

Figure 4.7 – 1988 and 1993 flooding events in the Hattah Lakes, showing lake levels before and after flooding.

Source: Damian Green (pers. comm., MDBC).

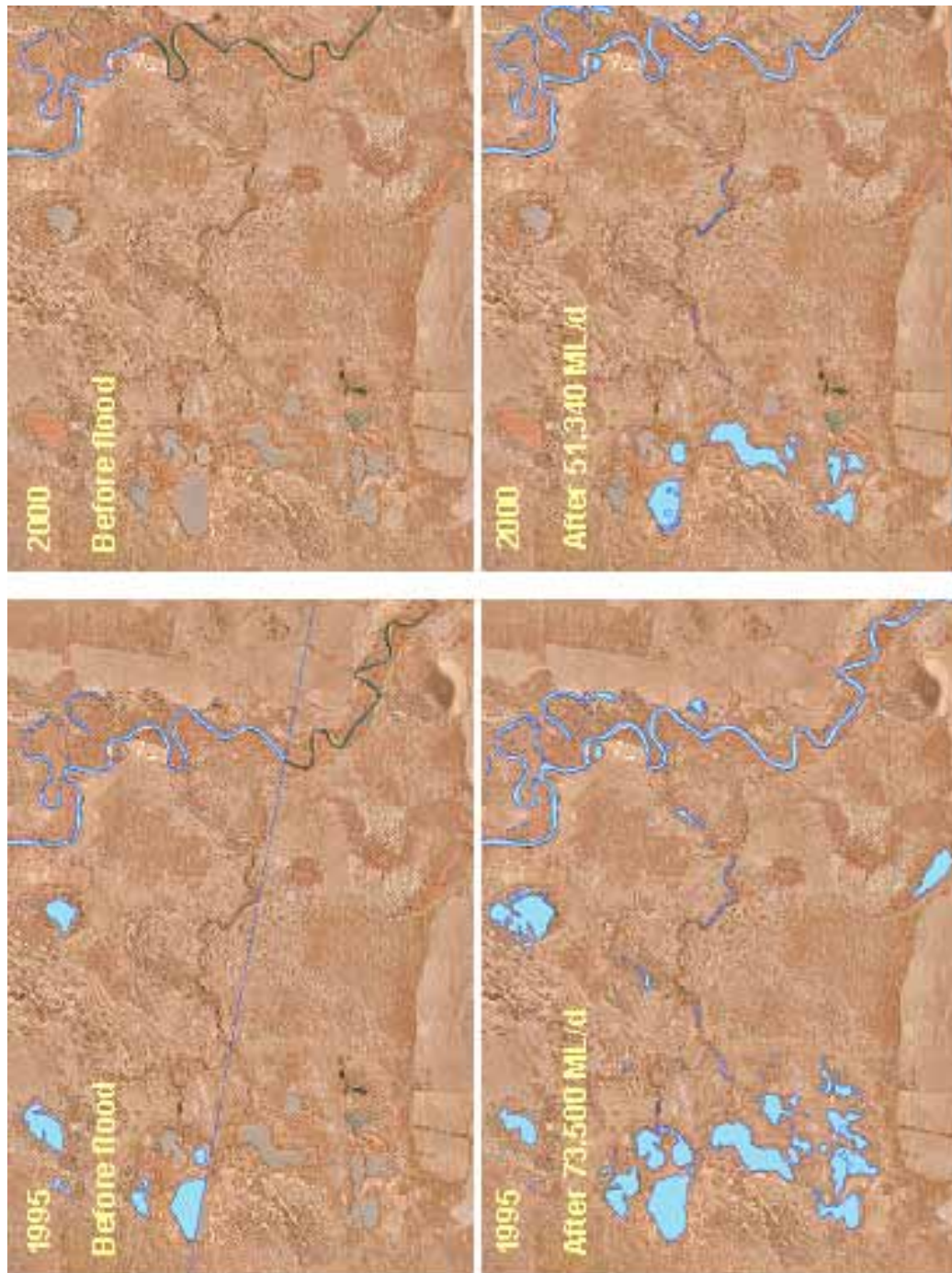


Figure 4.8 – 1995 and 2000 flooding events in the Hattah Lakes, showing the lake levels before and after flooding.

