3 Information base for the Gunbower and Koondrook–Perricoota forests

3.1 Introduction

The Gunbower and Koondrook–Perricoota forests SEA straddles the River Murray, with the Koondrook–Perricoota Forest on the northern side of the river in New South Wales, and the Gunbower Forest on the southern side of the river in Victoria (**Figure 3.1**). Gunbower Island comprises some irrigated farmland, but the majority of the island is covered by Gunbower Island State Forest, which we abbreviate here to Gunbower Forest. Gunbower Forest is a floodplain ecosystem, defined by the River Murray on the northeast and Gunbower Creek to the southwest.

The Gunbower Forest, with an area of 19,931 ha (Department of the Environment and Heritage, 1995), is managed by Department of Sustainability and Environment Forests. The eastern half of the forest (9,712 ha) is also a proclaimed Wildlife Sanctuary and all land between the River and the 'River Track' is part of the River Murray Reserve managed by Parks Victoria. The Koondrook–Perricoota Forest, south-west of Deniliquin and adjacent to Gunbower Forest, on the northern side of the River Murray has an area of 31,150 ha, and is managed by Primary Industries Trading (formerly State Forests of NSW).

In combination, the contiguous Gunbower and Koondrook–Perricoota forests form the second largest River red gum forest (the largest being the Barmah–Millewa Forest) (**Figure 2.1**). These forests have a combined area of 51,081 hectares, and are located just downstream of Torrumbarry Weir between Echuca and Swan Hill, about 1,600 km upstream of the Murray Mouth (**Figure 1.1**). Both forest areas are Ramsar listed.

The Gunbower and Koondrook–Perricoota forests are dependent on flooding from the River Murray (including its tributaries) for its existence, as rainfall contribution to the soil water balance is not sufficient to sustain a forest structure. In the Gunbower and Koondrook–Perricoota forests a diverse range of habitats is created by the interaction of flows with a landscape of variable topography. These habitats include permanent and semi-permanent wetlands, creeks and open woodlands. The Gunbower Forest provides breeding habitat for colonial waterbirds, including the Nankeen night heron and Intermediate egret, and other rare or threatened species such as the Carpet python and White-breasted sea-eagle.

Koondrook–Perricoota Forest represents a substantial proportion of the River red gum forest in New South Wales (Forestry Commission of NSW, 1985). The lower areas are dominated by Giant spike rush, with dense emergent growth of Water milfoil, Spike rush and Moira grass (Spiny mudgrass). When flooded the forests support large numbers of waterbirds.

Under natural conditions the flow in the River Murray featured strong annual and inter-annual variability, creating a range of water regimes (URS, 2001). By causing a reduction in flood frequency, river regulation has created a water deficit in the

Gunbower and Koondrook–Perricoota forests, with some permanent wetlands becoming semi-permanent (URS, 2001).

The First Step Decision Interim Ecological Objective for the Gunbower and Koondrook–Perricoota forests is to maintain and restore a mosaic of healthy floodplain communities (**Table 1.2**). The expected outcomes are: 80% of permanent and semi-permanent wetlands in healthy condition; 30% of River red gum forest in healthy condition; successful breeding of thousands of colonial waterbirds in at least three years in ten; and healthy populations of resident native fish in wetlands (**Table 1.2**). These outcomes will be achieved through various management opportunities, described later in this chapter. The following sections describe the characteristics of the forests, exploring the links between the biophysical and hydrological conditions of the forests and other factors.

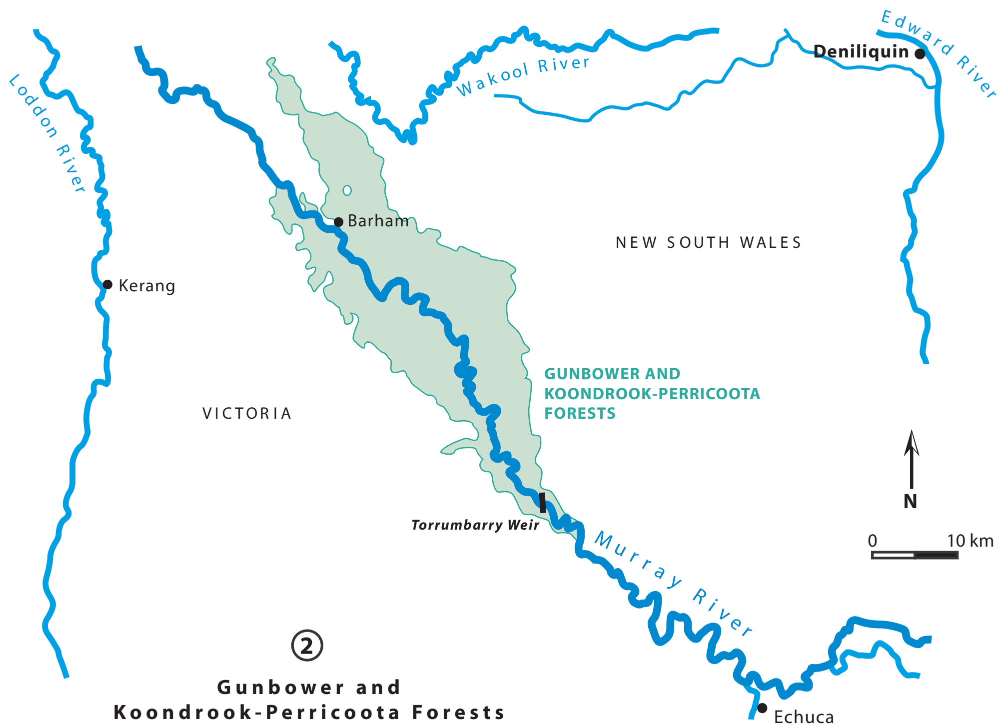

Figure 3.1 – Gunbower and Koondrook–Perricoota forests. Source: MDBC

Figure 3.2 – River Murray passing through the Gunbower and Koondrook–Perricoota forests (photo: John Baker)

Figure 3.3 – Gunbower Creek (photo: John Baker)

3.2 Value and condition of Gunbower and Koondrook–Perricoota forests

3.2.1 Conservation significance

The Gunbower Forest was Ramsar listed in December 1982, while the Koondrook Forest is part of the NSW Central Murray State Forests Ramsar Site listed in May 2003, so the entire SEA is of international importance (**Figure 1.2**). The Gunbower and Koondrook–Perricoota forests have internationally significant biodiversity values, particularly in regard to waterbirds, and floodplain and wetland vegetation.

Despite reduced flooding due to river regulation, the Koondrook–Perricoota Forest is an area of comparatively high water availability and habitat productivity in a semi-arid rainfall zone. The forest contains six threatened flora species (Department of the Environment and Heritage, 1992), and it may provide, directly or indirectly, habitat for four globally threatened fauna listed by the World Conservation Union on the IUCN Red List (IUCNNR, 2000); 13 species listed in migratory bird agreements between Australia and Japan (JAMBA) and China (CAMBA) (Department of Foreign Affairs 1995a, b); 27 fauna species listed under NSW threatened species legislation; and 38 fauna species listed under Victorian threatened species legislation (D Leslie, pers. comm., June 2004).

Species which have been listed as endangered at a state level include the Bush stone-curlew (NPWS, 1998) and the Magpie goose (NPWS, 1998). Species which are listed on JAMBA and/or CAMBA which have been recorded within the area include the Great egret, and the Glossy ibis (NPWS, 1998). When flooded, forests also support large numbers of waterbirds (Department of the Environment and Heritage, 1992).

The Koondrook–Perricoota Forest also contains significant social, cultural and economic resources. It has been managed under multiple use principles including forestry for almost 150 years, making it one of the longest continuously managed natural resources in Australia (D. Leslie, pers. comm., June 2004).

Department of the Environment and Heritage (1995), Department of the Environment and Heritage (1999) and URS (2001) listed records of significant species in Gunbower Forest. Threatened fish species in Gunbower Forest include Crimson-spotted rainbowfish, Golden perch and Murray cod (Koehn & Morison, 1990). There are 15 species of threatened flora and 15 species of threatened fauna listed as present in Gunbower Forest by the Department of the Environment and Heritage (1999).

Barking owl, which occurs in Black box, is ‘endangered’ under Victorian Rare or Threatened Species (VROT) classification and is listed under the *Flora and Fauna Guarantee Act* (FFG Act). Gunbower Forest is one of the sites in Victoria where the more recent records have originated (DNRE, 2002). A list of 10 ‘threatened’ (under VROT classification) colonially nesting waterbirds has been recently recorded as breeding and roosting in Gunbower Forest. They are: Little egret, Intermediate egret, Great egret, Nankeen (Rufous) night heron, Royal spoonbill, Great cormorant, Little pied cormorant, Little black cormorant, Darter and Australian white ibis. Three of these, Little egret and Intermediate egret (both listed under VROT as 'critically endangered') and Great egret ('endangered'), are listed under the FFG Act.

Gunbower Forest (along with Barmah–Millewa Forest) has historically been a main site from which egret breeding has been recorded. Egrets will only nest during flooding events and utilise live River red gum saplings and mature trees both within the flooded forest as well as adjacent to open areas surrounded by flooded forest (DNRE, 2002). Gunbower Forest supports the only breeding colony of the Intermediate egret in Victoria (Horricks *et al*. 1989). In 1974 there were an estimated 500 nests, and in 1982 there were more than 100 nests (Department of the Environment and Heritage, 1999). Sections of the Forest also support breeding colonies of the Rufous night heron, the Little egret, and the Great egret (Department of the Environment and Heritage, 1999).

The Carpet python is endangered and listed under the FFG Act (DNRE, 2002). Records of Carpet python are from Reedy Lagoon in Gunbower Forest (also in Barmah Island). A total of some 660 ha in the Gunbower State Forest, comprising high-quality habitat for Carpet python in the vicinity of recent records of the species, has been placed in Special Protection Zone and is to be managed principally as a Carpet python management area. This area lies adjacent to the 230 ha Spence Bridge Education Area, which is also regarded as a conservation reserve (DNRE, 2002).

3.2.2 Hydrology and geomorphology of Gunbower and Koondrook–Perricoota forests

The uplift of the Cadell Fault block (see **Section 2.2.2**) produced three alluvial fans. The Barmah fan was formed by deposition to the east of the ridge (where Barmah–Millewa Forest has established), the northern end formed the Wakool fan, and the southern end formed the Gunbower fan, where the Gunbower, Koondrook–Perricoota forests can be found (Young, 2001, p. 103). The fan itself has a number of distributary or anabranch channels, the main one being Gunbower Creek, which forms the southern boundary of Gunbower Island. The Forest is about 2 km wide at the upstream end, and it reaches a maximum width of 8 km before progressively narrowing as Gunbower Creek and the River Murray merge.

The hydrology of the Gunbower Forest was first described by Atkins *et al*. (1991), and summaries of this, or descriptions of certain aspects of hydrology, appear in Atkins and Lloyd (1993), URS (2001), EarthTech (2001), Cooling *et al*. (2002) and Ecological Associates (2004). The description below was drawn from these sources. The hydrology of the Koondrook–Perricoota Group of forests was initially described by Wyatt (1992), but since that time there has been a considerable amount of work done by Primary Industries Trading. Details of this work were provided by David Leslie (Primary Industries Trading, pers. comm., June, 2004).

Regional hydrology

The Barmah Choke (see **Section 2.2.2**) limits how much water can pass via the River Murray channel, with the majority of floodwaters being diverted north via the Edward–Wakool system. Thus, a maximum flood flow of only 30,000 ML/d can enter Gunbower Forest sourced from the River Murray. The substantial Broken–Goulburn and

Campaspe river systems enter the River Murray between the Choke and Gunbower Koondrook–Perricoota Forest, so they add more flow. Synchronisation of flood peaks will create a fairly high flood entering the Gunbower and Koondrook–Perricoota forests.

The flow downstream of Torrumbarry Weir depends largely on flows in the River Murray at Barmah and the flow from the Goulburn River, which joins the River Murray near Echuca (**Figure 2.1**). Median monthly flows under natural conditions are shown in **Figure 3.4**. It is noteworthy that:

- the median monthly flows in the River Murray at Barmah were of a similar scale to those from the Goulburn River into the River Murray; and
- the median monthly flow in the River Murray at Torrumbarry Weir peaks in September, and exceeded 25,000 ML/day between July and November, and was approximately 35,000 ML/day for three months of the year.

To allow further consideration of the flooding of the Gunbower and Koondrook–Perricoota forests under natural conditions, a plot of monthly flows for the River Murray at Barmah and the Goulburn River under natural conditions is provided in **Figure 3.5**, and a plot of flow percentiles is provided in **Figure 3.6**. Importantly, from **Figure 3.5**, the magnitude of flooding in the Gunbower and Koondrook–Perricoota forests is strongly dependent on whether high flows in the River Murray and Goulburn River coincide. Both **Figure 3.5** and **Figure 3.6** demonstrate that the largest floods (highest 10%) in the Goulburn River are considerably higher than those in the River Murray at Barmah. This is explained by the significant attenuation effect of the Barmah Choke on River Murray flows.

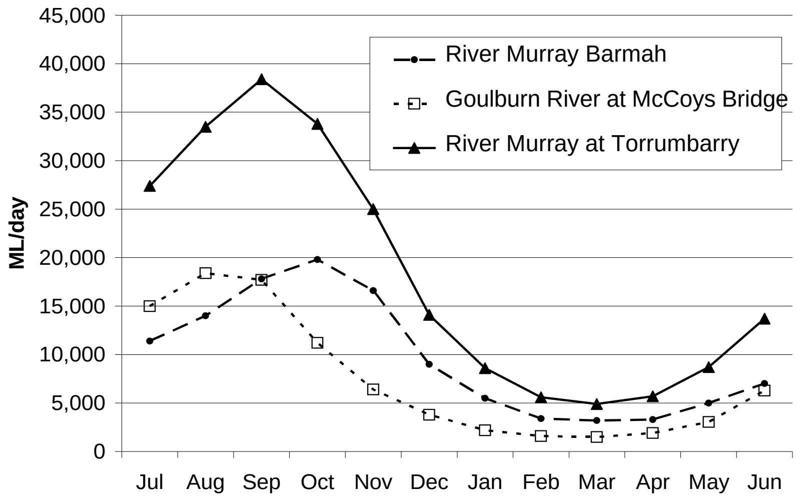

Figure 3.4 – Median monthly flows in the River Murray at Barmah, in the River Murray at Torrumbarry Weir, and in the Goulburn River at McCoys Bridge under modelled natural conditions. Unless otherwise stated, all references to the Goulburn River are at the flow gauge just upstream of the junction with the River Murray (McCoys Bridge). Source: MDBC analysis of 109 years of modelled data.

