop based largely on export markets for such items as furniture components, there is less risk if there is also a domestic manufacturing focus such as for furniture and joinery. Development of a competitive manufacturing sector will depend on a number of factors including creative design capabilities, marketing and promotional skills, and effective training and education. With comparatively low investment, however, there is good potential in these sectors to add significant value and generate substantial employment opportunities.

Panels

Of all the wood-based panel products, particleboard probably has the best potential to use a component of native and plantation hardwood residue. Though currently high wood costs limit the competitiveness of a Western Australian-based plant, should these decline over time, then an additional particleboard plant based on a combination of softwood, plantation and native hardwoods and sawmill residues could be viable. As particleboard is overlaid in most applications, the impact of any slight change in colour as a result of incorporation of native hardwoods is likely to be minimal.

The already large global market for particleboard is expected to continue to grow, thereby creating new opportunities. There is therefore the potential for an additional particleboard line to be established before 2010, based on a mixture of softwood and plantation and native hardwood.

There will also be potential for expansion of the MDF capacity before 2010, though this is likely to be based on softwood with incorporation of some *E. globulus*. The Asia Pacific market for MDF is expected to be in balance by around 2001 creating opportunities for new investment. Raw material supply, however, will limit expansion until nearer 2010 unless significant volumes of plantation hardwood are used.

The consultants concluded that there would be limited opportunities for an OSB plant to be established in Western Australia as most growth in the market will occur in North America and it would be very difficult to compete with domestic producers in the United States. Regional suppliers of OSB would have to capture a significant market share. It therefore seems unlikely that a Western Australian producer would be able to compete with manufacturers nearer the major markets, as transportation costs would be prohibitive on such a comparatively low-value product.

Pulp and paper

Considerable investigations into the viability of establishing world-scale pulp mills in Western Australia have already occurred. A recent feasibility study concluded that a Western Australian-based pulp mill would not be competitive because of:

- uncertainty over the availability of sufficient wood resource in the immediate future for a bleached hardwood kraft pulp (BHKP) mill;
- relatively high woodfibre costs because of the need to pay parity prices with export wood chips to Japan;
- comparatively high power prices impacting on the overall cost competitiveness of a bleached chemo-thermo mechanical pulp (BCTMP) mill; and
- imminent increases in production for Indonesian pulp and paper, which will add to the risk associated with market pulp-based mills.

These factors could change over time. There will undoubtedly be increasing volumes available from maturing *Eucalyptus globulus* plantations; woodchip prices paid by Japan are forecast to decline over time; deregulation of the power market could lead to reduced power prices; and as Indonesia shifts to use plantation timber, rather than native forest residues, their competitive position may be diminished.

The availability of a large-scale plantation hardwood resource, supplemented by native hardwood residues, is expected in the future to provide the basis for investment in pulp and paper manufacture. The resource is of high quality and will be able to produce a premium pulp for the manufacture of high-quality papers. A BHKP mill is more likely because of the greater ease in selling market pulp (compared to BCTMP), suggesting that investment in a paper-making plant could occur at a later date. Additionally the BHKP process has the potential to use a major component of the native hardwood (karri and marri) resource.

Over the period 2010 to 2020, the competitive position of a Western Australian BHKP mill is expected to have improved sufficiently to warrant investment, with further investment in a paper making machine towards 2020. The timing of such an investment will depend on such factors as the availability of the native forest and plantation chiplog volumes, the extent to which plantation resource is committed to overseas pulpmills, and the overall market value of pulpwood relative to pulp.

Other uses

Further market opportunities need to be developed to encourage the use of jarrah residues. Between 1998 and 2010 the silicon metal manufacturing facility will probably expand, providing the potential for increased use of jarrah residues. There may also be the potential market for the export of jarrah wood chips for charcoal manufacture. A further possibility is the use of jarrah residues in the manufacture of activated carbon, as this market now appears to be entering a period where there is opportunity for new investment. Continued growth is likely because of increasing use in environmental applications.

A summary of the possible industry expansion opportunities developed by the consultant is outlined in Table 4.9.

Table 4.9 Summary of industry structure under proposed development scenario

Current	2010	2020
Existing industry	*Expansion or refurbishment*	*New plants*
Sawmilling structural and appearance	Sawmilling - greater emphasis on value adding	BHKP mill
MDF	MDF, 2nd line	Wood free printing and writing paper
Particleboard	Expansion of charcoal	
Furniture		
Remanufacturing	*New plants*	
Woodchip exports	Plywood mill	
Charcoal	LVL mill	
	Particleboard	
	Expanded remanufacturing and furniture sector	
	Activated carbon	

Interest in the availability of both hardwood and softwood for local processing is currently strong in Western Australia. CALM and the Department of Resources Development report that both local and overseas companies are actively investigating the feasibility of extending existing plants or establishing new plants involving a wide range of solid wood, engineered and reconstituted wood products. It is likely that hardwood woodchip exports, sourced increasingly from plantations, will remain an important component of residue markets.

5 Plantations

5.1 PLANTATION EXTENT

According to the National Forest Inventory (1997), the South-West Forest Region had 148 000 hectares of plantations in 1995. This consisted of: *Pinus radiata* (42%), *Eucalyptus globulus* (34%), *P. pinaster* (19%) and minor eucalypt species (5%) (see Table 5.1).

Table 5.1 Western Australian plantations species and area (ha)

Regional Total	*E. globulus*	Minor eucalypt species	Hardwood Total	*Pinus radiata*	*Pinus pinaster*	Softwood Total
148 000	50 280	6770	57 050	62 740	28 250	90 980

Source: NFI (1997)

The rate of plantation establishment for *E. globulus* has been exponential, with an increase of 20 400 hectares being reported in 1996 (CALM 1997e) and another 20 000 hectares planted in 1997. The area of softwood estate remains largely unchanged with an increase of 464 hectares in public plantations and an increase of 905 hectares in private plantations. There was no reference to the area of private plantations clearfelled.

5.2 PLANTATION OWNERSHIP

From CALM and NFI data, Western Australia's plantations are approximately 58% publicly owned and 42% privately owned.

Statistics on the total area of State-owned softwood plantations and the total area of State-managed hardwood plantations are presented in Tables 5.2 and 5.3 respectively.

Table 5.2 Area of State-owned softwood plantations as at 31/12/96 (ha)

Regional Total	*Pinus radiata*	*Pinus pinaster* (and other species)
70 758 (8223)	44 245 (7262)	26 513 (961)

Source: CALM's Annual Report 1996-1997

Note: Areas shown in brackets have been established under sharefarm agreements. They are included in the totals.

Table 5.3 Area of State-managed hardwood plantations as at 31/12/96 (ha)

CALM-owned		CALM-managed		Total		
E. globulus (ha)	Other eucs (ha)	*E. globulus* owned by other Govt agencies (ha)	*E. globulus* Privately owned (ha)	*E. globulus* (ha)	Other eucs (ha)	Total State-managed hardwood
7617 (7473)	**6736 (17)**	**1124**	**12 933**	**21 674**	**6753**	**28 427**

Source:CALM Annual Report 1996-1997

Note: Areas shown in brackets have been established under sharefarm agreements. They are included in the totals.

5.3 PLANTATION POTENTIAL

During the 1980s CALM developed policies to encourage the development of treecropping of *E. globulus* and *Pinus radiata* on agricultural land (Shea and Hewett 1997). Both CALM and the private sector now have extensive *E. globulus* hardwood plantation programs in place and further increases in the size of the plantation estate are expected. Pulpwood production from new Western Australian plantations has attracted considerable interest from overseas investors. Table 5.4. shows the total areas and production rates of these plantations. Some figures presented (shaded) are speculative.

Table 5.4 Current and potential interests in developing plantations in Western Australia

Company	Agent	Production tonnes/year	Total area (ha)
Albany Plantation Forest Co. (Oji/Itochu/Senshukai)	CALM	500 000	20 000
Collie Hardwood Plantation (Hansol Forest Products)	CALM	500 000	20 000
Bunbury Tree Farm Project (Nippon Paper Industries-Mitsui and Co)	CALM	500 000	20 000
Sub-total pulpwood plantations managed by CALM		1 550 000	60 000
Sharus	Self	100 000	7000
Taiwan (through Austrade)	Current inquiry	1 000 000	40 000
USA (through Austrade)	Current inquiry	500 000	20 000
Total all overseas companies		2 850 000	117 000
Wesfarmers Bunnings	Self	3 000 000	100 000
Others – Prospectus promoters and independent investors, say:	Self	1 250 000	50 000
Total prospects all companies		**7 350 000**	**277 000**

Source: Lancefield Consultants (1995)
Note: Volumes and land areas are nominal (shaded areas include speculative figures).

CALM has also launched a plantation development program for maritime pine (*Pinus pinaster*) on cleared agricultural land in the 400mm to 600mm annual rainfall zone and sandy soils in the higher rainfall zone. The first 9600 hectares of *P. pinaster* were established on farms in 1995 and 1996. This was increased to 1300 hectares in 1997, and the proposed annual rate of establishment is 15 000 hectares by the year 2000. CALM's target is to establish up to 150 000 hectares within 10 years—the potential land area suited to *P. pinaster* in Western Australia has been estimated at three million hectares.

Availability of land

The suitable region for *E. globulus* plantation development extends from south of Perth to east of Albany. The 600mm rainfall isohyet had been assumed to be the limit of commercial tree growing (Meagher 1993). However, according to Shea and Hewett (1997) it is expected that commercial growing of *P. pinaster* can occur as a farm forestry crop in the 400mm to 600mm zone. Soil depth, texture and fertility are also important factors in determining tree growth and suitability for individual plantation species (Meagher 1993).

According to Meagher (1993) 25% of the 1.8 million hectares of freehold land in the region is uncleared. This is not proposed to be cleared, so 1.45 million hectares of the region is potentially available for tree planting. Approximately one third of this area (about 500 000 hectares) could conceivably grow *E. globulus* at returns that are competitive with agriculture.

Plantation capability study

A plantation assessment project is currently underway. This project will provide a further basis for considering the potential of the RFA region and adjacent areas to provide wood for industries now and into the future. The assessment involves identifying the current plantation information through the National Plantation Inventory and CALM's database. The assessment will follow a review of existing information. The focus will be on broad plantation capability for cleared land within the region that can be interpreted for a range of species. Recent soil mapping by the Department of Agriculture provides opportunity to refine existing capability information and provide a seamless spatial database for the study area. As the results of this new plantation capability work will not be available for this report, they will be made available separately.

Cost of land and other factors determining plantation potential

Land value maps are available for the region. Land values vary widely, depending on existing uses, rainfall, soil types and distance to particular towns. In order to evaluate land for plantations it is also necessary to consider location relative to processing centres/export facilities and plantation productivity. Suitable land should be available at an acceptable cost (Meagher 1993). In most cases there are other benefits of establishing plantations on farmland. The combined benefits need to be used when evaluating their viability.

It should be noted that plantation potential referred to here includes broad indications of suitability based on social and economic factors. A large number of factors can determine the plantation potential of land. Meagher (1993) lists several factors (see Table 5.5).

Table 5.5 Determining factors for plantation potential

In summary the principal factors are:

1. The value of native hardwood increasing sufficiently in price to ensure replacement by plantation softwood in the structural timber market.
2. Expected demand relative to the supply of timber products in Western Australia.
3. Anticipated or pre-negotiated price for plantation products at the time of harvest.
4. New plantation estates being large enough to under-pin, new or expanded processing plants.
5. A demonstrated or adequately perceived excess of revenue over costs, sufficient to attract the necessary investment funds.
6. Availability of agricultural land capable of growing marketable wood at suitable growth rates (not all agricultural land in the appropriate climatic zone is capable of production).
7. Cost of land relative to its location and productivity
8. Proximity of suitable and available land to markets and/or ports.
9. Plantation estates being staged at suitable age/size classes to enable continuity of harvest.
10. The existence of relevant community infrastructure.
11. Australia's maintenance of its export woodchip market share.
12. Farming community acceptance of an increased plantation estate. (Value and use of land after timber harvest are significant considerations).

Source:Meagher (1993)

Apart from the social and economic factors, policy initiatives by governments also provide an important impetus to plantation promotion and establishment, and these need to be considered along with the other factors in plantation potential. Government forest policies such as Plantations for Australia: 2020 Vision, the Wood and Paper Industry Strategy, the National Farm Forestry Program, CALM's plantation initiatives, Agriculture Western Australia's extension programs, Landcare, Integrated Catchment Management, Western Australia's Salinity Action Plan and other programs and policies are encouraging more plantations on cleared, privately-owned land in Western Australia. The benefits of plantations to the rural landscape are not just to provide wood. There are benefits in the lowering of watertables and implications for the amelioration of dryland salinity processes. Farm forestry can also provide shelter to crops and livestock and increase the aesthetic and wildlife values of farmland (Shea and Hewett 1997).

CALM's maritime pine project in the 400m to 600mm rainfall zone (and on the coastal plain sands), is a key initiative under the State's Salinity Action Plan. The 150 000 hectares of *P. pinaster* CALM aims to establish with private landowners, will help combat salinity problems.

6 Tourism and recreation

6.1 INTRODUCTION

This chapter defines tourism and recreation, summarises the major businesses that are part of and benefit from these industries, assesses the economic impacts of tourism on a State and regional basis, makes some estimates of growth in forest usage over the 20-year period that the Regional Forest Agreement (RFA) will be in place, and summarises some of the potential conflicts that may arise between the tourism and recreation industries, local communities and other forests users.

Definition of tourism, recreation and day-trippers

Tourism has been defined as "...the activities of persons travelling to, and staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes" (Industry Commission 1996).

Tourists include two groups:
- domestic tourists—those travelling within their own country, both interstate and intrastate; and
- international visitors—those travelling outside their home country.

In addition to those travellers who stay overnight, the United Nations Economic and Social Council, World Tourism Organisation definition of tourism includes day-trippers. These are people travelling more than 50 kilometres from their immediate environment for tourism or recreational activities but returning within the same day. The two groups may use many of the same facilities and visit the same attractions.

There is also an important link between tourism and recreation in terms of activities or experiences. Recreation is defined as the range of social, cultural, sporting and other activities undertaken in leisure time and leisure is defined as time uncommitted to work, family or personal nature. While not all recreational activities are classed as tourism, there is a significant overlap between tourism, recreation and day-tripping.

Management and promotion of nature-based recreation and tourism in the RFA area

Tourism and recreation have always been important uses of forest areas (see Map 4). Much of the initial infrastructure including towns, roads and car parks, has been based around facilities to which the timber industry has been a major contributor. Further infrastructure has been, and is continuing, to be developed through private investment by the tourism industry. In addition, forest users including the timber industry and mining companies are major contributors to the ongoing development of recreation sites. In its role as the State's forest manager, CALM has developed a wide range of nature-based recreation and tourism areas and facilities. These range from day use and camping areas to major attractions such as the Tree Top Walk at the Valley of the Giants east of Walpole. Other contributors include the local shires and regional development commissions. The Ministry of Sport and Recreation is also providing funds to help regional and local groups develop trails for a range of users from bushwalkers, families and occasional walkers to trails for mountain bikes and equestrian use.

Forest-based tourism is promoted by individual operators, the Western Australian Tourism Commission, tourist bureaux, development commissions, regional tourism associations, CALM and local shires. This local marketing thrust is also supported by the Australian Tourism Commission's promotion of Australia's ''Great Outdoors''.

6.2 TOURISM AND RECREATIONAL FACILITIES IN THE FOREST AREA

The forest is one of the cornerstones of tourism in the south-west. This area of the State is the only place where forests are found in abundance in close proximity to a large population. The perception by tourists as they drive through the region is that it is an area which is heavily forested, as one of the main views from the vehicle is of trees. The feeling of the region is of lush, green forest. The forest area is where tourists come to recreate whether it is to walk in the forest, camp out or stay in chalets and resorts under the canopy of trees.

The RFA area can be considered in the three CALM forest regions—Swan, Central Forest and Southern Forest. Each of these regions can then be sub-divided into three tourist and recreation sectors.

Swan Forest Region

The Swan Forest Region included in the RFA is almost contingent with the Darling Range running east of Perth. The range comprises the Darling scarp and the Darling Plateau east of the scarp. It is an area of outstanding beauty with forests, valleys, seasonal rivers and streams and spectacular views over the coastal plains to the ocean.

The conservation values of the Darling range are recognised by the large number of national parks, nature resources and conservation reserves in the area. Most of the wooded areas are State forest. The majority of forest lands set aside in the Darling Range, as well as State forest or national parks, are also protected as water catchment areas under the control of the Water Corporation. Consequently, this has a major influence on the use of the Perth hills including many areas that form an integral part of the tourism product. Parts of the Darling Range were favoured winter hunting and gathering grounds for the local Noongar tribes and the Bibbulmun Track bushwalking route, which runs south from Kalamunda, was named after a Noongar group.

Northern Swan sector

This sector includes Avon National Park and (the proposed) Walyunga National Park plus a wide range of scenic drives, areas of interest, picnic spots, walks, wildflowers and wildlife. The Avon River, the location of Western Australia's premier white water race, passes through both parks joining the Swan River at Walyunga. This event draws a large number of visitors to the State each year.

The Hills Forest

The Hill Forest lies half an hour's drive east of Perth. It is served by twin gateways, Mundaring and Kalamunda and stretches almost as far south as Karragullen near Brookton Highway. It covers 80 000 hectares and crosses four shire boundaries: Kalamunda, Mundaring, Swan and Gosnells.

It includes John Forrest National Park, Mundaring Weir, areas of State forest, Lake Leschenaultia, dam and reservoir sites and many other places of recreational and conservation significance. There is a range of walk and heritage trails, including the start of the Bibbulmun Track. CALM formed The Hills Forest concept in 1991 to offer visitors an enjoyable experience which also involves an awareness and appreciation of our forest values.

The area also produces a range of natural products (wine, fruit, etc.) and has many arts and crafts studios.

Peel forest sector

This section has four major reservoirs on the Canning, Serpentine, North Dardalup and South Dandalup rivers and includes the towns of Dwellingup, Boddington and Jarrahdale. Major recreation areas include Serpentine National Park and Lane Poole Reserve, both of which are popular with metropolitan and overseas visitors. Other attractions in the forest area include the:

- Forest Heritage Centre at Dwellingup which provides visitors with an understanding of the social, community, aesthetic and economic benefits that come from Western Australian forests;
- Hotham Valley Tourist Railway;
- Boddington Rodeo—an annual event which takes place on the first Saturday of November and attracts riders from all over Australia;
- Bibbulmun Track and other walk trails being developed by CALM and the Serpentine-Jarrahdale shire councils.

Central Forest Region

The Central Forest Region is divided by CALM into three districts as follows:

Mornington

The district's major forest-based attractions are associated with the waterways, especially Wellington Dam, a nature-based attraction offering good day tripping facilities, as well as international standard rowing and kayaking courses which attract major sporting events. Other dams in the region include Harris River, Logue Brook, Stirling, Wellington Weir and Harvey Weir.

This area also offers forest scenic drives, bushwalking and camping.

Blackwood

The Blackwood River sector has a dispersed nature-based tourism product with key themes developed around the river and other waterways, the jarrah forest and associated scenic drives. Major nodes for tourism in this area are the towns of Bridgetown, Nannup and Balingup, plus the Blackwood River itself. Nannup is also a centre for the timber milling industry.

South-West Capes

Most tourism attractions in this area are associated with the towns of Busselton, Dunsborough, Yallingup, Margaret River and Augusta. These towns, particularly Margaret River, offer a base from which visitors travel to nature-based attractions, including the forest area. Boranup karri forest in the Leeuwin-Naturaliste National Park offers an example of a regrowth forest after logging in the late 19th century.

Camping and picnic areas in State forest are generally associated with the Blackwood River and Conservation Parks. They include Canebreak Pool in the Rapids Conservation Park, Ten Mile Brook and Canebreak picnic area along Brockman Highway. Local walk trails include the Augusta-Busselton heritage trail and short walk trails adjacent to the picnic areas.

Southern Forest Region

The Southern Forest Region has a considerable amount of nature-based tourism focused on rivers, pools, State forest conservation areas, tourism drives and major forest features. CALM divides the region into Manjimup, Pemberton and Walpole districts.

Manjimup

This district stretches from the Donnelly River in the west, through Manjimup to Perup and Lake Muir Nature Reserves to the east. The area includes a range of current or proposed conservation parks and nature reserves with the major tourism attractions centred around Manjimup and Donnelly.

Attractions include walk trails, bush walks, scenic forest areas, water attractions, heritage and pioneer sites. Sporting events and festivals include the Manjimup Timber Festival and the 15000 Motorcross International event. Numerous picnic areas have associated walk trails, e.g. Fonty's Pool, One Tree Bridge, The Four Aces, Wheatley Dam (timber and other trails), King Jarrah and Diamond Tree. There is also fishing, mainly for trout and cobbler.

Pemberton

The Pemberton district includes Warren, Beedelup, D'Entrecastreaux and Shannon national parks and the tourism centres of Pemberton and Northcliffe.

The area is developing as one of the south-west's major nature-based tourism destinations incorporating walk trails, bush walks, water attractions, major forest-based scenic attractions, marron and trout farms, recreational and adventure-based tourism, vineyards and scenic drives and a wide range of accommodation.

Walpole

The Walpole district is bounded by South Western Highway and incorporates the existing and proposed reserves of Mt Frankland, Walpole-Nornalup and Mt Lindesay national parks, the Mt Roe reserve and significant areas of State forest and nature reserves.

The area includes forest drives accessible to on-road vehicles and the tourism centres of Walpole and Denmark. Other activities and events include the south-west angling championships, Walpole Yacht Club Regatta and the Walpole Art Group, Denmark arts and crafts market days and the Rainbow Festival. The Valley of the Giants and the Tree Top Walk have become key attractions, drawing large numbers of tourists to the area, and are being promoted around the world by the Western Australian Tourism Commission.

6.3 OPERATORS USING THE FOREST AREA

A wide range of tourism operators is licensed by CALM to operate in State forests and national parks in the Swan, Central and Southern Forest Regions. In April 1997, there were 126 licensed operators.

Of these, 70 were based in Perth, six in the Swan Forest Region, 26 in the Central and Southern forest regions, nine north of the RFA area and 15 interstate. The activities offered by these operators are set out in Table 6.1.

Table 6.1 Number of licensed operators offering specific activities

Activity	Number of operators
Aboriginal culture	10
Abseiling	20
Birdwatching	17
Bushwalking	53
Camping	54
Canoeing	21
Caving	21
Coach tours	16
Cycling/mountain bike riding	6
Day tours	28
Fishing	5
Forest heritage	7
Four-wheel drives	34
Horse trails	4
Mini-bus tours	5
Orienteering	3
Photography	7
Rafting	13
Rock climbing	14
Safari tours	10
School program	19
Scientific	5
Sightseeing	45
Wildflower viewing	30

Other operators located around these forested areas provide a wide range of services to tourists such as tourist bureaux, hotels, motels, resorts, guesthouses, bed and breakfast, lodges, backpackers and self-contained accommodation, caravan parks, camping areas, restaurants and cafes. There are also organisations offering tourist attractions such as vineyards, adventure experiences, train and tramways, art and fine wood galleries, fish farms and wildlife parks.

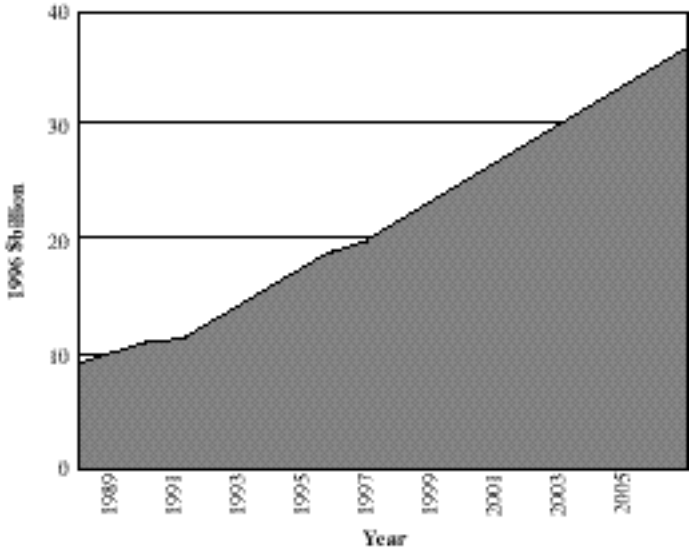
6.4 ECONOMIC IMPACTS OF TOURISM

Economic and employment benefits of tourism

Tourism has become one of the biggest industries in the world. According to estimates prepared by the World Travel and Tourism Council, tourism directly and indirectly accounts for about 11.5% of jobs, more than 14% of investment, just under 13% of exports, 12% of wages and about 10.5% of GDP in Australia, making it of major economic significance (Office of National Tourism 1997). The total contribution of inbound and domestic tourism is worth $60 billion to the Australian economy.

Inbound tourism has become one of Australia's leading export earners. In 1996, it contributed $16 billion to the nation's economy, up from $9 billion in 1989 (Office of National Tourism 1997). Growth is predicted to average 7.8% a year over the next decade to $34 billion (1996 dollars) in the year 2006 (Office of National Tourism 1997) as Figure 6.1 illustrates.

Figure 6.1 Tourism exports 1989-2006



Source: Office of National Tourism 1997

In Western Australia, the tourism industry is a major contributor to the State's economy and is predicted to become the State's fastest growing industry sector during the 1990s and into the next century (Western Australian Tourism Commission 1997a).

The most effective means of measuring the economic impact of tourism is derived from data on tourist expenditure. Tourists make a significant contribution largely through expenditures within the region. However, this information must also include the amount spent by tourists as they buy packages (airfares, accommodation, tours) in their country of origin. In 1995-96, total tourist expenditure in Western Australia was estimated at $1.9 billion and the value of the travel and tourism industries accounted for 3.7% of Gross State Product (GSP) (WATC 1997a). Communications with WATC indicate that for every additional $1 million spent by tourists in Western Australia, 13 new jobs are created in the economy when compared to the previous year. In 1996, the tourism industry contributed to the direct employment of between 55 000 and 68 000 people, representing 6.6 to 8.1% of the State's total workforce.

The benefits of tourism expenditure accrue firstly to regional economies through tourist spending which has direct contributions to incomes for local communities. Additional state and national benefits occur through the multiplier effects. These include a diversification of Australia's industry structure, contributions to the balance of payments, and an increase in tax revenues and social benefits.

Another measure of tourism's contribution to the economy is through investment. The value of CALM recreation and tourism assets in the Swan, Central and Southern forest regions is estimated to be $7.2 million, $7 million and $7.9 million, respectively. In addition, the value of the Bibbulmun Track infrastructure across all three regions is estimated at $2.5 million (C Ingram pers. comm.). The level of private investment in tourism projects which have been completed or are under construction in and around the Central and Southern forest regions in 1997 is estimated to be $102.8 million (WATC 1997b). Tourism is estimated to contribute to the employment of between 4300 and 5300 people in these regions, excluding self-employed people, based on ABS statistics (G Hodgson pers. comm.).

Number of visitors to Western Australia

Tourism statistics are normally considered in three sectors, international, interstate and intrastate. For all sectors, a total of 6.4 million tourists were recorded in Western Australia in 1996. Of these, 4.2 million were classed as leisure visits. More than 80% of both leisure visitors and tourists were travelling within their own State, with approximately 8% from each of international and interstate locations.

Table 6.2 Visitor statistics for Western Australia, 1996

	International		Interstate		Intrastate		Total	
	Visits	Nights	Visits	Nights	Visits	Nights	Visits	Nights
Total tourists ,000s	529	10097	546		5333	18415	6408	
Leisure visitors ,000s	422		301		3444		4167	
% of State total								
Leisure visitors	10.1		7.2		82.6		100.0	
Total tourists	8.2		8.5		83.3		100.0	

Regional Forest Agreement areas

Data for tourism and day-tripper activity in Western Australia is gathered by the Western Australian Tourism Commission. An assessment based on post codes within the RFA area has been made to determine visitors to this area over the two-year period 1995 to 1996. This has then been further sub-divided to determine tourists and day-trippers visiting the forest areas.

Tourist data

On average, 2.38 million visitor trips a year were made to the RFA area during 1995 and 1996. Of these, international visitors represented 5%, interstate visitors 8% and intrastate visitors 87%.

Table 6.3 Annual visitor numbers to the RFA area (1995 and 1996)

	Central and Southern forest regions		Northern Swan forest region		Total	
	Visitor nights (millions)	Visitor trips (millions)	Visitor nights (millions)	Visitor trips (millions)	Visitor nights (millions)	Visitor trips (millions)
Origin						
WA	5.344	1.760	0.696	0.328	6.040	2.087
Interstate	0.675	0.140	0.206	0.028	0.881	0.168
International	0.490	0.082	1.100	0.042	1.590	0.124
Total	**6.509**	**1.982**	**2.002**	**0.398**	**8.511**	**2.379**

Source: WATC Research Brief on Tourism

An assessment of activities indicates forests were a major attraction for visitors to the Central and Southern forest regions, with 18.3% of all visitors stating they had visited karri or jarrah forests. The forest was especially attractive to international and interstate visitors, of whom 45.5% and 43.2% visited forest areas, respectively. Visitation was much less in the northern Swan Forest Region, with fewer than 10% of all tourists stating they had visited karri or jarrah forests.

Total expenditure by tourists visiting a karri or jarrah forest in 1995 and 1996 has been estimated at $250 million a year. Of this, 77% was associated with intrastate travellers, 13% with interstate and 10% international.

Day-trippers

Day-trippers made more than 3.9 million individual trips and 1.3 million group trips a year to the RFA region during 1995 and 1996. These day-trippers are estimated to have spent more than $70 million a year.

Statistics on day trip activities indicate a yearly total of 411 500 or 10.5% of these day-trippers visited the forest in the RFA area. Visits were almost equally divided between the Swan Forest Region (203 000) and the combined Central and Southern forest regions (208 500). Expenditure by people visiting the forest areas is close to the average expenditure level across all activities. On this basis, expenditure associated with the forest areas during the years 1995 and 1996 is estimated at $7.4 million annually.

Table 6.4 Annual day-trip visits and expenditure in RFA areas (1995 and 1996)

	Central and Southern forest regions	Swan Forest Region	Total
Group trips ,000s	818	525	1343
Visitor trips ,000s	1670	2262	3932
Expenditure ,000s	22169	48166	70335

Ninety eight per cent of day-trippers visiting the Swan Forest Region came from the metropolitan area, while visitors from the metropolitan area made up 68% of day-trippers to the Central and Southern forest regions. More than 95% of all day-trippers travelled by car.

Major forest-based destinations were the Perth hills (23.8%), Serpentine/Jarrahdale area (10.8%) and Dwellingup (6.4%) in the Swan Forest Region, as well as the Southern Forest Region (11.1%) and Central Forest Region (10.8%).

6.5 EXPECTED GROWTH AND STRATEGIC DEVELOPMENT PLANNING

Expected growth in forest-based tourism

While there are no published growth estimates available for forest-based tourism and the general growth predictions that are available vary markedly (Table 6.5), it is necessary to scope the potential demand during the RFA period in order to estimate its impact on the study area.

Table 6.5 Growth predictions for tourism in Western Australia

- 25 to 30% over the next decade for nature-based tourism world-wide (Western Australian Tourism Commission 1997)
- 7.8% annual growth predicted for international tourism in Australia over the years 1996-2006 (Office of National Tourism 1997)
- 20% per annum for ecotourism in Western Australia (Shea 1993)

Growth can be stimulated by marketing campaigns. The Western Australian Government has recently embarked on a "Brand" marketing campaign overseas which will develop further on the Australian Tourism Commission's marketing of Australia's "Great Outdoors". These campaigns are particularly well suited to attracting visitors to Western Australia's forest areas.

International tourists

Western Australia attracts between 12 and 13% of the international visitors who come to Australia (WATC 1997). Assuming this remains constant, then based on the Office of National Tourism's estimate for long-term growth into Australia, the number of international visitors will increase by 7.8% per annum. Applied over the 20-year period of the RFA, the number of international visitors to karri and jarrah forests can be expected to increase from 37 500 in 1996 to 199 000 (approximately five times) by the end of the 20-year RFA period. The vast majority (more than 95%) of these tourists will be visitors to the south-west forests.

Interstate tourists

Predictions by the Office of National Tourism (1997) indicate that Western Australia can expect the interstate market to increase at an annual rate of 2% over the next decade. On this basis, numbers of interstate visitors will have increased from 66 500 in 1996 to 103 000 in 2018. Of these visits, about 90% will be to the Central and Southern forest regions.

Intrastate tourists

Over the 20-year period of the RFA, growth in intrastate tourism is expected to range between the long-term population growth rate of 1.5% to an estimated 2% increase per year (Office of National Tourism 1997). This indicates that intrastate tourism will increase from 297 000 in 1996 to between 400 000 and 441 000 in 2018.

Day-trippers

If visits by day-trippers to the forest areas are estimated to increase in conjunction with population growth (estimated at 1.5%) over the 20-year RFA period, then they will increase from 823 000 in 1996 to 1.1 million in 2018.

Overall growth estimate

Based on the above estimates, the overall number of visitors to the RFA area is predicted to increase from 1.2 million in 1996 to between 1.8 and 1.9 million in 2018. Based on current trends, 67% will visit the forests in the Central and Southern forest regions and only 33% those in the Swan Forest Region.

However, when compared to growth figures recorded by local tourist bureaux over the past six years, these estimates can be considered conservative and represent a baseline growth figure.

Over the period 1991-96, the increase in the number of visitors to tourist bureaux in the south-west, indicates an annual growth of around 10%.

Table 6.6 Visitor recorded numbers by south-west tourist bureaux

	1991	1996	Total increase over 6 yrs (%)
Margaret River	125 770	225 353	79.2 (13.2% per annum)
Pemberton	54 675	89 923	64.5 (10.8% per annum)
Nannup	15 221	21 900	43.9 (7.3% per annum)

Source:Local tourist bureaux statistics

Should this rate of growth continue throughout the RFA process, then the total number of tourists to the Central and Southern forest regions would approach three million by the year 2018 and 0.4 million in the Swan Forest Region. The expected increase in day-tripper numbers would be added to this figure.

These estimates, together with CALM's visitor statistics which show tourists visit an average three sites per trip, offer a range within which it may be reasonable to plan for tourism demand.

In order to service this projected increase in demand, planning will be required to determine how current facilities can be used more effectively and what developments may be required in regard to the introduction of major attractions and other new facilities, as well as planning for increased access for walking, rambling, mountain biking, horse riding and camping groups and supporting infrastructure in forest areas.

These data also clearly indicate that visitations by tourists staying one or more nights is far greater to the Central and Southern forests than to the Northern forests, while day-tripper visitations are similar in both areas. This suggests a potential to increase the appeal and hence the usage of the Northern forest to international and interstate visitors from or staying in the metropolitan or Peel region.

Development planning

A wide range of factors need to be considered when developing planning strategies for tourism development in the forest areas. CALM, as the manager of public forests, must continue to play a lead role in ensuring tourism development is compatible with other uses of the forest and is sustainable. While some recreation and tourism activities require broad areas of forest, it is worth noting that most high-use tourism facilities in forests involve site-based or corridor-based activities.

Developers (both private and government) need to provide appropriate facilities for the wide range of tourism and recreational interests including camping areas, picnic sites, walk trails, roads, information centres and major tourism attractions. In addition to these forest-based facilities, support infrastructure such as a wide range of accommodation, roads, utility supplies and complementary tourism attractions (vineyards, adventure experiences, restaurants, fishing, etc.) are required. These developments need to take into consideration the expected growth in tourism generally and in the specific market niches.

Any proposed tourism development aimed at meeting expected tourism growth should be ecologically sustainable. Any such consideration would also need to involve consultation with key stakeholders, particularly in relation to key areas of growth and the facilities required to support this growth.

Forest-based tourism clearly needs to be compatible with other uses. This would be facilitated be ensuring that future forest management plans involve greater consideration of tourism issues. To this end a forest-based recreation and tourism advisory group is being formed to assist CALM in the development of tourism and recreation initiatives.

Nature-based tourism in forest areas can and does operate across tenures and through different forest types and age structures and will need to continue this to provide the range of tourism products to meet the growth in tourism to the area.

6.6 POTENTIAL AREAS OF CONFLICT

There are a number of areas where tourism and tourism development can conflict with local groups and with other forest users. For example, some operators in the industry hold the view that protection of old-growth forest is required for tourism and that the short-term impact of timber harvesting and burning on aesthetics affects tourism. Others in the community feel that tourist growth could affect existing lifestyle and qualities of the community.

It is inevitable that conflicts will continue where disparate interests are concerned. These could be ameliorated through added emphasis on open and consultative planning for tourism in forest areas.

7 Water and catchments

7.1 INTRODUCTION

The wise management of water resources of the RFA area is central to the current and future needs of the economy, the environment and the community of the south-west of Western Australia. Reliable quantities of water, which meet quality standards for a range of uses, are essential for maintaining natural environments and for domestic, agricultural, industrial and recreational uses. As the region's population grows, further water resource developments in the RFA area will be required. As growth is expected well into the middle of the next century, the task of managing these developments in an environmentally sustainable way will be challenging and important. Equally important will be the continuing task of protecting water resources of high environmental and social (in-situ) value and completing restorative programs aimed at improving resources which are currently of marginal salinity. These water resource management issues are discussed in the context of the Comprehensive Regional Assessment process below.

7.2 HYDROLOGY, LAND TENURE AND LAND USE

The relationship between water, forests and forest use is complex and is based on extrinsic factors such as climate, geology, soils, and topography, in addition to intrinsic factors such as landcover and land use change. Streamflow yields in south-west Western Australia are low given the annual rainfall rates and are strongly dependent on rainfall and landcover. Reduction of the vegetation cover significantly increases catchment yields, but the subsequent impacts on groundwater recharge rates and stream salinity are the major hydrological issues in south-west Western Australia. Conversion of forest to agricultural land use clearly affects water quality and quantity and mining and timber harvesting have the potential to affect water quality and quantity in forested catchments. While conversion of forest to agriculture has been demonstrated to lead to increases in stream salinity, the impacts of timber harvesting and surface mining are much more subtle.

Land tenure and land use

The RFA region is used for timber harvesting, agriculture, mining, urban, recreation, conservation and social/cultural activities, which directly or indirectly affect water quality or quantity. The relative distribution of land tenure (see Chapter 2) and the consequent land use, particularly the development of the conventional annual crop and pasture-based agriculture on private land, in areas where salt has accumulated in the soil prior to clearing, have profoundly impacted the salinity of streams and rivers of the region.

River systems

The major river systems that drain the northern part of the RFA area include the Helena, Canning, Serpentine, North Dandalup and South Dandalup. With the exception of a small percentage of the Helena River catchment, all are largely uncleared. However the Swan-Avon and Murray river systems drain through the study region, rising inland in the true wheatbelt area of south-west Western Australia. The central portion of the RFA area is drained by the major systems of the Harvey, Brunswick, Collie, Preston and Margaret rivers. The catchments of the Harvey, Brunswick and Margaret rivers include some agriculture but only in areas where salts had not accumulated in the soil prior to clearing. The Collie River, which rises within the study region has significant clearing throughout its eastern and southern tributaries. The Blackwood River system also drains this central area, but like the Murray and Swan-Avon systems extends inland to the wheatbelt areas. In CALM's Southern Forest Region, the major river systems include the Donnelly, Warren, Gardner, Shannon, Deep, Frankland, Kent, Denmark and Hay. The Frankland River catchment is the only river that extends inland from the study area, however, the Hay, Denmark and Kent rivers have significant clearing in their upper catchments.

Streamflow

Most of the water yields of the large river systems are generated in the high and intermediate rainfall zones of the catchment, where rainfall exceeds 900mm per annum. In the forested high rainfall zone, where catchment average rainfall exceeds 1100mm, annual streamflows are commonly 10% to 15% of rainfall (up to 160mm per annum). These flows have relatively low annual variability and can be readily harnessed using moderate storage reservoirs. The larger river systems that have catchments which extend into the low rainfall zone (areas with annual rainfall less than 900mm) have much lower average water yields (often below 100mm). Annual variability increases and larger storage volumes are necessary to reliably divert the same proportion of streamflow than less variable streams.

Groundwaters

Groundwater resources of the region are centred on the high-yielding aquifers located in the Southern Perth Basin (Donnybrook Sunklands) and within Permian Sedimentary Basins (Collie Coal Basin).

7.3 IMPACTS OF LAND USE ON WATER VALUES

The physical, chemical and biological characteristics of water determine its quality. Any significant loss of quality may have a deleterious effect on aquatic ecosystems and reduce the value of the resource. Land use practices resulting in erosion and the transport of nutrients, urban runoff or point source discharges of pollutants are major causes of poor water quality in stream networks.

In the south-west, stream salinisation poses the greatest threat to water quality and impacts both the economy and environment.

Agriculture

Impact

Stream salinity increases occur in response to changes in catchment water balance, with consequent rising watertables mobilising salts stored in the deep soil profile (Schofield et al. 1988). Related disturbances to the ground surface through clearing, compaction and on-farm activities increase sediment mobilisation and transport. Sediment transport data (as turbidity or suspended sediment concentrations) are indicators of erosion within a catchment. Agriculture can also impact on water quality through the application of agrochemicals. The use of these chemicals is integral to the reduction of production costs and losses, together with increased production and product quality. Surface runoff and groundwater recharge contaminated by these chemicals can reduce the water quality of streamflow and the groundwater.