Source: Damian Green (pers. comm., MDBC).

Regional bankfull discharge

The bankfull flow level is when water just starts to spill onto the floodplain. On a stage-rating curve, this corresponds to the point where the rate of depth increase with volume starts to decline. According to rating tables records, River Murray Water, the bankfull discharge at Euston corresponds to approximately 48,000 ML/d, corresponding to a

stage height of 40.7 m. This value is similar to the discharge that previously resulted in inflows to Lake Lockie, and hence other lakes, before the Chalka Creek channel entrance was lowered and the channel expanded in 1972–73 (i.e., 48,900 ML/d – **Table 4.1**).

Groundwater

The Hattah Lakes area is underlain by highly saline aquifers (salinity 40,000–60,000 EC) that could potentially affect the environment of the lakes under conditions of rising groundwater tables. SKM (2003a) summarised the results from recent assessment of the long-term regional watertable trends within the Hattah–Kulkyne National Park as indicating the following trends:

- water table levels are generally static to the north and south east of the National Park, where irrigation activity is occurring;
- there has been a long term decline in groundwater levels in the low-lying areas and lakes, to the west of the National Park; and
- since 1993–94, there has been a general decline in water level in the regional Parilla Sand aquifer in the vicinity of the National Park.

Previous studies and groundwater monitoring within the Hattah Lakes region have been effective in identifying the broad spatial extent of the groundwater mound, which occurs beneath the Nangiloc–Colignan irrigation area (SKM, 2003a). Monitoring has not conclusively shown any long-term rise in groundwater levels. However, this monitoring network is limited in its spatial coverage, and the potential for groundwater inflow to the National Park from the inland disposal of irrigation drainage water to the north of the National Park requires further assessment (SKM, 2003a). One issue of concern is the fact that over the past 10 years, when most of the groundwater data have been collected, conditions have been dry, and a return to wetter conditions could see a significant change in groundwater trend (SKM, 2003a).

A recent study by Lamontagne *et al.* (2002) found that regional groundwater discharge tends to occur in the floodplain rather than the river itself in the Hattah–Kulkyne area. While considerable work has been done on the role of groundwater processes in mobilising salts to the river, this study investigated the role of groundwater in nutrient cycles. It was found that riparian groundwater tends to be enriched in nutrients, and these nutrients can be released to the river by hyporheic processes during baseflow, or by bank discharge following floods.

Lamontagne *et al.* (2002) concluded that the ‘surface flow-based flood-pulse’ concept, which implies severing of the hydrological link between river and floodplain at times of low flow, was overly simplistic for the case of Hattah–Kulkyne. Here the river remained connected to the floodplain in non-flood times through groundwater.

4.2.3 Vegetation distribution and hydrological regime

Vegetation classification schemes

Vegetation within the Hattah–Kulkyne and Murray–Kulkyne parks is currently grouped into three broad vegetation types (BVTs): riverine grassy woodland; mallee; and Boinka-Raak. Vegetation is also grouped into 11 ecological vegetation classes (EVCs) (SKM, 2003a). Of these EVCs, those most commonly associated with the Lakes and Chalka Creek are: drainage line grassy woodland; pine-buloke woodland; riverine grassy forest; and savannah woodland/savannah mallee/grassland mosaic. Details of the plant species generally associated with each EVC are not readily available floristic summaries are available for a range of relevant vegetation classes including: Floodplain woodlands and forests; Black box–Chenopod woodland; River red gum forest; Black box woodland; grasslands; and grassy woodlands (SKM, 2003a).