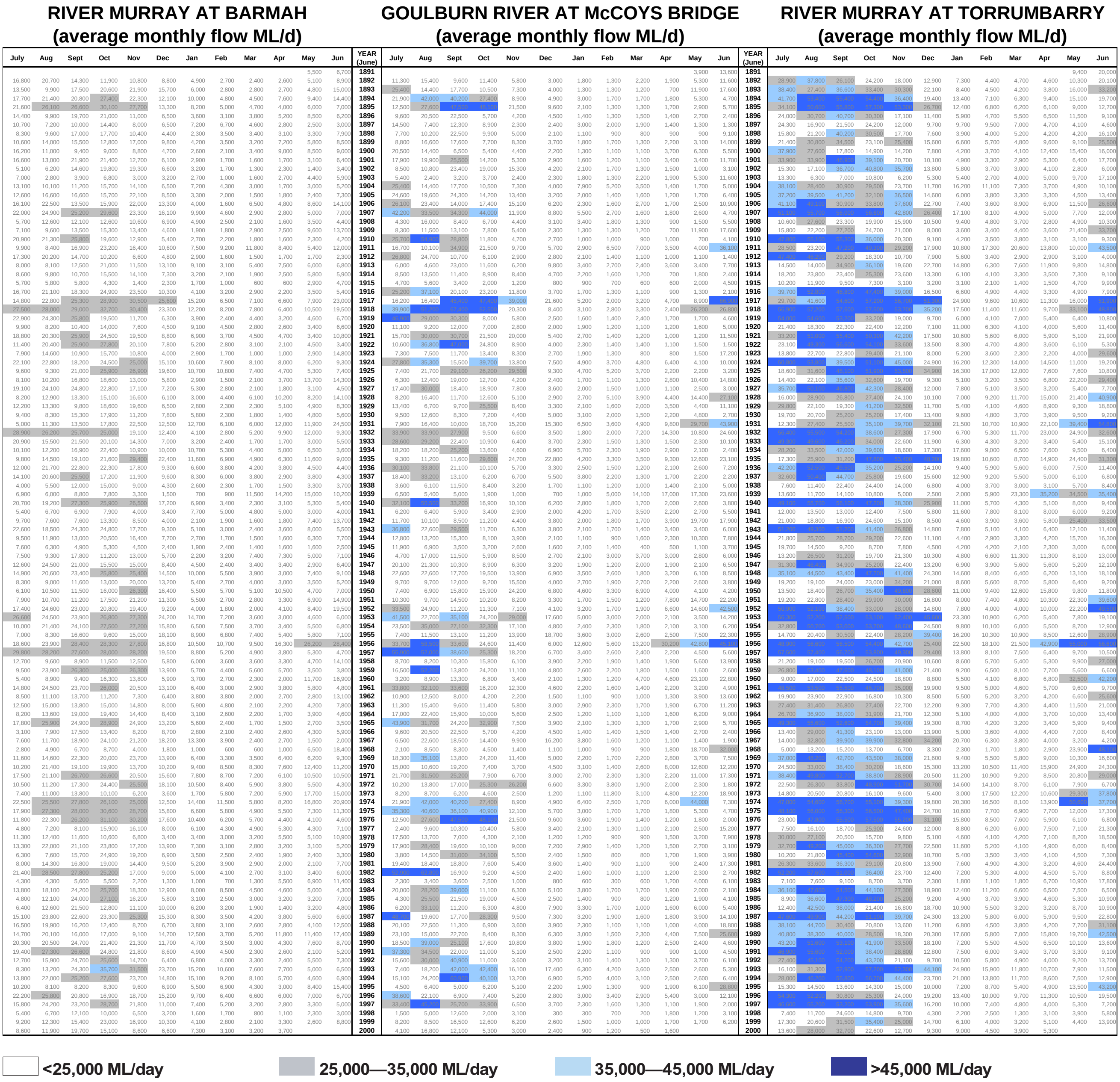

Figure 3.5 – Summary of modelled natural flow data from 109 years of records for the River Murray at Barmah and downstream of Torrumbarry Weir, and for the Goulburn River at McCoys Bridge

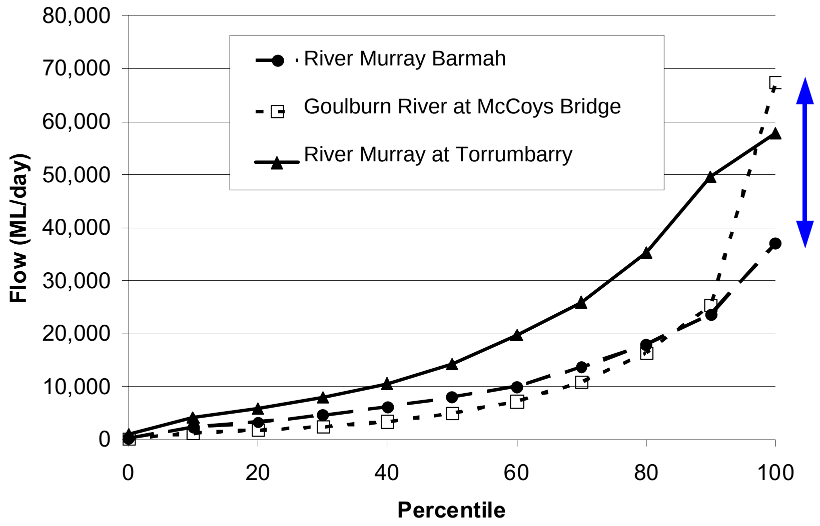

Figure 3.6 – Percentiles of natural flow, for the River Murray at Barmah, the Goulburn River, and the River Murray at Torrumbarry Weir, based on modelled data. The arrow indicates the divergence between the Goulburn and the River Murray at Barmah for large floods. Source: MDBC analysis of modelled data.

Gunbower Forest hydrology

Torrumbarry Weir on the River Murray is at the upstream end of Gunbower Forest (**Figure 3.3**). This weir acts to create a head of water to increase flow to the National Channel, and subsequently to Gunbower Creek Channel (**Figure 3.3**). Some farmland adjacent to the south-west part of the Forest is protected from small and medium-sized floods by levees. Prior to their construction (i.e., under a natural flow system), water would have flowed onto the lower parts of the floodplain, entered Gunbower Creek, and then returned to the River Murray at Koondrook, on the downstream end of the Forest system (**Figure 3.3**). Irrigation supply offtakes associated with Torrumbarry Weir and effluents from the Koondrook–Perricoota Forest into New South Wales limit the maximum flow at the downstream end of the Forest system to around 32,000 ML/d (Cooling *et al*., 2002).

Flows into the Gunbower Forest start at Spur Creek and at Yarran Creek (**Figure 3.3**) when the flow in the River Murray at Torrumbarry is 13,700 ML/d. As the river rises, flow starts to enter other parts of the Forest: Barham Cut commences to flow at 15,200 ML/d, Wattles Regulator begins to flow at 18,300 ML/d, flows into the Forest at Kate Malone Bend (**Figure 3.3**) into the upper reaches of Broken Axle Creek occur at bankfull flow of 27,800 ML/d; and widespread flooding in the Forest occurs with sustained flows of 30,000 ML/d or greater (URS, 2001).

Gunbower Creek receives flows from the Torrumbarry Weir pool. At present, unseasonal rain rejection flows can be delivered to the Forest via three outlet structures on Gunbower Creek. The main structure is Shillinglaws Regulator (**Figure 3.3**, **Figure 3.7**, **Figure 3.8**), which directs flow into Yarran Creek. This regulator has a maximum capacity of 900–1,000 ML/d. Smaller regulating structures are located at Reedy Lagoon and Black Swamp (**Figure 3.3**). Gunbower Creek has a maximum capacity of 900 – 1,000 ML/d. Smaller regulating structures are located at Reedy Lagoon and Black Swamp (**Figure 3.3**). Gunbower Creek has a capacity of 4,000 ML/d between the National Channel Regulator and Gunbower Weir, but it then reduces to 1,500 ML/d to Cohuna Weir, and below this point it has a capacity of 900 ML/d (URS, 2001). Other structures in the vicinity of Gunbower Creek are described in URS (2001, p. 3–4 to 3–5).

Koondrook–Perricoota Forest hydrology

The flow of water through the Koondrook Forest is dominated by the Burrumburry–Barber Creek system. Discharge is sourced from the Murray at a large oxbow formation known as Swan Lake. Several deep, well-defined channels known as the Burrumburry Creeks form the first 15 km of this system. These channels break down into a myriad of smaller, interlinked runners (Wyatt, 1992). The Koondrook Forests, which are flooded mainly by effluents and some overbank flow, require the Goulburn River to be in at least a moderate flood before effluents start running. The extent of flooding is dependent on how quickly the floodwaters drain away (Lyons, 1989). Wyatt (1992) divided the main block of Koondrook Forest into seven Water Management Areas (WMAs), plus additional areas for each of the smaller forest blocks. These WMAs, using the terminology of Maunsell *et al*. (1992), are sub-divisions based on vegetation type, topography and water regimes. Wyatt (1992) tabulated the hydraulic details of the NSW effluents that flow into these WMAs, plus effluents on the Gunbower Forest in Victoria, on the basis of observations made during a flood of 30,000 ML/d on 18 November 1991 (**Table 3.1**).

Table 3.1 – Major effluents into Gunbower and Koondrook–Perricoota forests. Source: Wyatt (1992).

Effluent	State	Gauge height[1,2] (m)	River discharge[1,2] (ML/d)	Capacity at 30,000 ML/d at Torrumbarry[3]
Swan Lagoon	NSW	3.3	11,000	
East				1,70
West				1,110
Burrumbury Ck		4.4	16,000	
Deep Ck	Vic.		100	
Spur Ck (U/S)	Vic.		250	
Horshoe Lag	NSW		290	
Spur Ck (D/S)	Vic.	3.96	13,700	330
Dead River	NSW	Not gauged		
Broken River	Vic.	5.80	23,150	80
Black Gate	NSW		80	
Penny Royal	NSW		50	

Table 3.1 – Major effluents into Gunbower and Koondrook–Perricoota forests. Source: Wyatt (1992). (Continued)

Effluent	State	Gauge height[1,2] (m)	River discharge[1,2] (ML/d)	Capacity at 30,000 ML/d at Torrumbarry[3]
Fire hut	NSW	4.8	18,000	140
Thule	NSW	5.6	17,000	140
Crooked Ck	NSW	Flows during Murray overbank flows only		
Yarran Ck	Vic.	3.96	13,700	575
Barham Cut	Vic.	4.27	15,200	Not gauged
Broken Axle	Vic.	4.88	18,300	Not gauged
Little Forest	NSW	5.1 (B)	21,500 (B)	Not gauged
CI Lagoon	NSW	4.4 (B)	17,000 (B)	Not gauged

1 Gauge heights and river flow at which effluents begin to flow.

2 All gauge heights and river flows downstream of Torrumbarry, unless denoted by (B).

3 Based on flows of 30,000 ML/d as recorded on 18 Nov 1991.

(B) gauged at Barham

Figure 3.7 – Shillinglaws Regulator when closed (photograph: supplied by Emer Campbell, North Central CMA)

Figure 3.8 – Shillinglaws Regulator when open (photograph: supplied by Emer Campbell, North Central CMA)

3.2.3 Forest vegetation distribution and hydrological regime

Vegetation classification schemes

A few different vegetation classification schemes have been used in the Gunbower Forest (**Table 3.2**). The River red gum classes used in Gunbower by Ecological Associates (2004) and REG C (2003) refer to similar plant associations to those described in the Barmah–Millewa Forest, except that Ecological Associates (2004) includes a descriptor for the understorey. The Permanent and Semi-permanent wetland classes appear to be similar to the Open water and Moira grass classes used in the Barmah–Millewa Forest. In this chapter we use the Gunbower convention from Ecological Associates (2004), because this appears in most of the Gunbower literature, and is likely to persist. Being in New South Wales, the River red gum site quality classification used in Barmah–Millewa Forest (i.e., SQI, SQII and SQIII) is used in the Koondrook–Perricoota Forest (Wyatt, 1992).

Table 3.2 – Equivalence of different vegetation classification schemes applied to the Gunbower Forest. WRC = Water Regime Class.

REG C (2003) Barmah–Millewa classes	REG C (2003) Gunbower classes[1]	URS (2001) Gunbower WRC	Ecological Associates (2004) Gunbower WRC	Area (ha)[2]	Area (% of total measured area)[3]
		Watercourses	Not modelled		
Open water (Giant rush)	Permanent wetlands (Ribbon weed)	Permanent wetlands	Permanent wetlands (PW)	113	1%
Moira grass (Spiny mudgrass)	Semi-permanent wetlands (Common reed)	Semi-permanent wetlands	Semi-permanent wetlands (SPW)	503	3%
		Temporary wetlands	Not modelled		
River red gum forest	River red gum forest with flood-dependent understorey (FDU)	River red gum forest with flood-dependent understorey (FDU)	River red gum forest with flood-dependent understorey (Red gum FDU)	7,403	48%
River red gum woodland	River red gum woodland with flood-tolerant understorey (FTU)	River red gum forest with flood-tolerant understorey (FTU)	River red gum forest with flood-tolerant understorey (Red gum FDU)	5,797	30%
Black box woodland	Black box woodland	Black box	Black box woodland (BBx)	1,563	10%
		Grey box	Not modelled		

1 The REG C (2003) Barmah–Millewa Open water and Moira grass classes are similar but not necessarily equivalent to Gunbower Permanent wetlands and Semi-permanent wetlands respectively.

