Chapter 11

Managing red gum floodplain ecosystems

11.1 Overview

The river red gum floodplain ecosystems of the Riverina bioregion are under high stress, and in some cases are transitioning to alternative states. They will require various levels of direct intervention to maintain their resilience, and to continue to provide ecosystem services that the community values.

We need to rethink our current approach to forest management. The NRC considers that management approaches for the river red gum forests of the Riverina bioregion should be based on recognition of ongoing water scarcity, clear management objectives, and build upon past forest conditions and management activities (rather than attempting to replicate them). In particular, we need to learn as we go by trialling and testing different approaches for these ecosystems.

This chapter recommends management approaches for the red gum floodplain ecosystems. The implementation of these approaches should help to achieve conservation outcomes, and a sustainable future for the forests and the industries and communities that are dependent upon them. It supports Step 5 of the analytical framework by:

- describing goals for future management
- proposing a set of principles for the management of red gum floodplain ecosystems.

The key findings of this chapter are:

- River red gum forests are a component of a dynamic floodplain ecosystem. Future management under all forms of tenure must address the ecosystem as a whole, which no longer receives sufficient flood flows or groundwater to sustain some forest components and values of those ecosystems.
- Naturally occurring processes will contribute to changes in red gum floodplain ecosystems. However, targeted and active management interventions can achieve outcomes with a greater degree of control and certainty than naturally occurring processes and/or passive approaches. This applies across both private land and all public tenures.
- In some forest areas, ecological thinning can be a useful tool to enhance conservation outcomes. However, little research has been undertaken on the effects of different thinning techniques on conservation values, and outcomes are subject to considerable uncertainty. There is a strong imperative to develop robust, prudent adaptive management frameworks to guide ecological thinning in river red gum forests in both production and reserved areas.
- The current implementation of Australian Group Selection (AGS) in river red gum forests should be modified to better:
    - reflect the availability of water in river red gum forests
    - maintain the ecological character of the forests (DEWHA, 2008)
    - protect matters of National Environmental Significance[1].
- AGS remains an appropriate silvicultural system for river red gum forests managed for production, as well as for other values as long as management prescriptions are improved. These include prescriptions for adequate watering regimes, the provision and maintenance of ecological values (principally the retention of habitat trees and coarse woody debris), and the intensity of its implementation.

11.2 Goal for red gum floodplain ecosystem management

The NSW Government has adopted a long-term, aspirational goal to achieve:

resilient, ecologically sustainable landscapes functioning effectively at all scales and supporting the environmental, economic, social and cultural values of communities (NRC, 2005).

The NRC considers that a general goal for the future management of red gum floodplain ecosystems should be:

to implement activities that maximise the potential to maintain resilient, diverse, sustainable ecosystems, which continue to deliver ecosystem services, under anticipated changes to water availability and climate.

This goal is consistent with NSW's aspirational goal and other strategies for biodiversity conservation under climate change (Biodiversity and Climate Change Expert Advisory Group 2009; Commonwealth of Australia, 2009).

This goal could be pursued in different ways across the Riverina bioregion, according to the current and desired balance between uses – for example conservation and production. It should be applied to ensure that ecosystems function to support the communities' values for the environment, economy, society and culture. An integrated and adaptive approach to red gum forest management based on sound scientific knowledge is the best way to sustain the diversity and values of these floodplain ecosystems over the long term.

11.3 Management principles for resilient river red gum forests

River red gum forests are components of dynamic floodplain ecosystems. These ecosystems have been shaped by geomorphic processes and human interventions – especially river regulation, timber harvesting, silvicultural management, fire management and grazing. These ecosystems will continue to be affected by past interventions, as well as by changes and variability in climate, changes in water availability, human activities and other disturbances.

The Murray Darling Basin Authority (MDBA) has characterised the ecosystem functions that underpin the Basin's river systems in relation to three interdependent physical processes listed in **Table 11.1** (MDBA, 2009).

Natural resource management actions are often focused on one component of a system in isolation of others (NRC, 2007; NRC, 2008). While this can deliver measurable benefits for that component, it can fail to recognise both positive and negative changes in the larger system. From a landscape perspective, the different parts of an ecosystem, its productivity, and its

[1] Environmental Protection and Biodiversity Conservation Act 1999 (C'th)

Table 11.1: Physical processes that underpin the Murray-Darling Basin's key ecosystem functions (MDBA, 2009)

Physical process	Examples of dependent key ecosystem functions
Inundation of river beds, banks and floodplains	• Creation of physical habitats for plants and animals • Mobilisation of carbon and nutrients
Material mobilisation, transport and dispersal	• Creation and maintenance of physical habitats (e.g. scouring of river beds to create pools, deposition of materials to create bed formations and bank formations) • Mobilisation, transport and dispersal of minerals and nutrients to wetland and floodplain ecosystems
Lateral, longitudinal and vertical flow connectivity	• Transport of carbon, nutrients and minerals • Dispersal of seeds • Migration of aquatic animals for reproduction or foraging • Export of pollutants (e.g. salt) from key parts of the river system (e.g. Murray mouth) • Connectivity with groundwater

ecological components are all interconnected and need to be managed in an integrated manner. For example, groundwater resources have been historically managed in isolation from surface water, yet both are important for the health and persistence of many river red gum forests.

A general principle of landscape management is to manage ecosystem processes within the range of historical variability (Wallin et al., 1996). However, in landscapes that have been changed substantially since European settlement and which are subject to ongoing change, novel management approaches are often required to enhance resilience and maintain conservation values (Walker *et. al*., 2009; Walker and Salt, 2006).

For example, in some conservation reserves in south-eastern Australia, active management interventions such as livestock grazing and ecological thinning have been proposed to achieve conservation goals (Lunt et al., 2007; VEAC, 2008; Parks Victoria, 2009). Similarly, in water-dependent systems, such as river red gum forests and wetlands, flooding regimes are commonly manipulated to achieve specific conservation goals.

In altered and changing forests, active management interventions are not necessarily more ecologically harmful or less appropriate than allowing natural processes to occur. Instead, active and targeted interventions can provide greater certainty and a greater degree of control in achieving the desired outcomes, than management approaches relying on natural processes or more 'passive' interventions.

As has been outlined in this report, river red gum floodplain ecosystems are likely to transition to new ecological states under climate change and water scarcity. The NRC considers that a range of active management approaches across all tenures will be required to maintain the health and resilience of these systems. The most appropriate management approach will depend on whether the ecosystems are being managed primarily for conservation or production or other purposes. For example, ecological thinning can be a useful technique to achieve conservation goals in some river red gum forests – it can promote the creation or retention of large hollow-bearing trees in areas dominated by dense regrowth (Horner et al., in press). This thinning can be implemented differently from that in areas managed primarily for production, for which prescriptions are already well established (Forestry Commission of NSW, 1984).

The NRC has developed a set of principles to guide a range of management activities in red gum floodplain ecosystems, including ecological thinning, grazing, fire management, silviculture and firewood collection (**Table 11.2**). The principles are intended to underpin the management of red gum floodplain ecosystems for both conservation and production outcomes.

These principles have been developed specifically for river red gum forests, within the context of their current condition and expected future trajectory. They build on more general principles for managing ecosystems under changing environmental conditions such as declining water availability or climate change (Lindenmayer et al., 2000; Lindenmayer et al., 2006; Lindenmayer et al., 2008 Millar et al., 2007; Dunlop and Brown, 2008; Mawdsley et al., 2009; Montreal Process Implementation Group, 2008a; NRC, 2005; Commonwealth of Australia, 2009).

If the principles are codified in management plans or formal agreements for all tenures, the NRC considers they will promote resilient, diverse and sustainable red gum floodplain ecosystems, continue to support community values, and drive adaptive management.

The remainder of this section:

- summarises the principles
- discusses the rationale for each in relation to ecological thinning, grazing, fire management and silviculture.

The descriptions do not attempt to cover all possible interventions. Instead they address a number of specific activities that can strongly influence forest sustainability under conservation and production management objectives.