About 2600 gigalitres of the 5900 gigalitres mean annual streamflow of the region are currently diverted each year to provide water for consumptive uses through construction of conventional dams and related diversion works. Prior to agricultural development virtually all these technically divertible surface water resources of the region were believed to be fresh. Currently only 53% remains fresh, 17% is of marginal quality and 30% is brackish.

The major source of additional salt in streamflow comes from cleared areas where salt has accumulated in the subsoil prior to clearing. Salts have accumulated in the deep subsoils of the Darling Range and the Leeuwin-Naturaliste Ridge, particularly in areas where the annual rainfall is less than 900mm.

For any stream east of the Darling scarp and the 900mm isohyet, clearing as little as 10% of its catchment is sufficient to cause it to become either brackish or saline. Without higher rainfall areas to dilute the additional salt discharge from the small cleared area, average stream salinities are commonly over 2000mg per litre of total soluble salts (mg/L TSS). Stream salinities frequently exceed 10 000mg/L at low flows.

The permanent clearing of native vegetation in the 900 to 1100mm rainfall zone can lead to average stream salinities of marginal quality. Streams draining these areas commonly have average salinities between 500 and 1000mg/L TSS. (Schofield et al. 1988). The salinity risk is low in areas where rainfall exceeds 1100mm per annum.

Table 7.1 shows the salinity of 10 of the major rivers of the south-west of Western Australia. The Swan-Avon, Murray, Blackwood and Frankland catchments, which extend into the wheatbelt region, have the

highest salinities and will continue to deteriorate well into the middle of the next century. This is primarily a consequence of the slow response times of groundwater systems to past clearing in these catchments.

The Collie, Warren, Kent and Hay rivers are the most highly salt-affected river systems which drain the study region. While diluted by fresh inflows from the forested higher rainfall parts of their catchments, the salinities of all four catchments are either of marginal salinity or brackish. The degree of dilution varies between catchments. The proportion of the total catchment cleared of the Warren and Kent river catchments is similar (36% and 40% respectively). The salinity of the Kent is significantly higher as it has less fresh streamflow from the higher rainfall portion of its catchment than does the Warren River.

Table 7.1 Stream salinity in major rivers in the south-west of Western Australia

River	Catchment area km^2	Annual flow mean m^3 x 106	Cleared as at 1996 %	Salinity mg/L TSS	Salinity increase mg/L/yr
Denmark	525	31	17	560	26
Collie	2 830	185	24	790	24
Warren	4 022	290	36	855	13
Kent	1 852	84	40	1 195	58
Helena	1 470	50	3	360	na
Hay	1 211	72	70	1 800	na
Murray	6 840	297	75	2 260	93
Frankland	5 800	179	56	2 750	74
Blackwood	20 500	659	85	1 760	58
Swan-Avon	119 000	335	75	6 300	na

Source: Government of Western Australia (1996)

Management response

Groundwater recharge is continuing under the current agricultural practices and stream salinities can be expected to increase further as the discharge from groundwater systems approaches the groundwater recharge. Salinity increases on the Helena, Collie, Warren, Kent and Denmark river systems have been limited by the introduction of clearing control legislation (under the *Country Areas Water Supply Act*) in the 1970s.

Studies have shown that high density reforestation plantings can lower the groundwater level up to eight metres relative to pasture over a 10-year period (Bari and Boyd 1994).

Active reforestation has been carried out on the Collie and Helena river catchments and private investment in commercial tree farming encouraged on the Warren, Kent and Denmark river catchments. Research and development programs to improve the commercial viability of reforestation and agro-forestry options have been carried out and actively promoted. These activities are being adopted by many landowners in target areas across the south-west (see Chapter 5).

Under the State Salinity Action Plan (Government of Western Australia 1996) increased resources are to be available to farmers to help implement the restorative programs in the catchments of the Collie, Warren, Kent and Denmark rivers. Targets have been set to achieve potable salinity levels in the supply from reservoirs on these rivers by the years 2015, 2030, 2030 and 2020 respectively.

The Salinity Action Plan is also promoting active involvement of the farming community in other areas to restore key wetlands, minimise areas of salt-affected land and protect designated rural infrastructure throughout the south-west.

Mining

Mining is a high disturbance activity which has the potential to impact on water quality and quantity. The jarrah forests and coastal zones of the south-west are subject to open cut mining. Major mining operations within catchments include coal, bauxite, gold and mineral sands. Bauxite mining is a major land use within the forests of the south-west, with leases covering 50-60% of the northern jarrah forest (CALM 1992b). Loh et al. (1984) concluded that over a 13 to 15-year period there were increases in streamflow draining from two catchments which had been under the influence of bauxite mining and rehabilitation. More recently, Ruprecht and Stoneman (1993) reported that bauxite mining in a high rainfall catchment increased water yield by 8% of annual rainfall with a return to pre-disturbance water yields after 12 years.

Management response

Future bauxite mining poses ongoing pressures on streams in the forested intermediate rainfall zone of the forest. This was recognised at the time bauxite mining expanded to the Willowdale mine and Wagerup area in the late 1970s. Bauxite mining was effectively excluded from the intermediate and low rainfall zones until long-term research and monitoring programs could demonstrate that the salinity of water supplies would not be significantly affected.

A long-term research program involving both field experimentation (trial mining) and detailed model development is ongoing. The trial mining studies will validate models so that regional scale predictions can be made.

Timber harvesting and regeneration

One of the main management issues within the jarrah and karri forests of the south-west is the possible effects of intensive timber harvesting and associated operations on stream salinity, sediment load and streamflow volume.

As with the impact of agricultural clearing, the risk of increased salinity following logging operations can be related to the high, intermediate and low rainfall zones.

Historic records of intensive logging within the karri forests in the south of Western Australia suggest that water quality has remained high and clearfelling in karri and heavy selection cutting in jarrah forests have minor effects on salinity and sedimentation levels (Christensen 1992). However, onsite soil erosion and compaction associated with harvesting can impact on downstream water quality. Mean annual sediment concentrations are higher during logging and for two to three years following harvesting and then revert to pre-treatment levels. Highest sediment loads are associated with logging during wet periods. There is no evidence to suggest that harvesting of jarrah and karri leads to long-term or severe increases in sediment loads and salinity, as long as regeneration occurs soon after completion of logging (Borg et al. 1987).

Moulds et al. (1994) studied the effects of forest thinning on streamflow and salinity associated with rainfall. The catchment studied had an average annual catchment rainfall of 1100mm and had low salt storage typical of the high rainfall zone. Results of the study indicated that salt flow increased, but increases in streamflow diluted additional salt load so that it was generally lower than pre-treatment levels. In effect forest thinning produces a significant increase in water quantity without reducing quality.

Detailed monitoring of experimental catchments in the Southern Forest Region identified some increases in groundwater levels and groundwater discharge areas and temporary increases in stream salinities following forest logging operations (Borg et al. 1987, Bari and Boyd 1993). The greatest salinity increases occurred within one catchment in the intermediate rainfall zone where complete clearfelling took place and where local groundwaters were shallow and salt storage moderate. The annual stream salinity increased by 300mg/L TSS to more than 500mg/L TSS in one dry year following clearfelling (Bari and Boyd 1993). Base flows exceeded 2000mg/L TSS. Five years following logging, groundwater levels and salinities began to return to pre-logging levels as the regenerating forest began to re-establish the original water balance. These temporary increases are minor relative to the impacts of permanent clearing for agricultural development. Earlier estimates indicated that streamflows would return to pre-logging levels within about 12 years of treatment (Water Authority of Western Australia 1987).

Catchment water yield increases immediately after timber harvesting as a result of lower evapotranspiration and reduced interception. Yields then decrease in response to greater water requirements of regrowth and return slowly to pre-logging conditions in response to revegetation and canopy recovery (Dargavel et al. 1995). A rate of 40mm per annum change in yield per 10% cover reduction has been estimated but this represents an upper limit (Bosch and Hewlett 1982). A decrease in water yield has the potential to:

- adversely affect aquatic ecosystems;
- produce conflicts between users downstream; and/or
- necessitate further development of water storage capacity/groundwater resource to maintain adequate supply.

The reduction of tree density in the low salinity, high rainfall zones of forested catchments is one of the least expensive options for increasing the existing water supplies to accommodate future demands (Moulds et al. 1994). Thinning in these areas provides an effective method to achieve increases in water supply (Stoneman and Schofield 1989).

Management response

Key management strategies to reduce sediment loads and maintain low stream salinity levels include the retention of vegetation, particularly along stream zones, as well as the exclusion of harvesting from all river and stream zones and diverse ecotype zones and sensitive design of roads.

The Forest Management Plan 1994-2003 modifies the informal reserve system on road, river and streams and reduces maximum coupe size, in part as a way to minimise the temporary impacts on stream salinity. These new procedures, together with the associated Ministerial conditions, minimise the risk of saline groundwater discharge to selected second order catchments considered environmentally sensitive to such saline discharges.

Experimental research and related modelling work will continue on the forest management regime set out in the Forest Management Plan 1994-2003.

7.4 WATER RESOURCE DEVELOPMENT

The Water and Rivers Commission is responsible for managing the water resources of Western Australia for the benefit of present and future generations. The Commission recognises that water resources are used for consumptive water supply, recreation and maintenance of ecosystems and other natural resources. The Commission therefore carries out regional water allocation planning studies jointly with other natural resource management agencies and the community, to ensure that environmental and social water values and water supply development needs are appropriately balanced and protected. The Commission interacts with the planning activities of other natural resource management agencies.

A key aspect of this interaction is to identify strategically important potential water supply reservoirs which may constrain the selection of new proposals for forest conservation reserves. The Commission and CALM have previously negotiated satisfactory outcomes in considering conflicts between proposed conservation reserves and reservoir sites through the public consultation period for the Forest Management Plan 1994-2003.

Regional inventories of water use, water resources and long-term demand have been updated so that the need for future reservoir developments is placed in context. Map 18 shows the strategically important potential reservoirs which should be considered as RFA options are developed.

Development of any of the reservoirs shown in Map 18 will require the following steps:

- confirmation of the allocation of the water resource to consumptive use through Commission regional or sub-regional planning studies, such as the Busselton-Walpole Regional Allocation Study and the Harvey River Basin Allocation Study;
- approval of the allocation plan and any associated environmental water provisions by the EPA;
- a water service provider (such as the Water Corporation) to seek access to develop the resource and carry out further engineering and environmental investigations at the site;
- approval by the Commission to the water service provider to develop the site at a set future time;
- the expected water demand to develop and the water service provider to prepare its detailed development proposal for review by the EPA within five years of proposed construction; and
- final approval by the Minister for the Environment.

While most of these sites will not be developed in the short term, and some not at all, it is important that their future value is recognised at this stage.

The potential reservoirs shown in Map 18 are only those ones which may directly impact land managed by CALM. Many additional potential reservoirs and dam sites have been identified. While not relevant here they will continue to be presented to community groups as part of the Commission's ongoing allocation planning program.

Pipehead development sites also have not been included at this regional scale. The pipelines and services associated with them can impact the conservation values of proposed reserves and may need to be designed in such a way to minimise their environmental impact. Consideration of the impact of any proposed reserves on potential pipehead sites will be necessary during the development of RFA options.

7.5 CONCLUSIONS

Potential impacts of forest management on catchment hydrology include dynamic changes to water quality and yield. Results derived from studies in a number of research catchments suggest that these impacts vary temporally and spatially. This research has identified and quantified potential and/or actual changes in water yield and quality in relation to a range of land use impacts on forests. New forest management practices have been developed to minimise the risk of saline groundwater discharges to streams considered sensitive to such discharges. Monitoring and research into the effectiveness of the new measures is continuing.

Regionally significant potential water supply reservoir sites, that would impact land managed by CALM, have been mapped (see Map 18). Their long-term importance should be recognised by considering them during the development of RFA options.

8 Mining and mineral processing

8.1 INTRODUCTION

Known and potential (undiscovered) mineral resources in the South-West Forest Region were assessed on a regional scale of 1:250 000 by the Geological Survey of Western Australia, the Bureau of Resource Sciences, geoscientists familiar with the region from the minerals industry and from a research institution.

Prior to the assessment of mineral resources, the Geological Survey of Western Australia undertook the major task of assembling the available geoscientific data. Part of the task was to translate hard-copy data into electronic formats suitable for geographic information systems (GIS) processing. Assembled data on which the mineral resource assessment is based include:

- more than 1500 reports on exploration programs conducted in the area;
- a spatial index of mineral exploration activity and geochemical anomalism, that provides standardised information on the type of exploration activity including geochemical and geophysical surveys, type of drilling, number of holes, number of geological samples, elements analysed, etc.;
- an updated mineral occurrence database (WAMIN) for the region which could be used to recognise district-scale controls on mineral occurrences and deposits;
- estimates of known in-ground mineral resources in GIS format linked to GSWA's MINEDEX database;
- a seamless coverage of digital 1:250 000 geological maps for surface and solid geology, including structural elements, regolith; and
- magnetics and Landsat images.

A detailed technical report on the assessment of mineral resources is available on request.

8.2 GEOLOGICAL SETTING

The main Precambrian geological provinces of the South-West Forest Region are the south-western part of the Archaean Yilgarn Craton, the Proterozoic Albany-Fraser Orogen along the south coast, and the Proterozoic Pinjarra Orogen along the west coast (Map 6). The Yilgarn Craton consists mainly of late-Archaean granite with narrow strips of greenstones. Gneisses which are older than the granites and greenstones form the Balingup and Jimperding/Chittering Complexes. These are inferred to have consisted originally of predominantly sedimentary rocks with some granitic intrusives which have been repeatedly deformed and highly altered under high temperatures and pressures (metamorphosed).

The Albany Fraser Orogen comprises two main complexes:

- Biranup Complex—gneisses and schists derived from sedimentary and granitic rocks and metamorphosed mafic and ultramafic rocks; and
- Nornalup Complex—granite and gneisses derived from granitic and sedimentary rocks.

The Pinjarra Orogen is exposed as:

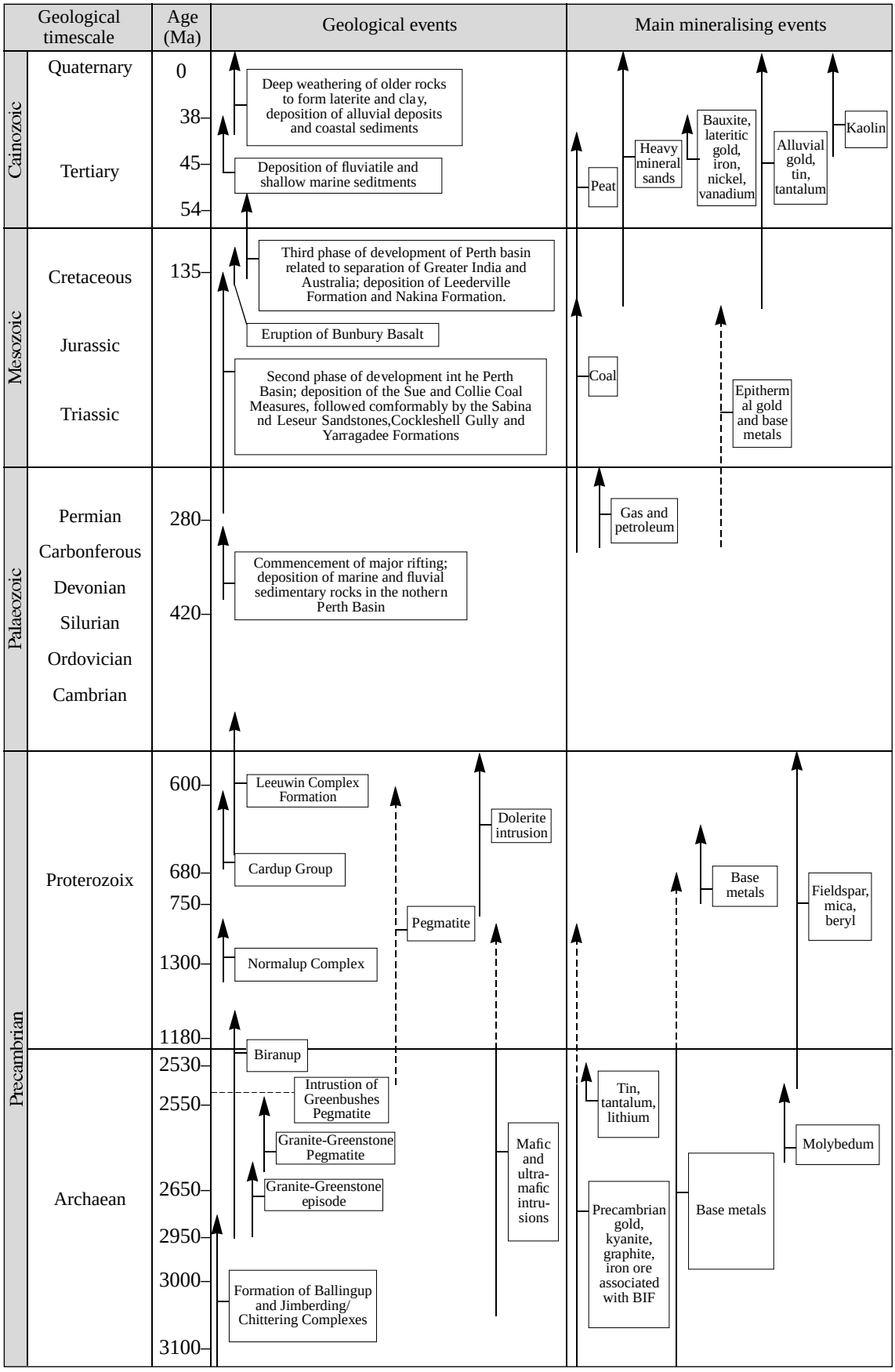
- Leeuwin Complex—deformed granite and granitic gneiss with some anorthosite and gabbro west of the Dunsborough Fault; and
- Cardup Group—a narrow belt of metasedimentary rocks along the edge of the Darling Fault.

Phanerozoic sediments of the Perth Basin overlie the Pinjarra Orogen and are bounded to the east by the Darling Fault. Phanerozoic sedimentary rocks of the Collie, Wilga and Boyup Basins are preserved in fault-bounded grabens and are surrounded by metamorphic rocks of the Yilgarn Craton.

A veneer of regolith (Tertiary to recent in age) covers much of the South-West Forest Region. The regolith comprises drainage-related sediments, coast-related sediments and weathering products such as laterite and bauxite, lateritic gravel, residual and transported sand, and clay.

The main mineralising events associated with each of the major geological provinces in the South-West Forest Region are shown in Table 8.1.

Table 8.1 Geologlical and mineralising events in the RFA region



Ma – million years

8.3 MODERN EXPLORATION ACTIVITY

Exploration starts with assessments of very large regions and is then systematically narrowed down as the exploration target becomes better defined. The direct costs facing explorers increase as the target area becomes smaller and exploration methods more intense. The environmental impact associated with exploration also increases as the area being explored becomes smaller and the exploration methods used become more invasive (e.g. drilling).

The initial phase of exploration using remote sensing from satellites involves no disturbance to the surface. The early stages of a surface exploration program involve activities such as mapping, geophysical measurements and geochemical sampling of stream sediments, soils and laterite. These activities are likely to have minimal effect on the environment. Follow-up that may have some localised and temporary effects include detailed geochemical and geophysical ground surveys.

If the results of this work are positive, additional follow-up work may include some drilling. However, it should be noted that not all exploration results in drilling.

In contrast to exploration, mining itself generally involves greater disturbance to the land surface in the immediate area of the mine and leaves potentially significantly changed landforms when mining is finished. Mining is generally seen as posing greater difficulties in terms of compatibility with other uses. Many potential environmental effects of mining activities can be eliminated or mitigated, though at a cost to the mining company. A major potential impact to the environment from mining in the South-West Forest Region, is the spread of jarrah dieback disease. The experience from existing exploration and mining projects is that this risk can be effectively eliminated by washing down all vehicles and machinery before moving from a dieback zone to a dieback-free area and by the careful planning of mine layout, development and rehabilitation with respect to the local topography, drainage and vegetation.

Water pollution is another potential impact on the environment from mining. However, this can be controlled by using well-established techniques such as impoundment and evaporation of tailings, sedimentation, filtration and pH neutralisation. Rehabilitation of minesites at the completion of operations can accommodate end land uses required by the land manager, including restoring many of the features of the landscape that existed before mining. Normal aspects of rehabilitation include the re-establishment of vegetation and effective pollution control measures.

Legislation requires that reports be submitted on exploration activities carried out on all mineral and petroleum tenements. These reports are held in confidential archives and indexed in the WAMEX and WAPEX computerised bibliographic database systems of the Geological Survey of Western Australia. For the purpose of this assessment, all relevant exploration reports in the WAMEX and WAPEX systems have been reviewed and used to construct exploration activity and anomaly layers in a multi-layer GIS database. The distribution of mineral exploration activities is an important consideration in assessing the mineral potential of each region because it gives an insight into the ideas and concepts which exploration companies have on the potential of these regions.

During 1996, $616.1 million was spent on mineral exploration and $419 million on petroleum exploration in Western Australia. Figures for the South-West Forest Region are not available but it is estimated that only a small percentage of the above figure was spent in the region due to the difficulty of land access. Apart from exploration for gold, coal, tin, tantalum, lithium, bauxite and petroleum, there has been exploration for nickel, chromium, platinum group elements, vanadium, titanium, base metals, iron, silica sands, kyanite, graphite, beryllium, feldspar, mica and limesand in recent years.

8.4 ASSESSMENT OF MINERALS/HYDROCARBON POTENTIAL AND LAND ACCESS

Mineral exploration is a long-term and ongoing process. It is extremely costly and a high risk activity. Even after mining begins, there is a continuum between orebody definition drilling and mineral exploration drilling aimed at discovery of additional resources. Because of incomplete geological knowledge, the discovery rate in Australia is roughly of the order of one mine for one thousand exploration programs. Thus areas are explored, often repeatedly, before a mineral deposit is found.

Increased geological knowledge and other factors can result in discoveries of world-class deposits both in highly-prospective areas (e.g. Kanowna Belle in Yilgarn, Western Australia) or in areas not previously known to be of very high potential (e.g. Olympic Dam, 300 metres below the barren cover rocks on the

Stuart Shelf, South Australia). Other examples of new mineral fields being located include gold at Boddington in the 1980s and in the Drummond Basin (Queensland in 1980s), base metals in the Canning Basin (Western Australia in 1980s) and nickel in the eastern Yilgarn (Western Australia in 1960s). Thus continued access to land for regulated exploration, which is a transient process rather than a long-term land use, is an important issue for the minerals industry and for future mineral development.

In general, petroleum exploration is even more expensive than mineral exploration but the rewards are potentially much greater. Early phases of petroleum exploration typically involve airborne geophysical surveys and ground-based seismic surveys. Seismic surveys assist in determining if suitable structural traps are present and may require some clearing of vegetation along survey lines. Because test wells are expensive, few are drilled unless the prognosis is encouraging. The site of test wells is very limited in area (0.3 to 0.5 hectares), and such wells involve minimal risk of damage to the environment. Even if oil or gas is discovered and production takes place, the production site typically occupies only a small area (0.8 to one hectare). Any activities likely to result in significant environmental disturbance are subject to review by Western Australia's Environmental Protection Authority.

8.5 MINERAL POTENTIAL ASSESSMENT METHODOLOGY

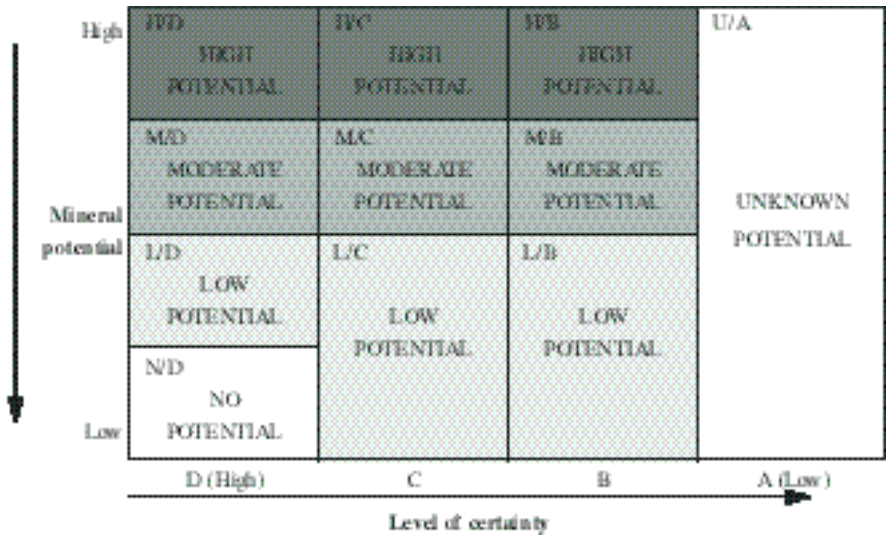
A qualitative assessment of the potential resources of an area is an estimate of the likelihood of occurrence of mineral deposits which may be of sufficient size and grade to constitute a mineral resource. The term "mineral resource" is here restricted to material, the extraction of which is judged to be potentially viable, either now or within the next 25 years.

The mineral potential of the South-West Forest Region has been assessed by determining the types of mineral deposits likely to be found within the geological framework known or believed to exist there. This approach identifies geological units (tracts) which could contain particular types of mineral deposits. The general methodology was developed by the United States Geological Survey and has been used successfully for mineral resource assessments of wilderness areas in North America and elsewhere. A summary of the qualitative assessment methodology is given by Marsh, Kropschot and Dickinson (1984), Taylor and Steven (1983), and Dewitt et al. (1986), and the methodology is described in detail in the technical report.

An assessment of a region's potential mineral resources combines knowledge of its geology, geophysics, geochemistry, mineral deposits and occurrences with current theories of mineral deposit genesis and results of mineral exploration. The assessment uses available geoscientific data to determine the history of geologic processes and environments. Geologic environments judged to have characteristics known to be associated with specific types of mineral deposits are then identified. In particular, the assessment draws on regional and local characteristics of mineral deposit models to establish whether or not specific types of deposits are likely to occur.

The mineral potential of an area—that is, the likelihood of a particular type of mineral deposit occurring—is assessed as high, moderate, low or (where there is insufficient data) unknown (Figure 8.1).

Figure 8.1 Relationship between levels of resource potential and levels of certainty



As geological knowledge of an area can never be complete, it is not possible to have a final assessment of potential mineral resources at any given time. Mineral resource potential needs to be monitored and periodically reassessed to take account of new data and advances in geological understanding, including new mineral discoveries. Advances in mineral exploration and mining technologies and market changes may also change the mineral resource potential of an area.

Geological areas (or "tracts") in the South-West Forest Region, judged to contain geological environments permissive of the formation of specific types of mineral deposits were delineated and the mineral potential of these tracts was assessed.

8.6 POTENTIAL MINERAL AND HYDROCARBON RESOURCES

Assessment of potential mineral resources has shown that within the South-West Forest Region there is potential for 13 metalliferous types of deposits, five industrial types and three types of deposits for energy resources. These deposit types are listed in Table 8.2 which also shows rankings of relative economic significance for each deposit type, levels of mineral potential, standard potential score and weighted potential scores. Mineral potential tracts were constructed for these types of deposits and tract maps, together with detailed descriptions of deposit types are presented in the technical report. Four additional deposit types were tentatively identified, but a lack of geological knowledge precluded delineation of tract maps for them. Only the mineral deposit types judged likely to constitute significant resources in the region have been assessed in detail.

Within each tectonic region, there is potential for the following deposit types:

1. Balingup Complex
   - bauxite (maximum weighted score in this tectonic region for bauxite is 144 (refer explanation below); includes tracts of high and moderate-high potential)
   - lateritic/saprolitic gold (126; h, m-h)
   - rare-metal pegmatites (90; h, m-h)
   - synorogenic/synvolcanic nickel-copper-chromium-platinum (108; h, m)
   - Archaean/Precambrian gold (108; m-h)
   - lateritic nickel (90; h, m-h)
   - epithermal gold (84; m-h)
   - silica sand and quartzite (72; h)
   - vanadiferous/titaniferous magnetite (72; h, m-h)
   - alluvial tin and tantalum (54; h, m)
   - placer gold (48; m-h)
   - pegmatite-related industrial minerals (36; m-h, m)
   - clay (36; m-h)
   - graphite (24; m-h)
   - kyanite (24; m-h)
2. Jimperding-Chittering Complex
   - bauxite (144; h, m-h)
   - lateritic/saprolitic gold (126; h, m-h)
   - Archaean/Precambrian gold (162; h, m-h)
   - epithermal gold (126; h, m-h)
   - synorogenic/synvolcanic nickel-copper-chromium-platinum (108; h, m)
   - lateritic nickel (90; h, m)
   - vanadiferous/titaniferous magnetite (72; h, m)
   - silica sand and quartzite (72; h)
   - clay (36; m-h)
   - placer gold (48; m-h)
   - pegmatite-related industrial minerals (36; m-h, m)
   - graphite (24; m-h)
   - kyanite (24; m-h)
3. Archaean granite/greenstones of the Yilgarn Craton
   - bauxite (144; h, m-h)
   - lateritic/saprolitic gold (126; h, m-h)
   - Archaean/Precambrian gold (162; h, m)
   - epithermal gold (126; h, m)

- titaniferous and vanadiferous magnetite (72; h, m-h)
- clay (36; m-h)
- pegmatite-related industrial minerals (36; m-h, m)

4. Biranup Complex
   - bauxite (144; h, m-h)
   - lateritic nickel (30; m)
   - silica sand and quartzite (72; h)
   - clay (36; m-h)
   - placer gold (48; m-h)
   - graphite (24; m-h)
   - kyanite (24; m-h)

5. Nornalup Complex
   - bauxite (144; h, m)
   - clay (36; m-h, m)
   - silica sand (48; m-h)
   - pegmatite-related industrial minerals (36; m-h, m)

6. Leeuwin Complex
   - heavy mineral sands (126; h, m-h)

7. Collie Basin
   - coal (108; h)
   - silica sand (72; h)
   - clay (36; m-h)
   - bauxite (144; h, m)

8. Perth Basin
   - heavy mineral sands (126; h, m-h)
   - coal (108; h, m-h)
   - silica sand (48; m-h)

To assist with land-use decisions, all the mineral tract maps were combined (overlain) to produce four summary maps of mineral potential, i.e. composite mineral potential, cumulative mineral potential, weighted composite mineral potential (Map 7), and weighted cumulative mineral potential.

Table 8.2 Summary of mineral and hydrocarbon resource potential as at February 1997

Deposit type	Ranking of deposit types (index)	Mineral potential	Standard potential score	Weighted potential score	Area of tract (sq km)	% of region covered by tract
Lateritic-type bauxite	8	High	18	144	14191	33.4
		Moderate	6	48	1887	4.4
		Low	1	8	8982	21.1
		Unknown			17369	40.9
Coal	6	High	18	108	1150	2.7
		Moderate-High	12	72	1328	3.1
		Moderate	6	36	997	2.3
		Low-Moderate	2	12	15467	36.4
		Low	1	6	1334	3.1
Laterite/ saprolite gold	7	High	18	126	456	1.1
		Moderate-High	12	84	2596	6.1
		Moderate	6	42	10462	24.6
		Unknown			3620	8.5
Archaean/ Precambrian gold	9	High	18	162	597	1.4
		Moderate-High	12	108	6180	14.5
		Moderate	6	54	21234	49.9
		Unknown			9370	22.0
Epithermal gold	7	High	18	126	51	0.1
		Moderate-High	12	84	3955	9.3
		Moderate	6	42	1101	2.6
		Unknown			23465	55.2
Placer gold	4	Moderate-High	12	48	2124	5.0
		Moderate	6	24	6172	14.5
Shoreline-fluviatile placer titanium (heavy mineral sands)	7	High	18	126	2382	5.6
		Moderate-High	12	84	1051	2.5
		Moderate	6	42	1903	4.5
		Low-Moderate	2	14	2710	6.4
		Low	1	7	34473	81.1
Rare-metal pegmatite	5	High	18	90	1539	3.6
		Moderate	6	30	4897	11.5
Alluvial tin and tantalum	3	High	18	54	388	0.9
		Moderate	6	18	1253	3.0
Hydrocarbons	6	Moderate	6	36	4524	10.6
Synorogenic/synvolcanic nickel-copper-chromium-platinum group elements	6	High	18	108	745	1.8
		Moderate	6	36	6551	15.4
		Low-Moderate	2	12	1744	4.1
		Low	1	6	18032	42.4
Lateritic-saprolitic nickel	5	High	18	90	377	0.9
		Moderate	6	30	2871	6.8
		Low-Moderate	2	10	739	1.7
Vanadiferous/ titaniferous magnetite	4	High	18	72	1501	3.5
		Moderate-High	12	48	214	0.5
		Moderate	6	24	5843	13.7
		Low-Moderate	2	8	1744	4.1
		Low	1	4	17766	41.8
Silica sand and quartzite	4	High	18	72	444	1.0
		Moderate-High	12	48	7995	18.8
Clay	3	High	18	54	1	0.0
		Moderate-High	12	36	14125	33.2
		Moderate	6	18	1890	4.5
Pegmatite-related industrial minerals	3	Moderate-High	12	36	3669	8.6
		Moderate	6	18	3710	8.7
Graphite	2	Moderate-High	12	24	496	1.2
Kyanite	2	Moderate-High	12	24	496	1.2
Banded iron-formation	4	Moderate	6	24	9	0.0
Volcanic massive sulphide	6	Moderate	6	36	336	0.8
Peat and/or lignite	1	Low-Moderate	2	2	12757	30.0

Some potential also for diamond-bearing kimberlites, rare-metal carbonatites, uranium-bearing pegmatites, sandstone hosted uranium deposits.

Only the *weighted composite mineral potential* is discussed in this report. Descriptions and analyses of the other methods of mineral potential assessments, as listed above, are contained in the technical report.

Map 7 shows the weighted composite mineral potential for the region as assessed in February 1997. This method of mineral potential assessment makes some allowance for the relative economic significance between different types of mineral deposits. In this approach, mineral deposits are indexed (ranked) for their relative economic significance. For example, bauxite was given an index of eight out of 10, whereas clay was given an index of only three out of 10. The indexes for the various deposit types are listed in Table 8.2. Standard potential scores are 18 (for high potential), 12 (moderate to high), six (moderate), two (low to moderate) and one (low). The weighted composite score is calculated by multiplying the deposit index by the standard mineral potential score. For example, heavy mineral sands tract (index of eight) with high potential (18) will have a weighted composite score of 144. Where there are *overlapping tracts with different weighted scores, the highest of these scores is assigned to the area of overlap.*

The weighted composite map highlights the significance of extensive areas with potential for bauxite, laterite/saprolite gold, Archaean/Precambrian gold over the Balingup, Jimperding/Chittering Complexes and the Yilgarn Craton. The map also highlights the tracts for heavy mineral sands and coal in the south-west part of the region over the Perth Basin and Leeuwin Complex and for epithermal gold along the east flank of the Darling Fault.

On Map 7, areas with weighted score classes 108 to 162 cover about 48% of the South-West Forest Region. This part of the region includes all of the areas (tracts) of high potential for the most significant types of mineral deposits (i.e. those with an index of six to nine (Table 8.2)).The major bauxite mines, the Boddington and Hedges gold mines, the heavy mineral sand mines and the coal mines also occur within this part of the region. The most extensive high potential tracts are those for bauxite (weighted potential score of 144 for high potential (Table 8.2)). The potential for other types of deposits in this part of the region is high and moderate to high potential for Archaean/Precambrian gold (score of 162 for high and 108 for moderate to high potential); high potential for laterite gold (126), epithermal gold (126), heavy mineral sands (126), coal (108) and synorogenic/synvolcanic nickel-copper-chromium-platinum group element deposits (108).

The area covered by weighted composite score classes of 72 to 90 comprises 6% of the region. This class range includes tracts of high potential for important rare-metal pegmatite type deposits similar to the Greenbushes deposit (index of five and a weighted potential score of 90). It includes areas with moderate to high potential for other significant deposit types (indexes of six and seven) such as epithermal gold (84), heavy mineral sands (84) and coal (72). Potential for other deposit types include high potential for vanadiferous/titaniferous magnetite deposits (72) and silica sand (72).

The area with weighted mineral potential classes below a score of 72 covers about 45% of the region. It contains only moderate or moderate to high potential for various types of deposits. For example, there is a moderate to high potential for clay deposits (36) and moderate potential for Archaean/Precambrian gold (54). Tracts of high potential for some deposits of lesser significance (index of three), such as alluvial tin and tantalum, are almost completely overlain by areas with higher weighted potential scores.

8.7 MINERAL RESOURCES AND MINERAL PRODUCTION

Map 8 shows the mineral occurrences and deposits within the South-West Forest Region and Map 6 shows the known mineral resources which have been delineated. Current mining leases and exploration licences, together with areas covered by past exploration, are shown on Map 9. The boundaries and locations of mineral tenements are always changing, however, and almost the entire region has been of interest to exploration companies at various times.

An overview of current mining operations is provided below on a commodity by commodity basis. These activities make significant economic contributions in terms of revenue and employment to the regional, State and national economies. In 1995-96, the industry generated revenue of $2.68 billion and employed 8118 people. Multipliers derived from input-output tables of the Western Australian economy have been used to provide estimates of the economic linkages of mining in the RFA region at the State and national level.

Alumina and bauxite

There are currently four alumina operations based on leases for bauxite mining in the south-west of Western Australia. Three of these are owned by Alcoa of Australia Ltd and the other by Worsley Alumina Pty Ltd.

Alcoa

Alcoa of Australia Ltd is jointly owned by the Aluminium Company of America and Western Mining Corporation. Alcoa established its first refinery in 1963 at Kwinana. The second, near Pinjarra, began production in 1972 and a third refinery was commissioned at Wagerup in 1984. Their combined production capacity is approximately 6.7 million tonnes. Expansion of the Wagerup refinery will increase annual capacity by 0.5 million tonnes by mid-1999 and a further 1.1 million tonnes by early in the next decade. Each refinery is serviced by separate mines at Jarrahdale, Huntly and Willowdale. However, Alcoa is in the process of closing down its Jarrahdale operation and supply to the Kwinana refinery will come from Huntly.

Worsley

Worsley Alumina Pty Ltd is a joint venture between Reynolds Australia Alumina Ltd (56%), Billiton Australia Pty Ltd (30%), Kobe Alumina Associates (Australia) Pty Ltd (10%) and Nissho Iwai Australia Ltd (4%). Worsley began mining at Mt Saddleback, near Boddington, in 1983 and commissioned its refinery west of Collie in 1984. Ore is transported overland by conveyor belt to the refinery 50 kilometres away. The refinery's current annual operating capacity is 1.75 million tonnes and Worsley recently announced plans to increase the refinery's capacity to 3.1 million tonnes by the year 2000.

Resource life

Bauxite resources in the south-west of the State are estimated to total around 2600 million tonnes (Gonnella 1997). This is considered sufficient to support the industry for approximately 70 years at the current mining rate.

Production

Australia is the world's largest producer of alumina. In 1996, total world production of metallurgical and non-metallurgical alumina was approximately 45 million tonnes of which Australia produced 13 million tonnes. Western Australian production of 8.2 million tonnes of alumina valued at $1968 million in 1996, accounted for almost 20% of world production. In addition 24 309 kilograms of gallium valued at $9.8 million were produced as a by-product. Map 9 shows the State Agreement Act Leases which cover areas of known bauxite resources.

The capacity and production from Western Australia's alumina refineries in 1995-96 are illustrated in Table 8.3. The production capacity of Western Australia's alumina refineries was 8.45 million tonnes a year in 1995-96, a 52% increase since 1985-86.

Table 8.3 Production and capacity of Western Australian alumina refineries 1995-96

	Refinery capacity Mt/year	Annual production	
		Bauxite Mt	Alumina Mt
Alcoa of Australia			
Kwinana	1.90	7.0	1.8
Pinjarra	3.10	11.0	3.0
Wagerup	1.701	6.5	1.7
Worsley Alumina Pty Ltd			
Worsley	1.751	6.5	1.7
Total	**8.45**	**31.0**	**8.2**

Note: Recent announcements will result in expansion of annual capacities to 2.19 million tonnes and 3.1 million tonnes to the Wagerup and Worsley refineries, respectively.
Mt million tonnes

Markets for Western Australian alumina production

Approximately 85% of Western Australian alumina is exported to smelting customers around the world.

Of the alumina further processed in Australia, around one million tonnes a year is shipped to Alcoa's Victorian operations—Point Henry smelter near Geelong and the company's joint venture smelter at Portland. Alcoa also processes some of its bauxite to produce chemical grades of alumina at its Kwinana refinery. These products include 270 000 tonnes of alumina tri-hydrate and 15 000 to 20 000 tonnes of a speciality alumina KA-25, which is sold to Australian Fused Materials Pty Ltd for the production of fused alumina for the refractory and abrasives markets, both in Australia and overseas. All of Worsley's production is exported.

Coal

Coal of low quality was first discovered in Western Australia in 1846 and the more significant Collie field was discovered in 1883. Extensive exploration of the Collie area and Perth Basin has resulted in the discovery of potentially economic coal deposits at Wilga (discovered 1920), Boyup Brook (1960), Hill River (1961) and Vasse River (1966). However, to date the Collie field has been the only deposit developed.