2 Areas are from Ecological Associates (2004).

3 Total measured area was 79% of total forest area.

Floodplain vegetation distribution

Like Barmah–Millewa Forest, River red gum associations overwhelmingly cover Gunbower Forest. Cooling *et al*. (2002) estimated that River red gum associations covered about 70% of Gunbower Forest. The measured areas given in **Table 3.2** for Gunbower suggest that the coverage could be even higher. The Koondrook–Perricoota Forest does not have wetlands to the same extent as the Gunbower Forest, but, like Gunbower, it has large areas of vegetation that are dependent on flooding. River red gum occupies 80% of the Koondrook–Perricoota Forest, of which approximately 18,000 ha (equivalent to about 60% of the entire Koondrook–Perricoota Forest area) can be considered to have a water dependent understorey. Drier vegetation types support a higher proportion of introduced species, particularly annual herbs in the family Poaceae, than areas that receive more regular flooding (D Leslie, pers. comm., June 2004).

The distribution of the vegetation in the Gunbower Forest WRCs has recently been mapped in detail by Ecological Associates (2004) (**Figure 3.9**). **Figure 3.10** shows the density of River red gum associations in the Gunbower and Koondrook–Perricoota Forests.

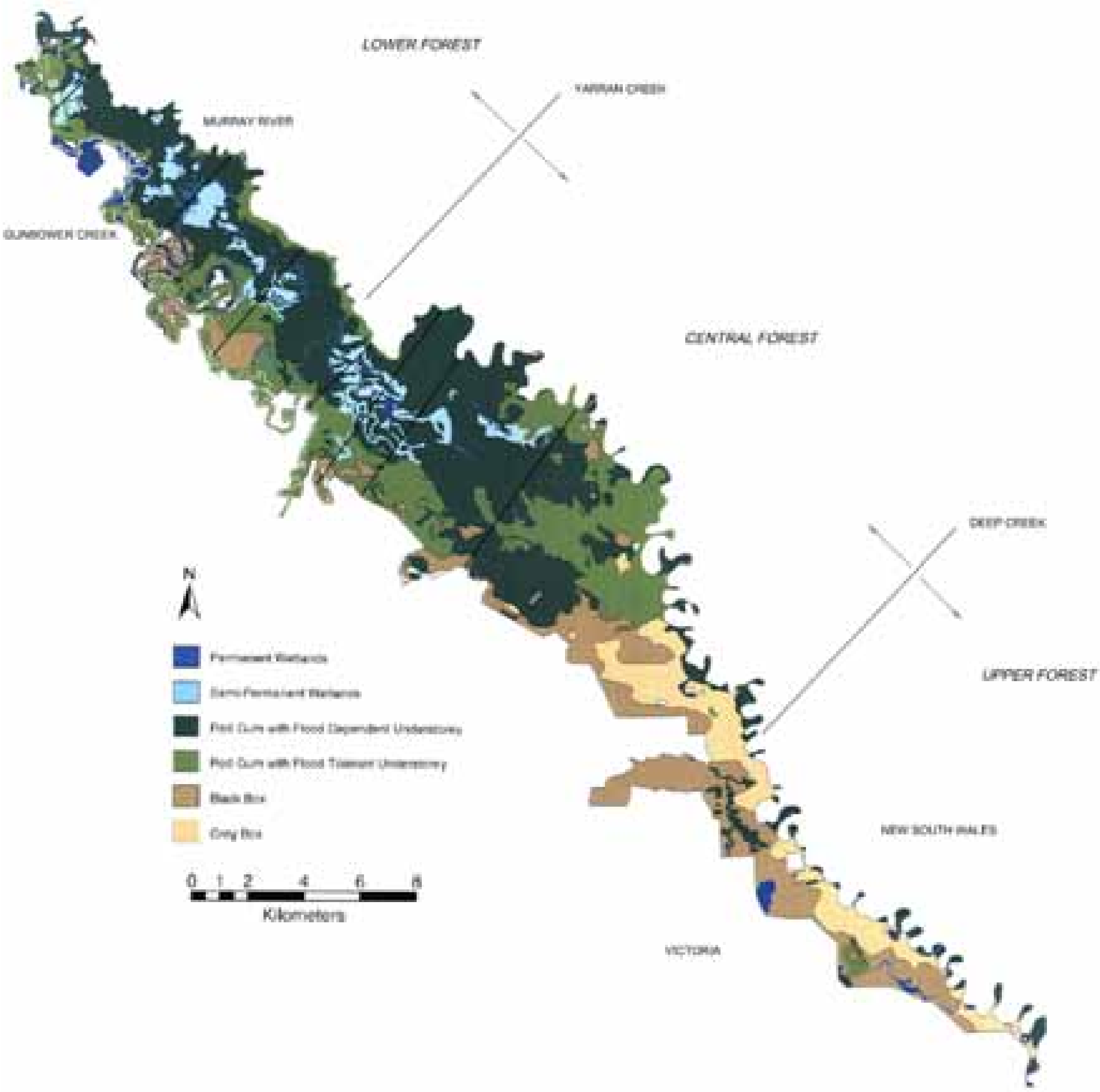

Figure 3.9 – Water Regime Class (WRC) distribution in the Gunbower Forest.
Source: Ecological Associates (2004).

Figure 3.10 – River red gum forests in Gunbower and Koondrook-Perricoota Forests divided by the River Murray Channel (photo: Andrew Tatnell).

An illustration of the vegetation communities typical of Gunbower Forest is provided in **Figure 3.11**. Gunbower Creek is at a relatively high elevation in the landscape. The central basin represents internally draining depressions of permanent wetlands, which have little emergent vegetation and support aquatic species such as Milfoil. They provide refuges for fish, tortoises, and limited breeding habitat for colonial nesting birds. These areas are surrounded by tall River red gum forest, which has an understorey of Water ribbons and Tube sedge. This is where the colonial nesting waterbirds nest. At higher elevations is the low ‘cauliflower’ form River red gum woodland, which has an understorey of Warrego summer grass and terrestrial grass species. Kangaroos and emus graze these areas. The highest levels are Black box with terrestrial species in their understorey. URS (2001) tabulated the flood frequencies of the major floodplain vegetation communities of Gunbower Forest before regulation (**Table 3.3**). For each community there is a range of flood magnitudes that is associated with a range of lateral extent of inundation (**Figure 3.11**).

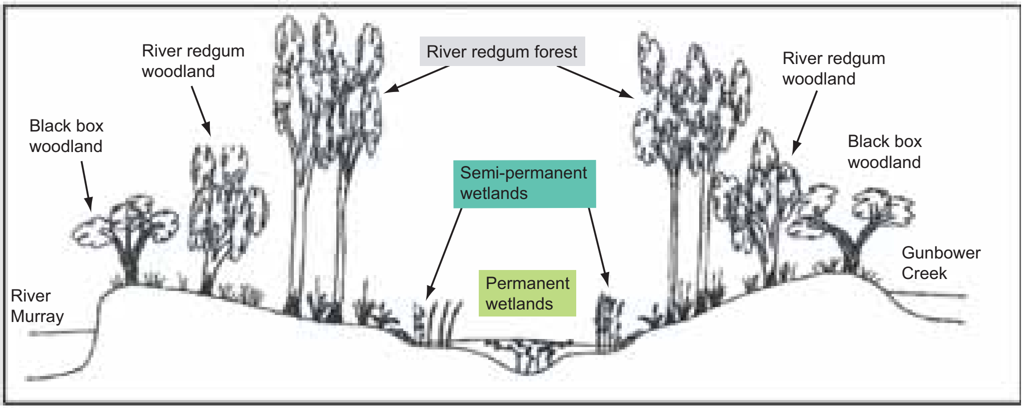

Figure 3.11 – Vegetation communities found in Gunbower Forest. Source: Marcus Cooling (Ecological Associates).

Table 3.3 – Flood frequencies of the major Gunbower Forest floodplain vegetation communities before regulation. Source: URS (2001). Also, the understorey species making up the communities may have a range of hydrological needs.

Vegetation community WRC	**Flood frequency (percentage of years with inundation)**	**Duration (months)**	**Season (ideal)**
Watercourses	Varies	Varies	Varies
Permanent wetlands	Some always wet	Some always wet	–
Semi-permanent wetlands	1:1 (100%)	Dries out only after 2 dry years	Spring
Temporary wetlands	1:1.4 – 1:5 (20% – 70%)	Range from 5 months to 4–6 weeks depending on community	Late winter – Spring
River red gum forest with flood-dependent understorey	1:1–1:1.14 (70% – 90%)	5 months	Spring
River red gum forest with flood-tolerant understorey	1:2.2 (45%)	1–2 months	–
Black box	1:10 (10%)	1 month	–
Grey box	1:20 (5%)	1 month	–

The higher areas of the Koondrook–Perricoota forests floodplain are forested with River red gum, while the low-lying marshes are typically dominated by Giant spike rush, with a dense emergent growth of Water milfoil, Spike rush and Mud grass (Forestry Commission of NSW, 1985). Black box and Grey box are concentrated in the Koondrook Forests. Reed beds also occur in the Koondrook Forests and include species such as Cumbungi with a ground cover of grasses and water plants (DEH, 1992).

Floodplain filling

Relationships between river flow, forest inflow and inundated area have been developed for Koondrook–Perricoota Forest (**Table 3.4**, **Figure 3.12**, **Figure 3.13**, **Figure 3.14**). The flow-inundation relationships were derived from three flooded-area maps corresponding to three flow events for which adequate gauging information was available. The work involved over 15 years of observations (D Leslie, Primary Industries Trading, pers. comm., June 2004). The forest inflow estimate was based on gauging of the natural inflow sources to the Koondrook–Perricoota Forest (e.g., Burrumburry–Barber Creek system which is fed from the River Murray above Torrumbarry Weir via Swan Lagoon, Horseshoe Lagoon, and Black Gate, Penny Royal, Fure Hut, Thule and Crooked creeks) (**Table 3.1**). Significant inflows to River red gum forests begin at flows exceeding 30,000 ML/d. The Forest has no internally draining areas and water quickly drains back to the river when the river flow recedes (REG C, 2003).

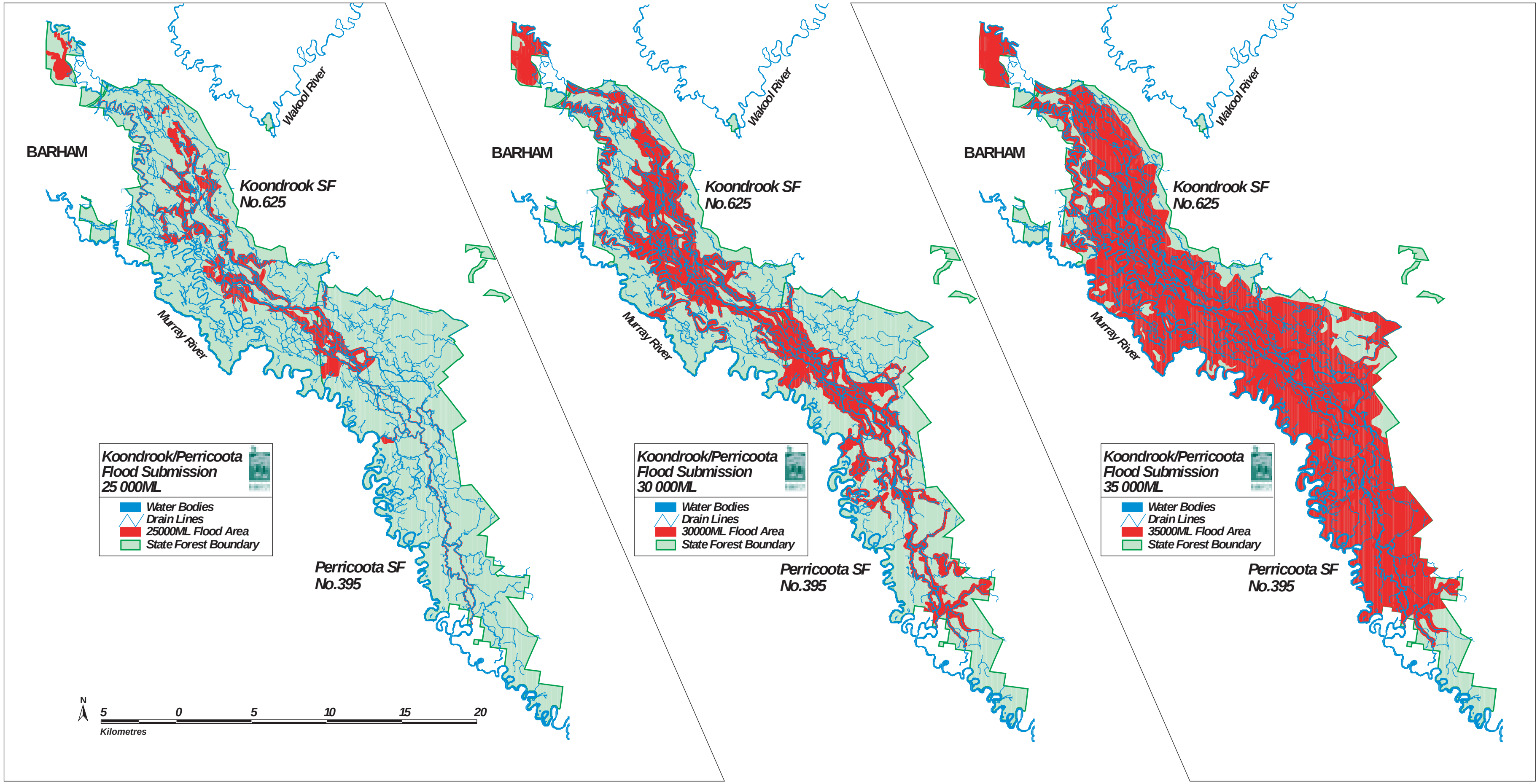

Figure 3.12 – Progressive increase in inundation of Koondrook–Perricoota Forest for flows of 25 000 L/d, 30 000 ML/d and 35 000 ML/d.
Source: unpublished figures supplied by D Leslie, Primary Industries Trading (formerly State Forests NSW), 2004.

Table 3.4 – Relationship between river flow, forest inflow and inundated area by Red gum vegetation type in the Koondrook–Perricoota Forest. Source: Unpublished data supplied by D Leslie, Primary Industries Trading (formerly State Forests NSW), 2004.