For MFAT modelling of Zone D (Wakool Junction to Lock 11), Treadwell (2003) described wetland vegetation in terms of Cumbungi, Phragmites, Spiny mudgrass grassland, Giant rush rushland and Ribbonweed herblands components. These components were also used by REG C (2003) for Gunbower and Barmah–Millewa forests, but they do not necessarily correspond to the same hydrologically classified elements in each of these areas. Treadwell (2003) described floodplain vegetation in terms of River red gum forest, River red gum woodland, Black box woodland, lignum shrubland, and Rats tail couch grassland components. Lignum shrubland and Rats tail couch grassland components did not appear in the REG C (2003) Gunbower and Barmah–Millewa forests classifications. The Hattah Lakes system is located in a different (drier and sandier) physiographic zone to Barmah–Millewa and Gunbower, Koondrook–Perricoota, and support mallee species that are not found further to the east. The River red gum and Black box tree classifications used at Hattah Lakes are the same as those used elsewhere in the River Murray system, but the composition of understorey communities varies from region to region.

Major vegetation types

Hattah–Kulkyne National Park supports a lake system in relatively natural condition with predominantly River red gum open woodlands in the lake margins and Black box in the more elevated areas (ID&A, 2001c; DSE, 2003). The shrub layer is composed primarily of chenopod shrubs such as Ruby saltbush, copper burrs and Bluebushes (DSE, 2003). Tangled lignum forms shrubby stands around three metres height around some lakes (DSE, 2003; Wetlands International, 2004). River red gum forests are generally confined to areas closer to the Murray River and are not widespread over the Hattah Lakes region (ID&A, 2001c). Rats tail couch grasslands are also a significant vegetation community at Hattah Lakes (Treadwell, 2003). A large part of the Hattah–Kulkyne National Park comprises sandy, semi-arid landscapes supporting mallee eucalypt species (Cumming & Lloyd, 1993).

Given that mean annual rainfall is low, climatic conditions tend to favour ephemeral plant species, although a number of perennial species do exist. Vegetation of the Hattah Lakes systems consist of mostly aquatic species and floodplain species. Within

the Ramsar site (i.e., the lakes) the vegetation is dominated by lake-bed herbfield species such as Southern liquorice, Sneezeweed and Lesser joyweed (DSE, 2003).

The distribution of vegetation classes across the Hattah–Kulkyne Lakes system is shown in **Figure 4.9** (an alternative vegetation distribution map based on Parks Victoria classifications is reproduced in SKM (2003a)). Black box and chenopod woodland are located in all areas of the Hattah–Kulkyne National Park, although River red gum is largely in the zones around the lakes, owing to its greater water requirements than Black box. Sampling of vegetation around the lakes by Souter (1996) indicated that most of the lakes in the drier parts of the Hattah Lakes system (i.e., away from the lakes and floodplains) supported mallee eucalyptus, with less coverage of River red gums with a native grass and sedge understorey (**Figure 4.9**).

SKM (2003a) identified five major groups of aquatic and floodplain plants within the Hattah Lakes system:

- trees and shrubs (e.g., Red gum, Black box and Tangled lignum);
- sedges and rushes;
- grasses;
- wetland herbs; and
- floodplain herbs.