The Collie field has been mined since 1898 and contains 55 potentially economic seams. There are currently two coal producers—Griffin Coal Mining Company Ltd and Wesfarmers Coal Limited.

Griffin Coal Mining Company

Griffin Coal's mining operations are situated at Ewington, east of Collie, and at Muja, to the south-east. Griffin has mined coal in Collie since 1927, and currently holds titles to mining leases in the Muja, Chicken Creek, Ewington and Stockton areas. Production in 1995-96 was 2.92 million tonnes. The Ewington II mine is being mined at a rate of 0.9 million tonnes a year, and Muja at two million tonnes a year.

Wesfarmers Coal Limited

Wesfarmers Coal Limited is part of Wesfarmers Energy Ltd, a division of Wesfarmers Ltd. In 1995-96, production was three million tonnes from the WO5 mine and Premier Pit 1. The WO5 mine ceased production in February 1997 and Premier Pit 4 is currently being developed.

Resource life

Resources in the Collie Basin have been estimated at 2.4 billion tonnes and proven resources are in excess of 0.7 billion tonnes. At the current production rate, estimated reserves would enable mining for at least 100 years. Extensive exploration by Wesfarmers Coal has identified more than 350 million tonnes of high-quality steaming coal in the Premier deposit, close to its existing mine. Current recoverable reserves amenable to large scale open-cut mining methods, are more than 200 million tonnes which is expected to be sufficient to meet Wesfarmers Coal's current and potential demand for at least 40 years.

Griffin's in situ open-cut coal resources are around 388 million tonnes.

Other inferred coal resources within the RFA area include Vasse (one billion tonnes), Wilga (264 million tonnes) and Boyup (60 million tonnes).

Production

From 1985-86 to 1995-96, coal production has increased from 3.8 million tonnes to 5.9 million tonnes. During the same period, the value of production increased from $229 million to $270 million (in 1995-96 dollars).

Uses

The most important use for Collie coal is as a fuel source for both State-owned and private power stations to produce electricity. It is also used as a reductant in the synthetic rutile process by local mineral sands producers, RGC, Westralian Sands, Tiwest and by lime producers.

Gold

Mines operating in the RFA area are the Boddington Gold Mine (BGM) and the Hedges Gold Mine (HGM) (Map 9). These operations are on adjoining leases and in 1995-96 produced 14.2 tonnes of gold valued at $235.4 million.

Boddington Gold Mine

The Boddington Gold Mine (BGM) was commissioned in 1987. Worsley Alumina Pty Ltd is the management company for Boddington Gold Mine Joint Venture comprising of Posgold Pty Ltd, Acacia Resources Ltd and Newcrest Mining. An Extended Basement Operation is currently proposed at BGM. The current planned life for this is approximately 20 years—no commencement date has been determined. Reserves are estimated at 300 million tonnes, which will be recovered at a mining rate of 16 million tonnes a year.

Initially mine life was estimated at eight years, however, this operation is now the second largest gold mine in Australia, and is also becoming a significant copper producer.

Hedges Gold Mine/Hedges Gold

Hedges Gold Pty Ltd (HGM) is a wholly-owned subsidiary of Alcoa of Australia Ltd. The Hedges Gold Mine, north-west of Boddington, is expected to operate for about the next four years. The mining rate is at 2.4 million tonnes per year with reserves at about 10 million tonnes.

Mineral sands

Economic deposits of mineral sands have been found from the south-west tip of Western Australia to Eneabba, either close to the present coastline, or as old coastline deposits up to 35 kilometres inland.

Companies operating within the RFA area include Westralian Sands Ltd, Cable Sands (WA) Pty Ltd, and BHP Titanium Minerals Pty Ltd. Significant new mining operations have commenced in the shires of Nannup (Cable Sands) and Augusta-Margaret River (BHP) in recent years (Map 9).

Minerals produced from these resources include ilmenite, leuxocene, rutile and zircon. About 40% of Western Australia's ilmenite production is converted to synthetic rutile. Of this, 30% is further processed to titanium dioxide pigment in Western Australia with the remainder exported. The two local manufacturers of titanium dioxide pigment are Millennium Inorganic Chemicals (SCM Chemicals Ltd) at Kemerton and Tiwest Joint Venture at Kwinana. Millennium obtains synthetic rutile from Westralian Sands at Capel and RGC's mineral sands operations in Capel and Geraldton. Tiwest has its own source from mining and processing operations at Cooljarloo and Muchea.

BHP Titanium Minerals

BHP Titanium Minerals is part of the World Minerals Division of BHP. The company has recently completed the construction of a large titanium minerals mine at Beenup, near Augusta. The deposit, on farmland owned by the company, was discovered in 1988 and the mine was commissioned in early 1997. The deposit covers an area of 3000 hectares and the operation will produce 600 000 tonnes per annum, approximately 12% of the world's ilmenite. BHP also has a deposit at Witchcliffe which is likely to be brought into production when current deposits are exhausted.

Cable Sands (WA)

Cable Sands (WA) Pty Ltd is a wholly-owned subsidiary of Nissho Iwai Corporation. Mining began in 1956 at Koombana Bay and has continued through mineral deposits at Busselton, Capel, Waroona, Wonnerup and Minninup. Cable Sands has a number of other deposits within the RFA area, including those at Jangardup South, Sandalwood and Gwindinup, which will be mined as current deposits are depleted.

Cable Sands began mining the Jangardup deposit in the Nannup Shire in 1994. This deposit consists of 30 million tonnes averaging 6.8% of heavy minerals. Production of 271 000 tonnes of concentrate is planned annually. A new mine has recently been commissioned at Yarloop, to replace the Waroona South mine.

Westralian Sands Ltd (WSL)

Westralian Sands Ltd, is based in Capel, and operates three mineral sands mines, two dry separation plants and two synthetic rutile plants. Of the mines, only the Yoganup deposit is operating within the RFA area.

Resource life

The indicative reserves for heavy mineral sands within and partially within the RFA area are illustrated in Table 8.4.

Table 8.4 Heavy mineral sands in the RFA region[1], 1995-96

Site	Ilmenite Mt	Leucoxene Mt	Rutile Mt	Zircon Mt	Monazite Mt	Total Mt
Blackwood Plateau	35.7	1.7	0.1	1.2	0.02	50.2
Yoganup-Happy Valley	19.2	2.0	0.7	2.4	0.06	26.6
Scott coastal plain	8.2	1.2	0.1	0.6	0.02	11.9
Waroona Shoreline						
- South	5.0	0.2	0.2	0.4	0.02	5.8
- North	5.3	0.2		0.2	0.01	6.8
Totals	**73.5**	**5.2**	**1.1**	**4.8**	**0.12**	**101.4**

Source: Department of Minerals and Energy 1996
Note: [1] Includes reserves within and partially within the RFA region.

Production

Production capacity for the operations working in the RFA area are detailed in Table 8.5.

8.5 Mineral sands projects within the RFA region, 1995-96

Company	Revenue ($M)	Direct employment		Production capacity (,000 tonnes)				
				Ilmenite	Rutile	Leuxocene	Zircon	Synthetic rutile
Cable Sands								
- Jangardup	23	50	212	10			16	
- Waroona	15	210[1]						
BHP[2] – Beenup	60	120	600				20[2]	
WSL – Capel	100	368	224			25	31	120
Total	**198**	**748**	**1036**	**10**		**25**	**67**	**120**

Notes: [1] Figure includes Cable Sands dry plant at Bunbury
[2] Plant commissioned 1997

Tin-tantalum-lithium

The metals lithium, tantalum and tin are commonly found together in pegmatite, a coarse grain rock associated with granite. In Western Australia, pegmatites containing these metals are found at Greenbushes in the south-west and Wodgina in the north-west. The deposits at Greenbushes, located within the RFA area, form Western Australia's largest tin and tantalum field. The mine at Greenbushes which has been in operation for several decades is now owned and operated by Gwalia Consolidated Limited.

Tin-tantalum

At Greenbushes, tantalum is the major economic mineral, and represents the world's largest tantalum mineral resource. Processing capacity was upgraded in 1992 making Greenbushes a major producer of tantalite. Tin is a co-product, but production is small by world standards.

Spodumene-lithium

The Greenbushes pegmatite has also been found to contain a large high-grade concentration of the lithium mineral spodumene. Separate extraction and treatment of spodumene began in 1983, and the operation is the only producer of spodumene in Australia. The spodumene treatment plant produces high grade spodumene products for the majority of the year, and chemical grade spodumene for the remainder.

In 1995, Gwalia Consolidated built Western Australia's first lithium carbonate facility at Greenbushes, to add value to spodumene through further processing.

Production

In 1995-96, Greenbushes produced 260 tonnes of tantalite valued at $24.5 million, 105 000 tonnes of spodumene valued at $13.4 million and 446 tonnes of tin valued at $3.1 million. Gwalia's lithium carbonate plant located in Greenbushes has the capacity to produce 120 000 tonnes a year of lithium mineral concentrates and 5000 tonnes of lithium carbonate a year. This represents around 60% of world consumption, making Gwalia the dominant supplier in the world's lithium market. Products are exported to more than 25 countries in Europe, America and Asia, and recently to China.

Resource life

Tantalum and tin
Some 29 million tonnes of tantalum-bearing pegmatite have been identified at Greenbushes. Development of underground mining is underway and mining is planned for the next 20 years. Total demonstrated resources of tantalum are 9500 tonnes, with additional inferred resource of 2500 tonnes.

Spodumene
Spodumene has known reserves of 40 million tonnes at 2.9% lithium oxide and 6 million at 4% lithium oxide. The ore body is estimated to contain sufficient ore to allow mining at the current rate for 100 years. Total demonstrated reserves are currently 0.53 million tonnes.

Other mineral resources within the South-West Forest Region include deposits of kaolin, beryl, mica and feldspar in pegmatites, vanadium-bearing titaniferous magnetite in lateritised gabbro, iron-bearing laterite, graphite, kyanite, silica sand, talc and peat.

Three exploration wells in the Whicher Range indicate that gas is present in the Permian sedimentary rocks to depths of 4300 metres. The gas deposit is currently being reassessed by Penzoil to determine if it can be extracted economically using modern techniques. The Permian coal measures on the Vasse shelf also have potential for coal-bed methane.

Economic linkages

In examining the significance of mining activities within the RFA region, it is useful to consider the linkages between mining and mineral processing in the region and the State and national economies. Input-output tables provide a first approximation to the magnitude of indirect impacts upon employment, output and income that flow through to the broader economy as a result of the mining and mineral processing activities in the region. To assess adequately how these indirect benefits would be likely to change with certain RFA policy options would require a more detailed analysis, such as a general equilibrium model of the Western Australian economy which captured the broader economy-wide implications of changes in mining and mineral processing within the RFA region.

The industry classifications and the respective output and employment multipliers used to measure the economic impacts at a State and national level are outlined in Table 8.6. These multiplier effects are based on recent input-output tables developed for the Western Australian economy (Clements and Qiang 1995). The input-output industry classifications used in this report are based on the Australian Bureau of Statistics classifications.

Multipliers

The *output multiplier* determines the effect on the value of production from all industries of a $1 increase in the demand for output of a given sector. This multiplier takes into account all the direct, indirect and consumption-induced effects resulting from the initial increase in demand. Similarly, the *employment multiplier* determines the effect of an increase in employment in one sector on employment on all other sectors of the economy.

Table 8.6 Industry classifications and employment and output multipliers

Industry classification		State output	Employment	National output	Employment
Basic metal products	- alumina - tin/tantalum	2.33	4.71	2.83	6.15
Coal, oil and gas	- coal	1.75	3.60	2.08	4.55
Metallic minerals	- gold - mineral sands	2.08	4.13	2.56	5.34
Minerals n.e.c.	- lithium/spodumene	1.80	2.89	2.20	3.70

Source: Clements and Qiang (1995)

The direct contributions of each industry generate additional indirect output and employment effects. Based on direct employment and values of output by the various mining industries in 1995-96, the direct and indirect State and national impacts in terms of revenue and employment are calculated in Table 8.7.

Table 8.7 Economic impacts generated from activities within the RFA region, 1995-96

	Revenue ($M/annum)			Employment		
	Direct	State indirect	National indirect	Direct	State indirect	National indirect
Alumina	1920	2554	3514	5900	21889	30385
Coal	270	203	292	800	2080	2840
Tin/tantalum	40	53	73	210	779	1082
Lithium/spodumene	18	14	22	20	38	54
Gold	235	254	366	440	1377	1910
Mineral sands	198	214	309	748	2341	3246
Total	**2681**	**3292**	**4575**	**8118**	**28504**	**39517**

Mining companies also make an important contribution to State revenue through direct payments such as royalties and payroll taxes and to regional revenues by employing local people and purchasing inputs from local companies.

9 Other forest products

9.1 APICULTURE

Various factors combine to make conditions in south-west Western Australia favourable for apiculture. The Mediterranean climate with short, mild winters, together with an abundant native plant resource which is rich in nectar and pollen, provide for nectar flows for most of the year. This enables honey production to occur for up to 11 months of the year. The absence of economically-important bee diseases such as European foul brood disease, chalkbrood and *Varroa*, as well as development of a quality queen bee breeding program, have also led to the success of the industry.

Size of industry

During 1995-96, the total farm-gate value of the beekeeping industry in Western Australia was $7.03 million (Agriculture Western Australia 1997). The total value of Western Australian apiculture exports during this period is estimated to be more than $3 million. Approximately 1300 tonnes of honey (half of that produced) valued at $3.1 million were exported to Germany, Singapore and other Asian and European countries.

In that year, there were 1025 registered beekeepers operating in Western Australia, using approximately 2500 apiary sites. An additional 72 beekeepers operated almost 1000 apiary sites solely on private property (Agriculture Western Australia 1997). The key apiculture zones within the RFA area are shown in Map 10. Although a beekeeper is considered to be operating a commercial operation when managing more than 50 hives, to remain economically viable a single full-time operator needs to maintain approximately 400 hives. Using this definition, during the 1995-96 financial year, there were approximately 226 commercial beekeepers managing 47 860 hives in Western Australia. Of these, there were approximately 39 full-time apiarists managing 24 704 hives.

More than 75% of the commercial honey production comes from registered apiary sites on public land (Manning 1992). Four honey packers handle the bulk of honey produced in Western Australia, including two packers initially set up as co-operatives. Honey is pre-packed for the domestic market into containers ranging from 300 gram jars to three kilogram plastic buckets. Honey supplied for export is provided in small pre-packed containers and in bulk quantities. There are numerous other small honey packing and processing operations in Western Australia.

9.2 FLORICULTURE

The Western Australian floriculture industry is concentrated around the northern sandplains and the southern forests, primarily between Mount Barker and Nannup (Atkins et al. 1993). The local industry is unique because an important component of total production comes from native vegetation. Up to 1500 species of native flora have been used by the floriculture industry in Western Australia (CALM 1993). Harvested components include flowers, blossoms, bark and foliage including stems, leaves, fruits and nuts. The products marketed include both fresh and preserved cut flowers and foliage and oil.

The floriculture industry is presently evolving from an industry based on bush picking to an industry based on cultivated wildflowers. The total production from bush harvesting has remained stagnant over recent years, while production from cultivation is increasing with the area of cultivated wildflowers being established. Map 11 depicts the relative quantities of material harvested during 1996 in forest districts in the RFA area and the relative dependence on Crown land of the total harvest.

Size of the industry

Australian wildflower production accounts for approximately 10% of the world wildflower trade. The floriculture industry in Western Australia is a major component of the wildflower industry in Australia, contributing 57% of the value of cut flower exports during 1992-93 (Karingal Consultants 1994). The farm-gate value of Western Australian wildflower production in 1992-93 was estimated to be more than $7 million, which included a bush harvested component valued at $3.7 million. The retail value of total production was estimated to be between $16.3 and 17.3 million (Karingal Consultants 1994).

During 1992-93, there were approximately 700 registered pickers operating in public native forest and approximately 350 registered pickets undertaking commercial harvesting on private bush (Karingal Consultants 1994). Picking occurs throughout the year according to the flowering period of targeted species, but most pickets operate part-time or only pick during a short period of the year for certain species. Less than 10% of registered pickers harvested wildflowers for more than half of the year during 1993 (CALM 1993).

Prospects

Wildflowers harvested from Crown land add significant value to the industry by providing product diversity. Denying access to public native forest would impact heavily on some sectors of the industry, since it could stop the availability of some species which are not yet cultivated. It has been argued, however, that a reduction in bush picking might stimulate some marketable products into cultivation which would benefit the industry in several ways. A cultivation-based industry would have a higher global profile and may receive higher prices for exports, which are currently reduced by some poor quality bush-picked produce (Karingal Consultants 1994). With the increase in export demand, cultivation is a preferred way of ensuring continuity of supply and quality.

Western Australian has natural competitive advantages which could see the industry strengthen into the next century. The climate enables native flowers to be harvested for longer periods, including during the northern hemisphere out-of-season periods. Western Australia is also closer than eastern states and northern hemisphere competitors to Asian markets and there is a large gene pool of unusual species. Native flower breeding programs undertaken by Agriculture Western Australia have been successful in developing varieties suited to current markets and which have a long vase life (Boylen 1997).

9.3 THE SEEDS INDUSTRY

The native species seed industry in Western Australia mainly services land rehabilitation programs, particularly for mining and local government projects. Seed is usually collected from local provenances for these uses, so native vegetation continues to be an important seed source.

The seed industry is highly competitive with five main traders and a number of small operations based in the south-west. The administration and regulation of seed collection is the same as for the harvesting and picking of floriculture material.

The seed collection industry responds directly to highly variable wholesaler demands, and therefore requires access to a wide geographic range of resources. The industry could be vulnerable to any decisions to increase the area of conservation reserves and restrict access to harvesting areas.

9.4 BIOTECHNOLOGY

A biotechnology industry based on Western Australia's south-west forests and woodlands is an evolving possibility. The south-west forests contain many species of native plants known to have desirable horticultural and chemical attributes, including essential oils and pharmaceutical products (Armstrong and Abbott 1995). Less is known of the microflora and microfauna.

Research into natural products as a source of commercial products has been increasing over the past decade. Western Australian forests are internationally recognised for their biodiversity and high level of endemism and consequently, are a potentially rich source of novel compounds.

A recent commercial arrangement demonstrates the potential for this industry. Species of *Conospermum* endemic to Western Australia have been found to contain a natural compound, conocurvone, which kills the AIDS virus in test tube trials (Armstrong and Hooper 1994). Conocurvone is still under investigation as a potential treatment for AIDS and the Western Australian Government will receive a royalty from the sale of any pharmaceutical developed from the project. The company licensed by the conocurvone patent holder to develop the compound has already paid the State Government $1.65 million for work undertaken by local scientists and for supply of the isolated compound.

The collection of biota on public land is regulated by licences issued by CALM. Specific land management requirements for biotechnology are not documented at this stage. However, increased forest reservation could have an impact on the biotechnology industry, as collecting flora for commercial purposes is not permitted in national parks and nature reserves.

9.5 BASIC RAW MATERIALS

Basic raw materials are sand, limestone, lime sand, clay, hard rock and gravel. For each of these materials, several sub-categories have been established by the respective industries according to the physical properties and final end use of the product.

Table 9.1 Classification of basic raw materials

Basic raw material	Basis of division	Categories
Sand	end use	filling, concrete, building and silica
Limestone	grade	high grade – cement and lime production low grade – road base and building blocks
Lime sand		modifying soil acidity in agriculture
Clay	plasticity	plastic, semi-plastic and non-plastic (varying end uses by plasticity)
Hard rock	type grade	granite and dolerite for concrete asphalt and road base/surfacing hard rock A + B relative to crushing and screening process with B grade being fines from production of A grade

The major uses of basic raw materials as detailed in Table 9.1 are the housing and construction industries.

Size of the industry

The market value of the basic raw materials industry in Perth and outer metropolitan region was assessed at $768 million in 1994. There were also 4127 jobs directly associated with the industry (Chamber of Commerce and Industry 1995). This assessment did not include road construction which is another major use for limestone, shale, granite and dolerite.

The value of basic raw materials used in the South-West Forest Region has not been estimated. However, these materials are essential for the development of domestic housing and roads in the region and the industry will have a substantial impact in regard to both revenue and jobs.

Land management and access

The major uses for basic raw materials are in the housing and construction industries. The major costs of these materials are associated with extraction and transport. Consequently, access to resources close to the point of use has a significant impact on the cost of housing and construction. An increase of 25 kilometres in haulage of hardrock would add approximately $550 to an average residence and associated infrastructure.

Resources close to population centres may be affected by the expansion of urban areas and also by the expansion or the establishment of new conservation reserves.

The National Parks and Nature Conservation Authority's policy on access to basic raw materials recognises the importance of resource protection, but recommends that other areas such as already cleared land be targeted before CALM-managed conservation reserves are considered. This policy can result in a significant restriction in access to raw materials especially for shires which are largely covered by publicly-owned forests.

Multiple and sequential land use planning

In controlling encroachment of other land uses around quarries, as well as when considering quarry development applications and associated rehabilitation proposals, consideration is often given to the final use of the quarry site after extraction activity is completed.

Forward planning of this nature permits quarry rehabilitation to be tailored to the land use needs of the locality and the expectations of the local community.

The range of potential uses for rehabilitation quarries is extensive and can include urban subdivision, sanitary landfill, water storage, lakes, wetlands, farming, wood production, natural vegetation and recreation.

Prospects

Demand for basic raw materials will increase in line with the population growth in Western Australia. However, this same population growth, plus additional legislation to conserve areas of natural vegetation, will place significant pressure on resources.

If resources close to urban developments are not used, then the cost of providing alternative, more remote resources can substantially increase building and accommodation costs.

Planning is required to ensure that the importance of resources security is clearly understood and is addressed in management plans developed by government and shires.

10 Economic assessment

10.1 OBJECTIVES OF THE ECONOMIC ASSESSMENT

One of the objectives of the Regional Forest Agreement is to ensure the long-term ecologically sustainable management of forests and the development of competitive and efficient forest industries. This will be achieved through the provision of secure access to resources for industry while still protecting the environmental and heritage values of the forests by means of a comprehensive, adequate and representative (CAR) reserve system (Commonwealth of Australia 1995) and ecologically sustainable forest management practices.

In line with the agreed goals of the National Forest Policy Statement (Commonwealth of Australia 1992), the economic and social assessments for each RFA seek to answer a number of questions pertaining to the forest resource, forest use and industry development opportunities in the region. This includes assessing the ability of forest-based communities to adapt to change and community response and development plans.

10.2 APPROACH OF THE ECONOMIC ASSESSMENTS

The economic assessments are used to inform the development of policy on issues relating to the economic costs and benefits of varying forest use and industry development within a region. Variations to the existing forest use or industry structure may arise for various reasons such as:

- alternative conservation reserve boundaries and tenures;
- management options for production forests;
- options for conservation of private forests;
- plantation development options; and
- development of industry structure, capacity or product markets.

For the Western Australian RFA, a framework has been developed to assess the viability and impacts of these options for local and regional forest-based industries. Impacts are identified through changes in forest use patterns for wood production and other values, including woodflows and the net returns to specific processing industries. The impacts on regional forest industries are measured through changes in net returns and employment in local wood-based industries and regional forest-use patterns. Broader economy-wide effects are measured through changes in State output and employment.

Western Australian forests have a broad range of commercial uses in addition to timber production and mining. These uses include water catchment protection, recreation and tourism, apiculture, floriculture and seed collection. The analysis of these industries focuses on the likely location and magnitude of change in access to resources resulting from changes in the tenure of a forest from multiple use to conservation reserve. Such analyses need be undertaken only where access changes with forest tenure.

Background data on the nature of the forest resource and the structure of existing industries have been collected to provide a profile of the forest-based industries as a benchmark for assessing alternative resource use and industry development options. These industry development options have been developed after consultation with industry, unions, government and other relevant stakeholders.

Another component of the economic and social assessments is the evaluation of likely social impacts arising from proposed options. Data such as the direct regional income and employment impacts are incorporated from the economic assessments.

10.3 ANALYSIS TOOLS AND METHODS

Direct timber industry impacts

Calculation of the direct economic impacts of varying the processing opportunities or level of resource available to the timber production sector involves quantifying changes to such factors as employment, income (wages and salaries) and the gross value of production. ABARE has previously developed a model—FORUM (Forest Resource Use Model)—to simulate such impacts. FORUM is a regional linear

programming model of production forestry, designed to measure the direct impacts to local or regional timber industries of changes in woodflow.

However, the FORUM model requires estimates of woodflows over the life of the RFA at a detailed, spatially disaggregated level. The level of spatial disaggregation used in FORUM does not match the yield-scheduling systems used in Western Australia where woodflows are analysed at three administrative levels (Swan, Central and Southern forest regions).

Consequently, a spreadsheet-based model has been developed to simulate the interactions between regional timber resources, wood-based forest industries and final product markets. The model enables the development of the wood-processing industry to be simulated, subject to certain assumptions relating to wood resources, industry cost structures and wood markets. The model is used to simulate the development of the wood processing industry and then to analyse the economic implications of changes to resource access.

Information on the gross value of production, employment levels, the net value of the timber production, or the land and tree resource rents, are generated for the 20-year RFA period. In each year, land and tree resource rents are equivalent to the net stumpage value of logs harvested. The stream of land and tree resource rents over the period are discounted to determine the present value of land and tree resource rents. Discounting back to the present value is necessary in order to be able to compare possible different development scenarios which have different time profiles. The model enables estimates to be made of which regions face the greatest changes when wood resources, market conditions or industry structure are varied.

Key data sources include CALM estimates of likely woodflows over the life of the RFA, an economic survey ABARE undertook of the Western Australian sawmill industry and industry development options developed by consultants BIS Shrapnel Forestry Group. The consultants have provided information and data relevant to assess the potential development of a technically feasible and world competitive hardwood-based industry in Western Australia through to 2020.

Model simulations are based on several assumptions concerning wood resource availability, industry cost structure and wood market conditions. Prices and costs are based on constant 1996-97 values, revenue is measured on a pre-tax basis, trade and other policies except where specified are unchanged from those currently in place. Rotation lengths, wood-conversion factors, real prices for end use forest products and real per unit harvesting, processing, transport and investment costs were assumed constant throughout the RFA period unless otherwise stated. Australia is assumed to be a small trading nation in forest products, so that forest product prices are determined by the rest of the world.

Over the duration of the RFA, the structure of the industry can change in response to wood resource quality and quantity, markets and the competitiveness of industry. Hence, impacts on the wood processing industry arising through changes to industry structure should be assessed against the industry structure that is likely to exist over that period. This requires modelling the development of Western Australia's wood processing industry through to 2020. The model, in conjunction with the assessment of development options produced by consultants BIS Shrapnel, is used to simulate the hardwood logging and wood processing industries in Western Australia between 1997 and 2020 under the assumption of no change in current access to State forest areas. This baseline provides a benchmark against which the economic implications of changes to wood resources that may occur under a Western Australian RFA are assessed.

Direct mining impacts

Methodology

The methodology used is consistent with the procedure used to examine economic impacts in the timber sector. The direct economic cost of a conservation reserve which affects current or potential future mining in the region is defined as the reduction in the present expected value of net economic benefits associated with known and undiscovered mineral resources in the region due to any resource access restrictions imposed by a new conservation reserve. Given practical difficulties in measurement, generic quantitative models for evaluating the economic costs of conservation reserves that may affect current or potential future mining have not been developed. Rather, a framework is provided and is used to outline the likely nature and extent of economic costs arising from conservation reserves that would constrain existing or potential mining operations within the region. The type of information that would be required to estimate such costs accurately is also discussed. This analysis then provides a basis for examining the issues regarding the manner in which the design of conservation reserves can affect mining and exploration activities. The following is a brief summary of this analysis.

Impact on sovereign risk

One of the key objectives of the RFA process is to deliver greater security of resource access for current and future investments which require access to forested land in Western Australia. However, the process itself is generating uncertainty in the short term. Changes to land access arrangements arising from the RFA which affect current exploration or mining operations have potential to have significant economic costs.

State Agreement Acts are, in effect, contractual arrangements ratified by the Western Australian Parliament and as such, any amendment to them has to be by negotiation with the company concerned. In Western Australia, most major mining projects operate under such agreements. The right of land tenure and access granted under State agreements are an important factor under-pinning the large-scale and long-term investments which have been made in the alumina and coal industries that operate in the RFA area. Any unilateral changes to land tenure affecting current mining activities could raise uncertainty as to the effectiveness of such arrangements for future projects in Western Australia, with potential adverse implications for levels of future investment. The State government, however, would not contemplate changing these rights of land tenure without the agreement of the relevant companies, owing to the sovereign risk which could arise.

Operating mines

The direct economic costs of a conservation reserve which precludes forest clearing in a particular area of a mining lease would depend primarily upon the amount of mineral resources contained in the conservation reserve, and its location in relation to plans for future mining. Consequences could range from a small reduction in output over the life of the mine, through restriction of expansion potential to the extreme case of forcing the operation to close.

In addition to size and location, the type of mining would influence the sensitivity of an operation's production to a proposed land access restriction. Open-cut mining requires initial surface clearing for a pit or mine shaft, after which mining occurs for a relatively long period of time. For these types of operations, any restrictions on land clearing could have implications on production that would otherwise have continued for a number of years. For surface (or strip) mining operations in the RFA area, there is a direct and ongoing relationship between production and surface clearing, as mining occurs at depths of typically less than 10 metres. Restricting access to areas for strip and surface mining operations will affect a shorter period of production than would be the case for a deeper mining operation.

The economic costs to society (both direct and indirect) of a conservation reserve option affecting resource availability are defined as the difference between the net economic benefits to society resulting from the 'business as usual' (or baseline) production profile and the net economic benefits to society associated with the production profile which results from the conservation reserve option in question. The costs of conservation reserve options can be broadly classified into direct costs and indirect costs. Direct costs are defined as the reduction in the present value of the net economic benefits associated with mining, processing and marketing the resource in question. These costs are primarily borne by the companies concerned.

Indirect costs are defined as those costs which occur in other markets as a result of a change in resource availability. For example, the early closure of a currently-operating alumina refinery could be expected to result in increased costs in markets for commodities used in the production of bauxite and alumina (e.g. coal and chemicals) and could have significant implications for regional economies. As discussed below, if time permits, a general equilibrium model may be used to enable estimates to be made of these costs to the Western Australian economy under the various reserve options.

Surface or strip mining

In the case of a surface or strip mine such as bauxite mining, any small conservation reserve which would lead to mine life being shortened but not to any other significant change in the production profile (e.g. the viability of future expansion plans are not affected) is likely to involve considerable direct costs, although indirect costs are likely to be small. It is important to note that the eventual closure of mining operations inevitably leads to costs in related markets, e.g. in markets for inputs to the mining and processing operations and on the regional economy in general. However, given that these adjustments will be made in any case, the relevant cost is the cost of bringing these adjustments forward as a result of the shorter mine life.

Should any proposed conservation reserve contain sufficient bauxite to affect the viability of future expansion plans (or the viability of current refineries) then direct costs are likely to increase substantially. In addition to the direct economic costs, any reserve option which would involve significant reduction in

the use of labour and capital may involve significant costs in other markets and the Western Australian economy.

Open cut mining
In the case of an open cut mine such as coal mining in the Collie Basin, the relatively inflexible nature of the mining operations would be expected to mean that any conservation reserve option which would impact on current operations is likely to involve significant direct costs and may also involve substantial indirect costs. There would be a reduction in direct costs by locating any conservation reserves away from areas which are required for mining developments in the foreseeable future.

Potential future mines

In the case of undiscovered resources, economic benefits cannot be known until they are defined in terms of location, quality and grade and found to yield economic benefits. A large proportion of the South-West Forest Region has been assessed to have high mineral potential (see Chapter 8). Accordingly, it is likely that, through exploration, such resources will be identified and new mines developed. As such, there will be a positive expected value to society from maintaining the option to explore and develop mines within the region.

To calculate this expected value would require a number of estimates and assumptions. Assumptions regarding the probability of various mineral deposits lying undiscovered within the region would be required. Specifically, for each deposit type, this would require estimates of the probability distributions of potential deposit sizes, grades and the number of deposits. Without extending the available geoscientific assessments of the region to include estimates of probabilities of resource occurrence, it is not possible to estimate quantitatively the expected value of undiscovered mineral resources within the region.

However, even if such a quantitative geoscientific assessment of the RFA region was available, further economic assumptions would be required to extend the geoscientific assessment of undiscovered resources to estimate the expected economic benefits from allowing exploration. Estimates of the likelihood of finding deposits through time (perhaps based on expected exploration effort) and the benefits of finding a deposit for all possible future discovery dates would underlie any such valuation.

Although there are practical difficulties in estimating the option value to society of allowing exploration (and the possibility of mining subject to environmental constraints) within an area, it is clear that such values are likely to be significant in some cases.

While the dollar value of such options has not been estimated, the right to explore for these resources is of significant value and therefore important in considering resource management options for possible reserves. Rather, it needs to be recognised that, for a number of reasons it has not been feasible to place a dollar value on undiscovered mineral deposits in the region. Accordingly, assessments of mineral potential need to be taken into account in considering reserve location and classification.

Undeveloped resources
The values associated with undeveloped resources (which are currently identified) are of a similar nature to those associated with undiscovered resources. While undeveloped resources are not producing any economic benefits at present, there is the possibility that they will be developed at some future date. There are numerous examples of changes in mining or processing technology, commodity prices or production costs leading to previously uneconomic deposits becoming economically viable over time.

Indirect economy-wide impacts

Any direct economic impacts in the timber, wood products and mining industries will have linkages to other sectors of the economy, at regional, State and national levels. To assess these effects, two methods are to be used. Input-output tables provide a first approximation to the magnitude of indirect impacts upon employment, output and income that flow through to the broader economy as a result of changes to the timber, wood-based and mining and mineral processing activities in the region. State-based input-output employment and income multipliers for Western Australia are available for use (Clements and Qiang 1995). However, input-output tables involve a range of assumptions, including assumptions of excess capacity in all sectors of the economy in all regions. As a result, inferring State or nationwide impacts from input-output based multipliers can over-estimate economic impacts.

General equilibrium models, in theory, provide more accurate estimates of the flow-on effects of changes in output or income from forestry-based and mining industries to other sectors of the State or national

economy. Spillover effects from one sector of the economy to another are captured through wage and price adjustments resulting from one sector's expansion or contraction in response to a policy change. For example, the effects of alternative wood supply options on the timber industry will have flow-on effects to other downstream wood users through changes in woodflows and prices. They will also have flow-on effects for other industries such as retailing and transport, because of the effect on prices of intermediate inputs and primary factors that affect other industries' costs of production and market demands. This also means that a policy change affecting the forest industry can indirectly affect the international competitiveness of other sectors through changes in the exchange rate and changes in the costs of production of export and import competing industries.

The Centre of Policy Studies at Monash University has been commissioned to provide a computable general equilibrium model of the Australian economy. The model is based on the centre's existing MONASH-MRF model (Peter et al. 1996) and will be available for use at the end of 1997. If time permits, it will be used to estimate the impact of different resource options on the State and national economies.

11 Social assessment

11.1 INTRODUCTION

Based on 1991 ABS census data (census collector districts), the Western Australian RFA region had a population of approximately 155 000. More than 40 000 families and 70 000 (full and part-time) employees lived and worked in the region. Employment sectors and approximate employee numbers included mining (2500), manufacturing (7000), construction (3500), wholesale (10 000) and finance (5500). 1996 ABS data indicates that approximately 1900 people are directly employed in native hardwood industries in the RFA region (including forestry and logging, services to forestry, sawmilling, timber dressing and woodchipping). Approximately 2500 people are directly employed in these industries if metropolitan Perth and coastal areas including Mandurah and Bunbury are included. As yet, 1996 census data have not been extracted for other occupational groups.

Apart from outer metropolitan Perth (e.g. Mundaring, Kalamunda and Armadale), there are no major cities in the region. Larger towns include Collie, Manjimup, Bridgetown and Waroona. There are numerous small towns of less than 1000 people, including Yarloop, Nannup, Greenbushes, Balingup, Pemberton, Dean Mill and Dwellingup.

Social assessment projects

The social assessment process for the Regional Forest Agreement consisted of four projects, three of which have been completed during the RFA assessment phase and are described below. Further social assessment will continue following the publication of the options report.

Post impact studies analysis

This project reviewed previous land use decisions in the region and the impacts arising from those decisions. Previous social impact assessment studies and mitigation programs were also reviewed.

Regional social profile

Surveys and personal interviews were used to develop a profile of stakeholder interests in the RFA region and a general understanding of local issues and concerns relating to forest use. Australian Bureau of Statistics (ABS) census data were used to extract socio-demographic and employment information, labour force characteristics, community infrastructure and services in regional towns. A random telephone survey of more than 1000 residents within the RFA region was conducted to gain an understanding of community attitudes and interest in the forests (preliminary analysis provided).

Forest industry assessment

This project surveyed industry groups which have an economic dependence on the forests. More than 2600 survey forms were distributed. Industry groups contacted were: timber, tourism, mining, wineries and other forest-based industries such as apiary, craft and speciality timber, firewood, wildflower pickers and seed collectors.

Because of the potential for immediate direct impacts resulting from any changes in forest use, timber industry employees were also surveyed. This project aims to understand the relationship between the industry, its workers and the local towns.

Details of each project are outlined below.

11.2 POST IMPACT STUDIES ANALYSIS

A consultant was engaged to review and describe the changes resulting from decisions that have affected land uses in the RFA area and to examine what mitigation could occur as part of the RFA process. The terms of reference were to review:

- previous land use decisions within the region and social impacts resulting from these decisions;
- previous social impact assessment studies; and
- mitigation programs undertaken within the region and more broadly.

Little social impact assessment has been conducted in the RFA region. Consequently, a range of issues that has driven social change across the region was examined. These were: government forest policy and direction statements; forest industry technology and general economic activity; planning; mining; water; agriculture; tourism; attitudinal change; demographics, and economic structure. From this, a picture was built of the current social structure across the region. Based on the social impacts resulting from previous land use decisions within the region, the consultant suggested several mitigation approaches which could be investigated if this became necessary as a result of the RFA process.

The starting point for this study was 1960. At this time, significant modernisation of the timber industry began and the issue of forest conservation for values other than timber began to be addressed.

Themes that have come from this study are: increasing complexity of the decision making processes; increasing centralisation of economic activity in fewer locations; economic competition through timber industry restructuring and development of other industries; and land use issues. These are discussed below.

Increasing complexity

Over the past 35 years, every issue that has driven social change has increased in complexity. There has also been increasing intersection between these multi-sector issues. Accordingly, government policy, planning and management have become more complex.

Changes in forest product technology

The forest products industry has changed in size and structure. Access to forests, logging operations, mills and support communities has changed from localised, product-specific operations to integrated and consolidated operations. Production is now oriented towards producing a wide range of products including sawlogs and value-added components, roundwood products and residues such as chiplogs and industrial firewood.

In the past, the native hardwood industry has been linked to the structural timber market and has been significantly affected by fluctuations in building cycles. This has created variable employment opportunities.

Many major mill closures occurred in the 1970s and 1980s. However, adjustments are still occurring with older, less efficient mills closing and shifts closing at other mills in recent times. When closures occur, the industry has attempted to help workers by offering redundancy or alternative employment in other locations.

Production facilities are becoming larger, more efficient and more centralised. Processing and value adding of timber products occurs at large regional centres and logs are transported over larger distances. This trend has created more stable employment opportunities in fewer locations and those jobs available generally require a greater skills base. Manufacturing industries are generally located outside the RFA region.

Opportunity exists for increasing employment in the value-adding parts of the industry, particularly in manufacturing. People consulted in this industry considered that manufacturing is currently not well supported by government policy or the forest products industry.

Mining

Mining is the major economic contributor in the region. While its presence is limited in geographic extent at any point in time, its economic effects are widely distributed. Major mines and processing works act as economic magnets to other development. Mining also tends to be on a technological trend that increases capital investment in plant and equipment while employing fewer people.

Mining and mineral processing has resulted in the rejuvenation of several towns in the region.

Agriculture and water management

Agriculture has caused a great deal of clearing in parts of the region. Since its heyday in the 1960s, this industry has been meeting challenges of increasing international competition through seeking economic efficiencies, new crops and increasing the size of operations. This has meant a decline in the rural population dependent on agriculture, particularly in the eastern part of the RFA region. As a result, some services have diminished and there has been a consequent slow reduction in the size and number of rural towns.

At the same time, environmental degradation attributable to land clearing has been increasing (e.g. erosion, salinity and loss of native vegetation). In response, there has been an increase in the role of landcare and community-based integrated catchment management (ICM) groups. The Water and Rivers Commission and other agencies have supported ICM. Agriculture Western Australia has responded by developing the Sustainable Rural Development Program, an holistic approach to agriculture that aims to link ecologically sustainable farm practices with community economic development.

Tourism

While a relative newcomer to the region's industrial base, tourism is already a significant economic contributor and a significant employer with further potential for growth. The south-west, with its diversity of forest and natural attractions and other land uses, is a valuable tourism resource. The industry has an increasing focus on nature-based tourism.

Attitudes to the environment

Over the past 30 years there have been large shifts in community attitudes towards the environment. New legislation and public policy, increasing awareness of the value of forest for non-timber values and community-based action have influenced government decisions and resulted in considerable areas of the forest being allocated as conservation reserves.