River flow (ML/day)	Inflow to forest (ML/day)	Inundated area in hectares (% of total)		
		River red gum forest	River red gum woodland	Total forest
15,000	0	–	–	–
20,000	300	–	–	500 (2%)
25,000	1,500	1,030 (54%)	2,060 (12%)	3,520 (11%)
30,000	3,800	1,330 (70%)	7,400 (43%)	10,300 (33%)
35,000	6,500	1,885 (99%)	16,245 (95%)	25,000 (80%)

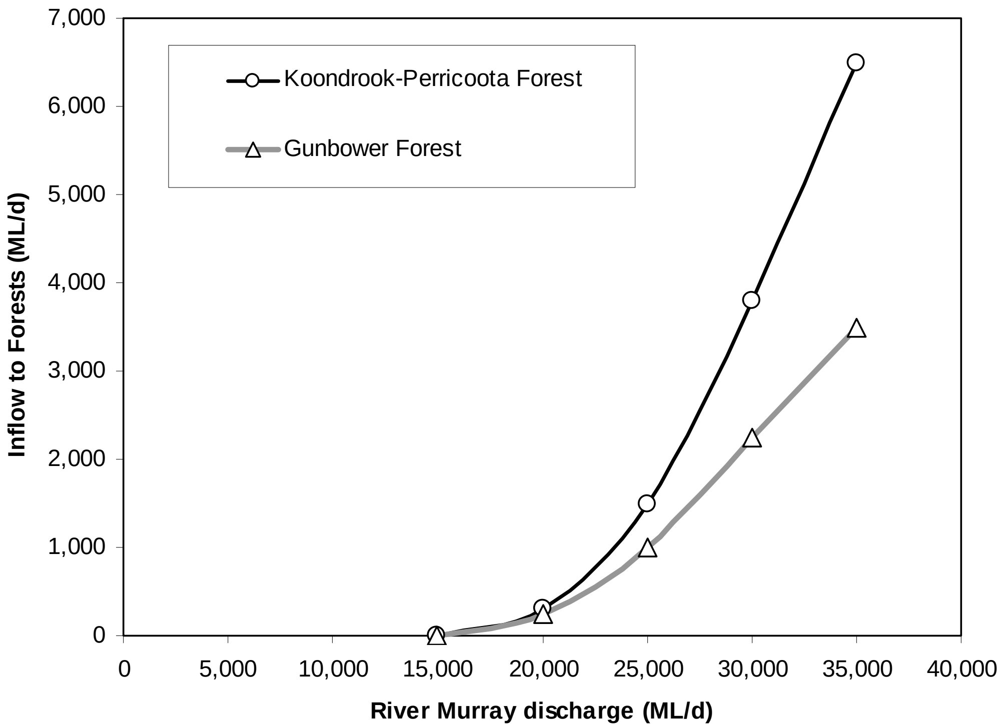

Figure 3.13 – Relationships between river flow and forest inflow in the Gunbower Forest and the Koondrook–Perricoota Forest. Source: unpublished data supplied by D Leslie, Primary Industries Trading (formerly State Forests NSW), 2004. See also Table 3.1.

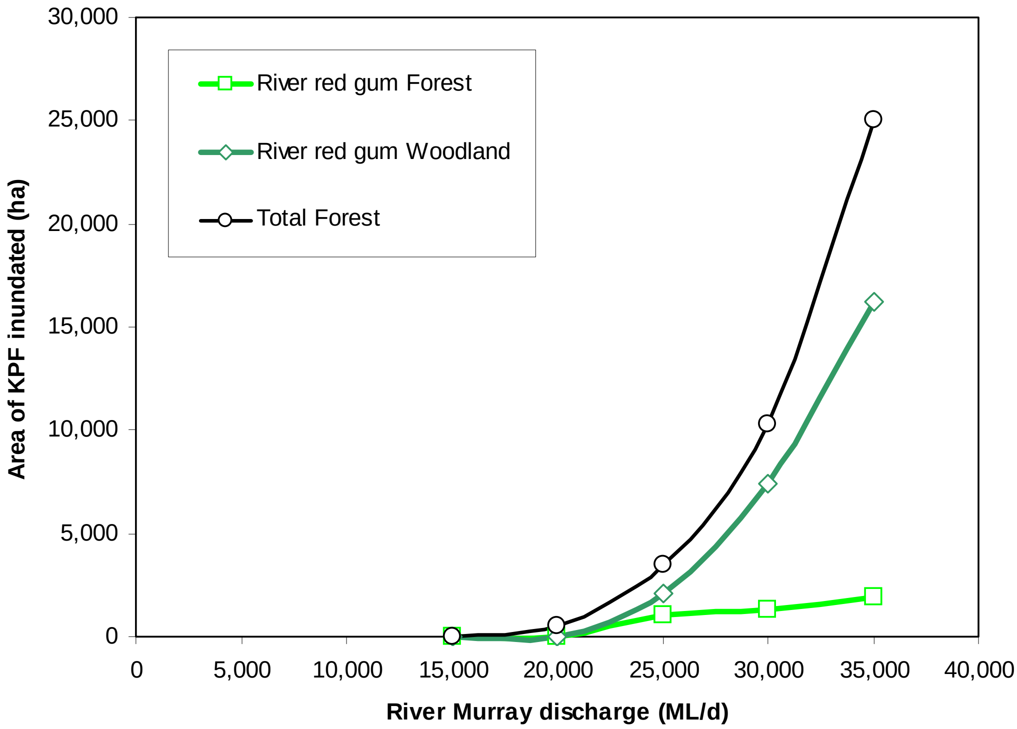

Figure 3.14 – Relationships between river flow and inundated area for River red gum areas and total forest in the Koondrook–Perricoota Forest. Source: Unpublished data supplied by D Leslie, Primary Industries Trading (formerly State Forests NSW), 2004.

The relationship between river levels and the extent of flooding of Gunbower Forest was ascertained from satellite imagery and the measured extent of flooding during historic flooding events. An example of flood extent for the October 1996 50,000 ML/d event is provided in URS (2001). Inflows to Gunbower Forest for a given discharge in the River Murray are somewhat less than the inflows to Koondrook–Perricoota Forest (**Figure 3.13**). A model for area of Gunbower Forest flooded versus cumulative volume of inflows was generated by Ecological Associates (2004) based on a digital terrain model (DTM). The volume of storage within each WRC is indicated in **Figure 3.15**. It is important to note that the cumulative flood volume is instantaneous. Most elevations above semi-permanent wetlands are free draining in Gunbower Forest. Volumes above this level represent water passing through the system and must be maintained by sustained flow (Ecological Associates, 2004).

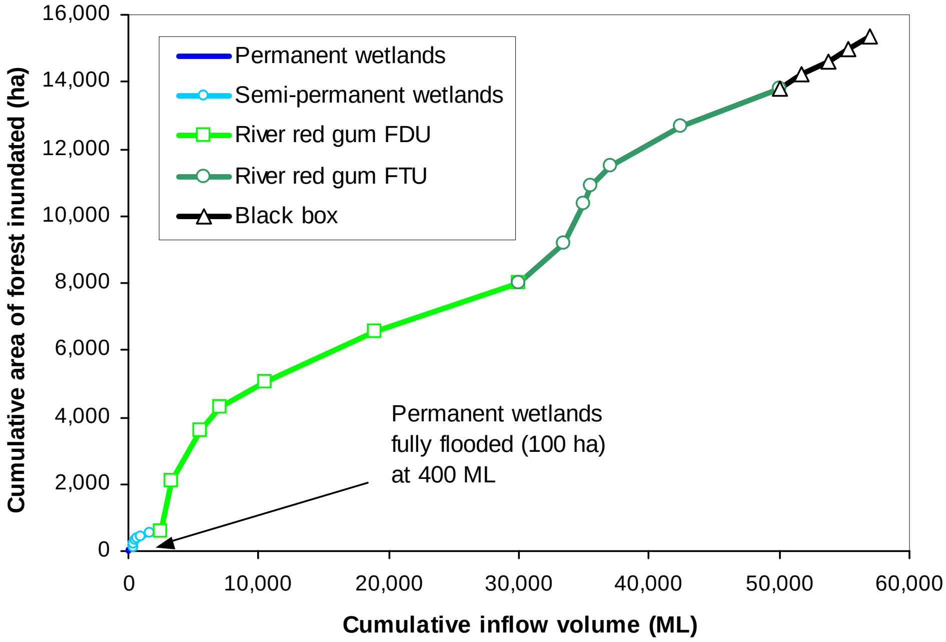

Figure 3.15 – Volume of storage in each water regime class in the Central Gunbower Forest (Ecological Associates 2004).

Note: River red gum and Black box storage is not dead storage—it is freely draining. Source: Plotted from model summary data in Ecological Associates (2004). These are the same data that are plotted in Figure 5 in Ecological Associates (2004) but, for ease of interpretation, the data are re-plotted here as cumulative area of Forest flooded, rather than cumulative percentage area flooded for each WRC.

Health of forests and woodlands

The forest and woodland areas of Gunbower and Koondrook–Perricoota forests provide habitat for native animals, particularly the Eastern grey kangaroo and Emu. The understorey vegetation includes many species with conservation ratings at a state level including Violet Swainson pea, Long eryngium and Squat picris. The endemic Winged pepper cress is endangered at a national level. The trees contribute to the nesting habitat of colonial nesting waterbirds and provide hollows, hunting and nesting sites for many other species including Myotis bats, the Vulnerable brush-tailed phascogale and Carpet python (URS, 2001; DNRE, 2001; DNRE, 2002).

Although the Gunbower and Koondrook–Perricoota forests have high ecological values, the altered water regime due to flow regulation has led to a decline in function (e.g., carbon exchange from floodplain to river), structure (e.g., less frequent regeneration and growth opportunities for River red gum) and composition (e.g., replacement of water dependent plants species with flood-tolerant and terrestrial plant species) (D Leslie, Primary Industries Trading, pers. comm., June, 2004).

URS (2001) tabulated the known or expected stresses or changes for the vegetation communities in Gunbower Forest (**Table 3. 5**). River red gum with flood-dependent understorey has declined in extent to a narrower zone around wetlands. River red gum with flood-tolerant understorey is believed to have become more extensive under regulated flow conditions, replacing the flood-dependent understorey at the wetter end of its range. At the dry end of its range, Black box woodland is believed to have encroached in response to declining flood frequencies (Cooling *et al*., 2002).

Table 3.5 – Impact of environmental changes on vegetation communities of Gunbower Forest. Source: URS (2001).

Vegetation community WRC	Known or expected stresses
Watercourses	• Reduced connectivity between wetlands and river. • Reduced fish breeding. • Loss of diversity of habitats within forest.
Permanent wetlands	• Loss of wetland type – flooded less and therefore those which remain would be now shallower and smaller.
Semi-permanent wetlands	• Extent of wetlands has declined. • Number of sites has declined. • Reduction in permanence. • Red gums encroaching. • Loss of grebes, terns, herons and egrets. • Alterations to littoral fringe.
Temporary wetlands	• Colonisation by red gum and weeds such as *Xanthium* and thistles. • Wet period too short to promote aquatic plants. • Wetland-adapted plants and animals out-competed by those with short-life cycles, rapid growth and maturity.
River red gum forest with flood-dependent understorey	• Extent has declined to a narrower zone around wetlands. • There has been an increase in weed species (thistle, fleabane, aster, Noogoora burr). • Decline in population of flood-dependent species.
River red gum forest with flood-tolerant understorey	• There has been an increase in weed species (such as horehound). • Probable increase in abundance of true terrestrial plants. • Reduction in red gum productivity and associated benefits to herbivores and insectivores.
Black box	• Box is tolerant of long dry spells, so possibly no significant changes. • Possibly has encroached on red gum with flood-tolerant understorey in response to declining flood frequencies (Cooling *et al*., 2002).
Grey box	• Probably no change in water regime.

3.2.4 Health of watercourses and wetlands

Primary effluent and confluent streams carry water early and/or late in the flooding cycle. They are the principal migration routes for fish such as Murray cod, Silver perch and Smelt from the rivers through the floodplain environment (DNRE, 2002). Species such as the Growling grass frog prefer this habitat (DNRE, 2002)—because they contain water for longer than the surrounding forest, there is potential for greater biological productivity in the River red gum trees bordering them. The watercourses provide nesting trees for the endangered White-bellied sea-eagle and Barking owls. Silver wattle, which grows along watercourses, is an important habitat component for the endangered Squirrel glider. In Gunbower Forest, Spur Creek is the primary effluent from the Murray River while Yarran Creek is the primary effluent/confluent stream for water from Gunbower Creek. Reduced frequency and duration of flows through these channels has most likely reduced their habitat value.

Most of the wetland areas in the Gunbower and Koondrook–Perricoota forests are within Gunbower Forest, where there are permanent and semi-permanent wetlands that rate high or very high in terms of both conservation value and priority for management (see later, **Table 3.6**). However, they have suffered decline in health (**Table 3.5**).

Semi-permanent wetlands are among the most important sites for significant species. Wetlands are a major site for colonial waterbird breeding for species such as the Nankeen night heron, the Little egret, the Great egret, the Intermediate egret and Cormorants. The wetlands provide habitat for small fish (such as Southern pygmy perch recorded at Black Charlie Lagoon), tortoises and water rats. They support diverse plant communities, including submerged, emergent and meadow plant species. Permanent wetlands are important for increasing the natural biodiversity, because they increase the diversity of habitats in dry periods. Anecdotal evidence suggests that drains cut into the banks of Little Reedy Lagoon, Little Gunbower Creek and other wetlands have reduced the capacity of the wetlands to retain water reported in URS (2001). Reduced inflows due to regulation have increased the frequency at which wetlands dry out.

The reduced frequency and extent of flooding has been a significant contributing factor to the decline of overall ecological values of the forests (URS, 2001). Wetland areas have reduced in area and retreated to the lowest lying parts of the forests. Reduced frequency of widespread flooding has enabled River red gum to colonise former wetland areas, which has reduced their value for waterbirds. Permanent water, which is an important habitat requirement for aquatic fauna, such as small fish, and colonial nesting waterbirds, has largely been lost from the forests as a result of the reduced frequency of small, regular flow peaks in late winter and spring. The wetland understorey plants have declined, and terrestrial understorey grasses and shrubs have spread (**Table 3.5**).