Table 11.2: Principles for red gum floodplain ecosystem management

Principles for red gum floodplain ecosystem management
Principles for all red gum floodplain ecosystem management under environmental change
• **Principle EM1**: Sustain large-scale hydrological and geomorphological processes. • **Principle EM2**: Maintain connectivity between communities, habitats and ecological processes across the bioregion. • **Principle EM3**: Implement a range of management strategies across different spatial, temporal and institutional scales to spread risk. • **Principle EM4**: Implement active management regimes within both protected and production areas. • **Principle EM5**: Maintain forest complexity within production forest areas, including stand complexity, large trees and threshold levels of coarse woody debris, and variability across space and time. • **Principle EM6**: Establish a comprehensive, adequate and representative series of reserved areas. • **Principle EM7**: Enable environmental stewardship by individual and groups on private land. • **Principle EM8**: Involve local communities in strategy development and implementation to ensure greater success in achieving identified goals. • **Principle EM9:** Implement adaptive management in reserves and production forests to allow lessons to be learnt from management actions, and to allow their refinement.
Principles for ecological thinning
• **Principle ET1**: Ecological thinning can provide a valuable tool to achieve specified conservation outcomes in some river red gum forests, including those managed primarily for production and for conservation. • **Principle ET2**: Ecological thinning can be undertaken in many different ways, with different impacts on forest structure, processes and biodiversity. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met. • **Principle ET3**: Ecological thinning should be applied to forest areas where clearly defined outcomes can be reasonably expected. • **Principle ET4**: All ecological thinning should be implemented using an experimental, adaptive management framework to ensure desired outcomes are achieved, maximise learning outcomes and reduce uncertainty. • **Principle ET5**: Thinning, like all other management activities, should be carried out in accordance with accepted principles for landscape management of forested areas (Principles EM1–9).
Principles for fire management
• **Principle FM1**: Prescribed fire can be a valuable tool to control fuel levels and achieve specified ecological outcomes in some forest areas. • **Principle FM2**: In areas managed for conservation rather than production values, prescribed fire can provide a useful tool to achieve management goals, such as manipulating vegetation structure and composition, thinning dense stands, reducing fuel loads, promoting tree and shrub regeneration and controlling the abundance of vigorous dominant wetland plants.
Principles for grazing
• **Principle GM1**: Uncontrolled or poorly managed livestock grazing has caused considerable damage to river red gum forests in the past, and has the potential to further degrade environmental attributes. • **Principle GM2**: Notwithstanding Principle GM1, livestock grazing has potential to achieve positive outcomes for conservation values in limited parts of the forest, especially degraded and weedy areas, where it can help to reduce weed cover and control fuel loads. • **Principle GM3**: Livestock grazing should only be conducted where it achieves clearly specified management goals, and where stock can be contained to designated areas, to prevent unintended outcomes to sensitive features. • **Principle GM4**: Ground vegetation (and fuel) levels vary greatly between seasons and years according to flooding and rainfall. On public lands, livestock grazing should only be permitted when vegetation and fuel levels are appropriate, and licensing or agistment arrangements must enable stock to be removed at short notice, to satisfy land management goals. • **Principle GM5**: Where livestock grazing is conducted, it should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.

Table 11.2: Principles for river red gum ecosystem management

Principles for red gum floodplain ecosystem management	
Principles for silviculture	
• **Principle S1**:	'Group selection' is an appropriate silvicultural technique for river red gum forests managed for production values, subject to the provision and maintenance of ecological values, principally retention of adequate habitat trees and coarse woody debris resources, and other constraints of intensity and implementation described by Principles S2–8.
• **Principle S2**:	Group selection should only be applied to river red gum forests that are expected to receive adequate future watering.
• **Principle S3**:	Habitat trees should be retained permanently and distributed across the forest landscape.
• **Principle S4**:	Gap intensity needs to explicitly consider the ecological character of river red gum forests, particularly those which are Ramsar-listed.
• **Principle S5**:	Selective harvesting in immature forests between 'gapped' areas should be constrained by timing and intensity, and ecological thinning should be guided by ecological principles.
• **Principle S6**:	Coarse woody debris loads should be enhanced to threshold levels where practicable and consistent with other management objectives, such as fire management goals.
• **Principle S7**:	Salvage logging has the potential to be ecologically damaging and should follow recognised best-practice guidelines and adhere to the silviculture principles above.
• **Principle S8**:	Outcomes of river red gum silviculture, and the assumptions underpinning them, need to be monitored and tested in a structured and systematic manner to generate new knowledge and reduce uncertainty over time.
Principles for firewood collection	
• **Principle FC1**:	As per Principle S6, coarse woody debris loads at threshold levels should be retained where practicable and consistent with other (e.g. fire risk) management requirements.
• **Principle FC2**:	Firewood collection is generally inappropriate in conservation areas unless undertaken to achieve specific ecological or management goals (e.g. fire management), or where used for in-park recreational use. In such instances the provisions of Principle FC1 should also be adhered to.

Wetuppa State Forest

11.3.1 Ecological thinning for conservation outcomes

As described in Chapter 8, a substantial proportion of existing river red gum forests will receive less water in the future than in the past. This will impact greatly on forest condition in many parts of the forest.

As water availability declines, river red gum stands can be expected to pass through a number of stages of stand decline – reduced growth rates, less frequent regeneration, decline in foliage cover and 'tree health', and increased mortality. Tree death can lead to an 'opening up' of the canopy and consequently lower stand densities. Under more extreme conditions, this can in turn lead to widespread tree mortality and transformation to another ecosystem type, such as box woodland, saltbush plain or grassland.

In these circumstances, a spectrum of management options exists, from attempting to reverse or prevent the decline in water availability (for example, through engineering works and environmental flows), to allowing ecosystem changes to occur unhindered. Both of these approaches are likely to be used in different parts of the river red gum forests. However, other management approaches can be utilised between these two extremes. In some areas, it may be possible to reduce the adverse impacts of declining water availability on valued forest attributes by manipulating forest stands.

One approach is to attempt to enhance the growth, health or survival of desired trees by thinning competing trees. For over a century, foresters have thinned dense regrowth stands to enhance the growth rate and quality of desired timber-producing trees (Forestry Commission of NSW, 1984).

While thinning has historically been undertaken for timber production reasons, it can also be a valuable tool to achieve conservation goals. For example, Horner et al. (in press) found that thinning increased the rate of production of tree-hollows in thinned stands. In this case, thinning in these regrowth forests greatly enhanced the rate of creation of this important, and increasingly scarce, environmental attribute of river red gum forests.

Ecological thinning can potentially provide positive outcomes for biodiversity (see also **Box 11.1**), by:

- enhancing survival of valuable large trees
- increasing tree growth rates and the rate of creation of habitat trees
- creating coarse woody debris (Killey et al in press)
- enhancing carbon storage
- enhancing habitat quality
- reducing fire hazard from standing live or dead trees.

Several submissions to the NRC's assessment also suggested that ecological thinning can play an important role in enhancing production and conservation values in river red gum forests (for example, Dexter, 2009; Gelletly, 2009). Others pointed out the limits of current knowledge (for example, Cunningham and Mac Nally, 2009; Cunningham et. al., in press).

It is well known that thinning of dense stands can enhance tree growth (Forestry Commission of NSW, 1984; Dexter, 1970; Horner et al., in press). Field experience also suggests that thinning may also benefit tree health in particular circumstances, although this is not well documented in the scientific literature. However, there has been no formal appraisal of the potential positive effects of thinning on conservation values in river red gum forests, especially under a declining water regime (other than Horner et al's (in press) work noted above).

There is an urgent need for managers to develop ecologically appropriate and operationally practical techniques to enhance ecosystem health in many river red gum forests that are already suffering severe stress. This requires robust, prudent management frameworks to guide ecological thinning in river red gum forests – in both production and reserved areas.

The NRC has developed a set of principles as a basis for implementing ecological thinning in river red gum forests (**Table 11.3**). These have been drawn from what is currently known about the potential biodiversity benefits from ecological thinning (**Box 11.1**).

Some of these approaches could also provide positive outcomes for timber production. However, ecological thinning may not enhance forest health in all areas (**Box 11.3**). Some stands experiencing severe declines in water availability may decline regardless of whether thinning is undertaken (Cunningham et al., in press). Adaptive management trials and reporting of results are required to develop a greater degree of certainty about the outcomes that can be achieved.