In the 1990s timber industry workers and communities also began to organise into grass-roots action groups because they considered that their jobs were threatened by inadequate security of the timber resource and less of the resource being available for use.

Increasing centralisation

Centralisation has two components. At a local level it describes the tendency for the economic activity and population to aggregate around the major towns in the RFA region. At a regional level it describes the weight of population and economic activity occurring on the coast in local authorities such as Augusta-Margaret River, Busselton, Mandurah and Bunbury.

Forest products industry

Economic pressures on the forest products industry have reduced the number of mills and processing centres. Operations are becoming more centralised in fewer locations.

Administration

Most areas of public and industry administration have become more centralised. Government and commercial services are increasingly concentrated in major towns or on the coast.

Demographics

Over the past 30 years the population on the coast has more than doubled. Over the same period, the population in the core RFA shires (e.g. Manjimup, Bridgetown-Greenbushes) has remained constant. Population has decreased slightly in the eastern RFA shires (e.g. Cranbrook, Boyup Brook). It is unlikely that the forest products industry can make a significant difference to these trends in the future unless dramatic expansion of downstream manufacturing occurs in the core and eastern shires.

Economics and planning

The region is dominated by several major centres that act as economic and employment engines. If communities are within easy travelling distance i.e. 10 to 15 minutes drive of these major centres, it is likely that their growth will be based on the prosperity of these centres. Towns more removed from these areas will be subject to increasing threat.

Economic competition

The regional economy is becoming increasingly diverse and is not as dependent as it has been on the timber industry. However, some towns, particularly in the core of the RFA area, remain dependent on the timber industry for employment.

The RFA process is examining economic decisions and employment in the timber processing industry and other industries dependent on forests. Policy and economic pressures have forced changes in

technology that have mechanised mills to process increasing amounts of wood at a few large processing centres. Similarly, the management of plantation wood industries is highly mechanised, mobile and not necessarily linked to small local communities.

While restructuring is driven by economic necessity in order to ensure a viable industry, the benefits largely accrue to the major centres. The value to smaller local communities is uncertain. In response to this, the consultant suggested that the following could be considered in the RFA process:

- maximising employment opportunities within the forest products industry—to maximise social benefit from the RFA it is important to consider how timber industry technology can provide maximum local community employment while still remaining economically viable; and
- supporting forest-related industries that provide local community employment—it is important that local social benefit is maximised by seeking, identifying and supporting forest-related industries that provide local community employment.

Land use issues

Historically, government policy has been to hold forest in Crown reserves. Clearing for agriculture has reduced the area of native forest on private land. The current demand for plantation timber and the impact of salinisation has resulted in farming land now being returned to (plantation) forests. Each of these events has had its social effects.

Most of the public land across the RFA region is controlled under government policy by State government agencies. CALM is the largest land manager and CALM's controlling bodies (the National Parks and Nature Conservation Authority and Lands and Forest Commission) are responsible for preparing management plans which affect several large industries (particularly mining, timber and tourism). Land-use decisions are taken by government following public consultation on draft management plans. Other agencies responsible for land and resource planning and management in the region include the Ministry for Planning, Agriculture Western Australia and the Water and Rivers Commission. Land-use decision making by these agencies also includes consideration of the well-being of the communities that they affect.

Regional synopsis – social impact

From the information presented above, the consultant has drawn the following conclusions about the region:

- If a town is adjacent to a major economic magnet then it is likely to grow with that centre.
- Towns outside easy travelling distance from these economic magnets, particularly in the east of the RFA area, are under threat.
- The timber industry is unlikely to provide any significant additional employment in milling and forest management. The principal opportunities for employment growth are likely to be in the manufacturing sector and related industries. This growth is likely to be in the major centres or on the coast.
- Significant structural adjustment in the timber industry has already occurred. Nevertheless, there are some localised issues that may affect specific towns.

Mitigation approaches

Mitigation is often narrowly viewed as giving money to offset change in communities. While this is one option, there are others that may be more appropriate. From the studies examined, 13 approaches to mitigation were identified. Applying these prescriptions should be decided on a case by case basis, taking account of the characteristics of the community and the nature of the changes. The mitigation approaches are summarised below:

- none—no mitigation is proposed;
- wait and see—a commitment is given to address an issue if it arises;
- review of options—options are considered and presented to be addressed in the future if required;
- off set—providing one-off payment or facilities to off set the impact of a project or decision;
- individual assistance—provide assistance to individuals impacted by a change such as help with retraining, relocation, re-employment etc.;
- conflict resolution—resolving conflict and mediation;
- community liaison—providing information and answering questions;
- using indicators—using indicators to trigger responses for mitigation;
- structural change—modifying the way in which administrative and bureaucratic systems respond to communities;

- feedback planning—involving community representatives in the planning process (e.g. focused discussions and community economic development);
- support for communities—seeking to develop a working relationship between governments and a community, with the emphasis on ongoing support and involvement;
- community control—the community drives the change process.

What mitigation is necessary?

From the review of the various impacts on land uses the question must be asked: *is any mitigation necessary?* When reviewing events in the RFA area over the past 30 years, it appears that some broad areas of mitigation could be examined as part of the RFA process.

Improved individual assistance

While structural change has already occurred in the timber industry, there are still cases where mills are closing and workers are made redundant. While this is occurring, resources are available within existing government services to provide retraining and business enterprise development opportunities. These services are available to redundant workers who meet the relevant criteria.

Supporting choice of technology

There is strong evidence, particularly in the 1987 Timber Strategy, that major changes in the timber industry can be influenced by strategic policy direction. Opportunities exist for government, industry and unions to re-examine relevant issues such as resource security, value adding technology, local manufacturing, marketing and research. Policy which improves the employment opportunities in regional towns and addresses the trend for the reduction and centralisation of employment should be considered. Similarly, economic analysis could extend to examining ways to maximise local community economic benefit from the forests that surround existing towns.

Supporting local community economic development

One avenue which could be pursued is to initiate a more open and consultative planning process for forest operations and timber industry development, involving all timber industry stakeholders. Documented case studies which have used this approach include the major timber industry restructure in Burnie, Tasmania, and the "Doing more with agriculture" project undertaken by Agriculture Western Australia (Chambers and Galloway & Associates in prep.)

11.3 REGIONAL SOCIAL PROFILE

Assessment of stakeholder issues

The focus of this study was to ensure participation in the RFA from all peak bodies and groups with resource management interests in the RFA area. Important issues, challenges and areas of concern are profiled according to stakeholder group and geographical area. In so doing, it should be noted that this study:

- comprises only one component within the overall social assessment;
- targets specific interests; and
- was not intended to measure representative opinion on particular issues.

The primary aim of the study was to capture a broad range of views about forest use and management to assist with option development.

Methodology

Upon commencing the social assessment, stakeholder contact lists were compiled. Many additional names were included as the consultation process developed. Gaps in the original list (in terms of key interests and localities) were identified and participants often nominated other people who should be contacted. At present, the contact list includes 344 people.

Survey

The survey form and interview included four general, open-ended questions about forest use and management and two further questions. These asked: *in what area of the south-west do you have most*

interests or responsibility? (town or shire; region or sub-region; State), and: *what stakeholder group best represents your interests?* (e.g. local government, conservation, timber, mining and tourism industries, farming, Aboriginal, etc.). Participants were asked to specify one answer for both questions. This was possible for most people, although several had difficulty "forcing" themselves into one stakeholder grouping.

Initially, a randomly-selected sample of 120 stakeholders was faxed the survey form (along with covering information). Telephone calls were used to prompt questionnaire returns. Contributions were further increased by holding personal and telephone interviews throughout the RFA area. To expand the range of stakeholder interests, approximately 70 additional survey forms were faxed to potential respondents. Altogether, 253 (or 73.5%) of the 344 people listed were contacted. In all, data from 148 surveys or interviews were analysed. (The number of stakeholders who took part was substantially higher than 148 as several interviews were attended by two or more people.)

A complete description of issues, including those pertaining to various stakeholder interest groups, will be published in a separate social assessment report.

Presentation of results

Based on responses obtained, some interest group classifications were added (e.g. scientist) or combined (e.g. tourism/recreation). Due to the low number of responses in some areas, a number of shire areas were also combined. The most frequently-mentioned issues are summarised and presented under themes. These are:

- forest use and access;
- employment/industry viability;
- forest management; and
- environment.

Overview of stakeholder issues

Many respondents from all areas wanted the opportunity to participate in the forest decision-making process. Further, many indicated they wanted a resolution to the forest management and use debate. Some argued that CALM's management plans did not reflect changing community needs and the agency appeared unaware of the impact of its decisions on local communities. Considerable mistrust existed between different community interest groups.

Several shire representatives expressed dissatisfaction with the damage caused by haulage trucks on local roads. Shires were forced to repair the damage but received no compensation.

Mixed views were forthcoming about timber plantations, with integrated tree cropping on farms more favoured. The latter was described as economically and environmentally beneficial. Most concerns centred on the loss of employment and decreased social structure resulting from large timber plantations. Aesthetic impact was also mentioned as a concern. However, others considered plantation timber to be the timber industry's future.

The lack of agreement about what constituted sustainable forest management and the definition of old growth forest, emerged as major issues across all shires. Consistency and certainty of supply was the key issue for timber industry participants. Tourism and mining industry representatives also strongly stated their need for resource security to protect current and future investments.

A key issue for the timber industry was management of a changing resource—it increasingly relies on timber from regrowth forests. Log diameter was decreasing and this required different technology. Coupled with this, the availability of first and second grade sawlogs was diminishing. The industry's view was that any changes in reserve systems would compound the difficulties it faced.

Albany/Denmark/Plantagenet/Cranbrook

Forest use and access issues involved: maintaining forest access and hunting and gathering rights for indigenous people; preserving the cultural values of the forest; and adequately managing the relationship between tourism and the presence of old growth forest.

Issues relating to **employment/industry viability** raised the need to compare the number of jobs created with the jobs lost through the use of bluegum plantations; and value adding has flooded the market and forced the price down.

Forest management issues included: diminishing log quality and quantity; declining population and changing social structures from timber plantations; new tree species and markets (including indigenous,

high-value, hardwood timber species) required for farms in different rainfall zones. Farmers required greater knowledge of forest management practices.

In relation to **environment issues,** opinions were divided about the long-term sustainability of current forest management regimes. In particular, logging and clearfelling were described as causing: loss of habitat and biodiversity; loss of landscape amenity and community sense of place; decreased aesthetics and tourism potential; increased nutrient export; increased salinity; and high levels of soil pathogens. Protection of riparian vegetation was also considered important.

Augusta-Margaret River
A key **forest use and access issue** was to prevent indiscriminate forest access due to increasing pressures and competing demands.

Forest management issues included: ensuring maximum use of native forest resources; and allowing CALM to implement its timber strategies.

Environment issues raised were: the perceived tourism significance of old-growth forests; and opposition to logging or mining in national parks.

Bridgetown-Greenbushes
A **forest use and access issue** was to improve equity between old growth forest conservation and the timber industry

Forest management issues were: future timber demands should be met by plantation timbers; the forest was not managed ecologically sustainably but for timber production; the shire has an unreasonably low percentage of conservation reserves; timber recovery rates require improvement; current rotation practices "juvenilise the forest"; locking up large areas of forest increases stress on the remaining resource; and security of tenure is required by the timber, mining and tourism industries.

Environment issues included: the recognition that there were many conflicting community views and pressures about forest values; and old growth forest protection.

Bunbury
Forest use and access issues covered: protecting the native forest resource for security and future investment of the growing nature-based tourism industry; and meeting the needs of the silicon industry for consistent access to low-grade jarrah log supply.

Employment/industry viability: Western Australia's Farm Forestry Task Force identified 2600 potential jobs in farm-based forestry; the non-competitive pricing structure between native timbers and imported timber discouraged greater expansion of plantation forestry; and the claim that more than half of the workforce in some south-west towns are employed in the tourism industry.

Forest management issues were: placing timber reserves into national parks puts pressure on the rest of the resource; plantation reserves on agricultural land are less favoured than integrated farm forestry; balancing productive forest with multiple-use forest areas; providing a secure supply of quality timber logs; the criticism that political decisions are made without industry or community consultation; and sustainable use of the forest resource is imperative.

Environment issues related to conserving adequate areas of old growth forest for protection of biodiversity and catchment hydrology. Forest hygiene and forest residues were recurring concerns.

Busselton
A key **forest use and access issue** raised was that mining leases in native forests automatically raises public objection.

An **employment/industry viability issue** was that timber communities are declining due to industry rationalisation and increased automation.

Issues relating to **forest management** included: forest recovery rates must continue to improve; opposition to the use of jarrah for the silicon smelter; sawmills required an adequate supply of quality timber; and opposition to clearfelling and woodchipping.

Environment issues were: current forest management practices create a monoculture and juvenilise the forest; and mixed views exist about prescribed burning practices.

Collie/WestArthur/Williams
The key **employment/industry viability issue** was that timber workers face job insecurity.

Forest management issues included: balancing the retention of old growth forest with the demands of the timber industry; increasing plantation areas reduces the local population; and salinity problems have developed from the logging regime.

Environment issues were: there is pressure to conserve the remaining forest; and mining land is rehabilitated to the original forest type.

Donnybrook/Capel/Dardanup
A key **forest use and access issue** was that timber and tourism could coexist with improved public understanding. Overcoming the "emotional distortions" of the green movement and achieving a balanced view were also stated.

Employment/industry viability issues raised were: the need for job security for young timber industry workers; balance conservation and employment; and assistance for local communities to develop broader value-adding opportunities.

Forest management issues included: producing high quality jarrah sawlogs on a hygienic and sustainable basis; better management to protect biodiversity (e.g. adoption of an improved prescribed burning program); sharing forest management between the community and CALM; and the view that politics and the media prevent an informed community forest debate.

Environment issues were: to conserve the remaining native forests; provide adequate conservation reserves; the need to adopt an integrated catchment management approach; and opposition to the creation of wilderness areas unless they can be created as a result of genuine conservation areas first being created.

Harvey
Employment/industry viability issues included the assertion that the timber industry needs to remain viable and, if further resources were locked up, it would not continue to be sustainable. A number of people interviewed did feel threatened by the loss of the town mill and the "domino effect" of dwindling services (e.g. school teachers, local shops).

Forest management issues included the view that CALM does an excellent job but not in the eyes of the public. In this regard, "they don't advertise what they are doing and when they do it"; "if it is sustainable, people need to be convinced"; "there is no communication/education and most of the general public wouldn't have a clue what is happening". Other comments concerned the importance of burning and fire control. For instance, "bush needs fire to germinate—good hot burns destroy dieback—if we don't burn we'll end up like the fire in NSW".

Manjimup
Issues relating to **forest use and access** were: scientific answers will overcome the polarisation of forest views; Pemberton and Northcliffe requires multiple forest activities and access to old growth forests; and forest access is required for Aboriginal people for hunting and cultural reasons, recreational activities and low impact tourism.

Employment/industry viability issues involved: the timber industry is rationalising and shedding jobs; timber industry employment has substantially declined in the last decade; significant community impacts will occur in Manjimup and Pemberton if the timber industry closed; Manjimup depends on a viable timber industry and a stable work force; the Commonwealth Government's tariff policies restricted the timber industry's international competitiveness; and Pemberton and Northcliffe's future lies in tourism.

Forest management issues covered: the need to recognise that Australia's wealth came from its primary resources; long-term resource security sought by timber, mining and tourism industries; without harvesting forests will die of old age, revenue will be lost, wildfire risk increases and towns die; the biggest industry operators were considerably less efficient than smaller mills; the timber industry's resource problems are due to "slash and burn" mentality rather that conservation pressures; forest management is hindsight management; CALM has an excellent forest management policy; contention about whether present forest management practices were sustainable; political decisions were taken without awareness of the local impacts; mixed views about hardwood farm forestry plantations due to social impacts perceived; criticism that some areas were given national park status when better areas existed (e.g. Shannon); current regeneration practices were contentious; and native forest timbers were significantly undervalued in royalty structures which encouraged inefficiencies.

Environment issues were: retaining as much old growth forest as possible to ensure a future for Northcliffe and Pemberton; jarrah logs are undervalued and inadequately used; it is "trendy to be green"; burning programs were contentious; and the limited wandoo forests must be conserved.

Murray/Waroona/Boddington
A key **forest use and access issue** was requiring better recognition of the value of tourism.

Employment/industry viability issues were: value adding can create additional employment opportunities; and recreational facilities can lead to employment opportunities.

Forest management issues were: blanket exclusion zones are highly unsatisfactory to the mining industry; allow increased participation by community and industry groups into forest management; the mining industry requires negotiation opportunities to mine in forests; a sustainable timber industry was paramount; better use of forest resources was required; and the use of jarrah forest residues for charcoal was opposed.

Environment issues were: conferring national park status creates a negative public attitude towards mining; and clearfelling and prescribed burning regimes severely impact upon apiarists.

Nannup
A **forest use and access** issue was that tourism will suffer due to over-harvesting practices.

An **employment/industry viability** issue was that Nannup's sawmill would not remain.

Forest management issues included: sustained yield logging was subjective; current sawlogs production methods and forest management practices were unsustainable. The lack of old growth forest in the area, especially jarrah, was stated.

An **environment issue** was opposition to logging in gazetted and non-gazetted road reserves.

Outer metropolitan Perth
Forest use and access issues were: to manage and control forest recreation; and concerns related to the apiary industry which requires continued access to quality forest areas for honey production and bee-breeding purposes.

Employment/industry viability issues concerned the decline in the apiary industry; and the need for enhanced value-adding processing to create more jobs.

Forest management issues included: sustainable use of the forest was essential; maintain areas for tourism and recreation; jarrah should only be used for high-value end products; the extent of clearfelling affects the viability of the apiary industry; concerns about prescribed burning practices, regeneration techniques, jarrah dieback and weeds; and CALM's limited resources to manage national parks adequately.

Key **environment** issues were: to conserve and protect the natural environment and the need to keep the understorey in natural condition for the benefits of other industry groups.

Perth
Forest use and access issues were: strong opposition to blanket forest exclusion areas by the mining industry; limiting access to quality resource areas, e.g. jarrah forest, and addressing Aboriginal heritage issues prior to forest use.

Employment/industry viability concerned the declining apiary industry; declining timber industry employment; the need to have accurate investments of future log yield and quality for investment planning; and value adding provided skill upgrade opportunities.

Forest management issues included: ensuring a consistent and secure resource supply for the timber industry; establishing a well-researched and managed farm forestry and plantation timber industry; comments regarding Western Australia's world-class forest management; that a native forest timber industry was not sustainable in the long term. Others, however, said the current forest management policy ensured sustainability and should be continued and extended.

Environment issues involved: retaining sufficient areas of old growth forest for its tourism, aesthetics, biodiversity and conservation values. Another view was that water quality could be affected by forest management and therefore its protection was important.

Overview of areas of concern

In addition to key issues, participants were asked: *are there any areas of forest that you are particularly concerned about and why?* Responses are discussed below.

While people were asked to be as specific as possible, many could be no more specific than noting their concern for the whole RFA area. Reasons included comments such as "it's under threat", many of which were provided by people who saw that the future of timber supply areas was in jeopardy.

The security of these areas was essential for sustaining the industry and, as a result, the immediate future of towns including Yarloop and Nannup.

Others who held that forest areas were threatened perceived problems with current management regimes included over clearing, "unnatural" burning practices, forest fragmentation, loss of carbon to the atmosphere, dieback and infestations of other diseases, weeds and pests. Another frequently-mentioned issue was sustainability, with the related concern being that the yield in timber production was unsustainable. Issues including questionable regeneration rates and soil quality.

It was suggested that some old growth forest should be set aside in each shire, and that a continuous forest belt connecting the shires be maintained to assist migration of native animals. Also noted was a need to ensure that aboriginal sites and areas with identifiable heritage value were recorded and protected.

Another common response to the question of concern areas was "none". Reasons included "not just greenies—the local community highly values the forests too", and "I have strong confidence in CALM's management", and "their judgement should be respected". In a similar vein, others gave reasons such as:

- things are adequate and should remain the way they are;
- many south-west communities rely on the forests to survive;
- these areas need to be managed to promote timber supply;
- the resource is eroding—many production areas being placed into conservation reserves;
- access to all areas containing premium grade logs is needed – to lock up all areas will only restrict management options and future production;
- there is green pressure on government to cease all logging in native forests;
- there is too much focus on this area but not on other neglected forest areas such as those in the wheatbelt, CALM always cops criticism and you never hear a good news story.

Concerns with national park and reserve areas were also stated several times. Comments included, "these were set aside in the past and yet continue to expand", and they often "prevent proper management and control, and are potential high risk areas for wild fires".

Others stated a concern about degradation of waterways. Examples included the Blackwood, Donnelly, Warren, Deep and Margaret rivers. Degradation included weeds, erosion and siltation (noted as caused by farming practices and clearfelling too close to river banks). From an Aboriginal perspective, this has caused a loss of spiritual as well as physical value.

Others were concerned about all areas of jarrah and karri forest. Reasons given included issues such as:

- its high intrinsic value—does not occur anywhere else in the world;
- the belief that clearfelling is (a) "juvenilising" the forest (b) producing monoculture and equal-aged forests (c) is reducing the quality and quantity of available honey;
- questions about whether healthy regrowth is occurring;
- there is too much waste when trying to produce first grade saw logs;
- there is inadequate reservation of trees in large blocks;
- key conservation areas (and biodiversity/ecosystem integrity) need to be preserved;
- timber production should be phased out for the "higher" and "longer-term" values of conservation and tourism.

In contrast with some of the points above, it was stated that the regeneration that is occurring shows that the timber industry is sustainable

"All old growth areas" was frequently mentioned. Common issues related to the need to place more emphasis on plantations for wood chips, enable more transparency and public voice in management decisions, and to use remaining old growth timber only for maximum value, high-quality products. In this regard, many agreed that access to old growth areas was required to allow value-added products to be developed. Another widespread view was that insufficient areas of old growth remain and how, for example, "this area falls below the criteria for reserve areas". One person also held the opinion that

species diversity was an essential part of the economic survival of south-west towns but that this was being lost.

Summary and conclusions

In summary, there was a recurring debate about what sustainable forest management practices entailed. Some, for example, referred to forest regeneration as an indicator of sustainable management, others though mentioned the need for biodiversity and overall health of the ecosystem. While there was consensus about the imperative for sustainable management, there was, however, no agreed definition of what it meant.

The long-term viability of the timber industry was often discussed. Those with timber industry interests argued that the industry faced uncertainty over its resource supply, and therefore its long-term future, as a result of conservation actions.

An opposing view was that the timber industry was presently downsizing due to economic rationalisation, rather than as a consequence of resource supply issues. Many commented that their town had a history of social and economic dependence on the timber industry. They feared a dramatic snowballing effect throughout the community if further job losses occurred and statements such as "the town will die" were put forward. Other examples were given of towns that had strengthened in new directions following the reduction in timber industry activities (e.g. Denmark, Margaret River). Both points of view were also raised in the post impact studies project.

Other industries, particularly tourism, were said to have made significant capital investments in local towns and, in some areas, tourism was heralded as the emerging growth industry. Limits were seen, however, on the "style" of tourism appropriate for the region. The emphasis was for a low impact, nature-based approach with infrastructure sympathetic to the surrounding environment. Industry operatives and many locals did not wish to emulate nearby commercial tourist towns. Despite their positive outlook, tourism representatives perceived the industry was at risk because of the impact of logging activities around them, particularly in old growth areas. They persistently criticised what was considered to be an unwillingness by CALM to engage in a constructive dialogue and negotiate acceptable outcomes for all parties.

Considering comments received, it would appear that more frequent, open and timely communication between CALM, industry and the local communities would assist with improving the multi-faceted interrelationships.

At the same time, a number of participants were quite satisfied with CALM's management and, notwithstanding some concerns about management and policy issues, CALM often had a solid profile in local/regional areas. In this regard, there may well be a "good news story" to address negative public perceptions, particularly in Perth, major centres and coastal areas. Comments varied from "CALM has a world-class management system" to "CALM has failed to consider issues such as biodiversity fully".

It should also be noted that while many concerns about "bad science" were directed towards CALM and the timber industry, the tourism industry and conservation groups also received similar criticism.

Forest management is clearly a highly-emotive issue and, according to many, interest-based assumptions and world views may be influencing the debate more than hard and fast data. A key issue needing to be addressed is accountability. According to those surveyed, this would entail providing information on request, enabling public and professional scrutiny of forest-related decision making and using the best scientific knowledge available to manage the resource.

Many stated that there was room for both the timber industry and other forest dependent activities. On the other hand, some representing these activities (e.g. tourism, recreation, nature conservation, water supply) considered their activities were devalued by current forest management practices.

A major issue in south-west communities is the incompatibility of positions. In short, there were those who perceived forest management objectives as solely timber production and others who stated they were for timber production *and* ecological sustainability.

Attitudes towards the future use of individual forest blocks highlight different views about the inherent value of a forested area. Given the level of media attention, it was not surprising that Giblett and other "icon" blocks were widely mentioned throughout the region. For example, Giblett was referred to by conservation and/or timber (as well as other) stakeholders in Manjimup Shire and also those in Perth, Donnybrook, Capel, Dardanup, Augusta-Margaret River, Murray, Waroona, Boddington, Harvey and Bridgetown.

There may well be many instances where both the timber industry and other forest-dependent activities can coexist. Indeed, in discussing the potential for overlap, particularly in the area of value adding, one person noted that "the unions and the conservationists may have more in common than they think". Fundamentally, timber and conservation (and often tourism) interests hold divergent views yet share the same basic motivation, namely *how are we going to get more trees?*

Apart from extreme positions, many people are not opposed to logging per se and would like to see the timber industry continue to operate in the RFA. A number of participants with conservation interests empathised with timber industry employment and industry restructuring concerns. Relating to process/management and production issues, key words here included *value adding* and striving for *maximum value*, *quality* timber products obtained via *sensitive*, *sustainable* management regimes. These themes are also reflected in results obtained from the survey of the regional community.

Others agreed there was a need for further industry development but cautioned that companies have to invest large amounts of money in order to value add. Related to this, there were views that "the greens don't see these impediments", and that while many companies were poised for further development, "no one is going to spend the money without security of supply". It was proposed a number of times that a new government/industry policy is needed to support increased value adding and to kick start the potential for further processing of timber, including manufacturing).

In conclusion, it is observed that an effort to move the debate away from its polarities and towards common ground is desirable. An approach that includes stakeholder input and is based on balance and partnership could be facilitated. Potentially-impacted communities require some sense of control of change, meaningful involvement in the planning process, trust in the planning bodies, and a belief that decision-making processes have been fair to all. This is consistent with the mitigation approach recommended in the post impact studies project.

Survey of the regional community

Methodology

The objective of this study was to identify the social values associated with forested land within the population of the Western Australian RFA region. The study was based on a random sample of 1106 participants drawn from across five sub-areas within the region. These areas were:

- Urban (Kalamunda, Lesmurdie);
- Central (Jarrahdale, Collie);
- Southern forests (Donnybrook, Bridgetown, Manjimup, Northcliffe, Pemberton, Denmark);
- Margaret River (Yallingup, Margaret River, Augusta); and
- Eastern (from Talbot Brook to Mt Barker).

This approach allowed for comparisons across each of the five areas, and inferences drawn in relation to the population throughout the region. Telephone interviews assessed a range of questions in relation to:

- forest values;
- the use of native forests; attitudes towards management planning;
- the level of concern for native forests; and
- the perceived impacts of changes in the forest industry on communities and families.

A full list of questions is included in Appendix 2. The responses to two of these questions are illustrated in Diagrams 1 and 2 in Volume 2. Each diagram shows the way respondents in certain locations responded to a particular survey question.

Forest values

There was significant geographic variation in social value systems towards native forests (see Table 11.1). This suggests that the development and implementation of forest policies may need to address regional differences.

Data analysis on the 12 items suggests that there are three primary groupings or "clusters" of values (see Table 11.1). They consist of four items that reflect concern for native forests, three that reflect the environmental value of native forests and two that reflect functional uses of the forest (i.e. uses of the forest by various industry groups).

Within the regional population, high levels of concern were expressed in relation to the management of native forests. When comparisons were made across the five regions, higher levels of concern were expressed within the Urban and Margaret River areas when compared to the Southern forest area.

While concern in the Southern forest was still high, it is probable that the difference in concern is related to the level of community involvement in forest-management issues. Less dependency and direct contact with forest-management issues in the Margaret River and Urban areas suggests that many of the concerns in these areas may develop through indirect information sources, in particular media representations of forest management and the forest industry.

Responses relating to functional forest uses differed significantly between the Central, Margaret River and Southern forest areas. An item referring to a possible value conflict between employment and the preservation of native forests, showed that 58% of the population within the region held conflicting values between the need for employment and the need for protection of native forests. This was particularly high in the Central and Eastern areas, when compared with Margaret River.

Table 11.1 Summary of social value scales: percentage agreement with social values

Value scale	WA	Sub-regional areas				
	RFA region	Central	Urban	Eastern	Southern Forest	Margaret River
Value conflict						
I sometimes feel torn between the need for jobs and the need to preserve native forests in WA	57.6	*67.9*	*55.5*	*66.4*	*55.8*	*50.2*
The conservation and protection of native forests in WA will harm the WA economy	66.4	*60.6*	*71.2*	*61.2*	*64.8*	*73.4*
Composite index score	**2.44**	**2.57**	**2.41**	**2.53**	**2.37**	**2.31**
Timber and logging industry dependency						
The area in which I live is very dependent upon the timber and logging industry	27.9	*39.0*	*16.5*	*23.7*	*58.9*	*13.1*
Laws to protect native forests						
Laws to protect native forests do not affect me greatly	46.4	38.6	50.2	45.5	48.3	52.3
Tourism dependency						
Tourism is very important in the area in which I live	81.4	*72.6*	*78.5*	*66.8*	*92.2*	*96.4*
Environmental concern						
I am not confident that native forests are being well managed in Western Australia	65.9	*68.2*	*71.2*	*59.4*	*58.2*	*76.6*
Better laws are needed to protect the use of native forests	77.6	*77.3*	*85.0*	*73.3*	*68.7*	*79.9*
I am very concerned about the management and use of native forests in WA	79.9	*80.3*	*84.9*	*75.8*	*73.2*	*87.3*
People who access native forest should have more say in how forests are managed	73.9	77.7	76.9	73.7	69.9	74.5
Composite index score	**1.98**	**1.97**	**1.87**	**2.07**	**2.15**	**1.86**
Intrinsic value						
One of the main reasons I live in this area is the natural beauty of the forest	76.8	*73.9*	*80.4*	*54.8*	*80.2*	*81.4*
Trees are important for their own sake	96.7	98.7	96.3	98.1	94.9	96.8
The balance of the forest ecosystem is very delicate	94.7	95.0	96.8	95.0	93.0	93.7
Composite index score	**1.64**	**1.64**	**1.57**	**1.81**	**1.74**	**1.55**

Source: Environment and Behaviour Consultants (1997)

Note: Values in italics indicate a statistically significant difference across regional areas. Composite index scores vary between one (high) and four (low) and are the mean of the items forming the index.

All areas reported high levels of environmental values, there being no significant difference between the Southern forests, Margaret River and Urban areas.

It is generally believed that environmental and functional value orientations distinguish between different groups of people in society, similar to the way that individuals are identified on a political scale from "left to right" or from "green to brown". However, in the case of forest values it appears that many in the

community hold both environmental and functional values concurrently. More than half of the population reported conflict between employment and the use of native forests, and the need to preserve forest areas.

Forest use and recreation

Seventy seven per cent indicated they had visited native forests within the past year, with 50% of the population visiting native forests at least once a month or more. While a significant percentage visited native forests near Pemberton and John Forrest National Park, near Perth, an analysis of the locations of native forests visited within the past year indicated the majority visited highly-localised areas often in close proximity to their homes. The majority of those visiting native forests did so to undertake passive recreation activities such as bushwalking, picnicking and sightseeing.

Planning of native forest areas

Eighty per cent had sufficient interest in the management of native forests that they were able to identify issues they believed should be considered in the development of management plans. Across the region the two core issues the community believed should be addressed were the conservation of forest areas for future generations and the need to regenerate areas of native forest through planting of appropriate tree species. Other issues identified were the need to manage fire in native forests and the need for better control of dieback and other diseases.

Concern for native forests

Fifty-three per cent indicated they were concerned about specific places in Western Australia where changes to native forests had occurred from human use. The areas of most concern were native forests in the Pemberton area and native forests in the south-west generally. Many of the areas of native forest that were identified were highly specific and localised areas in the south-west. The main issues of concern were logging, woodchipping and clearfelling.

Impacts of changes in forest industry activity

Over one quarter of participants perceived that in the past two years there had been a change in the use of forests in their area by industry operations that had affected their community. The most significant change was the loss of local employment. Again, there were significant regional variations in the perceived impacts of forest industry activity on communities. Thirty eight per cent in the Southern forest and 18% within the Urban area indicated there had been changes in forest industry activity that had affected their community.

When participants were asked to indicate if a decrease in the future use of forests by the timber, mining or tourism industries would affect their community, more than half of the total sample agreed this would be the case.

Again, the most significant community change was stated as a loss of employment. There were highly significant regional variations in response to this question, with 74% of the population within the Southern forest, 39% of the population in the Urban area and 33% in the Eastern area believing a decrease in forest-based activity would affect their community.

Although a high percentage of the population believed a decrease in forest-based activity would affect their community, a lower percentage (26%) indicated that such a decrease would directly affect their families, with the loss of employment being the most significant effect.

Attitudes towards industry development

Participants were asked to identify what they considered would be the main industries in their area within the next 20 years and what new industries, if any, they would like to see developed.

More than half indicated that tourism would be the main industry in their area within the next 20 years. In contrast, 6% indicated the processing of native timbers and 15% indicated the processing of plantation timbers would be the main industry. However, there were significant regional variations in response to this question. For instance, within the Margaret River area 84% indicated tourism as being the main industry, while in the Central area 60% perceived mining would be the main activity. Within the Southern forest, 20% thought the processing of native timbers and 60% thought the processing of plantation timbers would be the main activities within the next 20 years.

Fifty-seven per cent of the sample stated they would like to see new industries develop in their area, with tourism being the preferred type of new industry development (47%), followed by the processing of

plantation timbers (29%). The development of the tourism industry was also found to be the preferred type of industry development across all regional sectors within the region.

Ability to deal with change

One component of the social assessment process includes an investigation of the resources a community has at its disposal and its degree of sensitivity to respond to changes in land use. Using research by Cottrell (1976) and Goeppinger and Baglioni (1985), more than 20 measures were identified and analysed for each of 43 towns within, or in close proximity to, the RFA region. The measures were combined into a composite indicator, the community sensitivity index (CSI).

Using 1991 and 1996 ABS census data, measures for the CSI include: distance from major centres; ratio of dependants; occupancy rates; median age; and median family income. Also included are the percentage of: a town's population employed in agriculture/forestry, bought homes, housing authority rentals, and occupied dwellings.

The CSI also includes an estimation of the "community vitality" for each town. Community vitality includes as assessment of the resources existing within a particular community including number of: educational institutions, medical and other agencies, forest industries, other businesses, shire councillors, community groups, annual events, and awards won.

Most measures were weighted equally (i.e. not rated as more significant than another). It is most likely however, that some measures are more indicative of a community's ability to respond to change than others. It was considered that higher weightings should apply to measures relating to timber mills and contractor employment, the proportion of the town's workforce population employed in these areas, and distance from the nearest major centre. All measures were then combined for each town in the RFA region to produce an index indicating sensitivity to change.

The CSI provides valuable information by indicating towns that appear to be most vulnerable to responding to change. However the CSI need not be used as a stand-alone measure. It can be combined with information gathered by the forest community coordinators during surveys, interviews with stakeholder groups and from the industry expenditure surveys to make this assessment. Initial data analysis revealed that towns fall into four categories ranging from those with a high sensitivity to change, to those with a low sensitivity to change. The CSI is a relative-rather than an absolute index. That is, the CSI rating is relative only to other towns in the region.

11.4 FOREST INDUSTRY ASSESSMENT

Objectives

The core objectives of this study were to:

- identify the number of forest industry and related businesses (including those involved in timber processing, contracting, seed collection, wildflower collection and beekeeping) in the RFA region and their town distribution;
- identify the town location and number of timber industry employees resident in the region;
- develop a social profile of timber industry employees; and
- identify the local and regional expenditure patterns of timber industries and employees.

In addition to timber industries and employees, the research also examined the town distribution and expenditure patterns of mining industries and tourism businesses in the region.

Methodology and expected outcomes

Information required to address each of the core objectives was based on surveys of timber industry and related businesses and their employees, and surveys of tourism and mining industries; and an examination of secondary data derived from existing databases and mailing lists of forest and related industries in the region.

Existing databases and mailing lists were used to identify the location of industries and businesses, with questionnaires then being distributed via a mail-out survey.

In relation to forest industries and businesses, it is expected that links will be highlighted showing the relationships between various industry groups and local towns. This analysis will identify specific town

catchments or town resource clusters (TRC) representing groupings of towns with dependency on specific areas of native forest. Industry and employee profiles will be developed to identify the type and distribution of forest industries within the TRC. The employee profiles will identify age and life-cycle structure to give an indication of dependence on social and community services within the region. In addition, the pattern and location of industry expenditure for forest industries within each TRC will also be identified, as will the pattern and location of household expenditure by employees.

In addition, in the survey of logging contractors and forest user businesses, each business was asked to indicate the town in which the main supplier of particular goods and services was located.

Table 11.2 shows the items of expenditure for timber processing and contracting businesses (including sawmills). Also shown are preliminary findings relating to the minimum, maximum and median distances from the location of the forest business and that of the goods/services supplier. The median distances for usual business expenses indicates that, except for power (including gas and electricity), accounting and insurance, all usual business expenses are made to suppliers in close proximity to the town location of the business. All repairs and maintenance costs are also incurred within close proximity to the business. As might be expected, the table also indicates that major equipment or asset purchases come from outside the local area, and generally at major regional and urban centres adjacent to the RFA region.

Table 11.2 Preliminary findings: median distances for the location of timber processing and contracting business expenditure

Goods and services	Minimum distance (km)	Maximum distance (km)	Median distance (km)
Usual business expenses			
Power (electricity, gas)	1	339	38.5
Fuel	1	230	5.0
Freight (general business freight)	1	280	1.0
Freight (timber haulage)	1	277	1.0
Accounting	1	308	31.0
Insurance	1	281	46.0
Office supplies	1	182	1.0
Advertising and marketing	1	192	1.0
Banking	1	279	1.0
Printing	1	182	1.0
Median distance for usual business expenses	**1**	**279**	**1.0**
Repairs and maintenance			
Machinery or equipment	1	281	5.5
Vehicles	1	94	1.0
Building and office	1	127	1.0
Median distance for repairs and maintenance	**1**	**127**	**1.0**
Major equipment or asset purchases			
Machinery, plant or equipment	1	359	181.0
Vehicles	1	359	16.0
Computing equipment	1	233	33.0
Extensions or alterations to buildings	1	31	1.0
New building or land purchases	1	41	1.0
Median distance for major equipment or asset purchases	**1**	**233**	**16.0**

Source: Environment and Behaviour Consultants (1997)

Note: Distances are road distances between towns.
A minimum distance of 1 kilometre was used where the supplier was in the same town as the industry.
Several industries purchased major machinery, plant and equipment from interstate and overseas. The primary source of machinery within Western Australia was from Perth.

In addition, the pattern and location of household expenditure by employees within each TRC will also be identified.

The Australian Bureau of Statistics household expenditure survey, when used concurrently with survey information in the project, will also identify the magnitude of household expenditure by forest industry employees within the region and the percentage of household expenditure attributable to and generated by forest industries.

Similar analyses will be undertaken for tourism and mining industries including an identification of the distribution of these industries and the locational patterns of industry expenditure in the region.

The analyses undertaken as part of this project will provide a direct link between industry use of, and town dependency on, specific forest areas in the region. Analysis of forest industry dependency of towns will allow some understanding of how a change in resource volumes or resource availability within a specific area may affect communities throughout the region.

The results of this project will be published in a subsequent report.

12 Biodiversity

12.1 INTRODUCTION

Biological diversity is the variety of all life forms and is usually considered at three levels:

- genetic diversity refers to the variety of genetic information contained in all individual plants, animals and micro-organisms;
- species diversity refers to the variety of living species; and
- ecosystem diversity refers to the variety of habitats, biotic communities and ecological processes.

The nationally agreed criteria for the establishment of a comprehensive, adequate and representative reserve system for forests in Australia (JANIS 1997), jointly developed by the Commonwealth and States, identify the following objectives for biodiversity conservation:

- 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 forest species.

To achieve these objectives, the JANIS document includes a number of biodiversity criteria for establishing a comprehensive, adequate and representative (CAR) reserve system. These are outlined in Table 12.1.

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.

Both the Commonwealth and Western Australia have a number of responsibilities in connection with the conservation of biodiversity. A list of key Commonwealth and State legislation relating to the RFA in Western Australia is given in Appendix 1.