3.2.5 Colonial nesting waterbirds

The breeding of colonial nesting waterbirds is one of the Ramsar values of Gunbower Forest and is one of the most important regional functions of the system (Ecological Associates, 2004). Of the species that breed at Gunbower, the Intermediate egret and Little egret are critically endangered, the Great egret is endangered and the Nankeen night heron is vulnerable. The provision of breeding habitat is therefore important to the maintenance of regional populations (Ecological Associates, 2004). Permanent water is an important habitat component for colonial nesting waterbirds, providing breeding opportunities during dry years. In flood years, colonial nesting waterbirds breed in large numbers in the semi-permanent wetland and River red gum with flood-dependent understorey water regime classes (Ecological Associates, 2003). Colonial nesting waterbirds build nests in branches that overhang open water (**Figure 3.16**, **Figure 3.17**).

Colonial nesting waterbirds rely on productive flooded and unflooded River red gum Forest areas to forage during breeding, where they prey on invertebrates, frogs and fish. Productivity in the red gum forest depends on regular flooding to promote aquatic and grassy woodland vegetation, woody debris, submerged vegetation and other prey habitats (Ecological Associates, 2004).

The potential for Gunbower Forest to support colonial nesting waterbird breeding has decreased in response to declining flood frequencies and durations (Ecological Associates, 2003). The Forest no longer provides reliable breeding opportunities due to the absence of permanent wetlands (**Table 3.5**). The interpreted decline in semi-permanent wetland habitat (**Table 3.5**) has reduced the extent of breeding habitat and the frequency of breeding opportunities (Ecological Associates, 2004). Declining flood frequencies in the River red gum forest has reduced the health of nesting trees but has not affected breeding opportunities as severely (Ecological Associates, 2004).

While the frequency and duration of flooding has declined since regulation, when floods do occur they can still trigger responses from some opportunistic species. Cormorants nested in Gunbower Forest during the November 2000 flood, and another successful breeding event occurred in the Spring 2003 flood which had large flows from the River Murray that added to the EWA. Some of the outcomes of this event (Emer Campbell, North Central CMA, pers. comm., June 2004) were:

- 15,000 ML water delivered to Gunbower Forest in Spring 2003.;
- water delivered using existing regulators on Gunbower Creek (surplus flows and Victorian EWA) and the River Murray (natural high flows);
- three key wetland areas inundated.
- breeding triggered of colonial waterbirds (cormorants, ibis, darters) over 200 nests with 400–600 fledglings. Feeding of Spoonbills, White-bellied sea eagles, Egrets, and Nankeen night herons (**Figure 3.16**, **Figure 3.17**).

Figure 3.16 – Cormorant nests in Gunbower Forest, Spring 2003
(photograph: Emer Campbell, North Central CMA)

Figure 3.17 – Detail of cormorant nest in Gunbower Forest, Spring 2003
(photograph: Emer Campbell, North Central CMA).

Priority vegetation classes for water management in Gunbower Forest

Based on 13 management objectives, Ecological Associates (2004) prioritised the various WRCs in Gunbower Forest. The priority of water demands was based on two factors:

- the importance of the WRCs to the ecological objectives; and
- the significance of deficits in water requirements in each WRC.

Conservation values, threats and priority for management of the main vegetation classes in Gunbower Forest are indicated in **Table 3.6**. An earlier and simpler attempt to prioritise the WRCs based on importance of threatened conservation values and degree of threat (URS, 2001) produced similar final rankings for River red gum, Permanent wetlands and Semi-permanent wetlands, except that this earlier approach produced a 'high' priority for Black box that did not emerge from the later analysis.

Table 3.6 – Priority of WRCs for water management. Source: Ecological Associates (2004).

Ecological objective	PW	SPW	RG FDU	RG FTU	BBx
Breeding and foraging by colonial nesting waterbirds	6	6	1	0	0
Breeding and foraging by White-bellied sea-eagle	9	4	4	1	1
Self-sustaining populations of wetland frogs	9	6	2	0	0
Self-sustaining populations of floodplain frogs	0	0	0	3	1
Abundance, colonisation and diversity of aquatic invertebrates	3	2	6	2	2
Self-sustaining populations of small floodplain fish	9	6	9	1	0
Temporary habitat for large fish	3	2	9	2	1
Submerged aquatic and herbland plant communities	9	4	2	1	1
Emergent wetland plant communities	1	6	6	0	0
Healthy red gum forest	0	0	6	0	0
Healthy red gum woodland	0	0	0	3	0
Healthy Black box woodland	0	0	0	0	3
Export of organic material to the River Murray	2	4	9	2	2
Priority total score	51	40	54	15	11

1. PW = Permanent wetlands; SPW = Semi-permanent wetlands; RGFDU = River red gum forest flood-dependent understorey; RGFTU = River red gum forest flood-tolerant understorey; BBx = Black box.
2. A score of 3, 2, 1 or 0 was applied according to the importance (from highest to lowest) of each WRC. A score of 3, 2, 1 or 0 was applied according the gap between current water regime and the required water regime. These two scores were multiplied to get the final score. Total score for each WRC was obtained by summing the score for each objective.

3.2.6 Human use values

Traditional owners and cultural heritage

Evidence of occupation of the area by Indigenous peoples includes middens, burial sites and canoe trees. The earliest dating of occupation of the area within close proximity of the Koondrook and Perricoota forests is at Kow Swamp, at 13,000 years BP (DEH, 1992). Areas of importance include rivers and their margins, wetlands including swamps, billabongs, streams and anabranches (Forestry Commission of

NSW, 1985). Indigenous populations in the area appear to have been more or less sedentary due to the resource rich nature of their environment (Lyons, 1989). The forests have high educational value regarding traditional land use in the forests of the area (DEH, 1992).

Land uses

The arrival of Hume and Hovell marked the commencement of European history of the area in 1824. By the mid-1800s large grazing leases had been taken up in the area (Forestry Commission of NSW, 1985).

On-site uses in the Koondrook–Perricoota forests include forestry (including sawlogs), firewood, beekeeping, grazing, charcoal production, irrigation and recreation. Land uses in the surrounding area include grazing, cropping, forestry and nature conservation (DEH, 1992).

Land uses in Gunbower Forest include timber production, grazing, nature conservation, recreation, beekeeping, flood mitigation, and sand and gravel supply. The many wetlands, creeks and effluents provide excellent recreation opportunities, and the area is popular for fishing, camping and hunting (DEH, 1995; DEH, 1999). The convoluted course of the Murray River provides many fishing spots. Wildlife, particularly waterfowl, is plentiful and hunting is permitted in designated zones. Cattle are currently agisted in the Forest (DEH, 1999).

3.2.7 Summary of knowledge of the condition of Gunbower and Koondrook–Perricoota forests

The high conservation value of the Gunbower and Koondrook–Perricoota forests is recognised by its Ramsar listing. The area is rich in flora and fauna, including threatened species and also contains significant social, cultural and economic resources. Despite its high conservation values, surveys have demonstrated significant environmental changes in the forest system. Of the various factors impacting the health of the forests, the altered flooding regime due to river regulation is the factor with the greatest potential to affect vegetation. River red gum with flood-dependent understorey has declined in extent to a narrower zone around wetlands. River red gum with flood-tolerant understorey is believed to have become more extensive under regulated flow conditions, replacing the flood-dependent understorey at the wetter end of its range. At the dry end of its range, Black box woodland is believed to have encroached in response to declining flood frequencies. There is evidence to suggest that some wetlands now have reduced capacity to retain water, and reduced inflows due to regulation have increased the frequency at which wetlands dry out. Permanent water, which is an important habitat requirement for aquatic fauna, such as small fish and colonial nesting waterbirds, has largely been lost from the forests as a result of the reduced frequency of small, regular flow peaks in late winter and spring. The wetland understorey plants have declined, and terrestrial understorey grasses and shrubs have spread.

Permanent water is an important habitat component for colonial nesting waterbirds, providing breeding opportunities during dry years. Colonially nesting waterbirds rely on productive flooded and unflooded River red gum forest areas to forage during breeding. Therefore, it can be deduced that the potential for the forests to support colonially nesting waterbird breeding has decreased in response to declining flood frequencies and durations. Also, declining flood frequencies in the River red gum forest has reduced the health of nesting trees. Despite these changes, when floods do occur they can still trigger responses from some opportunistic species.

Other than birds and vegetation there is little readily available information on the ecological condition of the Gunbower and Koondrook–Perricoota forests.

The relationships between flows in the River Murray and extent of flooding of the various vegetation communites of Gunbower and Koondrook–Perricoota forests has been well characterised, both through vegetation surveys and mapping of flood inundation.

The knowledge base for Gunbower and Koondrook–Perricoota forests is extensive, although primarily focused on flow-vegetation relationships. The various data on the ecological components of the forests have not yet been compiled into a single database or summarised in terms of relevant and consistent measures of diversity, extent, abundance, and long-term trends.

3.3 Factors causing loss in environmental values

3.3.1 Hydrology—degree of change to flows due to river regulation

The Gunbower and Koondrook–Perricoota forests are downstream of:

- major headworks storages on the River Murray (Hume and Dartmouth dams);
- the three largest point diversions from the River Murray, located at Yarrawonga (Mulwala Canal and Yarrawonga Main Channel) and several kilometres upstream of Torrumbarry Weir (National Channel);
- the Edward River offtake; and
- inflows from the Broken, Goulburn, and Campaspe rivers.

Flows to Gunbower and Koondrook–Perricoota forests are regulated by diversions from the River Murray, regulation of the Goulburn River and other effects of the management of flow using water management infrastructure. Prior to the completion of the Torrumbarry Lock in 1923 there was little control exerted on water flow except for small scale damming by locals to prevent flooding (DEH, 1999). Since then Gunbower Creek has been maintained at ‘top of bank’ level during the irrigation season (August to May) by weirs at Gunbower, Cohuna and Koondrook resulting in a protracted high flow period for the forest. Although the flow is at channel capacity, regulators between Gunbower Creek and the Forest prevent water entering the Forest during these times (DEH, 1999). Flow regulation has been identified as a major, if not the major, threat to health of the Gunbower and Koondrook–Perricoota forests (DEH, 1992; DEH, 1995; DEH, 1999; URS, 2001).

A comparison of the natural and current median monthly flows in the river zone of the Gunbower and Koondrook–Perricoota forests is shown in **Figure 3.18**. Although flow regulation and diversion has markedly reduced mean monthly flows, the natural seasonal pattern of flows is reinstated by tributary inflows. A comparison of flood categories over the last 109 years under natural and current conditions is provided in **Figure 3.19**. In particular, a significant decline in frequency of flows downstream of Torrumbarry Weir in excess of 25,000 ML/day has occurred. **Figure 3.19** shows that the occurrences of each shaded flow category have reduced significantly under current conditions relative to natural. These frequency and duration data are tabulated for a range of flood discharges in **Table 3.7**.

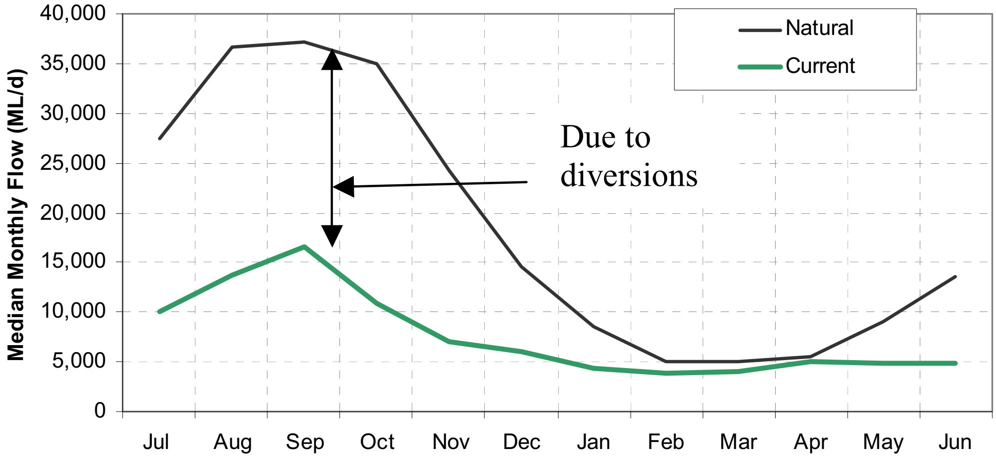

Figure 3.18 – Median monthly flows downstream of Torrumbarry Weir under natural and current conditions. Source: MDBC.