Large hollow bearing tree

Table 11.3: Principles and rationale for ecological thinning

Ecological thinning principles	
Principle ET1:	**Ecological thinning can provide a valuable tool to achieve specified conservation outcomes in some river red gum forests, including those managed primarily for production and for conservation.**
Thinning is a well established method to enhance production outcomes. Ecological thinning involves the selective removal of trees (usually regrowth or suppressed trees) to achieve specified ecological outcomes. In certain areas, thinning can provide a potentially useful tool to reduce competition among trees and alleviate water stress. Hence, it could play an important role in enhancing survival of key forest attributes (such as old trees) in a drying forest. Ecological thinning could potentially enhance tree growth rates and tree health; tree survival, including large hollow-bearing trees; the rate of formation of tree hollows; coarse woody debris loads; carbon storage; and habitat quality for species that prefer open areas and habitat variability (heterogeneity), although not all of these outcomes have been rigorously tested (see **Box 11.1**) (Dexter, 1970; Forestry Commission of NSW, 1984; Horner et al., 2009, Horner et al., in press, Killey et. al. in press). Many of these attributes in river red gum forests have been depleted by past management – although more recent management has recognised and sought to redress this – or are expected to decline with future reductions in water availability. In this context ecological thinning can be used as a forest restoration tool.	
Principle ET2:	**Ecological thinning can be undertaken in many different ways, with different impacts on forest structure, processes and biodiversity. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met.**
Ecological thinning can be undertaken in many different ways (**Box 11.2**), including: • reducing stocking levels to a uniform, pre-determined level across moderately large areas • creating small open gaps within larger areas of dense regrowth • reducing stocking levels (and/or creating gaps) around specified features (e.g. large trees). Each of these approaches will have different impacts on forest structures, processes and biodiversity. Approaches that may have the greatest utility from a silvicultural perspective are not necessarily the most appropriate to achieve conservation objectives. Wherever thinning is undertaken to achieve conservation goals, these goals must be clearly specified, and the most appropriate technique must be used to ensure that goals can be met.	
Principle ET3	**Ecological thinning should be applied to forest areas where clearly defined outcomes can be reasonably expected.**
The potential for thinning to enhance tree growth, health or survival will vary across forest areas according to the degree of competition and water availability. Consequently, ecological thinning has potential to enhance forest health in some parts of the forest only. Conceptually, this potential can be explained in terms of patterns of tree stocking and water availability (**Box 11.3**). Thinning should be restricted to forest areas where desired outcomes can be reasonably expected, monitored and assessed.	
Principle ET4:	**All ecological thinning should be implemented using an experimental, adaptive management framework to ensure desired outcomes are achieved, maximise learning outcomes and reduce uncertainty.**
Little research has been undertaken to assess the effects of different thinning techniques on conservation outcomes. Ecological outcomes are subject to considerable uncertainty, especially under a scenario of increasing forest drying. For example, the effects of thinning on arboreal and terrestrial fauna and ground vegetation are unknown. Therefore, all ecological thinning should be implemented using an experimental, adaptive management framework to maximise learning outcomes, consistent with approaches recommended by the Biodiversity and Climate Change Expert Advisory Group (2009). Ecological thinning and other forms of active management involve uncertainties and risks, such as harvest-induced damage to residual trees. However, allowing natural processes to occur also carries considerable risks – particularly in river red gum forests that are undergoing considerable change due to human-induced reductions in water availability. If carefully implemented, active management does not necessarily have higher risks than passive management.	
Principle ET5:	**Thinning, like all other management activities, should be carried out in accordance with accepted principles for landscape management of forested areas (as described in Table 11.2).**
Ecological thinning should be conducted within the context of broader management objectives and systems intended to maximise the potential to maintain resilient, diverse, sustainable ecosystems, which continue to deliver ecosystem services, under anticipated changes to water availability and climate. This is equally important in forests managed for conservation as well as those managed for production and conservation.	

11.1: Potential biodiversity benefits from ecological thinning

Enhanced survival of valuable large trees

Under reduced water conditions, large and small trees are declining in health. In many places, water stress is not just killing small and suppressed trees, it is leading to declines in health and survival of all trees, including old, hollow-bearing trees (Cunningham et al., 2009). In some cases, thinning of small trees in close proximity to stressed large trees may enhance the health and survival of large trees, although further experimental trials are required to assess the utility of this approach. By contrast, if large trees die it will take many decades or centuries to recreate the lost habitat values. Thus, if thinning around individual large trees improves the amount of water availability to them, it may help to maintain existing valuable habitat trees and potentially provide a supply of future habitat trees.

Increased tree growth rates and the rate of creation of habitat trees

Competition slows the rate of growth of trees in dense stands. By thinning stands, remaining trees can grow faster (Horner et al., 2009). This has obvious benefits for production forestry, but could also have conservation benefits in some forests, especially in areas of young regrowth. Large trees are currently relatively rare in many river red gum forests, and they contain habitat values that are not provided by small trees, such as hollows. Thinning early in the tree growth cycle accelerates branch growth, which in turn will lead to faster establishment of hollows, as noted above from Horner et al.'s (2009) work.

Coarse woody debris

Densities and breeding success of some fauna are higher in areas with abundant coarse woody debris (logs and branches on the ground) (Mac Nally, 2006; Mac Nally and Horrocks, 2008). Coarse woody debris accumulates slowly, especially in young forests. Horner et al. (2009) suggest that ecological thinning could increase habitat values for fauna if thinned debris is left on the ground to form coarse woody debris. Killey et al. (in press) highlight the importance of large senescing trees for the production of fallen branch debris, and support the thinning of regrowth stands to promote the growth of retained trees, ensuring they contribute to fallen branch debris stocks with a minimum time lag.

Carbon storage

Forests have a valuable role to play for carbon sequestration and storage. Moderate degrees of thinning can increase above-ground carbon storage levels above levels that are provided by dense, slow-growing, un-thinned stands (Horner et al., 2009).

Enhanced habitat quality

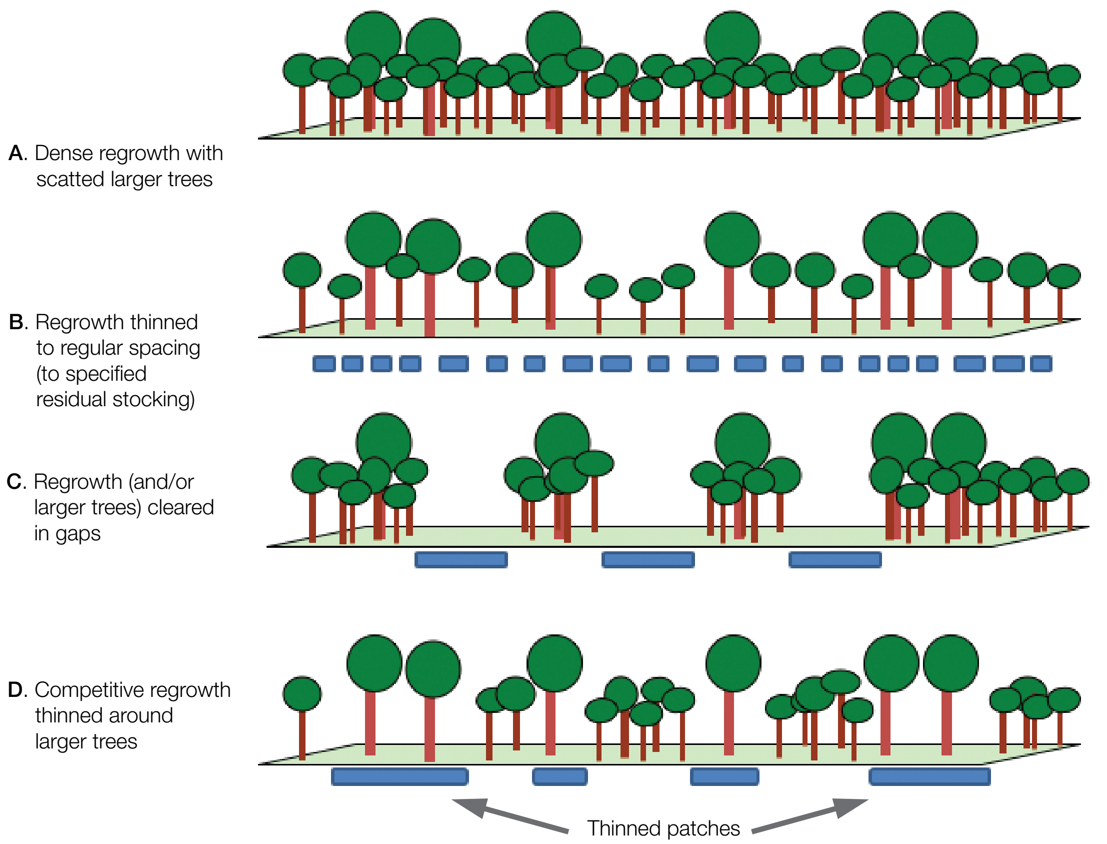
A general guideline for sustainable ecosystem management is to create spatially variable habitats, rather than large uniform stands (Lindenmayer et al., 2006). Different species value different habitat structures, and a diversity of habitat structures enhances species diversity across large areas. In areas dominated by large areas of dense regrowth, thinning has the potential to increase habitat variability, thereby enhancing its habitat suitability for a wider variety of species. This variability can be created through other processes, for example, through tree mortality caused by extreme water stress or severe fires. However, thinning provides greater levels of control over the number and species of trees removed than either process, and could enhance survival of valued habitat attributes such as large trees.

Reduced fire hazards

In some forests overseas, ecological thinning has been used to reduce fuel loads and lower fire hazards (e.g. *Pinus ponderosa* forests in USA; Allen et al., 2002). Thinning in river red gum forests could reduce leaf litter deposition rates and elevated fuel loads in the short to medium term. However, fine fuel levels derived from grasses and levels of coarse woody debris derived from thinned trees may be higher in thinned forests. The net outcome of these changes in river red gum forests is poorly understood and requires further research.