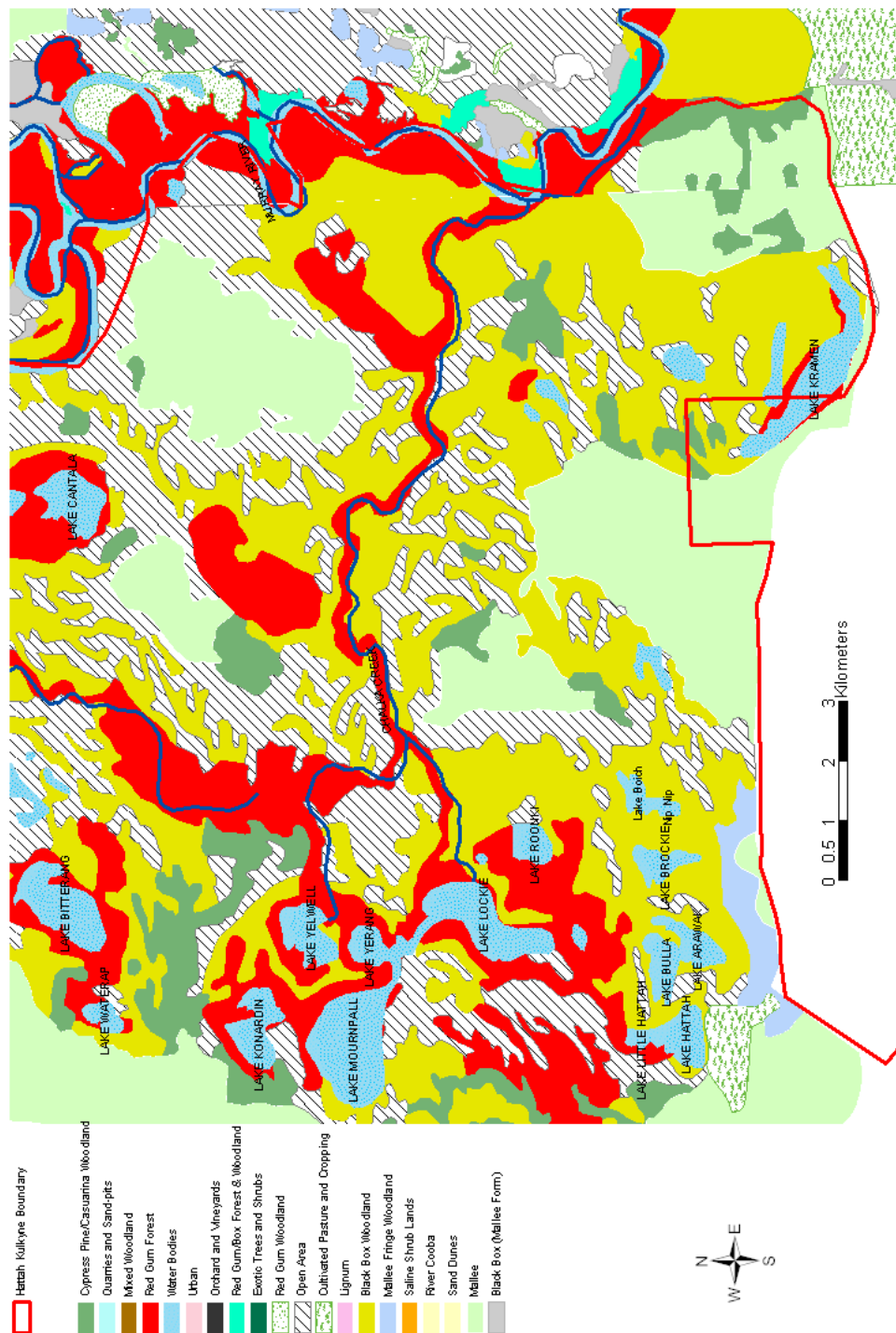


Figure 4.9 – Vegetation classes of the Hattah–Kulkyne Lakes system. Source: MDBC GIS Mapping.

Water requirements of major vegetation types

Specific information regarding the distributions and water requirements of both flora and fauna within the Hattah Lakes complex is extremely limited (SKM, 2003a), but

some of the information derived from other parts of the River Murray system is also relevant to Hattah Lakes. The major community types identified in Hattah Lakes vary in water requirements. For flood dependent species, flood depth, flood duration, and flooding frequency are important.