NATURAL CONDITIONS (average monthly flow ML/d)													CURRENT CONDITIONS (average monthly flow ML/d)											
July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	YEAR (June)	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
										9,400	20,000	1891											4,500	4,200
28,900	37,800	26,100	24,200	18,000	12,900	7,300	4,400	4,700	4,600	10,300	20,100	1892	14,000	12,500	9,700	6,500	4,700	4,400	4,100	3,600	3,500	3,500	4,000	7,200
38,400	27,400	36,600	33,400	30,300	22,100	8,400	4,500	4,200	3,800	16,000	33,200	1893	20,400	10,400	17,100	5,500	10,000	8,200	3,400	3,500	3,000	3,800	5,600	18,100
41,700	53,400	55,400	54,400	36,400	19,400	13,400	7,100	6,300	9,400	15,100	19,700	1894	25,500	33,700	34,300	39,300	17,900	7,000	4,400	4,000	3,900	4,500	5,300	10,700
34,100	50,600	55,800	57,300	53,300	26,700	12,400	6,800	6,200	6,100	9,000	12,700	1895	21,300	32,700	49,500	50,800	39,700	12,200	3,700	3,300	4,200	5,700	5,000	5,100
24,000	30,700	40,700	30,300	17,100	11,400	5,900	4,700	5,500	6,500	11,500	9,100	1896	9,000	13,000	23,200	13,400	3,900	4,200	3,800	3,800	3,800	4,100	3,800	3,500
24,300	16,900	21,500	24,200	12,000	9,700	9,700	9,500	7,000	4,700	4,100	4,600	1897	7,800	5,900	8,000	4,800	4,400	5,200	5,300	3,100	3,700	4,200	3,000	2,500
15,800	21,200	40,200	30,500	17,700	7,600	3,900	4,000	5,200	4,200	4,200	16,100	1898	5,600	6,300	14,300	5,000	4,500	4,700	3,800	3,500	3,100	3,700	5,200	5,900
21,400	30,800	34,500	23,100	25,400	15,600	6,600	5,700	4,800	9,600	9,100	25,500	1899	7,000	12,000	10,700	5,500	5,900	5,300	4,900	4,900	3,800	5,700	5,300	8,000
37,900	27,600	17,800	14,900	14,200	7,800	4,200	3,700	4,100	12,400	15,400	16,000	1900	19,400	8,500	4,600	3,400	4,700	6,600	6,000	5,300	6,100	6,100	5,800	5,400
33,900	33,900	46,900	39,100	20,700	10,100	4,900	3,300	2,900	5,300	6,400	17,700	1901	16,800	13,900	20,500	10,200	8,100	6,900	5,500	4,600	3,900	5,600	4,300	5,000
15,300	17,100	36,700	40,800	35,700	13,800	5,800	3,700	3,000	4,100	2,800	6,000	1902	5,300	7,800	15,600	12,400	9,200	6,800	5,300	4,700	5,700	4,800	3,900	3,200
13,300	6,300	7,000	10,800	6,200	5,300	5,400	2,700	4,000	5,000	9,700	17,100	1903	3,600	4,100	3,700	3,800	4,600	4,100	5,300	4,600	4,300	3,700	3,800	5,300
38,100	28,400	30,900	29,500	23,700	11,700	16,200	11,100	7,300	3,700	4,900	10,100	1904	20,400	10,500	13,200	8,200	6,300	5,500	5,900	4,800	4,000	4,000	3,800	3,500
37,200	39,500	41,200	32,100	36,500	14,600	6,000	3,800	3,300	3,300	4,500	13,400	1905	15,300	17,200	17,800	10,500	8,700	5,600	4,300	4,100	3,900	4,600	3,400	5,400
41,100	49,100	30,900	33,800	37,600	22,700	7,400	3,600	8,900	6,900	11,500	26,600	1906	19,800	24,600	8,200	7,900	8,400	6,100	5,000	4,500	5,000	3,000	3,600	9,000
51,100	55,700	56,000	56,600	42,800	26,400	17,100	8,100	4,900	5,000	7,700	12,000	1907	36,000	32,900	42,600	45,900	17,000	7,500	4,900	4,300	3,800	4,400	3,900	4,300
10,600	27,600	23,300	19,900	15,900	10,500	9,400	4,800	3,700	2,800	4,900	10,300	1908	3,600	9,100	6,600	4,200	4,800	6,300	4,600	4,300	3,400	4,100	3,000	3,500
15,800	22,200	27,200	24,700	21,000	8,000	3,600	3,400	4,400	3,600	21,400	33,700	1909	5,800	7,300	10,600	6,800	5,000	4,800	4,500	3,900	3,600	5,500	9,600	14,800
47,800	55,100	55,300	36,000	20,300	9,100	4,200	3,500	3,800	3,100	3,100	9,300	1910	28,500	46,100	35,800	8,200	5,100	4,800	4,700	3,500	4,400	3,400	3,400	3,900
28,500	23,200	47,200	49,300	29,200	17,900	10,800	17,300	20,600	13,800	10,000	43,500	1911	12,100	8,700	33,000	17,600	9,500	7,100	5,800	10,000	7,700	6,600	6,000	23,700
47,400	46,200	29,200	18,300	10,700	7,900	5,600	3,400	2,900	2,900	3,100	4,000	1912	25,300	20,600	7,300	4,200	3,900	3,800	3,700	4,100	3,800	3,600	2,700	2,600
14,500	14,000	34,900	36,100	19,600	22,700	14,800	6,300	7,600	11,900	9,800	14,800	1913	6,500	5,600	15,200	10,400	4,300	6,200	5,300	4,600	4,100	6,400	5,400	3,600
18,200	23,800	23,400	25,300	23,600	13,300	6,100	4,100	3,300	3,500	7,300	9,100	1914	5,100	8,800	7,100	4,300	4,700	4,900	4,100	3,700	3,300	3,400	2,500	3,000
10,200	11,900	9,500	7,300	3,100	3,200	3,100	2,100	1,400	1,500	4,700	9,900	1915	3,000	4,200	3,600	2,900	3,900	5,800	5,100	6,500	6,300	6,000	4,600	4,100
39,700	52,800	46,800	47,400	39,000	16,500	6,600	4,900	4,400	3,300	4,900	7,900	1916	17,200	28,400	18,200	21,700	8,600	6,700	6,000	4,800	3,700	5,300	3,900	3,400
29,700	41,600	54,600	57,200	56,700	51,300	24,900	9,600	10,600	11,300	16,000	51,900	1917	14,200	16,300	33,900	49,200	43,700	28,000	7,400	4,600	5,100	6,000	7,900	42,600
56,900	57,200	57,600	57,500	53,700	35,200	17,500	11,400	11,600	9,700	33,100	48,800	1918	49,000	56,200	56,900	55,600	43,600	20,500	5,000	5,100	5,900	5,900	20,700	38,200
54,000	54,600	53,200	33,200	19,000	9,700	6,000	4,100	7,000	5,400	6,400	10,800	1919	54,900	45,000	47,400	13,200	4,400	4,700	3,700	5,100	3,900	4,200	3,400	4,000
21,400	18,300	22,300	22,400	12,200	7,100	11,000	6,300	4,100	4,000	5,600	11,400	1920	6,100	5,800	6,400	5,600	7,000	7,200	4,800	4,100	3,800	5,400	3,800	4,000
33,200	51,000	55,400	50,300	42,200	17,500	10,600	5,600	6,000	5,900	5,100	21,900	1921	13,700	23,700	40,000	22,500	16,300	6,500	4,400	4,100	4,300	5,100	4,500	9,200
23,100	49,300	56,600	54,100	33,600	13,500	8,300	4,700	4,800	3,600	6,100	5,300	1922	9,500	29,800	44,600	30,500	14,500	3,900	4,100	3,800	3,400	3,800	4,200	2,600
13,800	22,700	22,800	29,400	21,100	8,000	5,200	3,600	2,300	2,200	4,000	29,600	1923	5,600	3,400	5,200	5,300	5,200	4,300	4,100	3,500	3,100	3,600	3,000	12,100
50,800	53,800	39,500	51,100	45,000	24,900	16,200	12,300	14,000	14,500	11,000	19,200	1924	24,800	31,300	9,800	22,100	11,500	4,900	5,100	5,500	5,600	6,400	5,100	7,300
18,600	31,600	48,100	51,900	53,500	34,900	16,300	17,000	12,000	7,600	7,600	10,800	1925	5,700	11,000	35,900	34,000	42,500	16,500	3,800	4,900	4,400	5,400	4,600	3,900
14,400	22,100	35,600	32,600	19,700	9,300	5,100	3,200	3,500	6,800	22,200	29,400	1926	4,400	4,800	18,100	12,900	4,700	4,500	3,700	3,300	4,500	5,500	8,900	10,200
35,700	50,100	46,800	42,300	28,400	12,000	7,800	5,100	3,500	3,200	5,400	7,700	1927	18,000	27,200	30,400	19,500	10,200	3,800	4,000	3,800	3,200	3,900	4,900	2,500
16,000	28,900	26,800	27,400	24,100	10,100	7,000	9,200	11,700	15,000	21,400	40,900	1928	5,200	7,100	3,500	6,400	5,700	5,500	7,600	5,200	4,700	6,500	10,700	19,800
29,800	22,100	19,300	41,200	32,500	11,700	5,400	4,100	4,600	8,900	9,300	18,800	1929	11,600	7,700	4,600	14,000	5,400	4,600	4,100	3,800	4,100	5,700	3,700	5,500
19,700	20,700	25,200	25,200	17,400	13,400	9,600	4,800	3,700	3,900	9,500	9,200	1930	5,700	7,000	4,000	5,400	7,200	6,900	4,400	4,100	4,200	5,100	4,400	2,700
12,300	27,400	25,500	35,100	39,700	32,100	21,500	10,700	10,900	22,100	39,400	54,800	1931	4,100	10,500	7,400	11,300	9,800	8,600	4,300	4,300	5,000	9,600	23,400	44,000
56,400	55,500	54,200	38,600	27,300	17,900	6,700	5,300	11,700	23,000	24,900	32,600	1932	50,700	45,400	44,300	20,100	9,300	6,900	4,000	4,700	5,700	8,400	9,300	18,800
49,300	49,600	46,200	34,000	22,600	11,900	6,300	4,300	3,200	3,400	5,400	15,100	1933	36,000	28,500	38,400	16,000	5,500	4,200	4,100	3,600	3,500	3,900	4,800	6,100
28,200	33,500	42,000	39,600	18,600	17,300	17,600	9,000	6,500	7,600	9,500	6,400	1934	13,800	12,600	19,600	9,000	4,000	6,800	4,500	4,900	3,700	4,500	3,400	2,500
17,300	25,900	31,200	47,800	53,400	48,200	19,800	10,600	8,700	14,900	24,400	31,300	1935	6,400	6,200	7,300	21,100	39,000	24,100	5,000	4,100	4,500	6,300	6,900	16,900
42,200	52,500	49,500	35,200	25,200	14,100	9,400	5,900	5,600	6,000	7,500	11,400	1936	29,300	45,900	38,300	22,900	10,500	4,200	4,100	3,200	3,400	4,600	5,800	4,100
32,600	50,400	44,700	25,800	19,600	15,600	12,900	9,200	5,500	5,000	6,100	6,800	1937	12,700	23,700	26,000	10,300	5,100	6,000	4,100	3,500	3,900	4,100	4,200	2,400
7,600	11,400	22,400	24,400	14,000	6,800	4,000	3,700	3,000	3,100	5,700	8,400	1938	2,800	5,100	5,100	5,800	5,900	6,000	4,600	4,400	3,600	4,500	4,000	2,600
13,600	11,700	14,100	10,800	5,000	2,500	2,000	5,900	23,300	35,200	34,500	35,400	1939	4,600	2,400	3,200	3,300	5,000	5,600	4,200	6,500	12,800	12,400	17,300	20,200
49,100	55,700	56,100	47,200	38,300	25,900	11,000	5,700	4,300	5,100	8,000	9,400	1940	39,200	30,600	43,500	23,000	21,000	9,700	5,000	4,000	3,400	4,500	3,600	2,800
12,000	13,500	13,000	12,400	7,500	5,800	11,600	7,800	8,100	8,000	6,000	9,200	1941	2,800	3,900	4,900	4,100	6,300	5,900	5,500	4,800	4,800	6,300	5,600	3,000
21,000	18,800	16,900	24,600	15,100	8,500	4,600	3,900	3,600	5,800	25,400	33,500	1942	6,800	6,900	6,200	4,800	4,300	4,600	5,000	4,400	4,200	5,400	11,300	16,200
51,200	49,300	51,700	41,400	26,800	14,800	7,800	5,100	4,100	6,400	12,100	11,400	1943	32,000	19,300	27,600	8,600	5,700	5,100	4,400	4,000	3,100	4,200	5,300	3,000
21,800	25,700	28,700	29,200	22,600	11,100	4,400	2,900	3,300	4,200	15,700	16,300	1944	5,900	5,200	8,000	6,500	4,900	5,700	5,100	4,800	5,500	7,000	5,500	4,800
19,700	14,500	9,200	8,700	7,800	4,500	4,200	4,200	2,100	2,300	3,000	6,000	1945	6,600	4,900	3,300	2,500	3,400	6,200	4,400	5,900	6,100	6,400	4,300	3,500
13,200	26,500	31,200	19,700	21,300	10,300	4,800	6,600	11,300	11,300	8,100	13,000	1946	3,900	6,100	7,900	5,600	6,200	4,900	5,200	5,100	4,600	6,800	5,300	4,400
31,300	46,400	34,900	25,200	22,400	13,200	6,900	3,900	5,600	5,600	5,200	12,100	1947	8,700	20,500	7,800	4,800	3,900	5,500	5,500	6,300	5,400	6,700	4,400	3,900
35,100	44,500	43,400	47,700	41,400	24,300	14,600	8,400	6,400	6,200	13,100	18,100	1948	11,000	17,000	17,200	19,300	13,100	7,600	6,000	4,600	3,300	6,200	8,100	5,500
19,200	19,100	24,000	23,000	34,200	21,000	8,600	5,600	8,700	5,800	6,400	9,200	1949	4,600	4,400	5,800	4,400	7,600	4,000	4,000	5,100	5,000	6,100	4,400	3,300
13,500	18,400	26,700	35,400	49,600	28,600	11,000	9,400	12,600	15,800	9,800	11,800	1950	4,200	5,400	9,900	11,500	18,800	6,900	5,400	4,500	6,500	6,500	5,800	4,100
19,200	22,800	28,400	29,900	30,000	16,800	8,000	7,400	4,800	10,300	22,300	39,600	1951	5,000	6,500	11,600	5,000	3,900	4,000	4,100	5,500	3,600	6,400	6,300	25,000
50,900	52,100	38,400	33,000	28,000	14,800	7,800	4,000	4,000	10,000	22,200	49,500	1952	27,000	33,200	23,500	12,000	11,500	3,500	3,900	3,900	3,700	6,600	9,400	28,000
56,300	52,200	52,500	53,100	52,400	45,600	23,300	10,900	6,200	5,400	7,800	19,100	1953	47,800	43,900	44,300	45,500	44,900	28,800	8,900	3,500	3,800	4,200	5,500	7,900
32,800	50,700	53,000	53,700	48,600	24,500	9,800	10,100	6,000	5,500	8,700	12,900	1954	14,000	37,800	39,600	47,700	34,900	10,400	4,300	4,600	3,900	4,300	3,900	4,400
14,700	20,400	30,500	22,400	28,200	39,400	16,200	10,300	10,900	8,500	12,600	28,900	1955	4,500	4,600	9,400	6,500	7,400	13,900	5,500	5,300	4,400	5,300	6,200	13,600
48,900	56,600	56,500	54,400	42,700	25,400	22,500	18,100	21,500	42,900	55,000	56,600	1956	33,900	44,400	54,700	50,000	27,000	12,100	6,400	4,300	11,700	32,400	49,700	56,900
57,500	57,400	56,700	53,800	49,300	29,400	13,800	8,100	7,500	6,400	9,700	10,500	1957	57,200	55,700	54,700	46,600	37,700	14,500	4,000	4,500	4,600	4,600	3,700	3,300
21,200	19,100	19,500	26,700	20,900	10,600	8,600	5,700	5,400	5,300	9,900	27,000	1958	7,600	6,100	5,900	5,400	6,300	4,500	4,600	4,300	3,700	4,200	3,700	10,900
26,800	53,400	47,600	48,100	41,000	21,400	9,200	6,500	8,100	7,700	5,600	6,600	1959	9,500	35,600	34,200	31,000	26,900	9,600	4,100	4,500	4,600	6,500	3,800	2,500
9,000	17,000	22,500	24,500	18,800	8,800	5,500	4,100	6,800	6,800	32,500	42,200	1960	2,900	4,100	7,200	3,600	5,000	3,600	3,400	4,200	4,300	5,200	14,000	26,800
48,500	53,500	55,500	46,700	35,000	19,900	9,500	5,000	4,600	5,700	9,600	9,700	1961	24,800	33,700	40,000	32,200	12,800	5,700	3,800	3,900	4,300	4,700	4,000	3,100
19,900	23,900	22,900	16,800	10,300	8,500	5,500	5,200	3,200	4,200	6,600	25,600	1962	5,500	9,500	7,500	3,700	3,600	5,400	4,200	3,100	3,900	4,400	4,800	10,000
27,400	31,400	26,800	27,400	22,700	12,200	9,300	7,700	4,300	4,400	11,500	21,000	1963	9,000	12,000	8,300	5,500	3,600	3,900	3,500	3,200	4,000	5,100	6,800	10,400
26,700	36,900	38,000	31,900	21,700	12,300	5,100	4,000	4,000	3,700	10,000	13,400	1964	14,200	14,000	13,600	9,700	7,800	6,300	4,600	3,800	3,500	6,900	6,000	6,800
49,300	55,600	52,600	54,700	39,400	19,300	8,700	4,200	3,200	3,400	5,900	9,400	1965	26,700	38,700	27,300	43,100	19,700	6,000	4,300	3,700	3,200	3,900	4,000	2,700
13,400	29,000	41,300	23,100	13,000	13,900	5,000	3,600	4,000	4,400	7,000	8,400	1966	3,300	10,600	18,900	6,700	4,600	5,000	5,200	4,600	4,000	5,400	5,300	3,000
14,000	32,800	39,900	39,900	32,800	34,200	20,700	6,300	3,800	4,000	3,200	4,200	1967	4,500	9,600	16,400	16,900	8,600	12,300	4,700	3,900	3,400	4,200	4,400	3,000
5,000	13,200	15,200	13,700	6,700	3,300	2,300	1,700	1,800	2,900	23,900	48,100	1968	2,200	2,200	3,400	4,600	7,200	7,200	3,800	3,700	4,300	5,800	8,300	29,200
37,000	48,200	42,700	43,500	38,000	21,600	9,400	5,500	5,800	9,000	10,300	16,600	1969	17,800	31,400	15,700	11,200	6,100	6,700	6,200	7,200	6,700	5,900	5,000	4,400
24,500	33,000	38,400	30,200	18,600	15,300	13,200	10,500	11,400	15,900	24,900	24,300	1970	7,900	13,700	20,100	12,900	6,000	4,000	4,400	3,200	4,900	5,000	9,300	11,400
38,400	49,800	52,700	38,800	28,900	20,500	11,200	10,900	9,200	8,500	20,800	29,000	1971	15,500	22,900	40,100	23,800	11,400	7,400	4,100	5,400	5,600	5,900	6,800	9,500
22,500	26,300	33,800	48,900	51,700	30,700	14,600	14,100	8,700	6,100	7,900	6,700	1972	10,500	10,400	17,200	24,500	32,200	13,600	3,900	6,200	3,600	4,700	3,700	2,500
14,800	20,500	20,800	16,100	9,600	5,400	3,000	17,500	12,200	10,600	29,300	37,800	1973	4,500	4,600	5,600	3,900	4,100	4,100	4,300	9,500	6,600	5,300	15,200	16,200
47,000	54,600	56,700	55,100	39,300	19,800	20,300	16,500	8,100	13,900	50,600	37,700	1974	30,600	46,400	52,900	43,300	31,500	8,600	11,500	8,900	4,100	6,900	41,500	31,200
48,100	56,000	56,300	56,500	47,400	24,700	10,600	7,700	6,900	7,700	12,000	17,300	1975	41,900	53,400	54,600	54,200	33,400	12,200	4,000	4,200	4,400	3,700	4,800	4,800
23,000	47,800	55,500	57,500	55,200	31,100	15,800	8,500	7,600	5,900	6,100	6,800	1976	7,600	23,300	46,400	56,600	46,400	16,700	6,000	4,100	3,800	3,900	4,700	2,500
7,500	16,100	18,700	25,900	24,600	12,000	8,800	6,200	6,000	7,500	7,100	21,300	1977	2,300	3,200	5,000	5,100	4,500	3,000	3,900	4,300	3,600	4,500	4,100	5,500
30,000	27,100	20,500	15,700	9,800	5,100	4,600	4,100	4,200	7,100	8,200	18,500	1978	12,200	7,400	5,300	2,600	3,700	3,800	4,100	3,700	4,400	2,800	3,500	6,500
32,700	49,200	45,000	36,300	27,700	22,500	11,600	5,200	4,100	4,900	6,000	8,400	1979	10,000	29,100	17,200	14,900	8,200	7,000	4,800	4,000	3,300	4,400	3,300	3,000
10,200	21,800	45,400	54,600	32,900	10,700	5,400	3,500	3,400	4,100	4,500	7,300	1980	3,500	6,200	24,700	43,200	11,500	3,500	4,200	3,500	3,200	4,600	3,300	2,400
26,300	33,600	36,300	29,100	20,800	13,900	7,600	4,900	4,300	3,200	4,600	24,400	1981	8,500	13,600	8,200	6,800	6,700	7,100	3,900	3,600	3,100	5,300	5,300	8,300
52,200	57,600	51,000	36,400	23,700	12,400	7,200	5,300	4,000	4,500	5,700	8,800	1982	36,900	56,800	39,000	20,000	7,600	4,700	4,200	4,400	3,900	5,400	4,700	3,100
7,100	7,600	9,100	8,700	3,700	2,300	1,800	1,100	1,800	6,700	10,900	17,800	1983	2,400	3,500	4,100	3,800	5,800	5,800	4,500	3,200	2,900	6,200	5,900	6,600
36,100	47,600	54,500	44,100	27,300	18,900	12,400	11,200	6,600	6,500	7,500	6,500	1984	11,900	29,100	45,100	15,900	7,000	6,600	7,500	4,000	3,800	5,700	5,000	2,600
8,900	36,600	47,300	48,200	25,200	9,200	4,900	3,700	3,900	4,600	5,300	10,900	1985	2,900	10,300	26,000	19,400	6,400	3,800	3,600	3,100	3,200	3,300	3,200	3,700
12,400	42,500	38,000	21,400	16,800	18,700	10,900	5,500	3,200	3,200	8,700	10,900	1986	3,300	13,900	19,500	5,000	4,600	5,600	4,200	3,800	3,100	3,700	4,500	3,700
47,600	49,900	44,200	51,100	39,700	24,300	13,200	5,800	6,000	5,900	9,500	22,800	1987	30,300	31,700	25,300	24,700	20,500	6,700	4,200	3,600	3,600	4,500	3,800	7,000
38,100	44,700	30,400	20,800	13,600	11,200	6,800	4,500	3,800	4,200	7,700	31,100	1988	22,600	24,700	7,600	5,400	6,100	6,600	4,300	4,500	4,000	4,400	4,000	14,400
40,800	38,300	40,000	28,500	18,300	20,300	17,600	5,800	7,000	15,800	19,700	42,500	1989	19,100	20,300	19,700	7,200	7,600	10,000	4,500	3,900	5,400	6,500	9,500	26,700
43,200	51,600	53,100	41,900	33,500	18,100	7,200	5,500	4,500	6,500	10,100	13,600	1990	26,400	37,400	33,500	16,000	11,300	4,100	4,500	5,200	3,800	5,700	3,500	5,100
46,900	55,600	52,000	38,400	28,800	12,800	7,500	6,000	3,400	3,700	3,300	9,100	1991	24,600	40,800	36,000	18,400	15,500	6,300	5,000	4,000	3,700	5,400	2,900	3,300
27,400	45,100	54,200	43,200	21,100	9,700	10,500	5,800	4,900	4,000	9,200	13,700	1992	10,500	13,000	32,100	21,900	5,300	4,900	4,400	4,300	3,900	3,900	5,000	5,200
16,100	31,300	52,900	57,200	52,300	44,100	24,900	15,900	11,800	10,700	7,900	11,500	1993	5,500	10,800	38,400	54,400	39,100	35,900	12,900	4,700	5,200	9,300	4,400	4,100
28,000	46,200	55,800	56,700	44,400	23,700	21,000	13,800	11,700	8,600	7,500	12,900	1994	19,500	35,600	51,600	56,800	29,100	9,500	7,200	5,400	5,800	6,000	5,100	4,100
15,300	14,500	13,600	14,300	15,000	10,000	7,200	8,700	5,400	4,900	13,500	43,200	1995	5,700	3,500	5,100	5,600	7,300	5,800	5,100	3,400	3,500	4,200	5,000	21,400
54,300	52,200	30,800	25,300	24,000	19,200	13,400	10,000	9,700	11,300	10,500	19,500	1996	31,600	39,300	8,100	7,500	12,400	6,600	4,600	3,900	4,400	5,000	5,400	5,200
46,600	55,200	53,200	53,900	35,600	16,200	10,000	7,400	4,800	4,000	5,300	7,200	1997	30,800	47,600	37,100	47,900	18,000	5,700	4,000	4,200	4,100	4,500	5,800	2,500
7,400	11,700	24,600	14,800	9,700	4,300	2,200	2,500	1,300	3,100	3,900	5,800	1998	2,300	5,000	6,800	3,900	4,200	3,900	4,000	3,900	2,900	3,400	3,000	2,400
17,300	20,600	31,500	35,400	25,000	14,700	6,100	4,000	3,200	5,100	4,400	13,900	1999	4,800	6,100	6,400	13,200	8,300	5,200	3,500	3,500	4,000	6,100	5,100	6,300
13,600	28,000	32,700	22,600	12,700	9,300	9,000	4,500	3,900	5,300			2000	4,400	8,200	10,700	5,200	4,800	4,500	4,600	4,600	3,600	5,400		