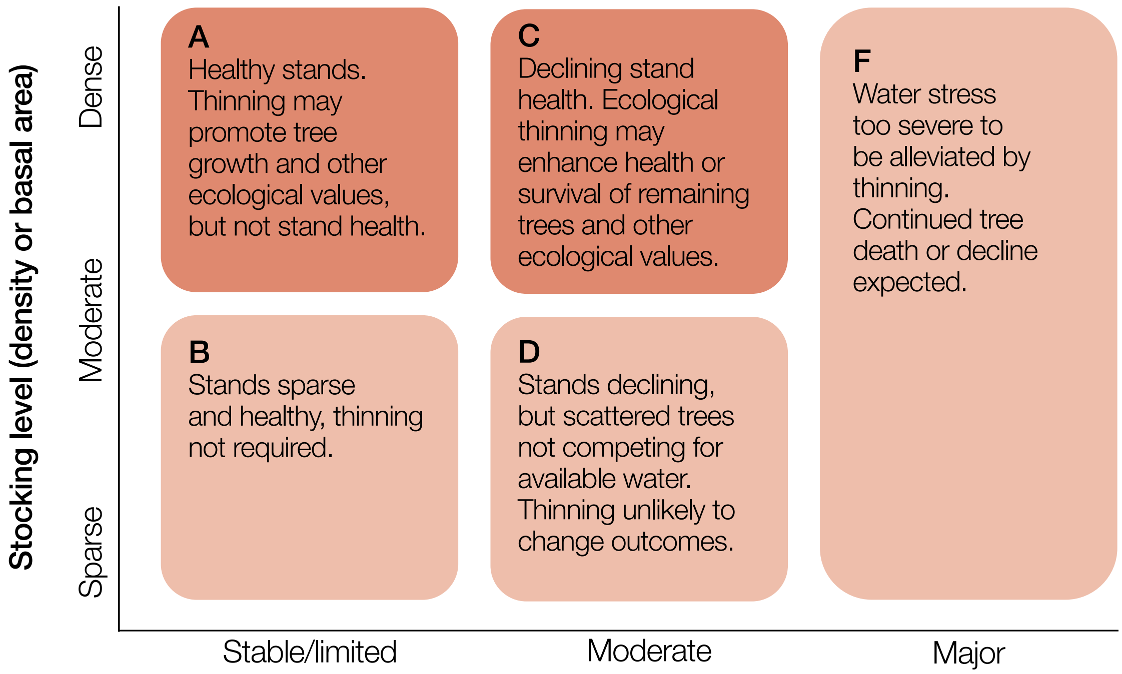
Dense even-aged regrowth

Box 11.2: Illustrative spatial arrangements of ecological thinning in a red gum forest



Each arrangement will have different impacts on ecosystem function, structure and composition. State A = un-thinned.

Box 11.3: Conceptual model illustrating possible benefits that could be obtained from ecological thinning in stands of contrasting stocking level and water stress



11.3.2 Fire management

River red gum forests supported high densities of indigenous people before European colonisation (**Chapter 6**). Indigenous people used fire extensively in this and other regions (Curr, 1883). As in other grassy woodland and grassland ecosystems across south-eastern Australia, fire regimes in red gum forests are generally believed to have been characterised by frequent, low intensity fires ignited by indigenous people and lightning. Unfortunately, more specific details about particular aspects of pre-settlement fire regimes – in red gum forests as well as other grassland and woodland ecosystems – are unknown (Bren, 1990; Donovan, 1997; Yates and Hobbs, 1997; Lunt and Morgan, 2002; Fensham, 2003), although these questions are actively debated (for example, Benson and Redpath, 1997; Bowman, 1998; Esplin et al., 2003; Jurskis, 2009).

Fire regimes influence river red gum forests in many ways. River red gum trees are more susceptible to fire than most eucalypts. Red gum seedlings can be killed by low intensity fires and mature trees by higher intensity fires (Forestry Commission of NSW, 1984). However, fires can also assist river red gum regeneration by promoting seed fall, improving seedbed condition and removing competition for red gum seedlings (Dexter, 1970; Forestry Commission of NSW, 1984). Fires can also promote germination and establishment of other species such as *Acacia*.

River red gum forests which are regularly inundated are less likely to burn than many other dry eucalypt forests, because of flooding and the associated high moisture contents of soil and litter, and low understorey biomass due to the patchiness of the shrub layer. Crown fires are rare due to the height of the trees and lack of shrubs (Benson et al., 2006). Intense fires can cause death of mature river red gum trees, and loss and degradation of arboreal habitat. For example, wildfire can impact significantly on core breeding habitats of important species such as the superb parrot (Forests NSW, 2009a).

Managed fire is widely used in Australia to reduce forest fuels to protect people and the environment from wildfire. However, because of the susceptibility of river red gums to fire, and the difficulties of managing fire in red gum forests (Forestry Commission of NSW, 1984), small-scale post-harvesting regeneration burning is usually the only managed fire used in river red gum forests. Fuel reduction burning is not usually used in red gum forests managed for wood production (Forests NSW, 2008).

VEAC (2008) proposed the use of ecological burning in the river red gum forest reserves in Victoria. VEAC considered that the managed use of fire was the optimum way to manage understorey biomass while promoting species diversity and thus resilience in the river red gum forests, where there was no livestock grazing. However, this recommendation has not been tested yet.

Table 11.4: Principles and rationale for fire management

Fire management principles	
Principle FM1:	**Prescribed fire can be a valuable tool to control fuel levels and achieve specified ecological outcomes in some forest areas.**
All land managers are required by legislation to ensure that fire hazard is controlled to ensure public safety and asset protection, following legislative requirements for public and private land managers. Prescribed burning has not been widely used in river red gum forests for a number of reasons, including low fuel levels in many places and seasons, potential damage to timber quality, and because fine ground fuel levels have traditionally been controlled using livestock grazing. River red gums are more fire-sensitive than many other eucalypts, and are often killed by medium to high intensity fires. Nevertheless, river red gum ecosystems have always been exposed to fires, and many native species have evolved adaptations to survive or regenerate after single fires. Consequently, fires do not necessarily ‘damage’ or ‘destroy’ red gum ecosystems, even though particular attributes (such as valuable large, hollow-bearing trees) may be killed. All natural ecosystems, including river red gum forests, are affected by fire regimes (the succession of fires that occurs over a period of time), and fire managers needs to ensure that fire regimes are managed to achieve management goals (Keith et al., 2002), including human safety, asset protection and other legislative requirements.	
Principle FM2:	**In areas managed for conservation rather than production values, prescribed fire can provide a useful tool to achieve management goals, such as manipulating vegetation structure and composition, thinning dense stands, reducing fuel loads, promoting tree and shrub regeneration and controlling the abundance of vigorous dominant wetland plants.**
In timber production areas, prescribed burning is generally avoided due to damage to merchantable timber. By contrast, in conservation areas, managers may have more flexibility in using prescribed burning to achieve management goals as damage to timber values is less relevant to management goals. Prescribed burning can potentially be used to achieve many management goals in conservation areas. For example, red gum seedlings are fire-sensitive and dense stands can be thinned using prescribed ecological burns. Prescribed fires can be used to reduce fine fuel levels, including eucalypt leaf litter which is not reduced by other methods such as livestock grazing. In wetlands, prescribed fires can be used to restore wetland structure and habitat values by helping to controlling vigorous encroaching species such as giant rush. In all cases, the ecological outcomes of prescribed burning are poorly documented in river red gum forests, and considerable uncertainty surrounds likely fire effects. Consequently, prescribed burning should be subject to Principles Et4 and Et5, which were presented above in relation to ecological thinning. All prescribed burning should be implemented using an experimental, adaptive management framework to maximise learning outcomes, consistent with approaches recommended by the Biodiversity and Climate Change Expert Advisory Group (2009).	

Table 11.4 describes the principles the NRC has developed for fire management for both conservation and production areas.

11.3.3 Grazing management

The majority of river red gum forest riparian areas are in private ownership. These areas have value for stock grazing, not only for their fodder, but as a reliable source of water. The presence of stock in these environments (including riparian zones in public lands) can have a deleterious effect on their condition and ecological values, particularly considering the habits of cattle congregating around watering points (Robertson, 1997).

NSW Forests has developed a strategy to guide its approach to grazing in NSW State Forests (Forests NSW, 2000a). This was developed through a Grazing Review Panel containing local and scientific expertise (Forests NSW, 2000a). In developing recommendations for future management, the panel was asked by Forests NSW to consider:

- the environmental affects of past livestock grazing practices
- the future environmental effects if grazing practices continued in their present form
- what changes are required to sustain present-day environmental values and remedy past grazing impacts (Forests NSW, 2000a).

From this, the panel identified a tactical grazing system and other measures that aim to strike a balance between conservation and production (Forests NSW, 2000a).

Grazing management plans are being developed for occupation permit areas greater than 2,000 hectares. These plans address stocking periods and numbers, sensitive area identification, rehabilitation, pests, environmental monitoring, significant archaeological sites and environmental impact assessment. Grazing management must also seek to address the grazing pressure originating from native and introduced feral herbivores, as well as from domestic stock.

Historically, intensive grazing has had many negative impacts on biodiversity and other environmental values. For example, grazing has altered flora species composition, and contributed to the loss of grazing-sensitive flora species in lower vegetation profiles (Forests NSW, 2009a). It has also reduced reed beds and fringing vegetation that are important habitats for crustaceans, aquatic and terrestrial invertebrates, frogs and waterbirds (Robertson, 1998; Jansen and Healey, 2003). However, on a positive note, Jansen and Robertson (2001) found that riparian and wetland areas in many State Forests were in better condition than those on privately owned lands, due to lower stocking levels over the last century.