Table 12.1 Summary of the biodiversity criteria

- As a general criterion, 15% of the pre-1750 distribution of each forest ecosystem should be protected in the CAR reserve system.
- Where forest ecosystems are recognised as vulnerable, then at least 60% of their remaining extent should be reserved.
- All remaining occurrences of rare and endangered forest ecosystems should be reserved or protected by other means as far as is practicable.
- Reserved areas should be replicated across the geographic range of the forest ecosystem to decrease the likelihood that chance events such as wildfire or disease will cause the forest ecosystem to decline.
- The reserve system should seek to maximise the area of high quality habitat for all known elements of biodiversity wherever practicable, but with particular reference to:
  - the special needs of rare, vulnerable or endangered species;
  - special groups of organisms, for example species with complex habitat requirements, or migratory or mobile species;
  - areas of high species diversity, natural refugia for flora and fauna, and centres of endemism; and
  - those species whose distributions and habitat requirements are not well correlated with any particular forest ecosystem.
- Reserves should be large enough to sustain the viability, quality and integrity of populations.
- To ensure representativeness, the reserve system should, as far as possible, sample the full range of biological variation within each forest ecosystem.
- In fragmented landscapes, remnants that contribute to sampling the full range of biodiversity are vital parts of a forest reserve system and should be protected.

Source: JANIS (1997)

12.2 METHODS USED IN BIODIVERSITY ASSESSMENT

The Western Australian and Commonwealth governments have agreed that the biodiversity assessment for the South-West Forest Region should be undertaken at the species and ecosystem levels. Because information about genetic variation within species is very limited and costly to obtain, genetic diversity

was not assessed, although it is recognised that it does overlap with species and ecosystem diversity and that these are addressed by the national forest reserve criteria.

The biodiversity assessment has therefore been based on an analysis of information about forest ecosystems and communities, flora and fauna species and their habitats. Reports have also been prepared on the responses of species and ecosystems to disturbance. This chapter summarises information gained on the biodiversity of the South-West Forest Region from a range of projects undertaken for the Comprehensive Regional Assessment.

Data review

Biodiversity assessment relies on having adequate information about the distribution of species. In assessing the adequacy of available data, it is important to know whether or not surveys undertaken for species or groups of species have been adequately distributed across the range of environments represented within the region. As part of the CRA process, a data review was undertaken to determine where biodiversity surveys have been undertaken in the South-West Forest Region, which species were targeted and whether survey sites were reasonably distributed to detect most species in most geographic or environmental components. The results of these analyses assisted in highlighting gaps in information and identifying those areas which may require further survey work.

Ecosystem assessment

Mapped forest ecosystems (Bradshaw and Mattiske in prep.) have been derived as the basis for the forest ecosystem biodiversity assessment for the South-West Forest Region. These mapped forest ecosystems were defined following the recommendations of a Panel of Independents Scientists and Experts convened by the Western Australian RFA Steering Committee, and were developed from the forest associations mapping of Bradshaw et al. (1997) and the vegetation complex and ecological vegetation system mapping of Mattiske (in prep.). A full description of the forest ecosystems database, the methodology used in its derivation, and its application in the CRA biodiversity assessment is described in section 12.4 of this chapter.

The first part of the assessment involved mapping the forest ecosystems occurring in the south-west forests and determining the remaining area of each ecosystem. An analysis was also completed to determine the area of each forest ecosystem which occurred in the landscape prior to European settlement. This was used to provide an assessment of current and past distributions of each ecosystem and the level of protection within conservation reserves, so that an assessment against the JANIS reservation targets could be completed.

Target flora and fauna groups

Species which are threatened (endangered or vulnerable to extinction), declining in numbers, patchy in distribution, migratory or mobile, or unique to the region have been reviewed in this assessment. All nationally endangered or vulnerable forest species listed under the Commonwealth *Endangered Species Protection Act 1992* and known to occur in the region were considered a high priority, as were species declared as rare flora under the Western Australian *Wildlife Conservation Act 1950* and those designated as priority flora.

Vulnerability assessment

The degree to which a species is vulnerable to decline or extinction is influenced by a number of factors. These include characteristics or attributes of the species itself such as its habitat requirements, reproductive output and longevity. Other factors such as rarity and whether populations are increasing or decreasing are also important in determining the risk of decline or extinction. This information assists in identifying and prioritising those species which are most in need of management actions to improve the prospects for their long-term survival.

Reservation analysis

Reservation analysis is another component of the Comprehensive Regional Assessment. Essentially it is an analysis to identify the degree to which a species or vegetation community is known to be represented in dedicated and informal reserves (e.g. national parks, stream reserves) within the region. The results of such analyses can be used to assist in the identification of species and communities that require particular attention because of their special conservation needs. Conservation objectives can in some cases be met

by increasing representation of populations and communities within reserves and/or minimising the impacts of threatening processes throughout the forested estate. Reservation analyses have been conducted for forest ecosystems and for selected fauna and flora taxa.

Endangered, rare and threatened species

The Western Australian RFA process requires a review of species listed on Schedule 1 of the Commonwealth *Endangered Species Protection Act 1992* and the preparation of recovery plans and threat abatement plans for threatening processes under the Act, to the extent possible within available funds and resources. State-listed species have also been identified and planning mechanisms will be implemented in accordance with State legislation, to the extent possible within available funds and resources.

Conservation statements will be prepared prior to the signing of the RFA for taxa which are listed as endangered or vulnerable on Schedule 1 of the *Endangered Species Protection Act*, as preparation of interim recovery plans will not be possible within the CRA process. Some flora taxa are currently addressed in Western Australian regional rare flora management programs and the development of recovery plans will be considered in the implementation of the RFA.

Response to disturbance

The decline of species can be attributed largely to the impacts of disturbances, both directly on the species and indirectly on essential components of their habitat. For example, predation of native animals by introduced species such as foxes and feral cats has a direct effect on population numbers. Habitat changes resulting from grazing by domestic stock, mining, fire, clearing for agriculture or other disturbances may also indirectly impact populations of native species. Reviews of the response of species and ecosystems to disturbance and the management arrangements currently in place to address these were prepared by consultants for the CRA (Table 12.2). These reports are available separately on request, and will be considered by governments in developing the Regional Forest Agreement for Western Australia. (The reports will also be available on the Internet – see page ii for addresses.)

Table 12.2 Consultants reports prepared for the CRA

Report	Authors
Ecosystem processes	B Lamont, M A Perez-Fernandez and R Mann
Vertebrate fauna (excluding fish)	P Christensen
Fish and aquatic invertebrates	P Horwitz, E J Jasinska, E Fairhurst and J A Davis
Terrestrial invertebrates	J D Majer and B E Heterick
Fungi	N Bougher
Flora	R Safstrom

12.3 DATA REVIEW

Introduction

The Western Australian biodiversity data review and evaluation process involved the identification of datasets relevant to biodiversity and national estate natural value assessments, collation of metadata and the broad scale evaluation of dataset quality. Approximately 250 datasets were identified from a range of sources, of which 37 were considered to be of value to these assessments. A copy of the data review is available on request and will be available on the Internet.

The primary aim of the data review process was to ascertain the adequacy of existing site-based biological data for determining the distribution of flora and fauna species, and relating this to their habitat requirements. Other information on species, communities and response to disturbance was also assessed. Outcomes from the review can also be used to identify data gaps and priority areas for additional survey work.

The first stage of the data review was identifying potentially useful data sets. Only those survey data which met required standards of accuracy, precision and reliability were used, providing a degree of confidence in the analyses of the distribution of species.

The second stage of the review involved assessing the extent to which the site records for flora and fauna were representative of the environmental and geographic variation within the region. This was addressed separately in the flora and fauna assessments.

12.4 FOREST ECOSYSTEMS

Defining and mapping forest ecosystems

The principal sources of information used in the mapping of forest ecosystems are forest associations and vegetation complexes.

Forest associations are based on work originally undertaken by the Forests Department of Western Australia in the 1950s and 1960s using 1:15 840 aerial photography and covered almost all of the forested land in the RFA area. Classification was based on the dominant tree species and crown cover density. “Non forest” areas were classified according to broad structural categories. This basic information has been refined and corrected by a variety of specific mapping projects since that time. These data were summarised and published at a scale of 1:250 000 (resolution two hectares) in 1997 in the form of forest associations. The methodology is described in detail by Bradshaw et al. (1997). The maps cover public land only.

Vegetation complex is a classification based primarily on understorey vegetation. Mapping is based mainly on land form, soils and climatic zones and their relationship to vegetation rather than direct mapping of the vegetation itself. The first mapping of this kind was carried out by Heddle et al. in 1980 for the Darling system (the northern part of the RFA). During 1997 this work was revised and extended to cover the whole of the RFA area including areas now cleared (Mattiske and Havel in prep.). This work is described in detail in the following section.

The JANIS criteria for forest ecosystems require a classification system which:
- discriminates forest from non-forest on the basis of 20% canopy cover;
- discriminates at a resolution requiring a map-standard scale of 1:100 000;
- preferably is defined in terms of floristic composition in combination with substrate and position in the landscape;
- is consistent with the examples given in the JANIS definition of forest ecosystems (i.e. Kirkpatrick and Brown (1991) for Tasmania, Beard (1979a, 1979b) for Western Australia, Young and McDonald (1989) for Queensland and ecological vegetation classes identified in Victoria);
- is recognisable in the field; and
- is able to mapped and able to have their pre-1750 distribution modelled or mapped.

A panel of independent scientific experts recommended that “forest ecosystems for use in the Western Australian RFA be developed by the subdivision (where appropriate) of the forest associations using the ecological vegetation system and other ecological and physical information as bases”.

The development of forest ecosystem categories was undertaken by Bradshaw and Mattiske in 1997. The key elements used in informing the decision on an appropriate subdivision of the associations were the key species in the overstorey (jarrah, karri, wandoo etc.), the height of the overstorey, the canopy cover of the overstorey (forest versus woodland) and the understorey vegetation communities which are primarily determined by a combination of climate, soils and landforms. The weighting attributed to each varied according to their perceived significance.

The outcome of this approach to subdivision is a sub-regionalisation within forest associations on boundaries derived from the grouping of several vegetation complexes.

The main emphasis was the subdivision of the large area of jarrah forest association. The approach described above resulted in a subdivision of the jarrah forest into 11 sub-regions based primarily on a combination of groupings of vegetation complexes and soil substrate. The karri forest was subdivided according to three broad regions of occurrence—the west coast, main karri belt and the south coast (most of which lies outside the RFA area). All complexes and associations were combined as one in the Darling scarp sub-region. Three other areas, representing small parts of a much larger group of ecosystems outside the RFA area were identified as sub-regions but not considered in further analysis. These are described as Swan coastal plain, Dandaragan Plateau, and western wheatbelt. While it is recognised that some associations (e.g. wandoo) occur beyond the RFA boundary, it is in general represented by different groupings of vegetation complex. The RFA boundary is therefore considered

appropriate for what has been called western wandoo in this analysis. All other ecosystems (generally non-forest categories) are the same as in the classification of the forest associations. For familiarity, the forest ecosystems have been named according to dominant tree species and geographic location. See Table 12.3 for the list of forest ecosystems. Map 12 shows forest ecosystems on Crown land.

Table 12.3 Present reservation staus of forest ecosystems

Forest ecosystem	Estimated pre-1750 area (ha)	Extant area all lands (ha)	Proportion of pre-1750 reserved				Extant area on public land outside reserves (ha)	Estimated area on private land (ha)
			Gazetted formal	Proposed formal*	Informal	Total reserved		
Bullich and yate	2800	2440	53%	24%	0%	78%	2	261
Darling scarp	29000	9938	4%	0%	1%	6%	1825	6468
Jarrah Blackwood	347200	281805	2%	6%	8%	16%	212474	13016
Jarrah Leeuwin	56400	19552	4%	0%	1%	6%	6984	9237
Jarrah Mt Lindesay	126600	44591	2%	7%	1%	9%	18867	14306
Jarrah north-east	717100	350234	4%	8%	2%	15%	161663	84062
Jarrah north-west	670600	499598	7%	2%	6%	15%	346388	50611
Jarrah Rate's tingle	1500	1246	63%	2%	0%	65%	96	177
Jarrah red tingle	350	269	30%	32%	0%	62%	13	40
Jarrah sandy	107900	71092	8%	13%	4%	25%	39008	5339
Jarrah south	557300	438912	8%	14%	7%	29%	260475	19052
Jarrah Unicup	81000	29459	6%	12%	0%	18%	2830	12093
Jarrah woodland	106374	67220	11%	8%	32%	50%	3109	10559
Jarrah yellow tingle	11600	9669	14%	1%	14%	29%	5125	1219
Karri main belt	193000	163905	19%	2%	15%	36%	84281	10000
Karri Rate's tingle	1100	860	67%	0%	0%	67%	0	124
Karri red tingle	7200	5860	38%	32%	0%	70%	89	755
Karri south coast	18500	#						
Karri west coast	14500	6274	27%	2%	0%	30%	458	1500
Karri yellow tingle	15800	13264	14%	1%	14%	28%	7359	1423
Peppermint and coastal heath	80100	70826	67%	5%	0%	72%	2678	10447
Rocky outcrops	26400	12444	16%	7%	20%	43%	1066	0
Sand dunes	10300	10342	95%	2%	0%	97%	307	0
Shrub, herb, and sedgelands	429900	296955	20%	13%	25%	57%	16021	36191
Swamps	15300	8070	33%	2%	6%	42%	208	1415
Western wandoo forest	363200	146598	7%	7%	2%	16%	47854	41404
Western wandoo woodland	163000	72079	8%	7%	2%	17%	23018	20950

Notes: * proposed in Forest Management Plan 1994-2003
not analysed - more than 90% outside RFA region

Estimate of the pre-1750 area of forest ecosystems

Several of the JANIS targets require an estimate of the pre-1750 extent of the forest. An estimation of the pre-1750 extent of forest ecosystems has been done on the basis of the relationship that exists between forest ecosystems and vegetation complexes (on mapped extant areas on Crown land) and extrapolation to cleared areas for which vegetation complexes but not forest ecosystems have been mapped. Because there is no direct correlation between forest ecosystem and vegetation complex it was considered impractical to attempt to map forest ecosystems directly, or to model them in a spatial context.
A statistical extrapolation was undertaken to estimate the area of each ecosystem on private land (regardless of the current state of cover) and on cleared public land. This was then added to the area of existing ecosystems to determine the pre-1750 area. This was done using the following technique:

- Within each sub-region, "vegetation complex" and "forest ecosystem" were intersected in a geographic information system to determine the area of each ecosystem within each vegetation complex (see Table 12.3 for forest ecosystems). This determined the proportion of each vegetation complex by ecosystems for public land on which the original vegetation remains.
- The area of each vegetation complex attributed with a "non-native" ecosystem code was apportioned to a native forest ecosystem using the same proportions as found in the "native forest" attribution derived above. Approximately 45% of the RFA area was attributed in this way.
- The existing and the re-attributed areas were added to arrive at an estimate of the pre-1750 ecosystem area in each sub-region. Where appropriate, ecosystems from each sub-region were added to arrive at the total areas for the RFA area.

- The pre-European karri forest has been mapped directly and is published as *Karri Distribution Before European Settlement* at a scale of 1:350 000 (Bradshaw et al. 1997). For karri the attributed data were adjusted to agree with the mapped areas and differences were re-attributed to appropriate ecosystems. For the whole karri forest, the extrapolation method gave areas that were within 4% of the mapped pre-1750 area. Areas of sand dunes were adjusted in a similar fashion.

The estimated pre-1750 area of each ecosystem is shown in Table 12.3.

12.5 VEGETATION MAPPING

Introduction

Vegetation mapping is an important tool for the development of a comprehensive, adequate and representative (CAR) reserve system and prescriptions and practice for ecologically sustainable forest management (ESFM). While the mapping of forest ecosystems (see section 12.4) will be used in meeting the quantitative JANIS criteria for forest ecosystems and old growth in the CAR reserve system, other methods of vegetation mapping may provide additional information used in reserve design. High resolution vegetation mapping based on floristics, landscape and other ecological factors may also help, for example, to define areas of habitat for species of conservation significance. Mapping at the level of vegetation complexes and ecological vegetation systems for the CRA was undertaken by Mattiske (nee Heddle) and Havel (1997).

In the South-West Forest Region, it is well recognised that there are underlying patterns which determine the distribution of native vegetation cover. Studies by authors such as Havel (1975a and 1975b), Strelein (1988), Wardell-Johnson et al. (1989 and 1995) and Heddle et al. (1980) have highlighted the significance of the underlying soils, landforms and climate in the determining the patterning of vegetation in the region.

A review of past studies and floristic and vegetation classifications has been prepared by Mattiske Consulting Pty Ltd (1997) and Mattiske (nee Heddle) and Havel (1997) have developed a vegetation classification system that integrates all the previous relevant vegetation classification systems and vegetation mapping studies in the region. This methodology is based on the previous regional vegetation mapping by Heddle et al. (1980) in the Darling System (System 6) which includes the northern part of the RFA area and Havel (1968, 1975a and 1975b) on the northern Swan coastal plain and in the northern part of the Darling Range.

In mapping the vegetation of the RFA region, the concept of vegetation complexes developed in the northern Darling Range by Heddle et al. (1980) was expanded to cover the remainder of the RFA region. This approach emphasises the detailed local site vegetation type mapping which integrated details on site characteristics, floristic composition and structural composition achieved at the scale of 1:10 000 in specific areas and provides mapping for the region at a higher resolution than the lower resolution mapping of essentially structural components and dominant species by Beard (1979a, 1979b, 1979c, 1979d, 1981). The vegetation mapping covered both the remaining relatively intact native vegetation and the disturbed and/or cleared areas of vegetation in the South-West Forest Region.

Vegetation complexes

Given the dominance of the forest canopy in the South-West Forest Region by comparatively few species, the concept of a continuum of forest and woodland types based on the composition of the species-rich understorey was considered most applicable for mapping vegetation at the 1:50 000 scale. A key element in defining vegetation complexes is the strong relationship between the physical environmental features in the landscape, the climatic conditions and the vegetation.

The landscape of the south-west does not have major variations in relief compared with other forested areas of Australia. Local variations in water availability and the physical and chemical composition of the soils are key determinants of variations in the vegetation at a given site. Floristic differences due to the soils are largely reflected in the composition of the understorey, and variations due to water availability are largely reflected in the composition and structure of the tree overstorey which is detectable from aerial photos. These variations in species composition are readily detectable in the field

by the presence of plant species typical for each soil/landform combinations and it is therefore possible to map the vegetation at a fine scale across the range of sites, from a combination of aerial photography and ground surveys.

The methods for the work were variable as this project enabled the integration of data from a large range of studies in the South-West Forest Region. Essentially the main methods were:

- floristic studies based on all species recorded in specific locations in varying assessment areas from 100 square metres to 10 000 square metres;
- site-vegetation type data based on site characteristics, indicator species or characteristic species from 100 square metres (understorey) and 1600 square metres (overstorey); and
- structural information from an assessment of the height and cover of overstorey species.

The principal sources of information used in the mapping of the vegetation complexes were:

- historical and collated new point source data, from more than 18 000 locations, collected by a range of authors and the consultants over the past 30 years;
- topographical and drainage data from the Department of Land Administration at a scale of 1:50 000;
- soil and landform mapping as collated and prepared by Smolinski et al. (1997) at a scale of 1:50 000 based on previous authors (1970 to 1997), where available;
- previous vegetation complex mapping by Heddle et al. (1980) for the Darling System (the northern section of the RFA area) reviewed and integrated at a scale of 1:50 000; and
- climatic data for the South-West Forest Region by Gentilli (1971, 1972, 1989) and the South-West Western Australia Climate Grids.

The total number of surveyed sites varied substantially between vegetation complexes as a result of the varying degree of clearing within the region and the area occupied by each vegetation complex. Although large areas of the region remain relatively undisturbed, in some places roadside vegetation and other remnants were important in defining vegetation characteristics. Any new survey sites established as part of the CRA data collection process avoided any recently burnt or grazed areas.

Soil and landform maps formed an important layer in the delineation of site selections and mapping types across the region. Aerial photo interpretation, the review of existing site data and the field survey data were then used to map the vegetation complexes.

The nomenclature followed the underlying soil and landform units to allow comparison with underlying determining soil types. Where climatic and regional differences were defined then numbers were also added to the mapping codes. For example, Dwellingup was subdivided into Dwellingup 1, Dwellingup 2, Dwellingup 3 and Dwellingup 4 or D1, D2, D3 and D4 on the basis of underlying differences in the dominance of overstorey species, the height of the overstorey, the cover of the overstorey and the composition of the understorey. This subdivision allowed for the recognition of the regional patterns of vegetation on the laterite gravel uplands from the western side of the Darling Range in the higher rainfall areas to the vegetation on the laterite gravel uplands on the eastern side of the Darling Range in the lower rainfall regions.

A total of 312 vegetation complexes was defined and mapped for the South-West Forest Region. In view of the degree of clearing in some sections of the survey area, the level of information collated for the respective complexes varied significantly within the project area. A full description of each of the vegetation complexes will be provided in a separate project report, which will be available on request.

Ecological vegetation systems

Mattiske and Havel have also developed a simplified vegetation classification system that integrates the vegetation complexes at a regional scale. For example, jarrah-marri forests with key indicator species for sandy soils found in per humid areas were grouped, as were all swamps in semi-arid climatic areas. This methodology differs from the mapping of forest associations by Bradshaw et al. (1997) through the reliance on underlying relationships between floristic composition and physical determinants such as soils, landforms and climate, rather than dominant species and structural vegetation mapped from aerial photographs.

The 306 vegetation complexes were grouped according to similarities in structure and floristic composition. This work resulted in an approximately four-fold reduction in the total number of vegetation mapping units. This latter work was based on a hierarchical system so that similar vegetation complexes were grouped into one ecological vegetation system. The number of vegetation complexes grouped into the ecological vegetation systems varied depending on the degree of similarity within and

between the groups. This grouping was tested using statistical tests through the PATN package (Belbin 1987a, 1987b, 1989).

The nomenclature followed a new system developed by the authors as part of this project which enabled a grouping of vegetation categories with similar vegetation which reflected climatic and soil and landform patterns in the South-West Forest Region. The name adopted expressed in the simplest of terms the groupings at this system level.

This approach allowed a grouping at a higher level and allowed similar vegetation on similar soil and landform units within similar climatic zones to be defined. This process of grouping was similar to the ecological vegetation classes adopted in the East Gippsland project area (Woodgate et al. 1994). The key feature of the ecological vegetation systems is that it is a hierarchical system which links the similar vegetation complexes together for presentation at the broader scale of mapping (1:500 000).

12.6 FLORA SPECIES ASSESSMENT

Introduction

Assessment of the South-West Forest Region flora has involved analysing the distribution and viability of individual plant species and their populations in the region. The purpose of this assessment is to help address the JANIS criteria relating to protection of species (see section 12.1).

The assessment process involved the compilation and validation of flora data from a range of sources, the development of the new database (WABiota) and the analysis and display of various themes.

Data acquisition

Data were obtained from a variety of existing sources internal and external to CALM (see Tables 12.4 and 12.5). Records from these databases were incorporated into a new database for the CRA flora assessments called WABiota.

Table 12.4 CALM data sources for the flora species assessment

Source	Vouchered?	Records
WA Herbarium – WAHerb original records	Yes	36137
WA Herbarium – vouchered specimens from vegetation mapping	Yes	3954
WA Herbarium – voucher specimens from RFA flora surveys	Yes	9392
Floristic survey of the Tingle Mosaic (Wardell-Johnson et al. 1989, Wardell-Johnson et al. 1995)	Some	15056
Havel site-vegetation type bulletins (Havel 1975a, Havel 1975b)	Some	5126
CALM Threatened Flora Database	Some	2949
Banksia Atlas (Taylor and Hopper 1988)	No	2896
Total		**70384**

Table 12.5 Other data sources for the flora species assessment

Source	Records
Alcoa of Australia Ltd	19784
Worsley Alumina Pty Ltd	9864
Scott River National Park survey for BHP (Mattiske Consulting 1996)	637
Griffin Coal	1985
Water and Rivers Commission and Water Corporation	9862
John Forrest National Park and Red Hill Survey (Mattiske and Burbidge 1991)	745
Mt Westdale – Dobaberry Swamp (Trudgen 1984)	813
Per Christensen PhD data (Christensen 1980)	4662
RFA Vegetation mapping – Mattiske Consulting (Mattiske Consulting 1997a)	27334
Shire of Mundaring (Mattiske Consulting 1997b)	2016
Total	**82828**

Systematic flora surveys have occurred sporadically throughout the region, primarily for the purpose of vegetation mapping in certain localities. Gaps in the data and the relative intensity of sampling across the region were well known. Three major surveys in the RFA region were undertaken to address these gaps.

Flora surveys

Field collecting was undertaken with the aim of sampling every taxon of vascular plant present at 150 survey sites throughout the region, stratified by landscape unit and fire history. Voucher specimens of each species were collected in addition to information on phenology, degree of flowering, presence of seed capsules, survival of plants from year to year and, importantly, age since last fire.

There were 13 410 voucher specimens collected and 11 009 of these were databased for incorporation into WABiota. The remaining 2401 voucher specimens were cryptogams (mosses and lichens) which will be identified at a later date.

Vegetation mapping surveys

Voucher specimens for about 4000 vascular plant species collected during the fieldwork for the *Mapping of Vegetation Complexes in the South-West Forest Region of Western Australia* project (see section 12.5) were lodged at the Herbarium. These data were incorporated into WAHerb and ultimately WABiota. Additional vascular plant species data (unvouchered) were provided from a range of sources, including a number of mining companies and other agencies.

Survey of threatened taxa

Surveys of threatened flora focused on taxa listed as declared rare flora (DRF) under Western Australia's *Wildlife Conservation Act 1950* or designated as priority species (P1, P2, P3, P4). Populations of DRF within the RFA region were field inspected to confirm their location and record current population details and other relevant information. Opportunistic surveys were also conducted for listed priority flora known to occur in areas containing DRF and specifically for priority flora under consideration for recommendation to be listed as DRF.

Altogether, 191 DRF populations from within the RFA region were surveyed during two periods in the springs of 1996 and 1997. Another 19 priority flora populations were also surveyed. The resultant data were entered in the CALM Threatened Flora Database.

Priority flora data entry

Data entry for priority flora previously collected, but not captured digitally, was undertaken as part of the endangered species assessment project. A total of 1476 priority flora data records from field survey sheets was added to the CALM Threatened Flora Database.

Development of WABiota

WABiota is essentially a warehouse of flora data obtained from a variety of sources internal and external to CALM. It was designed to contain not only individual site and specimen flora and fauna records but also taxonomic information and a variety of species-level attributes.

The database is structured to enable the updating of any given portion of the database from a recognised source such as WAHerb or the Threatened Flora Database. The nomenclature for the majority of taxa has been taken from WACensus, an authoritative database of names acceptable to the WA Herbarium, the relevant data custodian.

Data captured

A total of 153 212 vouchered and non-vouchered flora records (3244 taxa) were warehoused in WABiota from a range of sources internal and external to CALM.

Validation of WABiota records

The initial data validation involved removal of records which were:

- outside the RFA region;
- obviously misidentified; or
- exotic species.

Records with non-current names were also excluded.

A method for prioritising the validation of geocodes was developed using climatic attributes and BIOCLIM (McMahon et al. 1995) to identify potential outliers as targets for validation. This approach was required because the large number of points within WABiota meant a detailed analysis was not possible.

Using BIOCLIM, for each point in WABiota, 35 climatic parameters were evaluated and summary statistics calculated. A test was then applied to determine the extent to which the climatic parameters for each of the individual points were within the environmental envelope described by the points as a whole. Points for which a given climatic attribute was more than two standard deviations outside the mean of that parameter were then checked manually and WABiota was updated to reflect the validated coordinates. Records from other data sources were not validated any further as this was beyond the scope of the project.

A total of 5086 records was validated in this manner. Of these, 1752 existing geocodes were validated as being correct and 3334 records required a new geocode to be calculated. The data were then used to update the main WAHerb database records.

Attribution of taxa for conservation significance

Of the 3244 native flora taxa found within the RFA region, 72 are declared rare flora under Western Australia's *Wildlife Conservation Act* and 390 are designated as priority flora. These include 52 taxa also listed under Schedule 1 of the Commonwealth *Endangered Species Protection Act (ESP Act).* The declared rare flora are generally recommended for inclusion in Schedule 1 of the *ESP Act*, but this schedule has not been updated since 1994, and there is a disparity between the two lists. The schedule of declared rare flora is updated annually. Western Australian codes used to attribute conservation significance for all taxa are shown in Table 12.6.

Table 12.6 Categories of flora listed under Western Australia's Wildlife Conservation Act 1950 and those designated as priority flora by CALM

Category	Definition
Declared Rare Flora – extinct taxa	Taxa which have not been collected or otherwise verified over the past 50 years despite thorough searching, or of which all known wild populations have been destroyed more recently.
Declared Rare Flora – extant taxa	Taxa which have been adequately searched for and are deemed to be in the wild either rare, in danger of extinction or otherwise in need of special protection.
Priority One – poorly known taxa	Taxa which are known from one or a few (generally <5) populations which are under threat.
Priority Two – poorly known taxa	Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).
Priority Three – poorly known taxa	Taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i.e. not currently endangered).
Priority Four – rare taxa	Taxa which are considered to have been adequately surveyed and which, while being rare (in Australia), are not currently threatened by any identifiable factors.

Other taxa were attributed as candidates for JANIS reserve selection target groups. This included 350 taxa identified as narrow endemics (restricted to a range of less than 150 kilometres), 134 taxa with disjunct populations found within the study area and 85 taxa which were considered as primitive or relictual. A total of 726 taxa reach their distributional limits within the region, but the lack of systematic flora surveys across the entire region makes it difficult to determine the importance of these records for the analysis and protection of biodiversity, and they were used only to inform the analyses.

Species prediction modelling

It is recognised that large portions of the RFA region are under-sampled within existing databases while comparatively large numbers of records exist for some particular areas which have been the subject of intensive research. These sampling biases in the region can be overcome to some extent by predicting the distribution of species using computer-based models.

The SpModel software package (Ferrier and Watson 1996) was used to generate predicted distributions for each species within WABiota. Only vascular non-weed flora with current nomenclature were modelled. SpModel required a minimum of 10 point locations for any given species. This reduced the candidates for modelling from more than 3000 species to more than 2000 species.

SpModel has the capability to model using Generalised Linear Model (GLM) or generalised Additive Model (GAM). GLM was adopted in the South-West Forest Region species modelling as an acceptable compromise between processing time and confidence in the model in recognition that:

- the data to be modelled were primarily presence-only data due to the large proportion of opportunistic records;
- many of the historical records require caution regarding geocodes; and
- the increased requirement of processing time by GAM over GLM would have substantially extended the processing of the large number of taxa.

The spatial predictor variables for SpModel can include continuous surfaces such as climatic attributes or categorical variables such as geology or vegetation. A range of predictor variables was assessed for their potential use within the modelling process. A suitable subset of climatic parameters was chosen that incorporated temperature, precipitation and radiation levels at both annual and seasonal levels, aspect, slope, geology (regolith and Precambrian), forest ecosystems and ecological vegetation systems. The ecological vegetation system grid is a higher level classification of the vegetation complex database compiled as part of the "Mapping of Vegetation Complexes in the South-West Forest Region of Western Australia" project (see section 12.5).

Grids of these parameters were generated on a longitude/latitude base at a resolution of nine seconds of arc. This scale was determined by the resolution of the Digital Elevation Model (DEM).

Outputs from species prediction modelling

Distribution models were generated for 2202 current, native species occurring within the RFA region. Records were aggregated at the species level for processing by SpModel. Distribution maps were printed for each species and assessed for suitability.

The most common predictors for distribution were climatic surfaces, followed by slope and geology. The most common climatic surfaces employed by the model were those incorporating some aspect of seasonality in temperature and precipitation. Very occasionally forest ecosystems were used by the model.

Each model output was statistically analysed to assess whether the prediction was realistic. Unacceptable prediction maps, usually those over-predicting possible species distribution by about 25%, were omitted.

Botanical experts were asked to validate the prediction maps for families or genera with which they were familiar. These botanists included Neville Marchant (*Agonis*, *Calothamnus*, *Chamelauceum*, *Darwinea*, *Drosera*), Bruce Maslin (*Acacia*), Andrew Brown (*Orchidaceae*), Terry MacFarlane (*Amphipogon*, *Austrostipa*, *Stipa*, *Lomandra*), Ray Cranfield (various taxa) and Mike Hislop (various taxa).

Models were also compared against independently compiled distribution maps in Churchill (1961).

After assessment, 263 models were rejected because the model did not reflect true or likely distribution, leaving a total 1929 acceptable models.

Species richness modelling

Models accepted as valid were used to generate a species richness prediction map. A one kilometre grid was selected as suitable on the basis of the nine seconds (270 metres) unit for base data used to generate the predicted distributions and the minimum level of accuracy required by the integration and planning phases of the RFA process, noting that there is a large number of existing CALM reserves less than 100 hectares in area.

The number of species within one by one kilometre grids were counted across the entire RFA region. Counts for all taxa and for endemic taxa were generated and maps at 1:500 000 were generated for endemic taxa and for all taxa.

Several areas of high species richness were predicted, including the Leeuwin-Naturalist ridge, the Blackwood River plateau, the south coast and to a lesser extent the Darling scarp east of Perth (Map 5).

The species richness prediction maps were checked in a number of ways including sampling of raw data from WABiota and consultation with the experienced botanists including Neville Marchant, Greg Keighery, Libby Mattiske and Roger Hearn. All of these botanists agreed with the general species richness patterns. They also agreed that the very high species richness around the Blackwood River plateau is of scientific note, however, and warrants further investigation.

Species vulnerability assessment

A review of the reservation status of declared rare flora (DRF) and priority flora from the Threatened Flora Database has been undertaken (Table 12.7).

The purpose of the vulnerability assessment was to identify plant species of conservation significance that are likely to be at higher risk of decline or extinction. The assessment of risk considered the proportion of the geographic range of each species within the south-west forests, the narrowness of habitat requirements, current estimated population sizes, and susceptibility to threatening processes or natural catastrophic events. Species which have low overall number of records in the region, few records from elsewhere in Australia, narrow habitat requirements and most of their records from outside the reserve system are regarded as most likely to be of concern.

Reservation analysis for declared rare flora and priority flora

The CALM Threatened Flora Database was analysed using the most recent survey data for each population to provide a summary of the reservation status of each DRF or priority flora taxon with part or all of its known distribution within the RFA region.

Data were analysed for total populations, plus sub-populations occurring on land vested in the National Parks and Nature Conservation Authority (NPNCA—primarily national parks and nature reserves), the Lands and Forest Commission (LFC—primarily State forest), local authorities (Shire—primarily road reserves) and private property (Private). These four categories were chosen as being the main land tenures containing rare flora in the RFA area. Other populations occur on other tenures of Crown land, such as main roads, water reserves and unvested Crown reserves. Data were extracted as the number of (sub)populations and plants present in each category.

Sub-populations are defined where a population is split over different land tenures, or is separated by a distance that results in separate management being undertaken, but is still essentially the same population for the species. Population size estimates are provided for those taxa where the most recent survey records the number of individual plants.

It must be noted that for priority flora taxa in the Southern Forest Region (only), no data were entered for distributions outside the RFA region. This must be taken into consideration in any evaluation of the reservation status of these taxa.

Tables 12.8 to 12.12 provide information on the reservation status of DRF and priority flora found within the South-West Forest Region.

Map 15 shows the known locations of declared rare flora in the South-West Forest Region.

Endangered, rare and threatened vascular flora

The current list of declared rare flora and taxa listed on Schedule 1 of the *Endangered Species Protection Act* were reviewed to determine those taxa which had specific management actions documented for their protection. They include:

- critically endangered taxon (*Caladenia winfieldii*) with a published interim recovery plan;
- critically endangered taxa with interim recovery plans in preparation;
- taxa recommended for reclassification as critically endangered by the Threatened Species Scientific Committee, and hence will have interim recovery plans prepared; and
- taxa currently addressed in regional rare flora management programs.

A further species, *Leptomeria dielsiana*, was also omitted as it is known only from a herbarium specimen, and hence no information is available on which to prepare a conservation statement.

Altogether, 36 taxa (Table 12.7) which are listed as endangered or vulnerable on Schedule 1 of the *Endangered Species Protection Act,* require the preparation of interim recovery plans. As preparation of interim recovery plans was not possible within the CRA process, conservation statements will be prepared prior to the signing of the RFA. These taxa are currently addressed in regional rare flora management programs and the preparation of interim recovery plans will be addressed in the implementation of the RFA.

Table 12.7 ESP listed flora, without interim recovery plans, for which conservation statements will be prepared prior to the signing of the RFA and the development of interim recovery plans will be addressed in the implementation of the RFA

Acacia anomala	*Dryandra nivea* subsp. *uliginosa*
Acacia aphylla	*Grevillea flexuosa*
Anthocercis gracilis	*Kennedia glabrata*
Asterolasia grandiflora	*Kennedia macrophylla*
Asterolasia nivea	*Lambertia orbifolia*
Banksia verticillata	*Laxmannia jamesii*
Brachysema modestum ms	*Lechenaultia laricina*
Caladenia christineae ms	*Lechenaultia pulvinaris*
Caladenia dorrienii	*Meziella trifida*
Caladenia excelsa ms	*Microtis globula*
Caladenia harringtoniae ms	*Pimelea rara*
Chamelaucium roycei ms	*Pleurophascum occidebtale*
Corybas limpidus	*Pultenaea pauciflora*
Darwinia acerosa	*Restio chaunocoleus*
Darwinia apiculata	*Spirogardnera rubescens*
Darwinia ferricola ms	*Tetraria australiensis*
Drosera fimbriata	*Thelymitra stellata*
Dryandra mimica	*Verticordia fimbrilepis* subsp. *australis*

Responses to disturbance

Reviews of the responses to disturbance of vascular flora and fungi were undertaken by Safstrom and Lemson (1997) and Bougher (1997) for the CRA. These reviews gathered information, through literature searches and consultation with experts, on the responses to disturbance of individual species. These reports are available separately on request, and will be considered by governments in developing the Regional Forest Agreement for Western Australia. (They will also be available on the Internet – see page ii for addresses.)

The RFA region contains 462 taxa of conservation significance. The review was restricted to declared rare flora under Western Australia's *Wildlife Conservation Act* and those designated as priority 4 species. Of these species, information was readily available for 49 taxa, comprising 43 DRF and six priority 4 taxa. Other priority taxa are classified as poorly known and did not have sufficient data available to provide reliable information.

Attention in the review was given to human induced disturbances which alter ecosystem processes, such as fuel reduction burning or soil disturbance in roading operations, rather than natural periodic or stochastic disturbances, such as lightning induced fire or severe drought, which have been part of the evolutionary history of the south-west vegetation. The study recognised that:

- single disturbance events have different impacts from either repeated disturbances and combinations of disturbances;
- combinations of human induced and natural disturbances can have severe impacts; and
- some combinations of disturbances have cumulative self-reinforcing impacts, such as repeated fire encouraging weed invasion which in turn increases fuel load and thus encourages more frequent burning.

A disturbance can be evaluated in relation to the following factors:

- the extent of its occurrence in the South-West Forest Region;
- any other potentially threatening processes associated with it;
- the strength of association between threatening processes;
- the significance of the threats posed;
- attributes of flora that might predispose them to negative impacts from the threat (e.g. due to their ecology, life history or life form);
- attributes of flora that might provide potential resilience to potential impacts from a disturbance;
- taxa likely to suffer negative impacts due to the threat; and
- management, including policies and processes, to reduce impacts of the threat.

Western Australia's *Wildlife Conservation Act* affords special protection to DRF, requiring Ministerial permission to collect these taxa and controlling impacts from timber harvesting, burning, road building and other activities. Some taxa are in need of active management and the review by Safstrom and Lemson (1997) provides a summary of threatening processes to inform management actions.