<25,000 ML/day | 25,000—35,000 ML/day | 35,000—45,000 ML/day | >45,000 ML/day

Figure 3.19 – Comparison of flood categories between natural and current conditions for flows passing Torrumbarry Weir — 109 years of modelled record. Each row is a year, each column is a month. Shading corresponds to 'out of channel' flows. Note the reduced frequency of all flood categories.

Table 3.7 – Effects of regulation of the River Murray on flows at Torrumbarry, based on modelled monthly flows. Source: URS (2001, pp. 3–7).

River Murray flow		Duration (months per year)*		Frequency (events per 100 years)#	
ML/d	**ML/month**	**Natural**	**Current**	**Natural**	**Current**
5,000	150	10.0	6.3	70	155
10,000	300	7.1	2.7	97	67
15,000	450	5.8	2.0	98	57
20,000	600	4.8	1.5	98	44
25,000	750	4.0	1.2	95	38
30,000	900	3.2	0.9	83	32
35,000	1,050	2.5	0.7	73	29
40,000	1,200	1.9	0.5	62	24
50,000	1,500	0.7	0.1	31	5
60,000	1,800	0.1	0.0	6	1

* Duration is number of months per year in which the average monthly flow exceeds the given thresholds.

\# Frequency is the number of times per 100 years that continuous sequences of monthly flows exceed the given thresholds.

Table 3.8 indicates the effect of river regulation on the frequency of different flow events in Koondrook–Perricoota Forest, based on MDBC Monthly Simulation Model (MSM) runs of natural and current conditions. The period covered by the model is June 1891 to May 2000, but only data relating to the spring months (September, October and November) are presented here. The 'spring count' represents the proportion of spring months (out of 327) in which river flow exceeded the flow threshold shown in the first column. The 'spring flood' represents the proportion of years (out of 109) in which river flow exceeded the flow threshold for each spring month. For a flow of 30,000 ML/d, which equates to an inflow of approximately 3,800 ML/day and inundates 70% of River red gum forest (**Table 3.4**), it can be seen that river regulation has reduced the spring count from 54% to 21% of spring months, and the spring flood from 33% to 10% of years (**Table 3.7**). To summarise, spring floods in the Gunbower and Koondrook–Perricoota forests now occur less frequently than under natural conditions, and are of shorter duration.

Table 3.8 – Effect of river regulation on the frequency of a range of flow events in Spring months over period 1891-2000 in the Koondrook–Perricoota Forest. Unpublished source data provided by D. Leslie, Primary Industries Trading (June 2004) downstream of Torrumbarry Weir.

River flow (ML/ day)	Spring count (%)		Spring flood (%)	
	Natural	Current	Natural	Current
2,500	100	100	100	100
5,000	99	74	97	52
7,500	98	56	94	36
10,000	95	46	91	26
15,000	89	36	82	19
20,000	80	27	64	13
25,000	66	23	46	13
30,000	54	21	33	10
35,000	45	15	24	6

3.3.2 Other factors

In Gunbower Forest, timber harvesting and silvicultural practices have altered the age structure of River red gum stands and may have reduced the number of nest hollows available to wildlife (DEH, 1999). Grazing by introduced and domestic animals poses a threat to understorey communities at selected localities within the site (DEH, 1999; URS, 2001). Grazing, inappropriate recreational activities, and illegal deposition of irrigation drainage are other threats (DEH, 1995).