In areas that have been subjected to heavy livestock grazing for over a century, pre-existing values may not return following the removal of livestock. Lunt et al. (2007) assessed the effects of grazing exclusion on a degraded understorey dominated by exotic annuals in Gulpa Island State Forest. They found only minor differences in vegetation composition and cover between grazing and ungrazed areas after 12 years of excluding livestock. While the ungrazed plots had slightly more vegetation cover, there was no difference in species richness and little difference in species composition between grazed and ungrazed treatments.

In some native grasslands and grassy woodlands, rotational grazing regimes have been developed into a useful disturbance mechanism to increase species diversity and grassland health, akin to the likely disturbance and benefits of fire (Dorrough et al., 2004; Earl and Jones, 1996; Lunt and Morgan, 1999). However, these benefits have largely occurred in ecosystems that support thick, dense grass or abundant weeds in the absence of grazing, fire or other disturbances (Lunt et al., 2007). By contrast, many river red gum forests support relatively low cover and biomass of grass and other ground plants in many years, and livestock grazing is unlikely to promote ecological values in these cases (Lunt et al., 2007).

Well-managed grazing can be used in particular cases as a management tool to achieve specific management goals, with minimal adverse impact. In particular, livestock grazing may be a practical tool to control exotic annual grasses and herbs, which can accumulate high cover and biomass, particularly in degraded forest areas (Lunt et al., 2007). This may also reduce fine fuel loads for fire management purposes.

Careful consideration of the impact of grazing at the local level is required prior to implementing changes to grazing practices. It is important to consider the potential impacts of current or proposed grazing regimes rather than historical regimes, as future impacts are likely to differ from those that occurred up to a century ago. Understanding the impact of grazing is critical to ensure that informed adaptive management can be introduced (Lunt et al., 2007). Forests NSW recognised these issues in developing and implementing a grazing strategy (Forests NSW, 2000a) in the river red gum and associated forests.

Table 11.5 describes a set of principles the NRC has developed for grazing management of both conservation and production areas.

Livestock grazing

Table 11.5: Principles and rationale for grazing management

Grazing management principles
Principle GM1: Uncontrolled or poorly managed livestock grazing has caused considerable damage to red gum forests in the past, and has the potential to further degrade environmental attributes.
Livestock grazing has caused considerable damage to many river red gum forests and associated riparian and wetland ecosystems. These impacts are well documented in many ecosystems in southern Australia, including river red gum forests (Jansen and Robertson, 2005). Livestock grazing has caused local erosion, damaged streamsides, changed understorey plant composition by reducing perennial native plants and promoting weeds, and degraded habitat for wetland fauna (Forests NSW, 2009a; Jansen and Robertson, 2005; VEAC, 2008). The removal or control of livestock is widely recommended in riverine and riparian areas (Price and Lovett, 2002). The sensitivity of river red gum forests and associated ecosystems to livestock grazing varies greatly between vegetation types and places. Some ecosystems are highly sensitive to grazing, whereas others (especially degraded areas) are relatively resilient to current grazing levels (Lunt et al., 2007). The Grazing Strategy developed by NSW State Forests, for example, excluded livestock from many highly sensitive areas, such as large wetlands, while permitting grazing in more resilient and less sensitive zones.
Principle GM2: Notwithstanding Principle GM1, livestock grazing has potential to achieve positive outcomes for conservation values in limited parts of the forest, especially degraded and weedy areas, where it can help to reduce weed cover and control fuel loads.
In some areas, strategic livestock grazing can play a useful role in promoting conservation values (Forests NSW, 2000b; Lunt et al., 2007). This is most relevant in degraded and weedy areas, where livestock grazing can be used to reduce weed levels of exotic grasses and other weeds. This is particularly the case in relatively dry red gum forests and in other woodland ecosystems (Forests NSW, 2000a).
Principle GM3: Livestock grazing should only be conducted where it achieves clearly specified management goals, and stock can be contained to designated areas, to prevent unintended outcomes to sensitive features.
Given potential adverse impacts of livestock grazing, it is critical that any livestock grazing conducted within river red gum forests is managed to achieve clearly specified goals, and that livestock is constrained to areas of concern. The fine-scale mosaic of different wetland and dryland habitats in some forest areas makes it challenging to restrict livestock to particular areas. In such cases, livestock should be managed to ensure grazing is compatible with the areas of highest environmental sensitivity within the grazed area (Forests NSW, 2000a; Lunt, 2005).
Principle GM4: Ground vegetation (and fuel) levels vary greatly between seasons and years according to flooding and rainfall. On public lands, livestock grazing should only be permitted when vegetation and fuel levels are appropriate, and licensing or agistment arrangements must enable stock to be removed at short notice, to satisfy land management goals.
The cover and biomass of ground vegetation vary greatly over time as a result of the variable rainfall and flooding regimes experienced in river red gum forests. To maintain both ecosystem health and animal health, livestock grazing must be restricted to periods when grazing is appropriate and necessary to achieve management goals. Consequently, grazing licences, permits or agistment arrangements must enable stock to be removed at short notice, to ensure land management goals are not compromised. This requires considerable flexibility in livestock management and transport capacity by graziers, and necessitates positive interactions and regular communication between licence holders and management agencies. As an example, the Grazing Strategy for the Riverina Region specifically addresses the management of grazing within well defined biomass levels and according to seasonality constraints. This ensures that grazing is able to target introduced annuals and favour the establishment and long-term persistence of native perennials. Assignment of Occupation permits for grazing should only be done via a tender or similar process that reflects the intent of the grazing strategy and is able to give effect to the stated aims in the strategy. Occupation permit conditions should also give legal effect to the intent of the grazing strategy.
Principle GM5: Where livestock grazing is conducted, it should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.
Unfortunately, while many claims have been made about potential positive or negative impacts of current grazing regimes, these claims often cannot be rigorously evaluated because of the lack of adequate monitoring and evaluation procedures. Many studies have suggested that particular grazing regimes (such as short duration grazing, or protracted spelling) can provide positive environmental outcomes (Dorrough et al, 2004; Earl and Jones, 1996; Lunt et al., 2007). However, little evidence is available on how these grazing regimes affect environmental values in river red gum forests. A grazing monitoring program has been initiated by Forests NSW to address this lack of knowledge. Further trials will greatly increase our understanding of how to manipulate livestock grazing to enhance desired outcomes while reducing potential risks. Consequently, all livestock grazing should be undertaken using an adaptive management approach so that positive and negative impacts can be monitored and reported.

11.4 Silvicultural systems, management practices and principles

Forests NSW is a public trading enterprise which aims to balance commercial, environmental and social objectives. Forests NSW's goal is to manage the river red gum forests

for their conservation and sustainable use to benefit the community in a way that is compatible with the maintenance of the natural properties of their ecosystems and also under the wise use principles of the Ramsar Convention (Forests NSW, 2008a).

The silvicultural systems and management practices applied in river red gum forests have evolved as a result of experience and research since formal forest management began in these forests in the first quarter of the 20th century. Within this context, and subject to other environmental and economic constraints, Forests NSW has developed a range of silvicultural systems and management prescriptions to meet quota sawlog commitments, promote growth and regeneration of the stand remaining after harvesting and reduce impacts on environmental values (Forests NSW, 2000a, 2008, 2008a).

This section describes:

- how silviculture systems have evolved
- current silviculture systems and management prescriptions
- a set of principles for future river red gum silviculture.

11.4.1 Evolution of silviculture systems

The silvicultural systems and management practices applied in river red gum forests have evolved as a result of experience and research since formal forest management began in the first quarter of the 20th century. Jacobs (1955), Forestry Commission of NSW (1984) and Florence (1996) provide overviews of how these systems and practices evolved, and their scientific and management basis.

The silviculture applied since 1947 has been largely in response to very selective harvesting between 1910 and 1945, which left a large number of older trees unsuitable for wood production; these inhibited regeneration (Forestry Commission of NSW, 1984, Jurskis 2009). Consequently, removal of veteran trees by ringbarking (known as 'timber stand improvement') was common until the 1960s. Research had identified the benefits to tree survival and growth of reducing competition with regenerating stands, and so thinning was used increasingly from the 1970s in the forest stands which had regenerated during the 19th century (Forestry Commission of NSW, 1984, Jurskis, 2009).

Australian Group Selection (AGS) – a silvicultural system aimed at promoting vigorous establishment of the next generation of trees – was introduced as these stands approached their intended maturity for timber production of 90 to 120 years. AGS was first implemented in NSW forests in the 1920s (Jacobs, 1955, after Jolly, 1920), and has been applied in a variety of NSW moist and dry eucalypt forests (Florence, 1996). Forestry Commission of NSW (1984) noted that "something akin to a group selection system" was likely to be "quite well suited" to river red gum, and various forms of AGS were applied in river red gum stands originating from the 1870s floods in the 1980s and 1990s (when it was known as "gaps and clusters"). AGS in its current form has been applied in river red gum forests of higher site quality since 2001 (see the next section for a more detailed description of AGS).