Table 12.8 The occurrence of declared rare flora within and outside the Western Australian RFA area and within major land vestings

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Acacia anomala (V)	Y	13	10965	3	167	5	10556	9	55	13	187
Acacia aphylla (V)	N	7	2394	0	0	0	0	1	23	11	679
	Y	8	3023	4	822	5	99	0	0	1	102
Anigozanthos humilis subsp.	N	8	714	2	150	0	0	7	124	1	50
chrysanthus (V)	Y	3	3443	2	3019	0	0	3	27	3	397
Anthocercis gracilis (E)	N	1	1300	0	0	0	0	0	0	1	1300
	Y	7	2905	2	0	4	470	0	0	3	2026
Aponogeton hexatepalus (V)	N	24	23022	1	2000	4	430	10	1697	19	6084
	Y	1	4500	0	0	1	4500	0	0	0	0
Asterolasia grandiflora (V)	N	2	1659	5	1508	0	0	1	20	1	131
	Y	6	6633	3	5582	0	0	4	1001	6	50
Asterolasia nivea (V)	Y	7	1286	4	488	1	692	0	0	1	7
Banksia goodii	N	20	2256	12	900	0	0	9	191	6	1165
	Y	7	184	0	0	4	117	5	66	1	1
Banksia verticillata (V)	N	27	3778	24	1322	0	0	0	0	0	0
	Y	3	11801	3	11200	0	0	0	0	0	0
Brachysema modestum	Y	2	1100	0	0	2	1100	0	0	0	0
Caladenia bryceana subsp.	N	4	151	7	109	0	0	0	0	4	42
bryceana (V)	Y	1		1	0	0	0		0	0	0
Caladenia busselliana (E)	Y	2	63	0	0	0	0	2	0	0	0
Caladenia christineae (V)	N	1	0	0	0	0	0	0	0	1	0
	Y	10	184	0	0	4	4	0	0	1	0
Caladenia dorrienii (V)	N	3	0	1	0	0	0	0	0	2	0
	Y	6	142	0	0	6	102	1	0	1	40
Caladenia excelsa (V)	Y	14	96	6	16	0	0	1	1	4	38
Caladenia harringtoniae (V)	N	2	30	0	0	1	30	1	0	0	0
	Y	28	359	4	26	20	285	4	0	1	43
Caladenia huegelii (V)	N	28	381	2	8	0	0	9	47	17	263
	Y	11	56	7	46	0	0	2	10	1	0
Caladenia viridescens (E)	N	3	24	0	0	0	0	4	24	0	0
	Y	1	30	0	0	0	0	0	0	0	0
Caladenia winfieldii	Y	1	0	0	0	1	0	0	0	0	0
Centrolepis caespitosa (X)	N	3	7	1	7	0	0	1	0	1	0
	Y	1	200	0	0	0	0	0	0	0	0
Chamelaucium roycei (V)	N	11	2274	1	111	0	0	4	1351	2	3
	Y	4	116	0	0	0	0	2	22	1	20
Corybas limpidus (V)	N	3	5100	1	0	0	0	1	0	0	0
	Y	1	35	1	35	0	0	0	0	0	0
Darwinia acerosa (V)	N	4	1588	0	0	0	0	2	57	2	1530
	Y	4	15300	0	0	0	0	0	0	7	15300
Darwinia apiculata (E)	Y	2	2350	2	210	0	0	0	0	0	0
Darwinia ferricola (E)	Y	3	12675	1	1100	0	0	3	100	7	11475
Diuris drummondii (V)	N	1	75	0	0	0	0	0	0	0	0
	Y	10	335	6	230	2	5	2	21	1	20
Diuris micrantha (E)	N	4	540	1	20	0	0	1	20	1	0
	Y	2	100	0	0	0	0	1	50	0	0
Drakaea confluens (V)	N	2	3	2	3	0	0	0	0	0	0
	Y	4	30	1	3	0	0	0	0	2	27
Drakaea elastica (V)	N	23	1143	8	584	0	0	6	40	18	483
	Y	2	0	0	0	0	0	0	0	1	0
Drakaea micrantha (V)	N	6	8	1	0	0	0	0	0	2	3
	Y	10	170	0	0	11	130	0	0	1	40
Dryandra mimica (E)	N	2	26	0	0	0	0	0	0	4	26

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
	Y	1	100	0	0	1	100	0	0	0	0
Dryandra nivea subsp.	N	6	599	1	0	1	100	4	159	0	0
uliginosa	Y	7	325	1	0	1	100	2	110	1	100
Eucalyptus goniantha subsp.	N	24	7272	6	136	0	0	9	145	12	3591
goniantha	Y	1	50	1	50	0	0	0	0	0	0
Eucalyptus graniticola (E)	Y	1	1	0	0	1	1	0	0	0	0
Grevillea flexuosa (E)	Y	4	2619	12	754	0	0	4	193	19	1642
Hydrocotyle lemnoides (V)	N	1	11015	0	0	0	0	0	0	2	1000
	Y	6	44100	4	39100	1	5000	0	0	1	0
Kennedia glabrata (V)	N	3	25	4	25	0	0	0	0	0	0
	Y	5	281	4	279	3	2	0	0	0	0
Kennedia macrophylla (V)	Y	4	103	1	15	0	0	3	75	2	13
Lambertia orbifolia (E)	Y	7	7797	2	233	0	0	2	77	10	7487
Laxmannia jamesii (V)	N	11	235	5	3	0	0	2	122	1	0
	Y	7	233	2	50	4	150	0	0	0	0
Lechenaultia laricina (V)	N	3	58	0	0	0	0	2	9	2	40
	Y	5	1458	6	1359	1	3	1	96	0	0
Lechenaultia pulvinaris (V)	N	19	483	11	37	0	0	2	5	8	366
	Y	5	2855	3	1713	17	1142	0	0	0	0
Meziella trifida (E)	Y	1		0	0	1	0	1	0	0	0
Microtis globula (V)	N	3	1100	4	950	0	0	0	0	1	150
	Y	3		3		0	0	0	0	0	0
Pimelea rara (E)	Y	12	123	0	0	20	123	0	0	0	0
Pultenaea pauciflora (E)	N	3	100	0	0	1	19	1	52	0	0
	Y	16	10927	8	4318	18	6609	0	0	0	0
Restio chaunocoleus	N	2	11000	2	8700	0	0	2	2300	2	0
	Y	1	500	0	0	0	0	1	250	1	250
Rulingia sp. Trigwell Bridge	Y	1	4	0	0	0	0	0	0	1	4
Schoenus natans (X)	N	7	19403	2	600	1	10000	2	7100	0	0
	Y	2		0	0	2		0	0	0	0
Sphenotoma drummondii	N	11	595	10	594	0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Spirogardnera rubescens (V)	N	5	201	2	7	0	0	6	194	0	0
	Y	3	71	0	0	0	0	2	8	2	43
Tetraria australiensis (X)	N	5	2400	3	1200	0	0	0	0	3	1200
	Y	2	300	0	0	0	0	1	100	0	0
Thelymitra dedmaniarum (E)	Y	23	1204	20	607	11	488	5	18	3	91
Thelymitra stellata (V)	N	14	47	8	27	0	0	2	5	1	0
	Y	12	33	1	7	0	0	10	26	0	0
Verticordia fimbrilepis.	N	2	0	0	0	0	0	1	0	1	0
subsp *australis* (E)	Y	1	1000	0	0	1	1000	0	0	0	0
Verticordia fimbrilepis.	N	8	92	0	0	0	0	9	92	0	0
subsp *fimbrilepis*	Y	1		0	0	0	0	0	0	0	0
Verticordia plumosa var. ananeotes (E)	Y	2	260	0	0	0	0	2	260	0	0

Notes: 1 Population numbers within the different vestings are for subpopulations and may thus sum to more than the total number of populations.
2 Number of plants is that recorded at the last survey, and may be none where specific plant counts were not undertaken (e.g. herbarium collections).

Table 12.9 The occurrence of Priority 1 flora within and outside the Western Australian RFA area and within major land vestings

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Acacia brachypoda	N	4	733	0	0	0	0	0	0	4	1400
	Y	1	215	1	215	0	0	0	0	0	0
Acacia chapmanii subsp. *australis*	Y	1	100	1	100	0	0	0	0	0	0
Acacia lasiocarpa var. bracteolata	Y	1	1000	0	0	0	0	0	0	0	0
Acacia lateriticola glabrous	N	1		0	0	0	0	1		0	0
variant (BR Maslin 6765)	Y	1		1		0	0	0	0	0	0
Adenanthos cygnorum subsp. *chamaephyton*	Y	11	780	2	900	1	100	6	370	1	0
Andersonia macronema	Y	3	1000	0	0	3	1000	0	0	0	0
Andersonia sp. Collis Rd (G Wardell-Johnson GWJ5A)	Y	1	300	0	0	1	300	0	0	0	0
Andersonia sp. Ironstone	N	1		0	0	0	0	1	0	0	0
(BJ Keighery & N Gibson 227)	Y	3	1000	0	0	2	1000	1	0	1	0
Andersonia sp. Mitchell River (BG Hammersley 925)	Y	7	1530	0	0	7	1230	1	300	0	0
Asteridea gracilis	N	3		0	0	0	0	1	0	0	0
	Y	2		0	0	1	0	1	0	0	0
Baeckea sp. Chittering (RJ Cranfield 1983)	Y	2	400	0	0	0	0	0	0	2	400
Baeckea sp. Darling Range (RJ Cranfield 1673)	Y	3	8	0	0	0	0	1	8	0	0
Boronia exilis	Y	1	100	0	0	0	0	1	100	0	0
Boronia humifusa	Y	2		0	0	0	0	2		0	0
Caladenia caesarea subsp. *transiens*	Y	2	65	0	0	0	0	0	0	0	0
Caladenia evanescens	Y	1		0	0	0	0	1		0	0
Caladenia longicauda	N	5	81	1	0	0	0	3	80	0	0
subsp. *clivicola*	Y	2		0	0	1	0	1	0	0	0
Caladenia uliginosa subsp. *patulens*	Y	2	2	0	0	0	0	2	2	0	0
Calothamnus sp. Whicher	N	6	200	0	0	1	100	5	100	0	0
(BJ Keighery & N Gibson 230)	Y	2	150	0	0	1	50	1	100	1	0
Calytrix simplex subsp. *simplex*	Y	1		0	0	1		0	0	0	0
Carex tereticaulis	N	1		0	0	0	0	1		0	0
	Y	2		0	0	0	0	1	0	0	0
Chordifex jacksonii	N	1		1		0	0	0	0	0	0
	Y	10	150	1	0	5	150	2	0	0	0
Conospermum caeruleum subsp. *contortum*	Y	1		0	0	0	0	0	0	0	0
Cryptandra arbutiflora var. *pygmaea*	Y	1	220	0	0	2	220	0	0	0	0
Daviesia elongata subsp. *elongata*	Y	5	914	0	0	4	912	0	0	0	0
Dryandra squarrosa subsp.	N	5	393	0	0	2	0	3	300	4	23
argillacea	Y	5	1450	0	0	3	1300	0	0	2	100
Eriochilus scaber subsp. *orbifolia*	Y	2		3		0	0	0	0	0	0
Eryngium sp. Lake Muir (E Wittwer 2293)	Y	1		0	0	0	0	0	0	0	0
Eucalyptus lane-poolei var. Whicher (SD Hopper 6316)	Y	1		0	0	1		0	0	0	0
Eucalyptus loxophleba x	N	10	8	2	1	0	0	6	4	1	2
wandoo	Y	1	3	0	0	0	0	1	2	0	0
Genus sp. Shannon (PG Wilson 1237B)	Y	1		1		0	0	0	0	0	0
Goodenia arthrotricha	N	2	100	1	100	0	0	0	0	1	0
	Y	2		0	0	0	0	1	0	1	0
Grevillea althoferorum	N	1	100	0	0	0	0	1	100	0	0
	Y	1	30	1	30	0	0	0	0	0	0
Grevillea corrugata	Y	1		0	0	0	0	1		0	0

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Grevillea manglesii subsp. *dissectifolia*	Y	1		0	0	0	0	0	0	0	0
Grevillea rara	Y	5	1271	0	0	2	1001	2	120	0	
Grevillea sp. Scott River (GJ Keighery 4070)	Y	5	1150	0	0	0	0	4	150	0	0
Hakea sp. Williamson)	N	4	217	0	0	2	130	3	87	0	0
(BJ Keighery & N Gibson 226	Y	3	1100	0	0	2	1000	1	100	0	0
Jacksonia sp. Collie (CJ Koch 177)	Y	1		0	0	1		0	0	0	0
Johnsonia inconspicua	Y	5		0	0	3	0	1	0	0	0
Leucopogon florulentus	N	6		1	0	0	0	3	0	0	0
	Y	1		0	0	0	0	0	0	0	0
Microcorys longifolia	N	3	21	0	0	0	0	1	0	0	0
	Y	1		0	0	0	0	1		0	0
Nemcia alternifolia	Y	1	3	0	0	0	0	1	3	0	0
Nemcia cyanophylla	Y	1		0	0	0	0	1		0	0
Nemcia sparsa	Y	1		0	0	0	0	0		0	1
Philydrella pygmaea subsp. *minima*	Y	1		1		0	0	0	0	0	0
Pterostylis turfosa	N	4	200	4	200	0	0	0	0	0	0
	Y	13	320	9	220	4	100	0	0	0	0
Spyridium riparium	Y	5	1603	0	0	2	203	3	1400	0	0
Stenanthemum intropubens	Y	1		0	0	0	0	0		0	1
Stenanthemum nanum	Y	2		0	0	2		0	0	0	0
Stylidium marradongense	Y	1		0	0	2		0	0	0	0
Synaphea decumbens	Y	1		0	0	1		0	0	0	0
Synaphea incurva	N	1		0	0	0	0	0	0	0	0
	Y	2		0	0	2		0	0	0	0
Synaphea intricata	Y	9		0	0	9		0	0	0	0
Synaphea macrophylla	Y	1		0	0	0	0	0		0	1
Synaphea nexosa	Y	1		0	0	0	0	1		0	0
Synaphea odocoileops	N	2	20	0	0	0	0	1	0	0	0
	Y	1		0	0	1		0	0	0	0
Synaphea otiostigma	Y	2		0	0	1	0	0	0	0	0
Synaphea panhesya	N	1		0	0	0	0	1		0	0
	Y	1		0	0	0	0	0	0	0	0
Thomasia laxiflora	Y	4		0	0	4		0	0	0	0
Tripterococcus sp. Cannington	N	9	610	0	0	0	0	2	10	5	598
(AS George 16201)	Y	1	5	0	0	1	5	0	0	0	0
Verticordia endlicheriana var. *angustifolia*	Y	5	13000	0	0	4	12000	1	1000	0	0
Verticordia plumosa var.	N	4	501	0	0	0	0	4	501	0	0
pleiobotrya	Y	1		1		0	0	0	0	0	0
Verticordia plumosa var.	N	6	2156	1	1016	0	0	9	763	0	0
vassensis	Y	4	2476	0	0	0	0	7	1476	0	0

Notes: 1 Population numbers within the different vestings are for subpopulations and may thus sum to more than the total number of populations.
2 Number of plants is that recorded at the last survey, and may be none where specific plant counts were not undertaken (e.g. herbarium collections).

Table 12.10 The occurrence of Priority 2 flora within and outside the Western Australian RFA area and within major land vestings

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Acacia browniana var. *glaucescens*	Y	6		0	0	1	0	0	0	0	0
Acacia campylophylla	N	8	85	0	0	3	75	1	10	1	0
	Y	2		0	0	1	0	0	0	0	0
Acacia cuneifolia	N	2	20	1	20	0	0	0	0	1	0
	Y	11	2108	11	1069	4	988	0	0	2	51
Acacia gemina	N	4		3	0	1	0	0	0	0	0
	Y	5		0	0	5		0	0	0	0
Acacia mooreana	N	1		0	0	0	0	0	0	1	
	Y	28	29	1	0	19	29	0	0	3	0
Acacia oncinophylla subsp.	N	1	5	1	5	0	0	0	0	0	0
patulifolia	Y	5	38	0	0	0	0	3	16	0	0
Acacia subracemosa	Y	9	1	4	0	1	1	1	0	0	0
Actinotus sp. Walpole (JR Wheeler 3786)	Y	8		4	0	4	0	0	0	0	0
Actinotus whicherae	Y	3	300	0	0	3	300	0	0	0	0
Alexgeorgea ganopoda	Y	9	33100	4	20500	5	12500	0	0	0	0
Amperea micrantha	N	1		1		0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Amperea protensa	N	5	4	3	2	0	0	1	2	0	0
	Y	12	20	9	10	2	10	0	0	1	0
Andersonia annelsii	Y	1	1000	0	0	1	1000	0	0	0	0
Andersonia auriculata	N	3		2	0	0	0	1	0	0	0
	Y	8	723	3	100	0	0	4	111	1	12
Anthocercis sylvicola	Y	4	2400	4	2400	0	0	0	0	0	0
Astartea sp. Mt Johnston (AR Annels 5645)	Y	2		0	0	2		0	0	0	0
Astroloma foliosum	N	1		0	0	0	0	1		0	0
	Y	8	10	0	0	0	0	4	5	1	0
Billardiera sp. Walpole	N	2	100	1	0	0	0	2	100	0	0
(AR Annels 277)	Y	6	550	2	0	3	550	0	0	0	0
Boronia capitata subsp.	N	4		1	0	2	0	0	0	0	0
gracilis	Y	2		0	0	2		0	0	0	0
Borya longiscapa	N	1	2000	0	0	1	2000	0	0	0	0
	Y	11	10800	0	0	11	10600	0	1	200	0
Bossiaea modesta	Y	2		0	0	2		0	0	0	0
Caladenia abbreviata	N	1		0	0	0	0	0	0	0	0
	Y	3	50	3	50	0	0	0	0	0	0
Caladenia rubrichila	Y	1	50	0	0	0	0	0	0	1	50
Caladenia subdita	Y	1		0	0	0	0	0	0	0	0
Calothamnus sp. Mt Lindesay (BG Hammersley 439)	Y	2	2500	0	0	2	2500	0	0	0	0
Calothamnus sp. Scott River (RD Royce 84)	Y	6	301	0	0	3	0	4	101	1	100
Chamaexeros longicaulis	Y	3	2000	4	2000	0	0	3	0	1	0
Chamelaucium forrestii subsp. *forrestii*	Y	5		3	0	2	0	0	0	0	0
Conospermum	N	1	10	1	10	0	0	0	0	0	0
quadripetalum	Y	2		0	0	1	0	1	0	0	0
Cryptandra congesta	Y	3	1600	0	0	3	1600	0	0	0	0
Diplolaena andrewsii	Y	2	135	2	15	0	0	1	0	1	120
Diuris heberlei	Y	1	500	1	500	0	0	0	0	0	0
Drosera binata	Y	2	1500	0	0	0	0	2	500	0	0
Dryandra aurantia	Y	4	1735	4	1735	0	0	0	0	0	0
Dryandra sessilis var.	N	1		1		0	0	0	0	0	0
cordata	Y	1		1		0	0	0	0	0	0
Eremaea blackwelliana	N	1		1		0	0	0	0	0	0
	Y	3	2150	3	1350	0	0	0	0	4	800

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Eryngium pinnatifidum	N	9		1	0	0	0	1	0	3	0
subsp. *palustre*	Y	1		1		0	0	0	0	0	0
Eucalyptus virginae	Y	3	2010	0	0	2	1998	0	2	12	0
Euphrasia scabra	Y	1		0	0	0	0	0	0	0	0
Goodenia katabudjar	Y	2	100	0	0	2	100	0	0	0	0
Grevillea brachystylis subsp. *australis*	Y	2	230	1	100	0	0	1	130	0	0
Grevillea brachystylis subsp.	N	2		0	0	0	0	0	0	0	0
brachystylis	Y	3	100	0	0	0	0	1	0	0	0
Grevillea candolleana	Y	7	261	2	0	0	0	3	105	1	50
Grevillea fuscolutea	Y	3	2380	0	0	3	2300	0	1	80	0
Grevillea manglesii subsp.	N	1	5	0	0	0	0	1	5	0	0
ornithopoda	Y	1		1		0	0	0	0	0	0
Grevillea prominens	Y	1		0	0	1		0	0	0	0
Grevillea scabra	N	1	203	3	203	0	0	0	0	0	0
	Y	5	715	2	15	2	700	1	0	0	0
Hakea sp.Walyunga (L Penn s.n.)	Y	1		1		0	0	0	0	0	0
Hakea tuberculata	N	1		0	0	0	0	1	0	1	0
	Y	5		1	0	0	0	4	0	0	0
Hemiandra australis	Y	3	1020	3	1020	0	0	0	0	0	0
Hydatella dioica	N	1		0	0	0	0	0	0	0	0
	Y	1	1000	1	1000	0	0	0	0	0	0
Hydrocotyle hamelinensis	N	1		1		0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Lasiopetalum cardiophyllum	N	1		1		0	0	0	0	0	0
	Y	13	6585	0	0	9	6585	1	0	2	0
Lasiopetalum cordifolium subsp. *acuminatum*	Y	3		1	0	2	0	0	0	0	0
Laxmannia sp. Little Lindesay (BG Hammersley 1615)	Y	2	220	0	0	2	220	0	0	0	0
Leptinella drummondii	Y	5	50	1	0	3	50	0	0	0	0
Leptocarpus ceramophilus	Y	6		3	0	0	0	0	0	0	0
Leptomeria furtiva	Y	2		1	0	0	0	0	0	0	0
Leucopogon glaucifolius	N	8	100	3	100	0	0	3	0	0	0
	Y	1		1	0	0	0	0	0	0	
Leucopogon polystachyus	N	4		0	0	0	0	2	0	0	0
	Y	22	1176	9	0	12	1136	0	0	1	20
Leucopogon tamariscinus	N	13	231	8	207	0	0	3	24	1	0
	Y	2		1	0	0	0	1	0	0	0
Lysinema elegans	N	16	8453	10	6286	1	0	9	536	27	794
	Y	1	46	0	0	0	0	0	0	0	0
Lysinema lasianthum	N	10	507	5	127	0	0	3	80	0	0
	Y	3	8	0	0	0	0	0	0	0	0
Melaleuca incana subsp. Gingilup (Gibson & M Lyons 593)	Y	1		1		0	0	0	0	0	0
Melaleuca micromera	N	2	3	0	0	0	0	1	1	0	0
	Y	1	10	0	0	0	0	0	0	0	0
Millotia tenuifolia var. *laevis*	Y	1		0	0	0	0	1		0	0
Mitreola minima	N	2		1	0	0	0	0	0	1	0
	Y	5		1	0	1	0	0	0	0	0
Nemcia axillaris	N	17	246	7	59	0	0	5	152	1	5
	Y	1		0	0	0	0	0	0	0	0
Nemcia epacridoides	Y	10	10853	3	10000	2	200	7	350	7	303
Parsonsia diaphanophleba	N	2	6	0	0	0	0	1	6	0	0
	Y	1	4000	1	4000	0	0	0	0	0	0
Phyllota gracilis	N	4	320	1	300	0	0	1	0	1	0
	Y	3		0	0	3		0	0	0	0
Pithocarpa corymbulosa	N	1		0	0	0	0	1		0	0
	Y	4		2	0	0	0	2	0	0	0
Restio cracens	Y	10	476	0	0	12	476	0	0	0	0
Restio isomorphus	Y	3	2000	0	0	0	0	2	0	1	2000

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Rorippa dictyosperma	N	1		1		0	0	0	0	0	0
	Y	2		2		0	0	0	0	0	0
Schizaea rupestris	N	1	10	1	10	0	0	0	0	0	0
	Y	3		1	0	1	0	0	0	0	0
Schoenus capillifolius	N	2	200	0	0	0	0	0	0	3	200
	Y	2	100	1	100	0	0	0	0	0	0
Schoenus loliaceus	N	1		0	0	1		0	0	0	0
	Y	1		1		0	0	0	0	0	0
Sollya drummondii	N	8	175	0	0	1	0	3	119	0	0
	Y	10	48	0	0	4	4	1	6	2	23
Stylidium rigidifolium	N	1		1		0	0	0	0	0	0
	Y	2		0	0	1	0	0	0	0	0
Stylidium semaphorum	Y	1		1		0	0	0	0	0	0
Stylidium sp. Boulder Rock (AH Burbidge 2536)	Y	2		0	0	1	0	0	0	0	0
Tetratheca similis	N	1		1		0	0	0	0	0	0
	Y	5	25	0	0	0	0	2	25	0	0
Tetratheca sp. Granite (S Patrick SP1224)	Y	1	500	0	0	0	0	0	0	0	0
Trichocline sp. Treeton	N	1		1		0	0	0	0	0	0
(BJ Keighery & N Gibson 564)	Y	2		1	0	1	0	0	0	0	0
Trymalium urceolare	N	1	50	0	0	0	0	1	50	0	0
	Y	6	12	1	10	1	0	0	0	0	0
Verticordia apecta	Y	1	30	0	0	0	0	0	0	0	0
Verticordia bifimbriata	N	5	101	2	1	2	50	1	50	0	0
	Y	2	0	1	0	0	0	1	0	0	0
Verticordia citrella	Y	1		1		0	0	0	0	0	0
Verticordia densiflora var.	N	4	321	1	200	0	0	3	103	0	0
pedunculata	Y	2	10	0	0	0	0	1	10	0	0
Verticordia serrata var. *Udumung* (D Hunter & B Yarran 941006)	Y	1		1		0	0	0	0	0	0
Wurmbea sp. Cranbrook (AR Annels 3819)	Y	1		0	0	0	0	0	0	0	0

Notes: 1 Population numbers within the different vestings are for subpopulations and may thus sum to more than the total number of populations.
2 Number of plants is that recorded at the last survey, and may be none where specific plant counts were not undertaken (e.g. herbarium collections).

Table 12.11 The occurrence of Priority 3 flora within and outside the Western Australian RFA area and within major land vestings

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Acacia anarthros	N	9	262	0	0	0	0	5	42	0	0
	Y	6	1782	2	741	0	0	1	3	0	0
Acacia drummondii	N	4		0	0	0	0	0	0	0	0
subsp. *affinis*	Y	9		1	0	2	0	0	0	0	0
Acacia horridula	N	3	1236	7	186	0	0	3	1050	0	0
	Y	5	60	2	10	1	0	0	0	2	50
Acacia inops	Y	6		0	0	4	0	2	0	0	0
Acacia oncinophylla	N	1		0	0	0	0	0	0	0	0
subsp. oncinophylla	Y	5	25	1	0	0	0	0	0	1	0
Acacia semitrullata	N	10	982	2	580	2	0	2	400	5	0
	Y	14		0	0	9	0	2	0	3	0
Allocasuarina	N	4	100	2	100	0	0	2	0	0	0
ramosissima	Y	1		0	0	0	0	1		0	0
Andersonia amabile	N	1		0	0	0	0	1		0	0
	Y	8		4	0	4	0	0	0	0	0
Aotus cordifolia	N	1		0	0	0	0	1		0	0
	Y	4	20	0	0	1	0	1	0	1	20
Banksia micrantha	N	9	100	4	0	0	0	2	0	0	0
	Y	1		0	0	0	0	0	0	1	
Blennospora sp. Ruabon	N	7		4	0	0	0	1	0	1	0
(BJ Keighery & N Gibson 20)	Y	1		0	0	0	0	0	0	0	0
Boronia virgata	N	4	360	2	260	0	0	1	100	0	0
	Y	12	1440	8	290	7	650	2	500	0	0
Bossiaea disticha	Y	9		6	0	0	0	2	0	0	0
Calothamnus pallidifolius	Y	16	1226	0	0	15	1226	0	0	0	0
Calytrix pulchella	N	2		0	0	0	0	0	0	0	0
	Y	1		0	0	1		0	0	0	0
Chamelaucium floriferum											
subsp. *floriferum*	Y	6	1000	6	1000	0	0	0	0	0	0
Chordifex gracilior	N	2		0	0	0	0	0	0	1	0
	Y	8	745	3	230	3	515	2	0	0	0
Chorizema carinatum	N	5		2	0	0	0	3	0	0	0
	Y	1		0	0	1		0	0	0	0
Chorizema reticulatum	N	8		1	0	0	0	6	0	0	0
	Y	8	183	1	30	1	0	3	30	0	0
Conospermum	N	1		0	0	0	0	1		0	0
paniculatum	Y	6		0	0	4	0	0	0	0	0
Cyathochaeta stipoides	Y	10		7	0	3	0	0	0	0	0
Darwinia pimelioides	Y	8	375	6	325	0	0	1	0	2	50
Dryandra echinata	N	13	503	3	100	0	0	6	361	5	42
	Y	1		0	0	0	0	0	0	0	0
Dryandra praemorsa var.	N	1		0	0	0	0	0	0	0	0
praemorsa	Y	2		0	0	1	0	0	0	0	0
Dryandra praemorsa var. *splendens*	Y	1		0	0	0	0	1		0	0
Dryandra subpinnatifida var. *imberbis*	Y	1		0	0	1		0	0		0
Eleocharis sp. Kenwick	N	5	1000	1	0	0	0	2	1000	1	0
(GJ Keighery 5179)	Y	3	150	1	0	0	0	0	0	0	0
Eucalyptus brevistylis	Y	7		8	0	2	0	0	0	0	0
Gahnia sclerioides	Y	2		2		0	0	0	0	0	0
Galium migrans	N	8		5	0	0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Gastrolobium brownii	N	4	20	2	0	0	0	1	20	1	0
	Y	8	1074	3	24	5	1050	0	0	0	0
Gonocarpus simplex	Y	14	28750	9	15550	7	13200	0	0	0	0
Gonocarpus trichostachyus	Y	1	200	0	0	1	200	0	0	0	0
Grevillea papillosa	Y	14	1615	9	1190	1	0	4	425	0	0

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Grevillea uncinulata subsp. *florida*	N	2		0	0	0	0	0	0	1	0
	Y	5	526	0	0	0	0	4	118	0	0
Hakea myrtoides	N	2	20	0	0	0	0	0	0	1	0
	Y	17	4493	4	205	0	0	3	15	11	650
Halgania corymbosa	Y	5	30	0	0	1	0	2	0	2	30
Helipterum pyrethrum	N	11	2300	1	0	0	0	3	0	6	1300
	Y	1	300	1	300	0	0	0	0	0	0
Isopogon drummondii	N	29	5126	1	30	0	0	22	1597	20	2816
	Y	2	1484	0	0	0	0	2	1307	0	0
Isopogon formosus subsp. *dasylepis*	N	3		0	0	0	0	0	0	0	0
	Y	7		0	0	0	0	3	0	0	0
Jacksonia sparsa	N	4		1	0	0	0	2	0	0	0
	Y	4		0	0	4	0	0	0	0	0
Jansonia formosa	Y	13	214	7	200	3	0	4	14	1	0
Lambertia multiflora var. *darlingensis*	N	3		0	0	0	0	0	0	1	0
	Y	4		0	0	0	0	1	0	1	0
Lambertia rariflora subsp. *lutea*	Y	7	254	2	0	5	254	0	0	0	0
Lasiopetalum glabratum	Y	14	40	1	0	8	0	2	40	0	0
Lepyrodia heleocharoides	Y	7		0	0	3	0	3	0	0	0
Leucopogon gilbertii	N	1		0	0	0	0	0	0	0	0
	Y	29	2031	2	20	22	1511	2	0	0	0
Lomandra ordii	Y	8	3220	9	2220	3	1000	0	0	1	0
Loxocarya magna	N	1		0	0	0	0	0	0	0	0
	Y	8	40	3	30	1	0	0	0	3	0
Meeboldina crassipes	N	1		0	0	0	0	0	0	0	0
	Y	5		5	0	1	0	0	0	0	0
Meeboldina thysanantha	Y	6		1	0	3	0	0	0	1	0
Melaleuca diosmifolia	N	12	7	5	2	0	0	2	0	1	0
	Y	1	100	1	100	0	0	0	0	0	0
Monotoca leucantha	N	8	2000	4	900	0	0	1	0	2	1100
	Y	1		0	0	0	0	0	0	1	
Myriocephalus appendiculatus	N	5		2	0	0	0	1	0	1	0
	Y	1	50	1	50	0	0	0	0	0	0
Myriophyllum echinatum	N	8	300	4	0	0	0	2		0	0
	Y	1		0	0	0	0	0	0	0	0
Nemcia acuta	N	2	1000	1	1000	0	0	0	0	1	0
	Y	8	152	4	152	0	0	2	0	2	0
Petrophile plumosa	N	4	5250	3	4050	0	0	0	0	2	0
	Y	1	50	1	50	0	0	0	0	0	0
Platysace ramosissima	N	3		1	0	0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Pultenaea pinifolia	Y	5	1200	0	0	4	1200	1	0	0	0
Pultenaea radiata	Y	16	22700	0	0	13	22700	1	0	1	0
Schoenus benthamii	N	2		0	0	0	0	0	0	2	
	Y	1		0	0	0	0	0	0	0	0
Sphenotoma parviflorum	N	1		1		0	0	0	0	0	0
	Y	10	1720	3	1500	7	220	0	0	0	0
Sporadanthus rivularis	Y	14		4	0	9	0	2	0	0	0
Stenanthemum coronatum	N	2	20	0	0	1	0	0	0	0	0
	Y	7	135	1	0	2	30	2	0	0	0
Stenanthemum pumilum	N	2		2		0	0	0	0	0	0
	Y	1		0	0	0	0	0	0	0	0
Stirlingia divaricatissima	Y	5	1100	4	1100	3	0	0	0	0	0
Stylidium barleei	Y	9	300	0	0	7	300	0	0	0	0
Stylidium leeuwinense	Y	8		4	0	1	0	1	0	0	0
	N	4		0	0	0	0	1	0	1	0
Stylidium longitubum	Y	3		2	0	0	0	0	0	0	0
Stylidium mimeticum	N	8		2	0	0	0	2	0	1	0
	Y	10		3	0	0	0	4	0	1	0

cont/...

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Synaphea acutiloba	N	3		0	0	0	0	2	0	0	0
	Y	14		2	0	1	0	4	0	8	0
Synaphea cuneata	Y	1	9	0	0	0	0	1	9	0	0
Synaphea damopsis	Y	2		0	0	1	0	1	0	0	0
Synaphea hians	N	1		0	0	0	0	0	0	0	0
	Y	2		0	0	0	0	0	0	0	0
Synaphea pinnata	N	2	650	1	650	0	0	0	0	0	0
	Y	14	869	3	0	0	0	9	287	20	582
Synaphea preissii	N	5		2	0	0	0	0	0	0	0
	Y	1		1		0	0	0	0	0	0
Synaphea whicherensis	Y	9		0	0	9	0	0	0	0	0
Tetratheca pilifera	Y	6	11	0	0	0	0	2	10	1	0
Thelymitra jacksonii	Y	8	38	3	30	5	8	0	0	0	0
Thysanotus anceps	N	3		2	0	0	0	1	0	0	0
	Y	5	306	2	300	0	0	2	6	0	0
Verticordia huegelii var.	N	1		0	0	0	0	0	0	1	
decumbens	Y	6	50	0	0	4	50	0	0	0	0
Verticordia serrata var.	N	1		0	0	0	0	1		0	0
linearis	Y	3		3		0	0	0	0	0	0

Notes: 1 Population numbers within the different vestings are for subpopulations and may thus sum to more than the total number of populations.
2 Number of plants is that recorded at the last survey, and may be none where specific plant counts were not undertaken (e.g. herbarium collections).

Table 12.12 The occurrence of Priority 4 flora within and outside the Western Australian RFA area and within major land vestings

Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
Acacia clydonophora	N	11	7030	7	1020	0	0	2	10	3	6000
	Y	1	79	0	0	0	0	0	0	1	79
Acacia flagelliformis	N	6	36	1	36	1	0	2	0	1	0
	Y	8	100	0	0	2	0	3	0	1	0
Acacia tayloriana	Y	22	749	0	0	21	668	1	81	0	0
Anthotium junciforme	N	15	814	3	0	0	0	3	343	3	52
	Y	1		1		0	0	0	0	0	0
Asplenium aethiopicum	N	8	20	12	0	0	0	4	20	0	0
	Y	18	264	12	200	13	64	0	0	0	0
Astroloma sp. Nannup (RD Royce 3978)	Y	28	415	0	0	25	232	6	168	2	15
Boronia tenuis	N	4	211	0	0	0	0	3	0	5	211
	Y	13	3372	3	0	4	146	0	0	4	113
Caladenia integra (V)	N	9	2187	5	437	0	0	4	1000	1	750
	Y	3	352	0	0	1	300	0	0	0	0
Caladenia interjacens	N	1	3	1	3	0	0	0	0	0	0
	Y	5		8		0	0	0	0	0	0
Caladenia plicata	N	14	87	8	61	1	10	1	1	1	10
	Y	12	51	1	0	7	31	0	0	1	0
Calothamnus graniticus subsp. *leptophyllus*	N	5	104	0	0	0	0	1	0	2	4
	Y	9	101565	0	0	4	500	0	0	2	100000
Calothamnus rupestris	N	3	30	1	30	0	0	1	0	0	0
	Y	3	5	1	0	2	5	0	0	0	0
Calytrix sylvana	N	8	22609	1	20	0	0	1	150	1	0
	Y	10	1041	3	355	2	200	2	0	2	486
Chamelaucium erythrochlorum (V)	N	1	79	1	27	0	0	1	26	1	26
	Y	7	7177	0	0	8	6177	1	1000	1	0
Conospermum undulatum	N	14	6829	0	0	0	0	11	1071	32	3640
	Y	1	2585	0	0	0	0	2	2035	0	0
Conostephium minus	N	21	221	5	0	4	0	1	0	9	174
	Y	1		1		0	0	0	0	0	0
Darwinia thymoides subsp. St Ronans (JJ Alford & GJ Keighery 64)	Y	1	25	1	25	0	0	0	0	0	0
Daviesia microphylla	N	7	16	3	11	0	0	4	5	0	0
	Y	33	1663	41	1263	1	400	0	0	0	0
Drosera marchantii subsp. *marchantii*	N	9	330	0	0	0	0	1	0	4	300
	Y	5	38	0	0	1	0	0	0	0	0
Drosera occidentalis	N	13	23320	0	0	0	0	7	2257	5	20810
	Y	14	26081	6	15759	5	322	2	10000	1	0
Dryandra polycephala	N	4		2	0	0	0	0	0	0	0
	Y	11	29218	1	3000	4	25000	1	66	2	132
Eucalyptus aspersa	N	6	332	0	0	1	15	3	38	5	279
	Y	25	1119	5	718	16	310	1	0	0	0
Eucalyptus exilis	N	16	57	14	0	0	0	2	8	7	49
	Y	2	85	1	40	1	45	0	0	0	0
Eucalyptus latens	N	17	218	6	106	7	0	3	11	1	80
	Y	6	1594	0	0	4	1400	0	0	0	0
Grevillea cirsiifolia (V)	N	3		0	0	0	0	0	0	0	0
	Y	36	7329	6	207	32	6767	2	251	0	0
Grevillea drummondii	N	4	51	2	0	0	0	2	50	3	0
	Y	19	3276	1	50	17	2528	1	150	2	0
Grevillea pimeleoides	Y	4	80	3	50	0	0	0	0	0	0
Microtis media subsp. *quadrata*	N	1		1		0	0	0	0	0	0
	Y	1	20	0	0	0	0	0	0	1	20
Microtis pulchella	N	2		2		0	0	0	0	0	0
	Y	2	100	1	0	0	0	1	100	0	0
Reedia spathacea	Y	15	500	7	100	6	400	1	0	0	0
Rinzia crassifolia	N	3		0	0	0	0	0	0	0	0

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Species name (ESP status)	RFA	Total Pops	Total Plants	NPNCA Pops	NPNCA Size	LFC Pops	LFC Size	Shire Pops	Shire Size	Private Pops	Private Size
	Y	2		0	0	0	0	1	0	0	0
Senecio leucoglossus	Y	10	21	1	10	5	0	1	1	2	0
Stylidium scabridum	N	5	77	2	35	0	0	1	20	2	12
	Y	6	719	0	0	8	719	0	0	0	0
Templetonia drummondii	Y	7	3	2	0	0	0	2	3	2	0
Thysanotus glaucus	N	8		4	0	0	0	2	0	0	0
	Y	3		0	0	1	0	2	0	0	0
Tripterococcus brachylobus	N	1		1		0	0	0	0	0	0
	Y	2		1	0	1	0	0	0	0	0
Tyrbastes glaucescens	Y	30	1030	10	1030	13	0	1	0	4	0
Verreauxia verreauxii (V)	N	1	10	0	0	0	0	0	0	1	10
	Y	27	12584	2	53	42	12531	0	0	0	0
Verticordia lindleyi subsp.	N	25	13072	7	10375	0	0	7	70	11	2347
lindleyi	Y	1		0	0	0	0	1		0	0
Verticordia lindleyi subsp.	N	13	4532	1	0	0	0	10	758	1	15
purpurea	Y	3	0	1	0	0	0	1	0	0	0
Verticordia multiflora subsp.	N	8	1150	2	0	0	0	4	1150	0	0
multiflora	Y	1		1		0	0	0	0	0	0
Villarsia submersa	N	13	4145	3	4000	0	0	3	6	5	85
	Y	8	8350	2	3050	2	5300	0	0	2	0

Notes: 1 Population numbers within the different vestings are for subpopulations and may thus sum to more than the total number of populations.
2 Number of plants is that recorded at the last survey, and may be none where specific plant counts were not undertaken (e.g. herbarium collections).

12.7 FAUNA SPECIES ASSESSMENT

Introduction

The South-West Forest Region consists of a comparatively uniform forested landscape quite unlike the deeply incised and varied landscapes of eastern Australia. As a consequence of this uniformity, the forests of the south-west are depauperate in faunal diversity when compared to eastern forests. Species generally tend to occur broadly across the landscape. However this apparent homogeneity does not necessarily apply at the local level, where the distribution of fauna is affected by factors such as the diversity of understorey flora, soil moisture, rainfall, variations in relief and the presence of fire as a regular feature in the landscape.

The geological history of this landscape has greatly influenced the development of the fauna, supporting endemic species unique to the south-west such as the sunset frog (*Spicospina flammocaerulea*) and allowing the persistence of elements of terrestrial and aquatic Gondwanic invertebrates such as the mygalomorph spiders in small refugia where favourable environmental conditions have been maintained. Even fire, unquestionably one of the most defining elements of the south-west forests, has occurred as a mosaic across the landscape, producing a biota well-adapted to fire but also conversely, enabling the persistence of such relictual species in small, protected refugia in the landscape such as within the tingle forests. The south-west forests also represent refugia for a number of once widespread critical weight-range vertebrate species that have contracted south-westwards into the forest environment. For example, the numbat and chuditch were once widespread species in the arid and semi-arid regions of Australia and following their decline, Perup and similar areas represent important refugia in historical times for critical weight range species.