Grazing is known to impact on the survival of edge plants, such as Phragmites, around permanent wetlands. In addition, stock can exert physical damage on the substrate and plants (URS, 2001). Firewood collection reduces terrestrial habitat (URS, 2001).

Semi-permanent wetlands can be impacted by inflows of turbid water, which reduces light penetration, and ‘blackwater’. Floodwater passing over a floodplain dominated by River red gum can be expected to contain elevated levels of carbon and bacterial activity, which in turn may lead to the development of anoxic conditions, with water containing potentially toxic phenolic compounds—this is known as a ‘blackwater event’ (McKinnon, 1997).

In Koondrook–Perricoota Forests, feral animals including European carp, foxes, pigs, rabbits and hares have been listed as threats (DEH, 1992).

3.4 Opportunities to meet objectives for this site

3.4.1 Introduction

The hydrology of the Gunbower and Koondrook–Perricoota forests has been altered by regulation, mainly in terms of reduced frequency of medium-sized spring floods. Enhancement of naturally occurring floods has advantages over other means of watering the Gunbower and Koondrook–Perricoota forests. These advantages include temporary restoration of the connection between the river and floodplain, and generation of triggers to biota that would be similar to those under natural flood conditions. However, using flood enhancement to top up flood flows is by itself unlikely to achieve a significant increase in flooding for the Gunbower and Koondrook–Perricoota forests (even if the majority of the water is sourced from the Goulburn River in spring).

Managed watering of the Gunbower Forest through structural and operational opportunities has advantages over enhanced flooding in that:

- arrangements for monitoring can be established several months before the inundation event, which means better planned data collection as a component of adaptive management;
- users could be advised several months in advance of likely conditions in the Forest; and
- there may be opportunities for innovative transfers of EWAs between storages. For example, the water could be transferred between storages (between Lake Hume and Eildon Reservoir, with appropriate exchange rates) to avoid channel capacity constraints.

Past review of structural and operational opportunities in the Gunbower Forest include URS (2001), SKM (2002), and Ecological Associates (2004). Implementation of these measures is not water-neutral, but, to achieve similar environmental outcomes, the water required is less than that for enhanced flooding. The most recent evaluation of options for watering Gunbower Forest was done by Ecological Associates (2004). A summary extract of the relevant section of that report is presented below.

Potential actions under the First Step Decision involve: secure environmental water allocations for forests to water wetlands in most years, and River red gum forest areas at least every four years (approximately 90 GL/year on average); and, construction of flow management structures and channels to deliver water allocation to wetland and forest ecosystems (MDBMC, 2004, p. 32).

3.4.2 Gunbower Forest—Structural and operational options

Options to provide flows directly to wetlands in the central and lower Forest from Gunbower Creek

A number of options are available to increase the supply of water into Gunbower Forest. There are currently a number of existing regulators that could be used for this purpose including;

- Yarran Creek Regulator
- Reedy Lagoon Regulator
- Black Swamp Regulator

Although delivery is inefficient to the lower forest areas, the release capacity at the Yarran Creek Regulator is the preferred means of delivery in the absence of a new structure releasing the lower Forest. Alternatively, Reedy Lagoon Regulator has a slow rate of discharge, which could be used to fill Reedy Lagoon but may have limited use in watering other areas of the forest. The Black Swamp regulator also has a lower outlet capacity, which may also have limited use in watering the lower Forest wetland.

Extensive flooding of the upper forest channel red gum FDU and FTU can only be achieved by delivering water into the Forest from a water source above the ground level of the forest floor. Unfavourable levels limit the delivery of significant flows at Hipwell Road and more especially Deep Creek. The Upper Forest Channel provides the potential to flood significant areas of the upper, central and lower Forest by providing much greater flows. The operation of the channel would involve significant disruption to consumers dependent on Gunbower Creek and would presumably only be operated for short periods and with forewarning to other water users. This option would only be suitable for the delivery of large volumes, and would be inefficient for small, ad hoc deliveries to wetlands in the upper and central Forest. In this regard, options that allow the local delivery of relatively small volumes of water, such as Hipwell Rd and Little Gunbower, are still appropriate.

Options to enhance inflows from the River Murray

Low flow conditions could be supported by;

- Deep Creek, Kate Malone Branch and Upper Spur Creek are alternative sites to enhance flows to Spur Creek.
- Yarran Creek and Shillinglaws Regulator (Figure 3.7, Figure 3.8)
- Barham Cut Regulator

Providing inflows from the River Murray could be improved by deepening and widening the channels between the River and the River Track. These improvements could focus on the area around Spur Creek. Other options include the construction of lower sills between the wetlands and the riverbanks has the potential to divert water from the river at lower flows and increase the frequency with which the wetlands are filled.

The Yarran Creek, Shillinglaws and Barham Cut Regulators may be constrained by channel capacity although the control on when water commences to flow into the forest is the sill level at these regulators. The options for enhanced inflow through these structures are therefore related only to further channel widening. The Barham Cut could be used to deliver water to the lower forest (i.e., the Little Gunbower wetland areas) and retaining it there.

Options to control flooding in the Upper Forest

Compared to the rest of the Forest, water management options in the upper Forest address much smaller and fragmented areas. There are a number of options for introducing water into the upper Forest areas and these are simplified by the proximity of the elevated river levels created by the Torrumbarry Weir Pool and the upper reaches of the Gunbower Creek system. Options include;

- Cameron Creek Regulator and Black Charlie Lagoon
- Baggot Creek
- Straight Cut
- Cohuna Channel
- Torrumbarry Weir Pool

Improvement to the regulator on Cameron Creek and wetting and drying the system has the potential to provide most benefits. Cameron Creek wetland areas could be managed with re-establishment of control at the regulator structure. It is possible that water could also be allowed to flow out the northern side of Black Charlie Lagoon towards Dry Tree Creek. Baggot Creek connects the Upper Gunbower Lagoon with the upper Forest at Dry Tree Creek and could be used to deliver water to areas that Cameron Creek is unable to do. Straight Cut provides water from the Upper Gunbower Lagoon to the Brereton Farm area and could be used to release water into the Pig Swamp wetland area. Widening of the Cohuna Channel also has the potential to deliver water to the Upper Forest.

Torrumbarry Weir Pool could be raised to create flooding of the upper Forest areas adjacent to the weir and by pushing more water down the Cameron Creek system as part of a program for environmental flows in the river. Raising the Torrumbarry Weir Pool benefits a relatively low priority water management area, the upper Forest black box, and provides a low conservation return.

Red gum with flood-dependent understorey

Gunbower Creek (**Figure 3.2**) forms the southwestern boundary of Gunbower Forest (**Figure 3.3** and **Figure 3.4**). Water flows from Torrumbarry Weir pool into National Channel, and then into Gunbower Creek. During regulated periods, the irrigation flows in Gunbower Creek are at a level higher than the Forest, and releases can be made through regulators to inundate the Permanent and Semi-permanent wetlands in the Forest. There are opportunities to enlarge these regulators, or construct a new one, to assist with watering of the Gunbower Forest.

Through the ‘Sharing the Murray’ process (MWEC, 1997), DSE developed rules to trigger the release of surplus flows into Gunbower Forest via Gunbower Creek to meet the following objectives:

- to provide small annual volumes to top up what used to be permanent wetlands in Gunbower Forest;

- to top up small floods (those which cause minor flooding within the Forest) which range from 610 GL/month to 1100 GL/month at Torrumbarry Weir;
- to put water into the Forest during dry periods, when the River does not get high enough to flood the Forest; and
- to top up medium-sized floods, with the intention of wetting the elevated Black box areas.

To achieve ecological benefits, the current deficit in the flooding of River red gum FDU was defined by Ecological Associates (2004) as a need to:

- increase flood duration by 52 days to achieve an average duration of 120 days;
- initiate flooding earlier (up to 18 days) and prolonging the flood tail (by up to 28 days); and
- increase flood frequency from 6.4 years in 10 to 7.4 years in 10 by providing one additional 120-day flood every 10 years.

The DTM for Gunbower Forest indicates that the cumulative volume of inflows in the central Gunbower Forest fully water Permanent wetlands and Semi-permanent wetlands is 3 GL, and for River red gum forest it is 30 GL (**Figure 3.15**). The water needs for the lower Gunbower area are similar. Seepage, evaporation and drainage would mean that the volume of water needed to be supplied from the River in a managed flood lasting preferably several months would be much greater, because flows would have to be maintained over that period.

Ecological Associates (2004) estimated the volume of water required to water the most important component of the water regime deficit based on sustained through-flow and not storage. The most appropriate time for an annual release would be in winter, to initiate flooding earlier in anticipation of later spring inflows from the River Murray. If operated for 28 days in July, 6.4 years in 10, the average flood duration would increase from 68 to approximately 98 days. A plan to entirely meet the deficit in flood duration using the Upper Forest Channel would require the delivery of 4,000 ML/d over approximately 40 days, 6.4 years in 10. If Hipwell Road and Yarran Creek were used, the maximum release rate would be approximately 1,400 ML/d and would affect a smaller area. Operation over an equivalent period would require an allocation of 56 GL, 6.4 years in 10 (Ecological Associates, 2004).

A plan to increase flood frequency from 6.4 to 7.4 years in 10 by providing 120 days of flooding would require an additional 480 GL one year in 10 from the Upper Forest Channel or 168 GL one year in 10 from Hipwell Road and Yarran Creek. Ecological Associates (2004) were doubtful of the feasibility of these measures, both in terms of the volumes required and the likely significant disruption to other users of Gunbower Creek.

Significant ecological benefits may be achieved with less water by targeting the most important component of the water regime deficit. Assuming that water could be accumulated in an environmental water account over several years, or made available from a larger account when needed, then allocation of *at least* 112 GL is required 6.4

years in 10 (equates to a long-term average of *at least* 71.7 GL/yr) for a successful watering of the River red gum FDU (Ecological Associates, 2004).

The average annual requirement for these options is estimated from the results in Ecological Associates (2004) to be at least 82 GL, and this is just for watering the Permanent and Semi-permanent Wetlands and River red gum FDU. The environmental water could be transferred to the Gunbower Forest as regulated flow, and could be held in Lake Victoria or Menindee Lakes. Ecological Associates (2004) noted that if effluent improvements were jointly implemented with the Upper Forest Channel, it may be possible to reach the average flood duration target of 120 days.

It is important to note that estimation of the volumes of water required for watering the Gunbower Forest is a complex issue that must take into account the works and measures that are implemented, the capacities they are designed to provide and their complementary operation, so Ecological Associates (2004) warned that their preliminary estimates of storage volumes, through-flow, and loss rates of water must be clarified in further investigations.

3.4.3 Koondrook–Perricoota Forest—structural and operational options

The main structural and operational option for the Koondrook–Perricoota Forest involves gravitation of water from Torrumbarry Weir into the Koondrook–Perricoota Forest. Torrumbarry Weir is used to raise the running level of the River Murray by approximately 6 m, which allows water to be diverted by gravity to service irrigation requirements in the Kerang area. It is proposed to divert water from upstream of the Weir into Bullock Head Creek via a constructed channel (the ‘Torrumbarry Cutting’), such that the water then takes its natural course through the Forest, eventually returning to the Murray River at the Wakool River junction. A major part of this option is construction of an artificial channel leading from Torrumbarry Weir into the Koondrook–Perricoota Forest.

The main natural inflow points to the Koondrook–Perricoota Forest are located downstream of the Torrumbarry Weir. The ‘commence to flow’ of the lowest inflow point, at the off take of Burrumburry Creek in Swan Lagoon, is approximately 16,000 ML/d. However, river flow downstream of the weir must exceed 25,000 ML/d in order to fill the internal creek system and inundate a significant area of the floodplain (**Table 3.1**).

A number of additional natural inflow points occur downstream of Swan Lagoon, however, their capacity is limited to 50 ML/d to around 300 ML/day (**Table 3.1**). Survey information may indicate whether or not these effluents need to be regulated to contain water within the Koondrook–Perricoota Forest. However, given the hydraulic complexity of the floodplain, this issue may be best resolved through adaptive management (D. Leslie, Primary Industries Trading, pers. comm., June 2004).

Diverting water from Torrumbarry Weir into the Koondrook–Perricoota Forest obviously has the capacity to impact on water management opportunities within Gunbower

Forest, and river operations in general. Floodwater does not commence to enter Gunbower Forest from riverbank effluents until flow downstream of Torrumbarry Weir exceeds around 15,000 ML/day. Consequently, it would be possible to fully negate the impact of the Torrumbarry Cutting proposal on water management opportunities in Gunbower Forest by allowing maximum diversions to Koondrook–Perricoota Forest to take place only when flow at Torrumbarry is between 8,500 and 15,000 ML/day (D. Leslie, Primary Industries Trading, pers. comm., June 2004).

The structural and operational works for Koondrook–Perricoota program, being managed by State Forests of New South Wales and the New South Wales Department of Infrastructure, Planning and Natural Resources as part of the First Step Decision, is in the process of examining water management options to reduce the water deficit in the forest (MDBMC, 2004, p. 32). The program will investigate and implement the structural works required to gravitate water from Torrumbarry Weir pool into the forest. This will include the construction of a channel from the weir pool into Perricoota Forest and regulating structures on Swan Lagoon.

3.4.4 Links between ecological objectives for Gunbower and Koondrook–Perricoota forests and management opportunities

Other factors are known to affect ecological condition of the forests, but flow regime is of fundamental importance. Reduced frequency of medium-sized flood events in spring is the main factor implicated in observed environmental changes in the forests. The proposed opportunities for managing flows in the forests aim to reverse or partially reverse this effect of flow regulation.

Flow management structures and channels will be constructed or modified to deliver the water allocation to wetland and forest ecosystems (MDBMC, 2004, p.32). The water allocation will allow watering of substantial areas (at least 30% of total area) of River red gum forest at least every four years, which should maintain the health of these areas. The semipermanent wetlands are among the most important sites for significant species, especially for colonial waterbird breeding, so maintaining regular suitable flooding will provide adequate breeding opportunities. The wetlands of the forests also provide habitat for small fish, which will benefit from the additional watering.