Since 2001, there has been only limited seedling regeneration in many AGS gaps in river red gum forests, as a consequence of the extended drought and lack of flooding. The most recent flooding event was in the late 1990s; while environmental flows have been delivered to particular wetlands, these have not been widespread, and consequently seedling regeneration has not yet established in many AGS gaps. Seedling regeneration in river red gum forests is naturally episodic, following flooding or adequate rainfall, and the lack of regeneration in the current drought period reflects this. Coppice regeneration has occupied some parts of AGS gaps.

11.4.2 Application of current silvicultural systems in river red gum forests

The three silvicultural systems applied by Forests NSW in management of river red gum forests – thinning, selective harvesting and AGS – have some common goals and features, but also some differences.

Thinning and selective harvesting are applied principally to reduce competition between trees for water and other site resources, and encourage the growth of tall, straight trees that are valuable for timber. One of the key silvicultural issues for wood production in river red gum forests is that, in the absence of competition between trees of the same cohort to force vertical growth and restrict branch development and forking, young stems typically fork or branch early in their growth and retain low branching, leading to poor sawlog recovery. Therefore, a key management approach in river red gum is to follow natural post-flooding regeneration processes, and grow the regeneration in reasonably dense clumps to force vertical growth and restrict branch development, as straighter trunks and fewer branches are more suitable for timber for high-value uses. Once trees are about 20–30 centimetres in diameter, forest growth form has been attained, and dominant trees have begun to emerge, then thinning may be conducted to remove suppressed trees and reduce competition for dominant trees to grow (Forestry Commission of NSW, 1984).

Competition between trees will also influence regeneration success, and stand health and development, in river red gum forests (as in other eucalypt forests). Mature trees can out-compete new seedlings for soil moisture, and suppress seedlings to an extent of approximately two crown widths from each larger tree. As discussed earlier, reducing the number of trees per unit area through thinning or selective harvesting may improve the health and reduce the mortality of retained trees, although the effects may be relatively localised (Dexter, 1970).

The application of thinning or selective harvesting is unlikely to create gaps large enough for the development of the dense young regrowth stands described above. Therefore, AGS is applied to groups of trees which have reached maturity for production purposes – 90 to 120 years for river red gum – to create the conditions for good regeneration of dense, even-aged cohorts (Forests NSW, 2008a).

All silvicultural systems are required to respect environmental and other values through observing restrictions on harvesting to protect these values. These restrictions are summarised, and compared to those required for river red gum forest management on private land in NSW, in **Appendix 10**.

The three silvicultural methods applied in river red gum forests are described below.

Single Tree Selection (STS)

This silvicultural method is usually applied in mixed aged (or mixed size) or mixed species stands. More dominant trees are usually selected for harvesting from within the stand, leaving subdominant trees that ideally will grow with reduced competition and available light. This method may be applied where there is growing stock scattered amongst a mature stand, or where mature trees are scattered amongst a well-stocked regrowth stand.

The title of 'single tree' selection can be a misnomer, as more than a single tree may be removed at any location, depending on stand characteristics. Although basal area retention requirements in the implementation of STS are not formalised for public red gum forests as they are by the Private Native Forestry (PNF) Code, established practice conforms to those specified in the PNF Code, of retaining a minimum stand basal area of 12 square meters per hectare. Typically a higher stand basal area is retained. STS is only applicable where the stand structure and floristics permit successful regeneration in canopy openings created by removing single trees, or small groups of trees.

Figures 11.1 and **11.2** provide a schematic view of how STS is applied to stands. **Figure 11.1** indicates that single trees within a stand are marked for removal or retention. **Figure 11.2** indicates the composition of the stand following removal of the selected trees (figures taken from Forests NSW, 2008a).

Australian Group Selection (AGS)

AGS is a system applied to eucalypt forests of mixed ages or mixed-size classes (Jacobs, 1955). It involves harvesting groups of commercially mature trees. The objective of the system is to harvest groups of commercially mature trees to promote vigorous establishment of the next generation of trees.

AGS creates canopy gaps of sufficient size to reduce competition from the surrounding forest, while keeping gaps small enough to allow adequate seedfall from surrounding trees to be dispersed to all parts of the gap (Florence, 1996; McElhinny, 2009). The latter feature of AGS, and its concomitant

Figure 11.1: Trees marked for removal or retention using STS

Figure 11.2: Indicative stand composition following removal of trees using STS

smaller gap size, distinguishes AGS from silvicultural systems characterised as clearfelling; it also means that AGS gaps have the potential to regenerate over extended periods, so long as the seed bed is or can be made receptive (through mechanical disturbance or use of low-intensity fire), as seed is not a limiting resource (McElhinny, 2009).

AGS maintains an irregular forest at a patch scale and can be applied to more uniform stands to create a more mixed-aged forest to enhance diversity. The system was developed as a compromise between the need to conserve immature growing stock; regeneration requirements of competition-intolerant species; and the need to consider values other than efficient timber production (Florence, 1996). **Figure 11.3** indicates groups of trees within a stand that are marked for removal or retention. **Figure 11.4** indicates the composition of the stand following removal of the selected trees (figures taken from Forests NSW, 2008).

The maximum area of individual regeneration openings in AGS coupes in river red gum State Forests has been 0.8 hectares, with the constraint that AGS could not be applied over more than 30 per cent of any harvest area. Subsequent to a Land and Environment Court settlement of 2007, the maximum regeneration opening in an AGS coupe was reduced to 0.4 hectares, with a maximum diameter of twice stand height of up to 60 metres, and the proportion of area harvested under AGS to 20 per cent (L&EC, 2007)[2].

Thinning

Forests NSW practices 'thinning from below', where trees with the poorest growth or commercial potential (usually subdominant trees) are removed to promote the growth of retained trees. This practice is intended to realise some future high-value product and/or to produce trees of a specified size in a shorter period of time. It also allows trees that would otherwise die through competition and moisture stresses, to be commercially utilised. Thinning can also enhance the opportunity for the retained trees to survive periods of water stress (Forests NSW, 2009a).

Figure 11.3: Trees marked for retention or removal using AGS

Figure 11.4: Indicative stand composition following removal of trees using AGS

11.4.3 Management prescriptions for forestry operations

Management prescriptions are an important component of Forests NSW's Ecologically Sustainable Forest Management system and have been designed to maintain forest structural diversity to retain and enhance flora and fauna habitat, and protect and maintain soil and water quality, while providing a sustainable timber supply (Forests NSW, 2008).

There are two types of prescriptions generally applied during forestry operations. Tier 1 comprises general, forest wide prescriptions such as riparian buffers and a suite of habitat tree protection measures which are designed to protect key habitat across the landscape. These include prescriptions such as those for retention of habitat trees, found in individual management plans.

Tier 1 prescriptions are supplemented by Tier 2 threatened species specific prescriptions which are designed to maintain habitat for particular species. Prescriptions applying to harvesting in river red gum forests are found in s120 Threatened Species Licences, and in other requirements such as those for protection of cultural heritage.

11.4.4 Principles for future river red gum silviculture

As part of its assessment process, the NRC reviewed the silvicultural systems applied in the river red gum forests, taking particular account of two key factors:

- The concerns raised by environment groups, and pursued in the NSW Land and Environment Court and through the *Environmental Protection and Biodiversity Conservation Act* 1999 (Cth), about the impacts of the implementation of AGS silviculture on forest values. Many of these concerns focused on the potential impacts of AGS on the ecological character of the Ramsar-listed Central Murray State Forests.
- The recognition that the historical flood flows which established and sustained river red gum forests have been substantially changed by river regulation, and in conjunction with the current drought and predicted 'step change' associated with climate, is impacting (and likely to continue to impact) the health and persistence of the Riverina's river red gum forests.

Table 11.6 describes a set of principles the NRC has developed to guide future silviculture of river red gum forests managed for integrated wood production as conservation values. Once these principles are codified in an Integrated Forestry Operations Agreement, the NRC considers they will maintain the ecological character of the forests, and protect matters of National Environmental Significance, while continuing to support production values.

The principles were developed through discussion with forest managers and other agency staff, a literature review and a workshop conducted with independent experts. They have been developed considering the current and likely impacts of river regulation and drought, predicted climate change, and forestry activities.

In addition to the principles presented in **Table 11.6**, the NRC suggests that the riparian exclusion zone for major rivers (Edward, Lachlan, Murray, Murrumbidgee, Wakool) on public land be extended to 50 m, consistent with requirements in other forested regions of NSW. No additional modified harvesting zone would then be necessary in these cases.[2]

Australian Group Selection – Gulpa Island State Forest

[2] The present requirement (**Appendix 10**) is for a 20 m exclusion zone and a 30 m harvesting zone.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles

Principle S1: 'Group selection' is an appropriate silvicultural technique for river red gum forests managed for production values, subject to the provision and maintenance of ecological values, principally retention of adequate habitat trees and coarse woody debris resources, and other constraints of intensity and implementation described by Principles S2-8.

Australian Group Selection is usually applied to even-aged or even-size cohorts in production stands at the end of their intended growing cycle, typically at age 90–120 years, following one or more cycles of thinning and selective harvesting.