The hydrological systems the South-West Forest Region are complex. The region is characterised by short coastal rivers with greatly fluctuating flow rates and water levels, and a large number of permanent or ephemeral water bodies, including lakes and flats. The presence of palaeodrainage features forming swamps, and relict landscape features such as granite monadnocks where seasonal but important pools form, are examples of particular but important aquatic habitats in the south-west. Cave root-mat communities and tumulus springs are examples of sensitive microhabitats in the region.

The aquatic vertebrate fauna of the south-west is depauperate in comparison with eastern Australia, with 10 naturally-occurring native species of fish. There is a high level of endemism, with eight of the 10 species being endemic. At least one species is known to be migratory. The number of aquatic invertebrate species in the region is unknown and adequate distributional information exists for only

a few of these. Many of the known aquatic invertebrates are highly endemic, some being entirely restricted to a particular wetland, tumulus spring or cave root-mass community (Horwitz et al. 1997).

Data acquisition

Data acquisition for the assessment of fauna species biodiversity was directed towards those data which met reasonable standards of accuracy, precision and reliability and could be captured within the assessment timeframe. Metadata statements were compiled for all potential data sources as part of the biodiversity data review.

The biodiversity data review indicated that the capture of unpublished and published information on highly restricted primitive, relictual and endemic invertebrate and amphibian species in the RFA region would provide key data for the biodiversity assessment. This work was undertaken for the Comprehensive Regional Assessment.

It was also recognised that analysis of fauna data in the South-West Forest Region would be severely restricted by the absence of an amalgamated fauna database and the absence of systematic widespread survey across the RFA region. No extensive terrestrial fauna studies of the entire region have been undertaken. A limited number of studies of varying intensity has been completed over sub-units of the region, primarily in association with land-use changes such as dam construction, forest management and mining, or studies of particular taxa. One of the limitations to extensive faunal surveys in the region is that there are significant areas, notably in the south, where access is seasonally restricted by climatic events.

Several regional surveys for various groups have been undertaken, but to date no coordinated effort has been made to survey systematically the aquatic habitats and associated fauna of the region. Surveys of aquatic invertebrates in the south-west forests have been conducted by the Water and Rivers Commission and various research institutions, but much of the region has not been adequately sampled.

Gaps also exist in fish information for the South-West Forest Region as a result of the limited systemic survey data (although this is better than is available for many taxonomic groups) and the limited knowledge of life history, population characteristics and disturbance processes affecting species.

The taxonomy, distribution and ecology of aquatic invertebrates occurring in the south-west is generally poorly understood. Few species were able to be assessed because of the absence of sufficient data. This indicates a need for additional capture of available data and for further taxonomic and survey work on aquatic invertebrates.

Development of fauna database

A major component of the fauna assessment was the compilation of such data as could be gathered within a reasonable timeframe and its amalgamation into a relational fauna database.

The assessment of vertebrate and invertebrate fauna for the south-west forests used data and expertise from a range of sources, including the Western Australian Museum, CALM, other government agencies, industry, research institutions and consultants.

The database constructed for the CRA was the first large scale fauna database ever compiled for a wide range of taxonomic groups in Western Australia. Due to the time constraints for the process, bird data capture targeted 27 significant bird species including listed species (under Schedule 1 of the Commonwealth *Endangered Species Protection Act* or the Western Australian *Wildlife Conservation Act*) or species potentially sensitive to disturbances, such as fire or the removal of hollow trees. The other terrestrial vertebrate groups were considered in their entirety, based largely on museum records. Only a small proportion of the known terrestrial invertebrate taxa was captured. A database was compiled from Western Australian Museum records on freshwater crustacea. A database on fish of the south-west was drawn from Morgan et al. (1996) which yielded 886 records for the area between Busselton and Walpole. This work included survey work on fish taxa and data from past surveys conducted in the area. No other fish data were able to be used in the assessment.

The amalgamation of captured records yielded 63 710 vertebrate records across 286 selected taxa and 12 981 invertebrate records across 610 selected taxa. These records comprise a large number of validated historical records across the period 1830 to 1997, but very little data from formal systematic regional surveys. The data capture of relict and endemic invertebrate and amphibian taxa yielded 380 additional records.

A number of other data sources exist for the study region but these data could not be captured for the CRA due to problems with access, scale, validation or reliability.

While the compilation of this database is a significant achievement, its limitations are recognised. In brief, these are:

- the large number of incidental records and consequent strong bias in the data that is dependent on land use, access and observer bias;
- time constraints on data capture which introduced a bias towards easily captured records and effectively excluded a number of non-digital datasets that could not be captured within the time frame; and
- an absence of presence/absence records outside mining company records which places a strong reliance on incidental observation and limits the usefulness of modelling.

The primary sources of data used in the study were:

- pre-disturbance fauna surveys conducted by the mining companies Alcoa of Australia and Worsley Alumina;
- vertebrate fauna databases compiled by CALM;
- a regional study of south-western fishes conducted by Murdoch University in association with the Water and Rivers Commission;
- Glenn Storr Bird Database, captured by the Western Australian Museum;
- CSIRO cockatoo study for the south-west region;
- Birds Australia (RAOU) database for Western Australia;
- selected vertebrate and invertebrate records from the Western Australian Museum;
- dam sites fauna studies conducted by Water and Rivers Commission; and
- miscellaneous other studies provided by university researchers.

The data review and development of the integrated fauna database for the CRA indicate a need for comprehensive and systematic fauna sampling across the assessment region.

Validation of data records

The database was validated and audited using ARCVIEW and the Data Audit Management Toolkit (DAM) software supplied by Environment Australia (Bennet et al. 1997). Geocoding errors were removed during this process and the database restricted to records within the RFA boundary. Taxonomic anomalies and inconsistencies were resolved or removed. Vagrant or anomalous records, defined as species records outside known or accepted distribution ranges, were also removed or resolved.

Auditing revealed the lack of meaningful presence/absence data derived from systematic survey for anywhere in the region outside areas of interest to aluminium companies and a longer-term museum study through the extreme south of the assessment area. Presence-only data biases analysis towards sampling sites. For example, the aluminium company areas appear as species-rich areas, where in fact this is actually an artefact of the intensity of sampling in this area and the comparative lack of sampling elsewhere. Effectively, this means that subsequent fauna modelling and distribution mapping which rely heavily on incidental sightings are limited by the lack of validation to demonstrate that species do or do not occur where they have not been recorded.

Species attribution

Following data validation, the database was attributed for values that would allow species to be prioritised for modelling and inclusion in further analyses taking into account JANIS and national estate criteria. Species were considered on the basis of the following characteristics:

- known core distribution (e.g. core distribution in forested areas);
- relictual characteristics (e.g. species shows primitive characteristics);
- conservation status (e.g. State or federally-listed species or known restricted occurrence);
- distribution (e.g. degree of disjunction or continuity across species range);
- phylogenetic distinctiveness (e.g. unique taxa at species, genus or family level); and
- endemism (degree to which species was restricted to the RFA area).

Species were given a numerical ranking on each of the above characteristics. All species demonstrating high values for the above traits (i.e. forest distribution, highly relictual, high conservation status etc.) were mapped. It is important to recognise that the list of taxa available for consideration was incomplete and particularly poor for invertebrates, the group with the most restricted relict and endemic taxa to the south-west. Further work to identify JANIS target taxa would assist in developing biodiversity strategies for the region.

Taxa of conservation significance

Attribution of vertebrate taxa and selected terrestrial taxa allowed a ranking of species for analysis to highlight the species considered by experts to be of high conservation significance with reference to JANIS target groups and national estate values. This ranked list was validated by experts working with the relevant taxonomic group. Species were ranked by vulnerability (highest to lowest) as follows:

1. Major population declines and/or range reductions impacting on conservation status.
2. Species with naturally restricted ranges, specific habitat requirements or general population/range reductions.
3. Species with somewhat restricted ranges or species with broad ranges but only occupying limited number of habitats.
4. Widespread species but endemic forest species dependent on a general but widespread resource e.g. tree hollows.
5. Widespread species not dependent on, but using some forest resources.

The vertebrate fauna listed under State or Commonwealth legislation, or identified by the experts as of conservation priority according to these criteria, included 20 mammal species, 28 bird species, 19 frog species, 22 reptile species, 21 mollusc species, five spider species and eight aquatic invertebrate species. These species are listed in Table 12.13.

Table 12.13 Ranking of fauna taxa for the CRA biodiversity assessment

Scientific name	Common name	Code[1]	Priority[2]
Mammals			
Dasyurus geoffroii	Chuditch	3	1
Macropus eugenii	Tammar wallaby	2	1
Setonix brachyurus	Quokka	2	1
Myrmecobius fasciatus	Numbat	3	1
Bettongia penicillata	Brush-tailed bettong	3	1
Pseudocheirus occidentalis	Western ringtail possum	3	1
Antechinus flavipes	Mardo		2
Phascogale calura	Red-tailed phascogale	3	2
Phascogale tapoatafa	Brush-tailed phascogale		2
Sminthopsis gilberti	Gilbert's dunnart		2
Sminthopsis griseoventer	Grey-bellied dunnart		2
Macropus irma	Western brush wallaby		2
Isoodon obesulus	Quenda	2	2
Hydromys chrysogaster	Water rat		2
Falsistrellus mackenziei	Western false pipistrelle		2
Nyctophilus gouldi	Gould's long-eared bat		2
Cercatetus concinnus	Western pygmy possum		3
Rattus fuscipes	Bush rat		3
Trichosurus vulpecula	Brushtail possum		3
Tarsipes rostratus	Honey possum		3
Birds			
Cacatua pastinator pastinator	Western corella	3	1
Calyptorhynchus banksii naso	Red-tailed black-cockatoo		1
Calyptorhynchus baudinii	Long-billed black-cockatoo	2	1
Calyptorhynchus latirostris	Short-billed black-cockatoo	2	1
Ninox connivens	Barking owl		1
Calyptorhynchus baudinii/latirostris	White-tailed black-cockatoo	2	1
Climacteris rufa	Rufous treecreeper		2
Coturnix ypsilophora	Brown quail		2
Falcunculus frontatus leucogaster	Crested shrike-tit		2
Leiopoa ocellata	Malleefowl	3	2
Lophoictinia isura	Square-tailed kite		2
Stagonopleura oculata	Red-eared firetail		2
Stipiturus malachurus westernensis	Southern emu-wren		2
Eopsaltria georgiana	White-breasted robin		3
Malurus elegans	Red-winged fairy-wren		3
Phaps elegans	Brush bronzewing		3
Polytelis anthopeplus westralis	Regent parrot		3
Turnix varia varia	Painted button-quail		3
Tyto novaehollandiae	Masked owl		3
Ninox novaeseelandiae	Southern boobook		4
Pardalotus striatus	Striated pardalote		4

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Scientific name	Common name	Code[1]	Priority[2]
Platycercus icterotis	Western rosella		4
Platycercus spurius	Red-capped parrot		4
Barnardius zonarius	Australian ringneck		5
Falco peregrinus	Peregrine falcon	2	5
Neophema elegans	Elegant parrot		5
Tyto alba	Barn owl		5
Dacelo novaeguineae	Laughing kookaburra		
Frogs			
Geocrinia alba	White-bellied frog	3	2
Geocrinia lutea	Nornalup frog	2	2
Geocrinia vitellina	Yellow-bellied frog	3	2
Heleioporus barycragus	Western marsh frog		2
Spicospina flammocaerulea	Sunset frog		2
Crinia subinsignifera	Squelching frog		3
Geocrinia rosea	Roseate frog		3
Heleioporus inornatus	Plain frog		3
Heleioporus psammophilus	Sand frog		3
Metacrinia nichollsi	Nicholl's frog		3
Myobatrachus gouldii	Turtle frog		3
Litoria adelaidensis	Slender tree frog		4
Litoria moorei	Motorbike frog		4
Crinia georgiana	Quacking frog		4
Crinia glauerti	Galuert's froglet		4
Crinia pseudinsignifera	Bleating froglet		4
Geocrinia leai	Lea's frog		4
Limnodynastes dorsalis	Banjo frog		4
Pseudophryne guentheri	Guenther's toadlet		4
Reptiles			
Morelia spilota imbricata	Carpet python	2	1
Egernia luctuosa	Skink		1
Ctenotus delli	Skink		2
Egernia pulchra	Skink		2
Elapognathus minor	Short-nosed snake		2
Rhinoplocephalus bicolor	Square-nosed snake		2
Ctenophorus ornatus	Dragon		3
Egernia kingii	Skink		3
Glaphyromorphus gracilipes	Skink		3
Lerista microtis	Skink		3
Ramphotyphlops pinguis	Blind snake		3
Suta nigriceps	Snake		3
Acritoscincus trilineatum	Skink		4
Aprasia puchella	Worm lizard		4
Ctenotus labillardieri	Skink		4
Diplodactylus polyophthalmus	Skink		4
Hemiergis initialis	Skink		4
Hemiergis peronii tridactyla	Skink		4
Lerista distinguenda	Skink		4
Oedura reticulata	Gecko		4
Suta gouldii	Snake		4
Underwoodisaurus milii	Barking gecko		4
Snails (molluscs)			
Bothriembryon indutus	Land snail		2
Bothriembryon sp. nov. "Boddington"	Land snail		2
Bothriembryon fuscus	Land snail		2
Bothriembryon revectus	Land snail		2
Bothriembryon sp. nov. "Augusta"	Land snail		2
Bothriembryon sp. nov. "Denmark B"	Land snail		2
Bothriembryon sp. nov. "Nannup"	Land snail		2
Bothriembryon sp. nov. "Pt D'Entrecasteaux"	Land snail		2
Bothriembryon leeuwinensis	Land snail		3
Bothriembryon sayi	Land snail		3
Bothriembryon serpentinus	Land snail		3
Bothriembryon sp. nov. "Manjimup"	Land snail		3
Bothriembryon sp. nov. "SW Caves"	Land snail		3
Bothriembryon brazieri	Land snail		4
Bothriembryon jacksoni cf.	Land snail		4

cont/...

Scientific name	Common name	Code[1]	Priority[2]
Bothriembryon naturalistarum	Land snail		4
Bothriembryon bulla	Land snail		5
Bothriembryon jacksoni	Land snail		5
Bothriembryon kendricki	Land snail		5
Bothriembryon kingii	Land snail		5
Westralunio carteri	River and lake mussel	2	Not ranked
Spiders (Arachnids)			
Aganippe rhapiduca	Spider		Not ranked
Ambicodamus marae	Spider		Not ranked
Cercophonius sulcatus	Spider		Not ranked
Urodactus planimanus	Spider		Not ranked
Cormocephalus hartmeyeri	Spider		Not ranked
Acarines (water-mites)			
Pseudohydraphantes doegi	Doeg's water-mite	2	Not ranked
Acercella sp.	Poorginup Swamp water-mite	2	Not ranked
Copepods			
Fibulacamptus bisetosus		2	Not ranked
Calamoecia elongata		2	Not ranked
Cladocerans (water-fleas)			
Daphnia occidentalis		2	Not ranked
Ostracods (seed shrimps)			
Limnocythere porphyretica		2	Not ranked
Decapods (shrimps and crayfish)			
Cherax tenuimanus Engaewa sp.	Margaret River marron	2	Not ranked
(WAM 182-94)		2	Not ranked

Notes: 1 The following codes apply:
Code 1 Commonwealth *Endangered Species Protection Act 1992*
Code 2 State-declared species in Western Australia
Code 3 Listed on State and Commonwealth lists
2 See priority listings on page 148

Point distribution maps were produced electronically on ARCVIEW for all species ranked above five in the database and for the captured relict and endemic invertebrates and amphibians. National estate values are addressed in the National Estate report, to be available separately. The point distribution maps were used to conduct additional validation work. Historical records were included in the database in recognition of the significance of decline that has occurred in many mammal and bird species in Western Australia.

None of the 10 native freshwater fish species recorded from the South-West Forest Region is listed under endangered species legislation at State or federal level. Four species however, are on the list of threatened Australian fish complied by the Australian Society for Fish Biology. A report by Horwitz et al. (1997) also identifies a further five species as of conservation significance.

A total of 21 of the aquatic invertebrate species known from the south-west was identified as being restricted, vulnerable, rare or threatened in Western Australia. It is recognised that additional research and survey work is likely to add further taxa to this list.

Horwitz et al. (1997) have identified a range of aquatic species which they consider falls within JANIS target groups, although these species are not listed under State or Commonwealth legislation. These species are listed in Table 12.14.

Table 12.14 Aquatic fauna species occurring in the South-West Forest Region and listed in the Australian Society of Fish Biology's list of threatened fish or identified by Horwitz et al. (1997) as species of conservation significance

Species name	Common name	Conservation status
Fish		
Lepidogalaxias salamandroides	Salamander fish	Restricted, well conserved
Galaxiella nigrostriata	Black-striped minnow	Restricted, well conserved
Nannatherina balstoni	Balston's pygmy perch	Restricted, well conserved
Galaxiella munda	Western mud minnow	Restricted
Edelia vittata	Western pygmy perch	
Galaxias occidentalis	Western minnow	
Bostockia porosa	Nightfish	
Tandanus bostocki	Freshwater cobbler	
Geotria australis	Pouched lamprey	
Molluscs (mussels and snails)		
Austroassiminea letha	Cape Leeuwin freshwater snail	Restricted, primitve
Crustacea (general)		
Kapcypridoopsus asymmetra		Restricted
Protorcangonyx frontinalis		Restricted
Totgammarus eximius		Restricted
Insecta (general)		
Kosrheithrus boorarus		Restricted
Oligochaeta (general)		
Astacopsidrilus novus		Restricted
Amphipods		
Uroctena whadjukia		Restricted
Uroctena yellandi		Restricted
Acarines (water-mites)		
Larri laffa		Restricted, relict
Notoaturinae gen. nov.		Restricted, relict
Tartarothyas sp. nov.		Restricted, relict
Tillia davisae		Restricted, interstitial
Penemideopsis pusilla		Restricted, interstitial
Copepods		
Boeckella geniculata		Restricted
Cladocerans (water-fleas)		
Biapertura imitatoria		Restricted
Calanoida		
Hemiboeckella powellensis		Restricted
Ostracods (seed shrimps)		
Ilyodromus candonites		Restricted
Decapods (shrimps and crayfish)		
Cherax glaber		Restricted
Engaewa subcoerulea		Restricted
Engaewa reducta		Restricted
Engaewa sp. nov. 1		Restricted
Engaewa sp. nov. 2		Restricted
Odonatans (damselflies and dragonflies)		
Petalura hesperia	W. Petalura dragonfly	Restricted
Plecoptera (stoneflies)		
Dinotoperla sp.		Undescribed, restricted

Note: The conservation status classifications are defined as:
Well conserved = species well represented in reserves
Restricted = species known from a single location or a geographically confined area
Primitive/relict = see National Estate Report

The aquatic communities of the south-west contain most of the features suggested by Hopper et al. (1996) as being important for the endurance of relict and primitive species, and recent work shows the high levels of occurrence of such taxa in aquatic environments in the region (Horwitz et al. 1997). Cave root-mats, tumulus springs and wetlands all possess communities sensitive to microchanges in their environment and indirect disturbances, such as lowering of water-flows. Horwitz et al. (1997) have highlighted aquatic communities that in their view require protection. These are:

- tumulus springs (organic mound springs)—Perth to Gingin*;
- aquatic root-mat communities—Leeuwin-Naturaliste ridge*;
- *Baumea* wetlands—Lake Muir system, southern jarrah forest; and
- relictual peat community—Lake Surprise.

(* entered on CALM's Threatened Ecological Communities database and assessed as critically endangered)

The importance of monadnocks is recognised in providing surface pools and wetlands around their bases as habitat for a poorly understood but potentially important group of macroinvertebrates. Horwitz et al. (1997) have suggested that headwater aquatic environments in the region in good condition are potential refuges for Gondwanic relicts.

Species habitat modelling

Species modelling was attempted for all terrestrial vertebrate fauna groups. Only records with a geocoding accuracy of nine seconds were included for mammals and birds. A geocoding accuracy of one minute was accepted for amphibians and reptiles because of the insufficient number of records with higher resolutions.

Modelling was based on presence only data because of the high number of incidental records. Modelled outputs were examined by a panel of experts in the relevant taxa group. Of the 100 modelled distributions attempted, 24 vertebrate taxa yielded acceptable models, of which eight were for species ranked highly for conservation significance.

Although these models were regarded as acceptable, the predicted distributions were modelled at such a low probability of occurrence that the results must be interpreted with caution. Consequently, the point distribution data are considered more appropriate than the modelled distributions for use in subsequent analyses.

Species richness modelling

It was concluded that the available data for fauna were inadequate for species richness modelling, both in terms of point distribution and modelled outputs.

Species vulnerability

Indices of vulnerability in terms of broad conservation status, prepared in consultation with experts in the various taxonomic groups, were used in attribution and ranking species for analysis. This attribution is discussed under 'Taxa of conservation significance' above.

Responses to disturbance

Christensen (1997) has prepared a report for the CRA which reviews the current state of knowledge on the impacts of disturbance on vertebrate terrestrial species in the South-West Forest Region. Majer and Heterick (1997) and Horwitz et al. (1997) have prepared similar reports dealing with terrestrial invertebrates and fish and aquatic invertebrates respectively. Disturbances considered include fire, timber harvesting, mining and quarrying, agricultural clearing, dams, pest control, grazing, disease, recreation, predation and competition by introduced species, dams, groundwater extraction and waste disposal.

These reports are the initial stage in the identification of potentially threatening processes. They are available on request, and will be considered by Governments in developing the Regional Forest Agreement for Western Australia.

Endangered, rare and threatened fauna

The current list of nine species listed on Schedule 1 and 2 of the Commonwealth *Endangered Species Protection Act 1992* was reviewed to determine whether recovery plans or were in place or in

preparation, or whether specific conservation management actions being implemented for their protection. The status of recovery plans for these species is shown in Table 12.15.

Table 12.15 Status of recovery plans for fauna species listed under the Endangered Species Protection Act

Species	Scientific name	Recovery plan prepared?
White-bellied frog	*Geocrinia alba*	Yes
Malleefowl	*Leipoa ocellata*	No
Woylie	*Bettongia penicillata*	Yes
Chuditch	*Dasyurus geoffroii*	Yes
Numbat	*Myrmecobius fasciatus*	Yes
Western ringtail possum	*Pseudocheirus peregrinus*	In preparation
Orange-bellied frog	*Geocrinia vitellina*	Yes
Long-billed corella	*Cacatua pastinator pastinator*	No
Crested shriketit	*Falcunculus frontatus leucogaster*	No

Formal recovery plans have only been written for the six species listed in Table 12.15. The preparation of interim recovery plans will be addressed in the implementation of the RFA.

There are currently 18 listed vertebrate species relevant to the RFA which are declared as rare or threatened under the Western Australian *Wildlife Conservation Act 1950*. Eleven invertebrate species that occur in or near the RFA region are also declared as rare or threatened under the Act. CALM takes these species into account in the course of management activities.

12.8 SOILS AND LANDFORMS

Introduction

An understanding of geomorphology, soils and landforms is relevant to several aspects of the Comprehensive Regional Assessment. Maps of soils and landforms are an important foundation layer for the assessment of biodiversity and an aid to vegetation mapping, particularly in forest types where floristic differences are not reflected in the structure of the vegetation and are thus not capable of being mapped from aerial photographs. Maps of soils and landforms have been used as a basis for vegetation mapping in the south-west region (Heddle 1979; Wardell-Johnson et al. 1995).

Previous soils and landform maps

According to Mattiske (1997) the earliest mapping of geomorphological units began in the 1920s and 1930s (Clarke 1926, Jutson 1934). The main relevant development began in the agricultural areas (Mulcahy et al. 1961), and then in the forested areas (Mulcahy et al. 1972, Finkl 1976). It was at this stage that the linkages between geomorphology and plant ecology were developed through mapping of vegetation over a range of geomorphic units. The geomorphological mapping was extended by McArthur et al. (1977) to the Murray catchment and by Churchward and McArthur (1980) to the entire forested region north of the Blackwood River.

McArthur and Clifton (1975) extended the geomorphological mapping to the south coast near Pemberton, dealing not only with geomorphology, but also with vegetation and land use. Their work was subsequently expanded by Churchward et al. (1988) to cover the bulk of the south coast from Northcliffe to Mt Manypeaks.

Parallel to the work of the CSIRO Division of Land Resources by Mulcahy, McArthur and Churchward, a Land Resources Series was begun by Agriculture Western Australia which helped in filling in some of the gaps in geomorphological mapping. Initially the latter mapping did not include areas of State forest. The areas mapped were the Darling Range, east of Perth (King and Wells 1990) and the Northam region (Lantzke and Fulton 1992). In the southern region, Tille and Lantzke surveyed the Busselton-Margaret River-Augusta area in 1990. The last study of Churchward in Manjimup (1992) formed part of this series. There have been minor differences in the approach from the CSIRO and Agriculture Western Australia researchers, nevertheless both approaches have provided valuable linkages between geomorphology and vegetation.

Methods

Soil and landform mapping project for the CRA

A project was undertaken for the CRA to complete soil and landform mapping in all unmapped areas and to provide a single seamless map for the entire RFA region. Resources were provided to Agriculture WA to accelerate the current mapping program in areas within the RFA region boundary. All existing soil and landform maps were collated and standard descriptions prepared. Boundaries between all of the new and previous survey map sheets were rationalised and edge mapped to derive a single map for the region.

Results

A comprehensive digital map of soils and landforms has been completed for the entire RFA region. There are more than 200 landform and soil units in 27 groups within the region.

12.9 MAPPING OF REMNANT VEGETATION COVER ON PRIVATE LAND

The aim of the project was to provide a map of the extant forest and woodland vegetation derived from Landsat Thematic Mapper satellite data captured in 1990 and 1995 covering the South-West Forest Region of Western Australia. The output will be used in the integration phase of the Western Australian RFA to provide base data for identification of forest and woodland on private lands for the calculation of reservation targets.

The first phase of the project was contracted and completed by CSIRO Mathematics and Information Sciences using a method developed by the Western Australian Department of Land Administration and Agricultural Western Australia for a Commonwealth funded project, "Monitoring Agricultural Land Cover Change". In brief, the method involves image rectification and calibration to pseudo-reflectances. A statistical analysis is used to define spectral indicators of woody vegetation. A final map is produced to highlight the woody versus non-woody extents and thus a strategic picture of the spatial extent of remnant vegetation.

Subsequent analysis removed plantations and public land from the database to derive remnant native vegetation on private land. Patches of vegetation less than 25 hectares in area were also removed from the dataset to simplify the analysis.

No field validation or direct forest ecosystem attribution of this information has been possible. While it is expected that the technique will provide good estimates of tree cover it is unable to detect the condition of the understorey within these stands. The data will therefore include significant areas which consist of native tree cover over exotic pasture. Extensive field work would be required to determine the extent of this condition, particularly given the variable nature of past management of these private lands.

Attribution of the remnant vegetation native vegetation to a forest ecosystem was done using the statistical relationship that exists for forest ecosystems (mapped on public land only) and vegetation complexes and extrapolating to the remnant native vegetation on private land (for which vegetation complex mapping has been done). The method is similar to that used to estimate pre-1750 area of forest ecosystems described in more detail elsewhere in this report. The exception to this method was that used for karri forest which had previously been mapped directly on all lands.

The estimated area of remnant native vegetation on private property in the South-West Forest Region is 350 649 hectares (see Table 12.3 and Map 13).

12.10 HISTORICAL FIRE FREQUENCY

Introduction

Fire is an important agent of disturbance in the South-West Forest Region. To gain an improved understanding of the fire regimes that the biota of the region has been subjected to, this project sought to reconstruct fire frequency over the past 200 years by analysing grasstree stems.

Methods

Grasstree stems (*Xanthorrhoea* spp.) were cleaned to reveal coloured annual growth rings and bands of darkly pigmented leafbases that are observed where fires are known to have occurred in recent times. From the frequency of these dark bands in former times, an implied fire history can be reconstructed as far back as 1750. It has been shown that the technique can reconstruct fire history accurately for sites where the recent fire history is known, for example on farms, where living members of the family can verify fire history from the 1920s to the present (Ward in press).

A stratified random survey design was proposed, involving 36 sites throughout the jarrah forest. These sites were to cover different landforms, rainfall zones and vegetation types. At each site the aim was to sample at least two grasstrees, but more if possible, so giving a sample size of at least 72 grasstrees. Both tall and short grasstrees were to be sampled at each site to test the hypothesis that fires may pass under tall grasstrees without igniting them, so giving an underestimate of fire frequency.

Some chemical analysis was proposed to determine the nature of the dark pigment and its possible genesis, and also to determine if there was a link between fires and subsequent changes in nutrient and trace element levels in the stem of the grasstrees.

Results

The search for sample sites was constrained by the rarity of tall grasstrees in good condition. Eventually 50 sites were found and 150 grasstrees were cleaned and recorded, giving a data matrix of 1548 decades of record. The height of these grasstrees ranged from 0.6 to 4.3 metres, and the aim of at least one tall and one short grasstree at each site was achieved. Annual rainfall at the study sites ranged from 680mm to 1390mm. About half the sites were in the southern jarrah understorey community, and half in the northern type. It proved impossible to achieve a balanced number of sites on ridges, midslopes and valleys, since grasstree occurrence is strongly biased toward valleys.

A multiple regression was used as an initial test of the effect of annual rainfall on fire frequency over the past two centuries. This was intended only as a test of hypothesis and not as a prediction tool. This is a preliminary analysis and more sophisticated analyses may be possible, but will take more time than was available for this preliminary report.

Fires tended to be more frequent at study sites in the lower rainfall zones, and taller grasstrees (at the time of the fire) tend to give a lower estimate of fire frequency. No simple relationship with understorey community or landform was found.

Fires/decade = 23.8 minus 0.0014 rainfall (mm) minus 0.685 height (m) minus 0.0103 decade

N = 1548, F – 398, $p<0.001$, R-squared = 43.5%

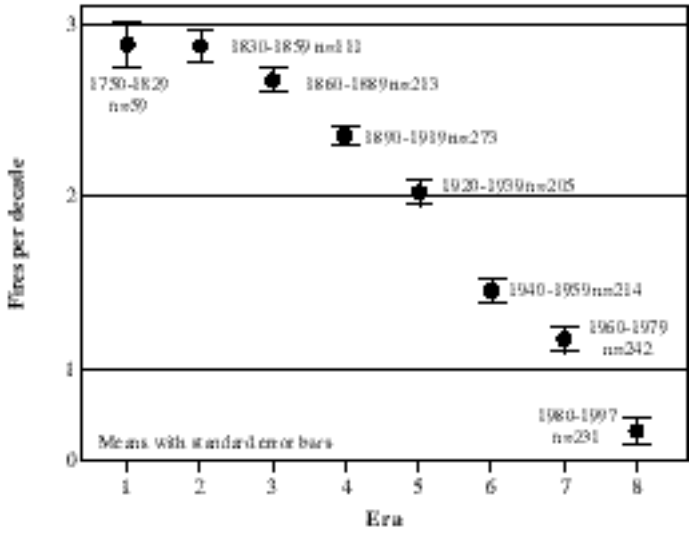
The data were grouped into eight historical eras, shown below with brief reasons for the selection of that era:

1. 1750-1829—pre-European era, fires from lightning and Noongar burning
2. 1830-1859—early settlement, with traditional Noongar burning still common
3. 1860-1889—decline in Noongar population
4. 1890-1919—uncontrolled logging with severe wildfires
5. 1920-1939—attempted fire exclusion by Forests Department, but severe wildfires
6. 1940-1959—World War II and post-war period
7. 1960-1979—introduction of controlled burning after Dwellingup fire
8. 1980-1997—recent

Figure 12.1 shows the pattern of fire frequency as far back in time as 1750, as interpreted from the black marks on stems of grasstrees. In the pre-European era, there appears to have been about 3 fires per decade. This same frequency of fire appears to have continued in the era of early settlement by Europeans. In the period 1860-1889, a drop in fire frequency is apparent, with an average of about 2.7 fires per decade.

The pattern of declining fire frequency appears to continue right through to the present era. In the period 1890-1919 average fire frequency appears to have been about 2.4 fires per decade; in 1920-1939 average fire frequency appears to have been about 2 fires per decade, in 1940-1959 average fire frequency appears to have been about 1.4 fires per decade; in 1960-1979 average fire frequency appears to have been about 1.2 fires per decade; and in 1980-1997 average fire frequency appears to have been about 0.6 fires per decade.

Figure 12.1 Fire frequency at 50 sites in the jarrah forest as interpreted from black marks on the stems of grasstrees



Although the standard errors shown in Figure 12.1 are small, there is considerable variation of the individual observations about the mean. Table 12.17 aids in understanding the variation in apparent fire frequency, and its implications for the fire regime of that era.

Table 12.16 Comparison of implied Aboriginal and recent fire regimes in jarrah forest

Frequency (fires per decade)	% of fires from 1750-1829	% of fires from 1980-1997
<1	0	49.4
1	5.1	45.8
2	15.3	4.8
3	64.4	0
4+	15.3	0

From Table 12.17, it appears that in the pre-European era approximately 80% of the study sites in jarrah forest was burnt at a frequency of 3 to 4 fires per decade (i.e. 2 to 4-year intervals between fires), with the remaining 20% burnt less frequently (i.e. 4 to 20-year intervals between fires). On average, fire frequency appears higher on sites in the low rainfall eastern jarrah forest, with only 2 to 3-year intervals between fires. Study sites in the high rainfall zone closer to the Darling scarp had a modal fire interval of 3 to 4 years. A wet site in the sunklands west of Nannup showed 6 to 10-year intervals between fires.

Very preliminary chemical analyses of leafbases of grasstrees has been completed. The current data on the dark pigment of the leafbases supports the hypothesis that the dark pigment is formed by fires killing green grasstree leaves. Thus, the dark pigment appears to be a reliable marker for fire. The chemical analysis also shows a rise in the calcium and zinc content of leafbases directly above the dark bands.

Discussion

In the recent era the fire regime appears to be quite different to that in pre-European times. Ninety five percent of study sites in jarrah forest was burnt with a frequency of less than 2 fires per decade. Only 5% of the study sites in jarrah forest appears to have been burnt at a frequency of 2 or more fires per decade, in contrast to the 1750-1829 era where the corresponding figure was 95% of sites in the jarrah forest. The estimate for the current era may be a slight underestimate because of fires not always igniting the thatch of tall grasstrees.

While the results of this study suggest a higher fire frequency in the jarrah forests under the pre-European Aboriginal fire regime than occurs today, the tendency of grasstrees to be located in valleys and the resulting sampling bias means that some caution is necessary in extrapolating these results across the landscape. Research into traditional Aboriginal burning practices and routes of movement may also assist in the interpretation of these data.

12.11 CONTEMPORARY FIRE REGIMES

Introduction

Fire management in Western Australian forests has been controversial. This project is about only one aspect, albeit an important one, of fire management—the changes in fire regimes that have taken place since settlement by Europeans in 1829. Changes over the past 40 years are given particular emphasis, as this is the period for which most data were available.

Methods

The project concerned the compilation and analysis of qualitative information and quantitative data concerning areas of prescribed and unplanned fires for the duration of the Forests Department (earlier) and CALM records (later). The methods used depended upon the nature of the information available. Background information essential to the understanding of the quantitative data was obtained from a detailed review of departmental and sectional annual reports, books, journal articles and unpublished sources. Quantitative analyses were carried out on figures gleaned from annual reports, or on those supplied by CALM, using the SYSTAT for WINDOWS package (SPSS 1996). Computer programs examined hypotheses using time-since-fire data from the Forest Management Information System (FMIS).

Results

General

A feature of the data for the south-western forests was that every data set showed considerable variation as a result of various policy changes, natural events or history of the area. Nothing was constant; equilibria did not exist. Apart from the expected variations in areas burnt, there was variation over time in the areas of State forest and Timber Reserves, the “Protected Area” and areas of fire exclusion; there was variation in fire cause and number of fires per year; there was variation in areas logged and in silvicultural systems. Categories of variables were not always considered uniformly—such as tenure categories for numbers of fires. Even the names or definitions of variables seemed to shift over time. Terms for areas where fire was actively used as a management tool include “Protected Area” and “area under fire control” while fires lit for management purposes may be “controlled burning” or “prescribed burning”. These name changes could be trivial but may well reflect changes made in attitude, policy, practice or area to which the data applied. These variations affected the quality of the analyses.

Fire regimes

Patterns of burnt ground may be observed *in situ* or on maps. They are generated by fire edges burning with different intensities, an important point ecologically. Burn patterns that we can see are the manifestation of stand-age or time-since-fire distributions for the entire landscape. In turn, time-since-fire distributions translate into fire-interval distributions (Johnson and Gutsell 1994). Fire-interval distributions and fire-intensity distributions may be seen as two major components of the fire regime, the others involving seasonality of fire occurrence and fire type (Gill 1975). Burn patterns, time-since-fire patterns and fire-interval distributions can be depicted as three levels of organization in relation to fire regimes, all of which are important in considerations of the effects of fires on biodiversity (Gill 1997).

Burning patterns

Where and when fires occur each year, and their sizes and intensities, determines the fire regime. In the 1930s there appear to have been large proportions of the forest estate burnt each year while other areas, particularly prime timber areas, were protected from fire. In the 1940s the area protected probably increased while the area burnt as often as possible probably declined. From the early 1950s until about 1969 the proportionate area of the forestry estate burnt by prescription increased, thereby shortening the average fire interval. After 1969 the area prescribed burnt progressively declined.

Today, prescribed burning levels—as a proportion of area managed—are similar to those existing around 1950, if the "Protected Area" is used as a base, and similar to those of about 1960, if the area of the forestry estate as a whole is used. The peak for the proportion of the forestry estate being burnt was in the late 1960s when it is likely that the effects of the 1960-61 Dwellingup fires were still strongly affecting burning policy and practice. At that time, aerial ignitions of prescribed fires were taking over from those ignited by hand.

The rise and subsequent decline in the proportions of the forestry estate being burnt was probably due to many factors including changes in policy, sources of ignition, cost, intensity of management and the rise of awareness of the environment by the public at large. In the past 40 or 50 years, management fires have burnt a much greater proportion of the forest estate per year than unplanned (or "wild" fires) have done. A qualified exception to this is the year of the economically disastrous Dwellingup fires, 1960-61.

Changes in burning policy in the early 1950s were directed towards better management of unplanned fires. Even so, in the early years of this policy, unplanned fires damaged the timber resource and, on one occasion, destroyed the township of Dwellingup. Maximum fire intensities for unplanned fires were, on average, much higher than those for prescribed fires. Interestingly, Forests Department records show that unplanned fires created burning patterns in which an average of about 56% of the area was burnt at low intensity.

Unplanned fires have a wide variety of sizes but it is the very few large fires that burn most of the cumulative area. The numbers of these fires attended by Departmental staff declined on average from 1937-38 to 1979-80 but have risen subsequently, apparently due to an increase in the number of deliberately-lit fires in pine plantations.

One might expect that unplanned fires would be distributed at random. While this may have the greatest chance of being true for fires ignited by lightning, it may not be so as far as deliberately lit fires are concerned. The many fires started by mill locomotives in the 1940s and 1950s would have been relatively predictable in location. The literature suggests that prescribed fires have been regular rather than at random intervals but, because an average of about 70% of the area designated for prescribed burning is actually burnt, there is opportunity for variability within a burning block. An appearance of randomness may arise when the forestry estate is examined as a whole because of the considerable variation in environments, vegetation types and logging patterns—and thus burning patterns—to be found within it. Some of the variety in burning patterns among Forests Districts was demonstrated.

Patterns of burning may be expressed mathematically, but not in a spatially explicit way, as "hazard" functions (Johnson and Gutsell 1994). Hazard functions describe the probability of a point in the landscape burning. They are the mathematical base for the derivation of stand-age and fire-interval functions. Usually hazard functions are derived mathematically once the stand-age functions for landscapes have been estimated from maps. This practice can create problems because a number of random models can produce similar stand-age functions which may be hard to distinguish when using field data (McCarthy et al. in review). However, with the successive yearly maps of fire data available for recent seasons from spatially-explicit FMIS, hazard functions can be estimated directly. This report proposes what hazard functions may be appropriate on the basis of *a priori* argument and we found some support for these in the spatially explicit research on fire histories of the Collie District conducted by S Lang (pers. comm.) in parallel with this study.

Lang found that hazard functions have changed with time implying a change from more random to more regular fires. Data for fires from the late 1930s to the late 1980s indicated that a threshold may be reached in the extent of prescribed burning in so far as it influences the extent of unplanned fires but Lang (pers. comm.) and the authors emphasise that this result should not be accepted uncritically.