Concerns about the implementation of AGS in river red gum forests focus on its impact on current and future habitat values, including those for threatened species; its impact on the ecological character of the forests as a whole; the susceptibility of gapped areas to weed invasion; and the appropriateness of the system in the absence of flooding (e.g. National Parks Association, 2008; Attiwill, et al., 1994). These issues were the subject of independent expert advice and review to the Commonwealth Government (Bacon, 2009; McElhinny, 2009; En Chee, 2009).

These issues are addressed through the other principles listed below. Provided they are observed, the NRC considers that group selection is an appropriate silvicultural technique for river red gum forests managed for production values. In even-aged or even-sized cohorts of river red gum managed for production, appropriately implemented (i.e. consistent with principles enunciated here) group selection is necessary to maintain productivity over successive harvesting rotations (Baur, 1984; Dexter, 2009; McElhinny, 2009).

Specific management prescriptions which give effect to this principle would benefit from further refinement based on expert knowledge of forest ecologists and forest managers, and should be codified into the Integrated Forestry Operations Approval (IFOA).

Principle S2: Group selection should only be applied to river red gum forests that are expected to receive adequate future watering.

River red gum forests are associated with channels and floodplains and are usually located either adjacent to, or in close proximity of, a major watercourse. They are flood-dependent and require certain flooding regimes to maintain ecological health and productive values (Jacobs, 1955; Forestry Commission of NSW, 1984, Florence, 1996; Bacon, 2009; Horner et al., 2009). Seedling regeneration is generally dependent on flooding, although seedlings can become established following adequate rainfall.

Consequently, group selection should maintain the ecological character of the river red gum forests – through realising dense seedling regeneration – only when it is followed by adequate flooding or rainfall. Only the former can be predicted with any certainty. It is also likely that, in the absence of watering, coppice regeneration would eventually restore the tree component in the gapped area. Such coppice would also require thinning to maximise its ecological value (e.g. in terms of hollow formation) and its value for wood production. Given the seedling origin of most river red gum stands, coppice is a less preferable alternative to seedlings in maintaining the ecological character of the river red gum forests.

This report has established that present drought has profoundly affected the health of most of the river red gum stands in the Riverina. If these conditions continue in line with the 'step-change' prediction of climate change, then much of the existing river red gum forests in the region will not persist in their present extent, structure and condition.

Future implementation of group selection should therefore be limited to river red gum forests which are expected to receive adequate flooding through managed watering regimes (i.e. areas of forest predicted to be inundated under specified flood flows that can be delivered under water sharing arrangements).

It is reasonable to allow group selection to proceed a number of years ahead of expected watering but the actual period should be clearly stated in both strategic and operational management plans. For example, current Forests NSW growth modelling allows a period of 10 years from harvest for seedlings to become established. The NRC notes that longer delays between harvesting and the establishment of seedling regeneration favours coppice regeneration that develops in the absence of flooding.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued
Principle S3: Habitat trees should be retained permanently and distributed across the forest landscape.
Habitat – principally hollow-bearing trees – provides a key ecological function in Australian forests (e.g. Gibbons and Lindenmayer, 2002). Hollows in both live and dead trees provide essential habitat for many arboreal species in river red gum forests, including those that are threatened (as further described in **Chapter 4**). Occupancy of hollow-bearing trees is related to their position and spatial configuration in the landscape. Literature reviewed by Gibbons and Lindenmayer (2002) reported average occupancy rates of between 43-57 per cent. There has a substantial decline in the numbers of hollow-bearing trees in the river red gum forests as a consequence of historical timber harvesting and silvicultural treatments (Forests NSW, 2009a), with impacts on both arboreal mammal populations (Forests NSW, 2009a) and threatened species (e.g. Forests NSW, 2009a, after Webster, 1998). The NRC notes that specific prescriptions for habitat tree retention and recruitment already exist (**Appendix 10**), both generally and for individual threatened species specifically, and that – provided habitat tree retention is adequate – the population of habitat trees may not be the limiting resource for particular species of concern (e.g. Leslie, 2005). Forests NSW (2009a) noted that: *"whilst there is no evidence that current tree habitat retention management prescriptions in the river red gum forests are not effective in maintaining a sufficient hollow resource to meet the needs of hollow obligate fauna populations over time… there may be a potential for residual or cumulative impacts resulting from current habitat tree retention strategies"* Forests NSW (2009a) suggested further research and peer review to clarify appropriate habitat tree retention strategies. The NRC has identified four key issues in respect to habitat trees: • The need to ensure adequate numbers of habitat trees are retained, and that these trees are distributed across the forest landscape. Expert opinion (Forests NSW, 2009a, Gibbons, P, ANU, pers. comm., 2009) suggest that numbers of habitat trees in unlogged river red gum forests are in the range of 6–25 trees per hectare. On the basis that production forests are complemented by a reserve system, and incorporate Forest Management Zones (see **Chapter 3**), in which all habitat trees are retained, a lesser number of habitat trees should be acceptable in those Forest Management Zones in which trees are harvested. Further research and modelling specific to river red gum forests would be needed to derive any specific science-based estimates for the minimum number and preferred configuration of habitat trees that should be retained in forests managed for production. On the basis of Forests NSW (2009a) assessment, current prescriptions for retention in each Forest Management Zone would appear appropriate, subject to further research and to increased levels of retention of habitat recruitment trees, as discussed below. Expert opinion emphasises the importance of ensuring that retained trees should be distributed across the forested landscape. • The need to ensure adequate numbers of recruitment trees. Modelling (Gibbons et. al., in review) suggests that the ratio of recruitment to habitat trees should be higher than 1:1, to allow for mortality. Based on the most comparable results reported by Gibbons et al (in review), for *E. fastigata* in NSW, an interim ratio of 1.5:1 might be appropriate. Further modelling specifically for river red gum forests will be required to inform prescriptions, which may vary at different stages of stand development. • The need to retain, as far as possible, individual habitat trees over successive harvesting cycles, so that individual trees are allowed to progress to maturity and eventual senescence. • The need to recognise the value of standing dead trees for habitat, and include their retention in prescriptions, as in other NSW State Forests. Specific management prescriptions for this principle need further development based on expert assessment of the best-available knowledge, and should be codified into the Integrated Forestry Operations Approval.

Coarse woody debris – Bama State Forest

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued
Principle S4: Gap intensity needs to explicitly consider the ecological character of river red gum forests, particularly those which are Ramsar-listed.
Gap intensity is related to the application of AGS in river red gum forests – the size of individual gaps, their spatial distribution and proximity to each other, overall extent, and return intervals. Managing gap intensity has been identified in prior studies (e.g. those cited in National Parks Association, 2008), and by recent reviews of river red gum silviculture (Bacon, 2009; McElhinny, 2009; En Chee, 2009), as critical to sustainable management of river red gum forests. Current prescriptions apply to only some elements of gap intensity; these are summarised in **Appendix 10**. Based on this literature and expert opinion, the NRC suggests that specific prescriptions to manage gap intensity be developed and implemented, based on the following parameters: • Individual gap sizes should generally be in the order of twice the height of surrounding trees – to minimise felling damage and promote regeneration – although occasional gaps of up to three tree heights may be necessary in particular cases. However, individual gaps should not usually exceed 80 metres in width. • Gaps created in any given harvesting operation should be separated by distances at least equal to gap width, preferably more, and the pattern of dispersal of gaps should ensure that regeneration in neighbouring gaps has established successfully before an adjoining gap is created. Regeneration success should be expressed in terms of density or basal area of regeneration, and its height, and thresholds may be related to the stage of stand development sufficient to deliver ecological benefits (e.g. the habitat provided by dense young stands). • The total area of a tract of forest that might be subject to group selection over the production rotation period (nominally 100 years) should be estimated, and the proportion of the stand gapped in a specified intermediate period (say 10 years, to allow some management flexibility) should not exceed the pro rata proportion which that period represents of the rotation period. Exact specification of these prescriptions requires further expert input, including that of operational forest managers. The consequence of implementing these criteria is that return intervals to adjacent areas of forest would depend on the period required to achieve successful regeneration of gapped areas.
Principle S5: Selective harvesting in immature forests between 'gapped' areas should be constrained by timing and intensity, and ecological thinning should be guided by ecological principles.
Selective harvesting includes both thinning and Single Tree Selection. The timing and intensity of selective harvesting in immature river red gum forest, and its interaction with any group selection in the same tract of forest, have the potential to impact on environmental values such as habitat, and on the ecological character of the forests. These impacts should not be significant if Principles S3 and S4 are implemented, where an adequate density of trees is retained, and where the timing of selective harvesting between gaps is scheduled to allow re-establishment of regeneration in any adjacent gapped areas, as discussed in Principle S4 above. Specification of a minimum retained basal area in selective harvesting operations, at not less than 12 square metres per hectare, should ensure retention of an adequate density of trees in selectively harvested forests. Principles guiding the implementation of ecological thinning in river red gum forests were discussed in an earlier section of this chapter.
Principle S6: Coarse woody debris loads should be enhanced to threshold levels where practicable and consistent with other management objectives, such as fire management goals.
Coarse woody debris (logs and branches on the ground) are an important habitat resource for a large number of ground-dwelling species (Mac Nally et al., 2001; Mac Nally, 2006; Lada et al., 2007; Mac Nally and Horrocks, 2008) and foraging resource for various woodland birds (e.g. Antos and Bennett, 2006). Densities and breeding success of some fauna are higher in areas with abundant coarse woody debris. Coarse woody debris may originate from natural tree and branch fall, as a consequence of commercial harvesting, or from ecological thinning. Representation of a range of size classes, including large and hollow logs, is desirable to maximise the biodiversity value of coarse woody debris (Mac Nally, 2006; Mac Nally and Horrocks, 2008). Recent ecological research suggests that a threshold level of 40 tonnes per hectare of coarse woody debris is ecologically desirable in river red gum forests (McNally et al., 2002; Mac Nally, 2006; Mac Nally and Horrocks, 2008). Forest managers have noted that current forest management prescriptions require the retention of all coarse woody debris present prior to any harvesting operation, and have also pointed out that high levels of coarse woody debris pose a fire risk, and may not be compatible with some recreational values. Exact specification of these prescriptions requires further expert input. The NRC therefore suggests that river red gum forest management should seek to progressively develop, and subsequently retain a target load of 40 tonnes per hectare of coarse woody debris, of appropriate size class distribution, in those areas of forest where this can be achieved without detriment to other ecological or operational values, and is compatible with fire risk management and asset protection requirements. It may also be desirable to reduce this level in areas of particular recreational use. These prescriptions could be implemented through Forest Management Zoning and related (e.g. fire and recreation) planning processes.

Table 11.6: Principles and rationale for river red gum silviculture

Silvicultural principles continued

Principle S7: Salvage logging has the potential to be ecologically damaging and should follow recognised best-practice guidelines and adhere to the silviculture principles above.

In some river red gum forests, such as those burnt by wildfire or killed by drought, salvage harvesting of dead trees may provide wood which can be recovered for use such as firewood, although this will last only for a limited period. Since timber quality declines as time progresses after tree death, economic values are maximised by rapid access to dead trees.

Salvage harvesting often has negative effects on natural ecosystems (Lindenmayer et al., 2004; Lindenmayer and Noss, 2006; Lindenmayer et al., 2008a) and a recent global synthesis concluded that "timber salvage is most appropriately viewed as a 'tax' on ecological recovery. The tax can either be very large or relatively small depending on the amount of material removed and the logging techniques used" (Lindenmayer et al., 2008a). Negative effects of salvage harvesting include:

- loss of important forest attributes such as large and hollow-bearing trees, coarse woody debris and other 'biological legacies'
- physical damage to soils, watersheds and other ecosystem attributes (e.g. understorey vegetation)
- cumulative impacts of successive disturbances, for instance where salvage harvesting follows wildfires or cyclones.

The negative impacts of salvage harvesting can be reduced by adopting the following best-practice guidelines (Lindenmayer et al., 2004; Lindenmayer and Noss, 2006; Lindenmayer et al., 2008a):

- Retain variable levels of dead standing timber in different areas of the forest, rather than harvesting all areas to the same minimum level of retained trees and stags.
- Exclude salvage harvesting from conservation reserves and areas containing sensitive environmental attributes.
- Minimise losses of important ecological attributes such as large dead trees, hollow-bearing stags and coarse woody debris.
- Ensure low levels of physical disturbance (e.g. to soils, watercourses and understorey vegetation) in harvested areas.
- Design and implement salvage harvesting to allow its impacts on ecosystem function and composition to be rigorously examined in the future.

These general principles provide a sound basis for managing salvage harvesting in river red gum forests, following disturbances such as fire, or widespread tree death caused by reduced water availability. In some cases, salvage harvesting may be pursued to reduce risk from fire, to firefighters and other forest users.

The potential economic losses associated with the death of merchantable trees in production from river red gum forests production forests can be significant. Where the guidelines and practices outlined above are followed, appropriate salvage harvesting can ameliorate some of the extent of these economic losses with minimal impact to environmental values.

Salvage harvesting should be excluded from conservation reserves, to ensure landscape heterogeneity in standing volumes of dead timber and to maximise biological legacies derived from dying trees. Exceptions may occur in particular limited cases where, for example, fire risk needs to be reduced in asset protection zones. In such cases, the principles noted above and those described for ecological thinning should be applied.

Principle S8: Outcomes of river red gum silviculture, and the assumptions underpinning them, need to be monitored and tested in a structured and systematic manner to generate new knowledge and reduce uncertainty over time.

Possingham (2001) describes adaptive management as 'learning by doing'. It describes a structured, iterative process of management and decision-making that is intended to generate knowledge; gradually reduce uncertainty; and improve performance through monitoring, evaluation and response. It adds transparency and accountability to decision-making and the allocation of resources, while providing a framework for learning and ongoing improvement.

To effectively apply adaptive management principles, an organisation's strategic plans and programs will need to be designed and delivered in ways that facilitate structured learning. Only then can the organisation undertake quantitative monitoring of these actions, and evaluate how successful it was in delivering the expected outcomes. Organisations also need relatively sophisticated management systems to support adaptive management. For example, these systems need to keep track of the changes in landscape expected as a result of the management actions within a project, and provide ready access to this and other necessary information when programs or approaches are being evaluated and decisions on improving its effectiveness are being made. These systems also need to keep track of new knowledge that is derived from the monitoring and evaluation process and other sources, so this can be used in making decisions.

Management agencies could draw on expert assistance, from within and outside the organisations, to further develop and improve their capacity to implement adaptive management systems appropriate to river red gum forest management. Doing so would further support the goals and processes identified in Forests NSW's Ecologically Sustainable Forest Management Plan for the Riverina Region (Forests NSW, 2008b).

Table 11.7: Principles and rationale for firewood collection

Firewood collection principles	
Principle FC1:	**As per Principle S6, coarse woody debris at threshold levels should be retained where practicable and consistent with other (e.g. fire risk) management requirements.**
The ecological importance of dead fallen timber has been described in **Chapter 4** and Principle S7 in **Table 5.7**. Firewood collection can reduce levels of coarse woody debris and reduce densities of standing dead trees in river red gum and other forest types. The NRC has proposed a new threshold level of coarse woody debris (i.e. potential firewood for collection) to be retained in river red gum forests to minimise any potential ecological impacts (Principle S6 in **Table 11.6**). Harvesting of standing dead trees for firewood should be undertaken following the principles described above for general silviculture, thinning and salvage logging of dead trees.	
Principle FC2:	**Firewood collection is generally inappropriate in conservation areas unless undertaken to achieve specific ecological or management goals, or where used for in-park recreational use. In such instances the provisions of Principle FC1 should also be adhered to.**
Given the ecological benefits provided by coarse woody debris, firewood collection is generally inconsistent with management objectives in conservation areas. Where firewood is collected in conservation areas for recreational use, it should be subject to the provisions of Principle FC1 above. Strategic management of fuel loads and fire risk must be considered in managing coarse woody debris levels in all forest areas.	

11.4.5 Firewood collection

Firewood is a significant product derived from river red gum forests on public land. For example, it accounts for 35 per cent of all river red gum products (see **Chapter 5** for more detail on the firewood industry). **Chapter 4** describes some of the potential impacts on environmental values from firewood collection.

Firewood can be collected by individual or on a commercial basis but requires either:

- a '30-l' permit – a short-term permit for domestic use, usually valid from two to three days up to two to three months and for small quantities of timber only
- a timber licence– usually issued on a yearly basis, but may be issued for shorter periods where practicable.

Most 30-I permits (about 95 per cent) are issued for the collection of river red gum firewood from the Deniliquin, Barham, Mathoura, Dareton and Yanco offices of Forests NSW (Forests NSW, 2009a).

Firewood collection for personal use is allowed in some specific zones of Regional Parks. However, this is subject to DECCW policy, including annual licensing and environmental assessments (McDonnell, R., DECCW, pers. comm., 2009).

Table 11.7 describes a set of principles the NRC has developed for firewood in both conservation and production areas.

11.5 Performance review

Adaptive management and regular performance reviews are essential to achieve our goals for future landscapes (Commonwealth of Australia, 2009; NRC 2005). As such, the implementation of the principles outlined in **Table 11.2** will rely on the application of effective adaptive management and reporting frameworks. These principles should be subject to on-going monitoring, review and improvement through the implementation of management plans and agreements.

The NSW Government adopted the *Standard for Quality Natural Resource Management* (NRC 2005) to guide and deliver best practice natural resource management. The NRC considers the Standard provides a useful framework to measure the performance of organisations and plans across all tenures,[3] and can be complemented with other performance criteria specific to the relevant land-use – for example, principles to measure performance of managers implementing the National Reserve System (Commonwealth of Australia, 2009).

River red gum firewood

[3] The NRC has recently used the Standard to audit the effectiveness of catchment management authorities in promoting resilient landscapes.

River red gum with spreading crown – Maude State Forest