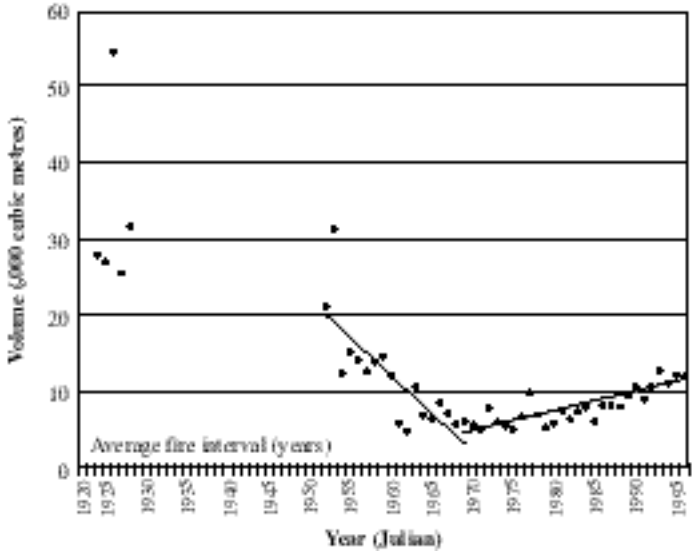
Times since fire

Times-since-fire can be reflected in the forested landscape as regrowth, soon after high intensity fire, and "old growth", long after high intensity fire. Similar expressions of change can be seen in the forest understorey even after low intensity fire. Indeed, ecological changes in understorey are often expressed in terms of the time since the last fire. As times since fire increase, it may be expected that the areas involved would decrease smoothly but the patterns we observed were somewhat irregular. All forest districts showed considerable variation in areas having different times since fire.

Intervals between fires

Intervals between fires are ecologically important for the survival of the biota. With inappropriate intervals, some Australian species have gone locally extinct (Gill and Bradstock 1995). Intervals between fires in south-western Australia have changed in concert with changes in policy. They declined from the early 1950s to the late 1960s then increased linearly with time subsequently. Figure 12.2 indicates this but any interpretation of the graph, quantitatively, needs to be made in conjunction with the details of its construction as outlined in the full report.

Figure 12.2 Changes in fire interval interpreted from Forests Department and CALM records



Early data are sparse and should not be regarded as being continuous with that from the early 1950s. The interval scale needs to be considered in the light of information given in the full report. Data, albeit incomplete, span the period 1921-22 to 1995-96.

Recommendations

1. Accurate mapping of internal as well as external perimeters of unplanned and prescribed fires should be undertaken. Given the cost entailed, it would be worth investigating new methods of data capture and recording. There has been no determination of the extent of overlap of repeated prescribed fires, an important point in relation to the quantitative determination of fire intervals at a point. The hypothesis that prescribed fires burn at random within a block should be tested. For unplanned fires, the hypothesis that the fire perimeter includes unburnt areas, the proportion of which changes with fire size, should be examined.

2. Fire maps, available from 1937, should be incorporated into a spatially-explicit data base. Commercially available packages could be compared and contrasted formally with the in-house FMIS package. Protocols have been established for the capture of the data from micromaps (S Lang pers. comm.). Times of fires, fire-category and association, if any, with logging should be stated. A computer file linked to the data base should be established and added to each year in order to detail pertinent aspects of each season's fires, and any associated silvicultural operation, in order to avoid possible future difficulties of retrospective interpretation of mapped categories. Having accurate maps should avoid the problem of knowing which administrative category was the basis of the observations made.

3. Spatially-explicit analyses of fire maps should be undertaken in order to determine past fire regimes throughout the forest estate.
4. Fuel measurements in long-unburnt plots should be taken to extend the range of current measurements and models.

12.12 SURVIVAL OF HOLLOW-BEARING JARRAH AND MARRI TREES

Introduction

There are 42 species in Western Australia's forests that use hollows in standing trees; 21 are birds, 16 are mammals and five are reptiles (Abbott pers. comm.). Twenty-four of these species are considered totally dependent on tree hollows for breeding. Logging of the jarrah forest since the 1860s has preferentially removed the larger trees that are most likely to provide hollows suited to the larger of these animal species. To lessen this impact, CALM marks and retains habitat trees when logging jarrah forest. The current tree-marking prescription specifies the retention of an average of four habitat trees per hectare on all forest logged under shelterwood and thinning prescriptions, and the retention of an additional six to eight potential habitat trees on areas logged to gap (CALM 1995). The specification of the type of trees to retain is based on the research of Inions (1985), Faunt (1992) and Whitford (unpublished data).

To manage for the ongoing availability and the timely recruitment of replacement habitat trees, it is necessary to know the probable fate of these habitat trees over time.

This retrospective study examined how long habitat type trees remain standing after logging, and how the probability of habitat tree fall (i.e. tree fall due to natural causes) is related to tree and site characteristics. Results from a preliminary analysis of the data are described in this report.

Methods

CALM's current habitat tree specification, (Appendix 5, Silviculture Specifications, CALM 1995a) specifies retained habitat trees be mature to senescent, greater than 70 cm in diameter and be from intermediate senescence classes (selected from an eight class pictorial scale). As trees of this size are less common across the forest than smaller trees, it was assumed that the mechanisms responsible for tree fall would operate similarly on smaller trees, and trees down to 50 centimetres in diameter were included in the study. This enabled the efficient collection of data from a large number of trees.

Tree fall after logging was surveyed on and around hardwood permanent increment plots (HPIPs) at 79 sites distributed throughout the South-West Forest Region. Trees on HPIPs, which were subject to the standard practices at the time of logging (between 1920 and 1992), have been measured since 1943. A range of logging practices has been applied over this period, with 18 of the sites never having been logged. On these unlogged sites the period of observation was taken as being from 1920 to the present and the fall date of logs on these sites, and on the transects around the HPIPs, was determined by assessing the degree of log decay. The period of observation of the sites ranged from five to 77 years with a mean period of observation of 46 years. A total of 2526 trees was assessed.

Results

Figure 12.3 shows the diameter distribution of trees observed in this study and Table 12.18 shows the source and status of these jarrah and marri trees.

Figure 12.3 Diameter distribution of all assessed trees and logs
n=2526

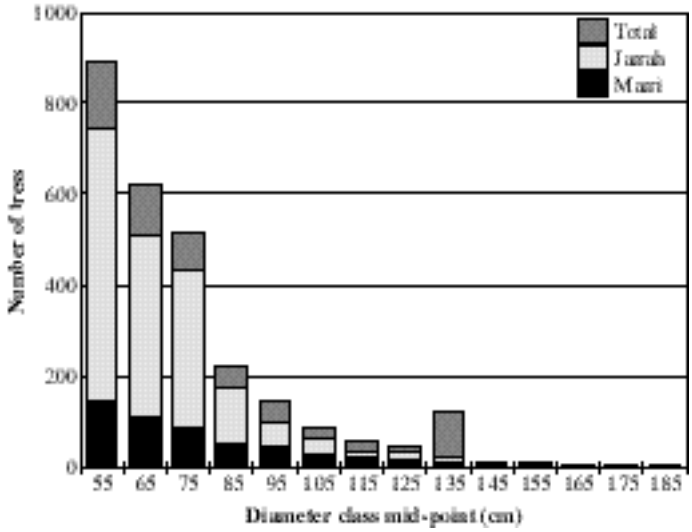


Table 12.17 Source, species and status of 2526 trees observed on 79 sites

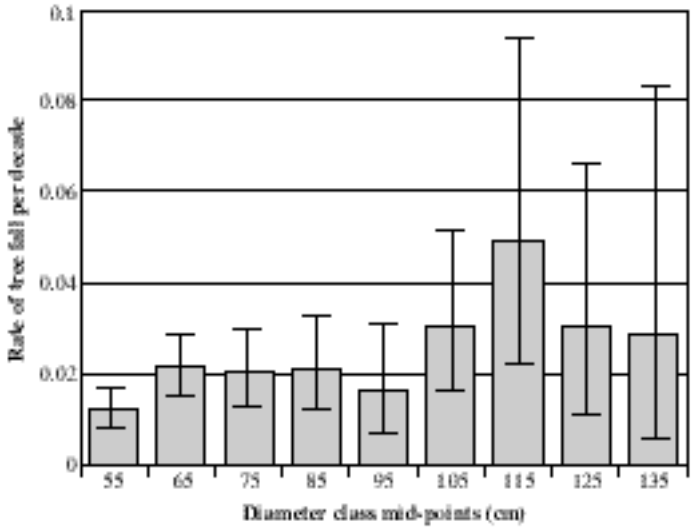
Source	Jarrah standing	Jarrah fallen	Marri standing	Marri fallen	All trees totals
HPIPs	612	17	150	6	785
Transects around HPIPs	1232	145	338	26	1741
Totals	**1844**	**162**	**488**	**32**	**2526**

Over the study period of approximately 46 years very few (7.7%) of the 2526 trees fell. It was expected that the lower decay resistance of marri compared with that of jarrah (Da Costa 1979) would result in marri trees falling more frequently than jarrah. This was not observed. There was no significant difference between the percentage of marri trees that fell (6.2%) and the percentage of jarrah trees that fell (8%).

Rate of tree fall

The rate of tree fall was calculated as the proportion of the observed trees falling per decade. Figure 12.4 shows the rate of tree fall in each diameter class. The rate of tree fall generally increases as the diameter of the trees increase, from 1.2% per decade for trees of 50 to 60 centimetres, to 3.1% per decade for trees of 120 to 130 centimetres.

Figure 12.4 Rate of tree fall per decade by diameter class
Error bars are 95% confidence intervals



The mean rate of tree fall for all sites was 2% per decade (see Table 12.19). Considering only those trees with diameters of 70 centimetres or greater, the mean rate of tree fall was 2.4% per decade.

Table 12.18 The rate of tree fall per decade for 61 logged sites and 18 sites that had never been logged observed over a mean period of 46 years

	All sites %	Logged sites %	Unlogged sites %
Trees >= 50 cm	2.0	1.7	2.6
Trees >= 70 cm	2.4	2.1	3.1

Comparing logged and unlogged stands

The rate of tree fall on sites that had never been logged (2.6% per decade, n = 18 sites) was greater than the rate of tree fall on logged sites (1.7% per decade n = 61 sites). This result most likely occurs because there are more large trees on unlogged sites and large trees are more likely to fall than small trees. This will be examined further in the final report.

Causes of tree fall

Hollow butt and fire

The major cause of tree fall was hollowing out of the base of the tree (hollow butt), and the subsequent failure of the tree at this point. The mean amount of hollow butt of the fallen trees was 62% while the mean amount of hollow butt of standing trees was 7%. Fire was assessed as a major cause of tree fall in 63% of cases.

Wind, termites, and rot

The effects of wind alone, or wind in association with causes other than fire, was assessed as a major cause of tree fall for 37% of fallen trees. These trees were either blown over with their root plate intact, or the stem was broken, frequently in association with termite damage or rot (74% of these wind blown cases).

Termite infestation was assessed as a major cause of tree fall in only 16% of cases. It was predominantly a contributing cause weakening the bole or roots, or aiding the development of hollow butt, and thus leading to wind damage. Similarly, significant weakening of the stem or roots by rot was rarely identified as a major cause of tree fall. Logging activities were a direct cause of the loss of four of the 2526 trees.

Table 12.19 Major causes of tree fall assessed on 194 fallen trees observed on 79 sites in the jarrah forest

Causes tree of fall	% of cases
Fire and wind	39
Fire and termites	4
Fire and rot	1
Fire alone	19
Wind alone	10
Wind and rot	16
Wind and termites	11
Termites alone	1

Management implications

The rates of fall of jarrah and marri trees greater than 70 centimetres in diameter (2.4% per decade) are an order of magnitude below those observed by Lindenmayer et al. (1990) in ash-type forest (36% per decade). Based on this estimate, 96 of the 400 habitat trees retained after logging of 100 hectares of jarrah forest will fall in a 100-year period. This low rate of loss of habitat trees is unlikely to have a major impact on hollow availability as many of the smaller trees retained on logged areas will grow into hollow-bearing size and condition over this period.

13 Old growth

13.1 INTRODUCTION

The 1992 National Forest Policy Statement (NFPS) provides a strategy to reserve old growth forest as part of a comprehensive, adequate and representative forest reserve system. The nationally agreed criteria for old growth (see Table 13.1) which were subsequently developed by the Joint Implementation sub-committee (JANIS 1997) are the basis for mapping and selecting old growth for reservation in the CRA for Western Australia.

The NFPS defines old growth as:

> "*Forest that is ecologically mature and has been subjected to negligible unnatural disturbance such as logging, roading and clearing. The definition focuses on forest in which the upper stratum or overstorey is in the late mature to over mature growth phases.*"

The national operational definition of old growth developed by JANIS is:

> *"Old growth forest is ecologically mature forest where the effects of disturbance are now negligible."*

The JANIS criteria acknowledge the differences which occur in the interpretation of old growth for forest of different ecological characteristics such as exist, e.g. between rain forest and dry sclerophyll forest.

Since there have been no comprehensive studies in Western Australia on the functionality of old growth forest relative to other stages of forest development, identification and mapping of old growth is based on structure (or development stage) and disturbance history. Because of their ecological differences, the methodology used in Western Australia for wet sclerophyll forests (karri and its mixtures) differs from that used for the dry forests (jarrah and wandoo).

Table 13.1 Summary of old-growth criteria

Noting that it is necessary to approach old growth in a flexible manner according to regional circumstances:
1 Where old-growth forest is rare or depleted (generally less than 10% of the extant distribution) within a forest ecosystem, all viable examples should be protected, wherever possible.
2 For other forest ecosystems, 60% of the old-growth forest identified at the time of assessment would be protected, consistent with a flexible approach where appropriate, increasing to the levels of protection necessary to achieve: representation across the geographic range of the ecosystem; the protection of high quality habitat for JANIS target species; appropriate reserve design; protection of the largest and least fragmented areas of old growth; and community needs for recreation and tourism.

13.2 METHODS

Development stage

Wet sclerophyll forest

Following germination, even-aged stands of karri forest develop through several distinct stages—establishment (nominally 0 to 8 years old), juvenile (9 to 25), immature (26 to 120), mature (121 to 250), senescent (250 plus). In terms of development stage mapping for old-growth purposes, recognition and mapping of the mature and senescent stages are of most interest. Fire disturbance plays several roles in stand development and condition. It provides conditions for germination of karri, it burns and regenerates the understorey and, if severe enough, may kill the overstorey trees. If large patches of trees are killed, an even-aged stand of karri is initiated, while less severe fire may result in a new patch of regeneration developing in the context of an uneven-aged stand.

The methodology for development stage mapping was developed to take account of this variable structure and mapping was already in progress for the karri dominant forest in the main karri belt (Bradshaw and Rayner 1997). The same techniques were used to extend this mapping to other forest

containing karri in the remaining public and private forest. The dynamics of the marri/karri and the karri/tingle forest were considered to be sufficiently similar to extend the technique to these forests for the purpose of old-growth mapping. The process is described below.

- Even-aged stands of known age (Armstrong 1984) were obtained from the most recent updated records in CALM's GIS database.
- Remaining areas were interpreted using to 1:25 000 colour aerial photography to categorise stands as immature, mature or senescent development stage. For uneven-aged stands, the stage attributed to the stands was that of the dominant cohort, i.e. the oldest cohort with a crown cover exceeding 25%, a level which had previously been established as being critical to the development of younger cohorts (Rotheram 1983). Immature stands were distinguished from mature on the basis of crown size and character. Mature forest was distinguished from senescent on the basis of stand structure rather than individual tree characteristics, which had proved to be unreliable. Photo interpretation was unable to separate late from early mature.
- Age was estimated at 121 sites within these categories using a sample of dominant tree diameters and a previously-derived regression of age versus diameter of large dominant trees. These age data were within the expected range for the development stage. 50% of the mature forest is estimated to be "late mature".
- Continuous field checking of the interpreted area was carried out on public land but private land was not field checked.

These data provide for the mapping of development stage which is independent of disturbance data.

Dry sclerophyll forest

Jarrah forest dynamics differ substantially from those of the karri forest. Jarrah seedlings may become established under a canopy following even mild disturbance. Seedlings which survive the initial establishment period develop into lignotubers. This process is repeated to some extent every time the area is burnt. As a consequence the majority of jarrah forest contains a substantial lignotuber pool. The lignotuber develops over a period of time (perhaps 20 years) to the stage where it is capable of rapid development into a sapling if overstorey competition is removed.

Jarrah has other characteristics that affect its dynamics. It is relatively resistant to fire, it has a very strong capacity to recover from defoliation, and it is persistent, i.e. it can survive under extreme competition.

Disturbance (typically fire in natural forests) which removes the overstorey competition will allow for the release and rapid development of the established lignotubers. If the overstorey removal is temporary (say defoliation) the development of the saplings will be arrested when the overstorey crowns recover. The released regeneration will then be subjected to varying degrees of suppression. Development will proceed again at the next temporary setback of the overstorey crowns. If the reduced competition is permanent (as a result of mortality of the overstorey) then the saplings will continue to develop if the gap in the overstorey is large enough. Release under these circumstances is not necessarily associated with fire. Mortality may be due, for example, to old age or windthrow.

This pattern of more or less continuous recruitment is reflected in the multi-aged structure of much of the jarrah forest. Cohorts occur at fine scale and are generally difficult to differentiate because of the overlap between dominant individuals of one cohort and suppressed individuals of another. This is exacerbated over the long term due to the impact of fire damage in the crowns. All of the jarrah forest shows indications of previous fire disturbance of varying intensity.

More or less single storey stands do occur where mature trees dominate the site and inhibit lignotuber establishment or development. Such stands also occur as woodlands where understorey competition inhibits lignotuber development.

While these differences in the mature and the immature strata are often readily apparent in cutover forests when examined on aerial photos, no such distinction is evident for virgin forests at a degree of reliability or significance. For these reasons the jarrah forest could not be interpreted for development stage in the same way as karri and the qualification for old growth is based on disturbance.

Disturbance history

Because of the fundamental role that fire plays in the normal stand dynamics of both karri and jarrah forest and the fact that all mature forests have been subject to many fires in the past, fire has not been included as a form of disturbance in the mapping of old growth. Consequently understorey age or development is not considered as a factor in the determination of old growth in these forests.

Disturbances which have been considered are past clearing for agriculture, logging, symptoms of *Phytophthora cinnamomi* infection, clearing for mining and grazing.

Records of past agricultural clearing in what is now forest are generally good. However, settlement of forest areas is too recent to have resulted in regeneration of forest which would be old enough to qualify as mature forest. The same comments apply to open cut mining areas. Areas subjected to these forms of disturbance have been excluded from old growth.

Logging records are maintained in the CALM Forest Management Information System (FMIS) system, recording logging activities which began in the forest area in about the 1870s. They are generally reliable, but these records underwent substantial field checking as part of the RFA process. Particular emphasis was given to confirming that areas recorded as uncut were indeed unlogged and to checking areas recorded as logged where there was a possibility that they may have been unlogged (e.g. steep areas). These new data have been incorporated.

To address the question of negligible disturbance, the intensity of past harvesting, the time since harvest and the number of times harvested have been considered.

The earliest harvesting of karri forest on the west coast resulted in even-aged regeneration which is only now approaching the mature stage and is therefore too young to qualify as old growth. Group selection harvesting practices from 1940 to 1967 resulted in patches of regeneration throughout the harvested areas. The resultant structural changes to the forest canopy in these areas are still evident, and the disturbance therefore cannot be considered as negligible in the context of identifying old growth. On this basis, all karri areas that are recorded as having been subjected to the practices described above are excluded from old growth.

CALM records show that intensive harvesting was characteristic of jarrah forest harvesting up until about 1940 (Stoneman et al. 1989). A high component of regrowth in the canopy which resulted from that logging remains an obvious structural change in these forests. Harvesting after 1970 was also relatively intense and the evidence of harvesting is both too recent and too intensive for the disturbance to qualify as negligible. Many of these areas have also been cut more than once. All of the above areas identified as being subjected to these practices have therefore been excluded from old growth.

On the basis of CALM records and the prescriptions known to have been applied, harvesting of jarrah forest between 1940 and 1960 was more variable in intensity (Stoneman et al. 1989). The intensity of logging was not recorded for this period and because of this there was a possibility that some areas would qualify as having negligible disturbance in the context of identifying old growth. Areas of forest which had been harvested only once between 1940 and 1960 were identified from FMIS and as far as was possible each area was jointly inspected in the field by Commonwealth and State officers. Using the operational old growth definition and experience from other old growth assessments, areas were excluded from old growth if they showed evidence of harvesting that was sufficiently intense to have resulted in persistent regrowth in the canopy 30 to 40 years on. In most cases the structural changes were easily determined and the decision to include or exclude areas was obvious. Three thousand and seventy hectares of additional old growth were included as a result of this inspection.

All areas of uncut jarrah forest were included as old growth.

Although not strictly included in the CRA old-growth assessment because they do not qualify as forest, jarrah woodland was assumed to have had minimal disturbance from logging and was included as old growth (see below).

In the absence of any detailed study, all uncut wandoo forest and woodland was included as old growth.

Areas known to be affected by *Phytophthora cinnamomi* are considered disturbed and are excluded from old growth, regardless of the status established to this point. The source of this information was the existing maps of known infection, the data originating from the 1970s to the present.

While specific areas of the forest have been grazed in the past, most leases in the forest areas were cancelled by the 1960s. There were no areas in the RFA area where it is considered that grazing impact would be sufficient to exclude candidate areas of old growth.

All areas known to have been subjected to intensive mining were excluded as old growth.

Private forest land was not subjected to analysis and was generally regarded as significantly disturbed and therefore excluded from old growth. The exception to this was one small area identified opportunistically as part of the joint field inspection of once cut jarrah described above.

13.3 RESULTS

Old growth forest was determined by the intersection of the various development stage and disturbance data layers. In the case of karri forest, 50% of the mature forest is estimated to be "late mature" (Bradshaw and Rayner 1997). In summary, the working definition for the mapping of old-growth is:

- karri and karri/tingle forest—uncut forest which is mature or senescent;
- jarrah and jarrah/tingle forest—uncut forest or forest subject to minimal disturbance as defined above and which is not known to be affected by *Phytophthora cinnamomi*;
- jarrah woodland—all woodland which is not known to be affected by *Phytophthora cinnamomi*; and
- wandoo forest and woodland—uncut forest or woodland.

Table 13.2 provides a summary of the areas of old growth within each forest ecosystem. Map 14 shows the distribution of old growth forest within each forest ecosystem in the South-West Forest Region.

Table 13.2 Present reservation status of old-growth forest

Forest ecosystem	Extant area of old growth (ha)	Proportion of extant old growth reserved				Area reserved (ha)	Area on public land outside reserves (ha)	Area on private land outside reserves(ha)
		Gazetted formal	Proposed formal*	Informal	Total reserved			
Jarrah Blackwood	48496	10%	13%	10%	33%	15830	32666	0
Jarrah Leeuwin	477	75%	0%	1%	76%	364	113	0
Jarrah Mt Lindesay	14003	5%	42%	3%	50%	6953	7050	0
Jarrah north-east	11561	17%	20%	8%	45%	5241	6320	0
Jarrah north-west	7923	69%	11%	5%	85%	6700	1222	0
Jarrah Rate's tingle	1021	88%	3%	0%	91%	927	94	0
Jarrah red tingle	214	48%	48%	0%	96%	205	8	0
Jarrah sandy	2171	97%	2%	0%	99%	2149	23	0
Jarrah south	160667	23%	26%	7%	56%	90308	70360	0
Jarrah Unicup	4464	23%	61%	2%	86%	3839	625	275
Jarrah woodland	13220	32%	14%	51%	98%	12932	288	0
Jarrah yellow tingle	7249	21%	1%	19%	41%	2951	4298	0
Karri main belt	53576	47%	4%	21%	72%	38712	14864	0
Karri Rate's tingle	674	100%	0%	0%	100%	674	0	0
Karri red tingle	3283	71%	26%	0%	98%	3206	77	0
Karri south coast	#							
Karri west coast	492	90%	10%	0%	100%	491	1	0
Karri yellow tingle	6969	28%	1%	20%	48%	3367	3602	0
Western wandoo forest	7856	20%	54%	6%	80%	6275	1581	0
Western wandoo woodland	2987	27%	22%	12%	61%	1818	1169	0

Notes:

* proposed in Forest Management Plan 1994-2003

\# not analysed - more than 90% outside RFA region

14 Wilderness

14.1 INTRODUCTION

The National Agreed Criteria for a Comprehensive Adequate and Representative Reserve System for Australia's Forests (JANIS 1996) specify that 90% (or more, if practicable) of an area of high quality wilderness that meets the minimum area requirements should be protected in reserves.

The assessment of wilderness in the South-West Forest Region of Western Australia used the National Wilderness Inventory (NWI) methodology, developed by the Australian Heritage Commission and adopted as the standard approach to the assessment of wilderness in Regional Forest Agreements throughout Australia.

14.2 DATA

The data used in the NWI analysis come from a number of sources. The distance-related indicators (settlement, access and apparent naturalness) are essentially current AUSLIG digital mapping data updated with additional information in the detailed study areas. The disturbance information, which provides the base data for the biophysical naturalness indicator, is based primarily on the disturbance data developed for the identification and assessment of old-growth forest (see Chapter 13).

14.3 METHODS

The concept of wilderness embraces measures of remoteness, naturalness and lack of disturbance. The National Forest Policy Statement: A New Focus for Australia's Forests (Commonwealth of Australia 1992b) states that "forested wilderness areas will be protected by means of reserves developed in the broader context of protecting wilderness values of all lands." Consistent with this, the approach to the identification of wilderness areas in the South-West Forest Region included non-forest vegetation types where they form a mosaic within largely forested areas.

The NWI methodology developed by Lesslie and Maslen (1995), produces a database of "wilderness quality" across the region. This is achieved by measuring the variation in wilderness quality across the landscape using four wilderness quality "indicators" that represent the two essential attributes of wilderness: remoteness and naturalness. These indicators are:

- remoteness from access;
- remoteness from settlement;
- apparent naturalness; and
- biophysical naturalness.

Map 17 shows biophysical naturalness for the South-West Forest Region. The index of wilderness quality derives from a summing of these individual indices and is represented by a range from zero to 20. To identify areas with high wilderness quality, the criteria used in this assessment were areas with a NWI wilderness quality of at least 12 and an area larger than 8000 hectares.

14.4 RESULTS

This assessment of the South-West Forest Region identified no areas that meet the threshold requirements. Although some area of wilderness quality greater than or equal to NWI 12 occur within the South-West Forest Region, none of these areas reaches the wilderness area size threshold of 8000 hectares.

Areas below the wilderness size threshold, but with high values of remoteness and naturalness identified through this study, were used in the assessment of national estate values discussed in Chapter 15. Map 16 shows wilderness quality for the South-West Forest Region.

14.5 CONCLUSION

No areas of wilderness above threshold have been delineated within the South-West Forest Region.

15 National estate

15.1 INTRODUCTION

Background

The Register of the National Estate is a national register of places in Australia which have national estate heritage value—defined by the *Australian Heritage Commission Act 1975* as "places of aesthetic, historic, scientific or social significance or other special value for future generations as well as for the present community". National Estate places may relate to cultural or natural values and may be of significance to the national, regional or local community.

Many forest areas are listed in the Register of the National Estate. The Commonwealth Government, in making decisions concerning forests, such as the granting of licences to export woodchips, must consider the possible effect of these decisions on the National Estate.

A regional assessment model for identifying the National Estate was developed in 1991-92 by the Australian Heritage Commission and CALM for the Southern Forest Region of South-West Western Australia, (AHC and CALM 1992). The assessment of national estate values in the South-West Forest Region for the Regional Forest Agreement builds on this earlier regional assessment process and is consistent with the statutory requirements of the *Australian Heritage Commission Act*.

The objectives of the national estate study for the South-West Forest Region CRA are to:
- identify indicative national estate values across the region and assess their representation in the nature conservation reserve system and other protective land tenures;
- identify those areas in the region which may be considered for listing in the Register of the National Estate; and
- provide management guidelines on the protection and maintenance of national estate values.

15.2 APPROACH TO THE NATIONAL ESTATE ASSESSMENT

The national estate study involves distinct phases which are outlined below.

The identification phase involves assessing the available information against the national estate criteria to determine areas of indicative national estate value and areas for consideration by the AHC for listing in the Register of the National Estate.

The protection analysis involves an assessment of:
- the regional level of protection of values within the conservation reserve system;
- the importance of reservation for each national estate value, and
- protection through other mechanisms.

Conservation principles are developed by considering the sensitivity to disturbance of each value, as well as current international "best practice" in natural and cultural heritage conservation.

This summary report addresses only the identification and assessment of national estate values within the Comprehensive Regional Assessment. The analysis of protection of national estate values and the development of conservation principles will be addressed in the CRA National Estate Report and in the RFA options report, which will be available separately.

Data review

Much of the data used in the assessment of national estate values derives from extensive data sets assembled by a wide variety of institutions, industry, government organisations and private individuals over many years. Many of the projects undertaken for the CRA biodiversity assessment and the old growth and wilderness assessments also provided data used in the assessment of national estate values. Where possible, one source of data was used to complement or confirm another to ensure that the most robust data sets were compiled.

Seven broad types of information were used in the assessment:
- existing scientific studies and reports;
- site-specific data obtained from field research;
- data collected from mapping, usually aerial photo interpretation;
- information derived from models, using limited ground data;
- studies conducted by consultants;
- existing databases of cultural heritage places;
- community information; and
- information from experts.

Consultation process for national estate assessment

The main objectives of the consultation process are to:
- involve the community in the identification of its heritage;
- inform all sectors of the community (local people and organisations, industry groups, conservation organisations and unions) about the National Estate;
- be open and transparent about process, methods and decisions;
- encourage a better understanding of heritage, the AHC's role and processes; and
- encourage a stronger understanding of management and conservation measures.

Elements of the consultation process are listed below.

Peer review

A peer review of technical procedures was considered necessary to validate methods and to explore specific issues such as the assessment of diversity under national estate criteria and the identification and assessment of significance of flora and fauna taxa (e.g. disjunct and primitive) which related to national estate values.

Key stakeholders

Participating key stakeholders were briefed on the national estate assessment through the RFA Stakeholder Reference Group. Other opportunities for comment will be provided through the public submission period for the RFA options report.

Public meetings

Public meetings were held in a number of towns throughout the region in order to provide information to local communities on the Comprehensive Regional Assessment and Regional Forest Agreement process. These briefings included information on the Register of the National Estate and the national estate assessments being undertaken for the CRA.

Information and media

An RFA newsletter which included information on the national estate assessments being undertaken for the CRA was published and distributed through the South-West Forest Region.

Community heritage workshops

Information on the CRA and RFA process was provided to participants at workshops for the identification of national estate community heritage values held throughout the region.

Aboriginal consultation

An extensive Aboriginal consultation program was initiated in keeping with the commitment of both governments to consult with Aboriginal communities on all aspects of the RFA process. Elements of the program included:
- an initial workshop to which Aboriginal community organisations within the region were invited, as well as organisations such as the Noongar[1] Land Council, the Aboriginal Legal Service and the Aboriginal Affairs Department;
- the establishment of the Western Australian RFA Noongar Action Group (initially known as the Aboriginal Action Group);

[1] The spelling of "Noongar" in this form should also be seen to encompass the following spellings: Nyoongar, Nyungar, Noongah,Nyoongah, Nyungah

- a series of workshops throughout the South-West Forest Region which provided an opportunity for Noongar communities to identify issues of concern to them in relation to the protection of Aboriginal heritage and forest management in the South-West Forest Region; and
- participation by Noongar community representatives and organisations such as the Noongar Land Council and the Aboriginal Legal Service in the RFA Stakeholder Reference Group.

15.3 SUMMARY

The national estate assessment included a wide range of values relating to the natural and cultural heritage of the forests of the region. Values identified will be discussed in the CRA national estate report, which will be available separately. The following section is a summary of the assessments undertaken and the broad themes assessed.

Extensive natural values

The natural landscapes identified in the national estate assessment are relatively large areas of land that have not been significantly disturbed by European activity. The largest examples of these in the region, where essentially natural processes dominate the landscape and disturbances have been minimal, are in the southern forest. It is this region which contains the majority of the areas of extensive natural national estate value.

A wilderness quality survey of the region undertaken using the AHC's National Wilderness Inventory (NWI) found no areas of wilderness above the nationally agreed thresholds, as a result of the region's long history of European activity. Some relatively remote and natural areas do survive in the southern forest, which is also where the majority of the remaining old-growth forest areas in the region are to be found.

Flora

Flora values identified in the region included those at the individual species level, as well as values which related to vegetation communities and/or features within the landscape, such as rare or uncommon old-growth forests, flora refuges and areas of flora species richness.

The attributes for the identification of national estate values relating to individual taxa include:
- endemic taxa, primitive and relictual taxa, taxa with disjunct distributions and taxa at the limit of their range (criterion A.1); and
- rare and threatened taxa (criterion B.1).

Fauna

Fauna distribution data for the South-West Forest Region were compiled and collated into a centralised fauna data base at the Western Australian Museum. Each fauna taxon was attributed according to characteristics relevant to the assessment of national estate significance, such as:
- endemic taxa, Gondwanic or relict taxa, taxa with disjunct populations and taxa at the limit of their range (criterion A.1); and
- areas providing habitat for rare, uncommon or endangered fauna taxa (criterion B.1).

Other natural values

Places important as refuges from climatic change, as refuges from drought and frequent fire, as research, teaching or type localities and as sites of geological or geomorphological significance were also assessed under the relevant national estate criteria.

Places important as research, teaching or type localities included:
- teaching sites where teaching is occurring or had taken place, where the primary aim of that teaching was to increase understanding about Australian natural history;
- type localities-biological, where the locations of type specimens are internationally recognised and are important for taxonomic reference; and
- type localities-geological, which are localities for fossils and stratigraphic sections.

Cultural values

Cultural values identified through the CRA national estate assessment included social, aesthetic and indigenous values. Preliminary work on the identification of historic values was also carried out. Documentary and community-derived information reveals a wide range of cultural places within the forests of the South-West Forest Region. These places are indicative of the rich and diverse history of human interaction with, and response to, those forests.

Community heritage values

The identification and assessment of national estate social value was based on a community consultation process. A series of 10 consultative workshops was held throughout the region which brought together individuals who represented a broad range of community groups and interests. These individuals worked together as a community to identify places of social value.

Aesthetic values

National estate aesthetic value has been identified and assessed through the analysis of information drawn from a range of sources, namely existing aesthetic value and place studies and databases, published tourist literature, information gathered through interview with forest experts, information derived from the social values project and visual resource management data. The drawing together of these sources allowed for the consideration of both expert and community perceptions of aesthetic value throughout the region.

Indigenous values

The identification and assessment of national estate indigenous value were also based on a community consultation process. Workshops, held in seven community-selected locations, were attended by Noongar community representatives.

In addition to identifying places of Noongar cultural heritage value, these representatives discussed issues of forest and cultural heritage management which were of concern to them. Resolution of these issues is being sought by the RFA Noongar Action Group, which throughout the process of the CRA has provided guidance and advice on the development of indigenous consultative strategies for the RFA.

Historic values

Preliminary work on the identification of historic national estate values included an audit of existing information and databases concerning historic values within the region and the compilation of a thematic history exploring the development of the region from the time of European settlement to today.

15.4 CONCLUSION

The national estate assessment has to date resulted in:

- a regional approach to identification of national estate values, assessing heritage values across the South-West Forest Region;
- a comprehensive information base for a wide range of national estate values on public land within the region; and
- a firm basis on which to incorporate the national estate values into the integration and options development processes for the South-West Forest Region RFA.

An analysis of the protection of national estate values in the region will be undertaken during the integration and options development for the RFA and this information will be included in the CRA national estate report, which will be available separately.

APPENDIX 1

COMMONWEALTH AND STATE LEGISLATION RELEVANT TO THE RFA PROCESS

Commonwealth legislation

The Quarantine Act 1908
Forest and Timber Bureau Act 1930
Environment Protection (Impact of Proposals) Act 1974
Australian Heritage Commission Act 1975
Export Control Act 1982
Wildlife Protection (Regulation of Exports and Imports) Act 1982
World Heritage Properties Conservation Act 1983
Endangered Species Protection Act 1992

State legislation

Soil and Land Conservation Act 1945-1988
Country Areas Water Supply Act 1947
Wildlife Conservation Act 1950
Conservation and Land Management Act 1984
Environmental Protection Act 1986
Town Planning and Development Act 1928
Aboriginal Heritage Act 1972
Heritage of Western Australia Act 1990
Aboriginal Affairs Planning Authority Act 1972
Mining Act 1978
State Agreement Acts (e.g. Alcoa 1961, Worsely 1973)
Agricultural and Related Resources Protection Act 1976

APPENDIX 2

REGIONAL SOCIAL PROFILE QUESTIONNAIRE

INTERVIEWER NAME: _____

Hello, my name is _____ . I'm from a company called EBC and we are doing survey for the Commonwealth and West Australian Governments. The survey is part of work being done to look at the best ways of managing forests in Western Australia.

It will take about 15 minutes for me to go through the questions and all information is confidential. Would you mind answering a few questions for me?

IF YES, THEN RECORD:

1. Area Code: _____ Town or Suburb _____
2. Gender: ☐ Male ☐ Female

ASK THE FOLLOWING QUESTIONS:

3. What do you think will be the main industries in your area in the next 20 years? *(Read out list. May report more than one)*

   ☐ Agriculture ☐ Tourism
   ☐ Processing native timbers ☐ Mining
   ☐ Processing plantation timbers ☐ Manufacturing
   ☐ Or any other industry _____

4. Would you like to see new industries develop in your area?

   ☐ No (GO TO QUESTION 6) ☐ Yes

5. What type of industries would they be? *(Read out list. May report more than one)*

   ☐ Agriculture ☐ Tourism
   ☐ Processing native timbers ☐ Mining
   ☐ Processing plantation timbers ☐ Manufacturing
   ☐ Or any other industry _____

6. During the last year have you or your family visited areas of native forest in Western Australia?

   ☐ No (GO TO QUESTION 9) ☐ Yes

7. How often have you visited these forests?

   ☐ Once a month or more ☐ Once every three months
   ☐ Once every six months ☐ Once a year

8. What was the name of the forests you visited and why did you go there?

Name of Place *(Specific Location)* *(i.e. National Park name)*	**What do you do there?** *(Type of recreation or other activity)*
1. _____	_____
2. _____	_____
3. _____	_____
4. _____	_____

9. Are there any areas of native forest within 20 kilometres of your home?

☐ No ☐ Yes

10. What do you think are three of the most important things that need to be considered in planning for the future of native forests?

☐ Don't know

1. _____
2. _____
3. _____

11. Are there any places in Western Australia where the use of native forests has concerned you?

☐ No (GO TO QUESTION 12) ☐ Yes

Name of Place *(Specific Location)* *(ie National Park name)*	**What issue concerns you in this area?**
1. _____	_____
2. _____	_____
3. _____	_____
4. _____	_____

12. How do you think these concerns might be better managed? (correspond to above nos.)

1. _____
2. _____
3. _____
4. _____

13. In the last two years, has there been a change in the use of forests in your area by any industry which has affected the community in which you live?

☐ No (GO TO QUESTION 15) ☐ Yes

14. What has changed?

    1. _____

    2. _____

    3. _____

15. If there was a decrease in the future use of forests by the timber, mining or tourism industries in your area, do you think this . . .

    . . . would affect you community?

    ☐ No. Why not? _____

    _____

    ☐ Yes. In what way?_____

    _____

    . . . would affect your family?

    ☐ No. Why not? _____

    _____

    ☐ Yes. In what way?_____

    _____

When people talk about native forests a lot of different issues are raised. I am going to read out some statements that people make about forests and I would like you to indicate in general how much you agree or disagree with each statement. I want you to tell me if you strongly agree, agree, disagree or strongly disagree with each statement.

(1 = Strongly Agree, 2 = Agree, 3 = Disagree, 4 = Strongly Disagree)

16. The area in which I live is very dependent on the timber and logging industry	1	2	3	4
17. Tourism is very important in the area in which I live	1	2	3	4
18. I am very concerned about the management and use of native forests in Western Australia	1	2	3	4
19. I sometimes feel torn between the need for jobs and the need to preserve native forests in Western Australia	1	2	3	4
20. Laws to protect native forests do not affect me greatly	1	2	3	4
21. People who access native forests should have more say in how forests are managed	1	2	3	4
22. One of the main reasons I live in this area, is the natural beauty of the forest	1	2	3	4
23. Trees are important for their own sake	1	2	3	4
24. The balance of a forest ecosystem is very delicate	1	2	3	4
25. I am not confident that native forests are being well managed in Western Australia	1	2	3	4
26. Better laws are needed to protect the use of native forests	1	2	3	4
27. The conservation and protection of native forests in Western Australia will harm the West Australian economy	1	2	3	4

28. Living is this area gives me a sense of community 1 2 3 4

29. I feel that I belong to the community in which I live 1 2 3 4

30. The friendships I have with other people in my community mean a lot to me 1 2 3 4

31. Have you had any involvement in forest management, planning or protection in Western Australia?

☐ No (GO TO QUESTION 33) ☐ Yes

32. What type of involvement have you had?

_____

_____

33. Are you, or any members in your household, employed in the timber, tourism, mining, beekeeping, seed or wildflower collection industries?

☐ **None of these industries**

☐ Timber ☐ Seed collection

☐ Tourism ☐ Wildflower collection

☐ Mining ☐ Beekeeping

34. How many years have you lived in the area?

_____ years

☐ All my life/Always lived here (GO TO QUESTION 37)

35. Where did you move from (Record STATE if outside WA; Town if within WA)

_____

36. Why did you move here?

☐ Family related reasons

☐ Work related reasons

☐ Other reasons _____

37. How many years do you think you will stay in the area?

_____ years

☐ Rest of life

38. Can I ask you in what year you were born? _____

39. What is your usual occupation? _____

40. Do you have any other comments or suggestions about the management of forests in Western Australia? *(Record as much verbatim detail as possible)*

_____

_____

_____

_____

_____

THANK YOU FOR YOUR TIME.