The season and timing of flooding has a significant impact on the floristic composition of wetland communities in the River Murray system, given that germination and subsequent growth respond to climatic variables in the season. Roberts and Marston (2000) demonstrated the general principle that if flooding changes from winter to spring/summer, a change might occur in species to favour those that grow in summer. Similarly, in the absence of any seasonal flooding, some species will find it difficult to replenish seed stocks. Thus, flood timing and frequency is just as important as the volume of water required for wetland inundation.

Hattah Lakes water levels are highly variable from season to season. Ideal watering conditions occur in the form of a flood that inundates the lake for several months of the year before periodic drying of the lakes occurs (**Figure 4.10**).



Figure 4.10 – Vegetation of the Hattah Lakes system during dry and wet times

River red gum, Black box and Tangled lignum communities

River red gum is particularly well adapted to the variability of water availability from season to season. Studies from the Barmah–Millewa Forest show that ideal watering conditions for River red gum are once every two years with complete drying of the soil in between events (Chesterfield, 1986). A key to survival between floods is access to

groundwater (SKM, 2003a). Although River red gums are resilient to variable hydrological conditions, frequent seasonal flooding provides the best conditions for their germination and growth. Sheet flooding is not believed to be essential for maintenance of adult River red gum, but it is vital to seedling establishment (SKM, 2003a). In the Hattah Lakes system, sheet flooding is most common from the River Murray into Lake Kramen, although this only occurs for high flow events (**Figure 4.5**). This area of the Hattah Lakes corresponds to the occurrence of most of the River red gum and Black box communities in the National Parks. However, Thorburn *et al.* (2004) argued the general principle that groundwater, or the presence of a shallow aquifer, may be equally, if not more important, than surface water characteristics for the health of River red gum.

Studies from the Barmah–Millewa Forest show that winter–spring watering is ideal for River red gum, with the duration of flooding between four and seven months providing the best conditions for growth. Summer flooding, while providing adequate water for growth of small trees and maintenance of established trees, may alter the understorey community (Robertson *et al.*, 2001).

Black box is normally located at a higher elevation in the landscape than River red gum, which is explained by its lower flood tolerance. The Black box community is healthiest when flooded for a period of between four and six months every four to five years. As for River red gum, the most successful periods of regeneration of Black Box occur after large-scale flooding. In western New South Wales and on the lower Darling River, germination is most successful if it occurs during the cooler months—May to October (SKM, 2003a). Black box seedlings do not have any specific adaptations for flood tolerance, and seedlings can tolerate flooding for about one month (SKM, 2003a).

Tangled lignum is extremely tolerant of waterlogging and moderately tolerant of salinity (Craig *et al.* 1991). It appears to grow most vigorously when soil moisture is high, and when pH and conductivity are relatively low (Craig *et al.*, 1991). Maintenance of Tangled lignum populations requires flooding every three to ten years, with more frequent flooding required in saline areas (Craig *et al.*, 1991). Although Tangled lignum is tolerant of waterlogging, it cannot survive in continuously wet conditions, requiring a phase of complete drying between floods (Roberts & Marston 2000). Natural flood duration is 3–5 months in southern areas of the Murray–Darling Basin, or 6–12 months in northern areas (Roberts & Marston 2000).

Grasslands

Spiny mudgrass, Water couch and Cane grass grasslands are present in Hattah–Kulkyne National Park. Although information on grassland water requirements is not as widely available as for River red gum and Black box, indicative studies from the River Murray system have shown that flooding every one to two years for a period of approximately six months is required for ideal germination and growing conditions. Roberts and Marston (2000) have shown that periods of inundation up to 18 months can result in a significant level of vegetation dieback.

Cane grass is drought and flood tolerant, but is relatively sensitive to alterations in its water regime (SKM, 2003a). Spiny mudgrass or Moira grass forms wet grasslands in

open areas where flooding is frequent or nearly annual (Roberts & Marston, 2000). Research from Barmah Forest suggests that a minimum flood duration of 5–7 months, with a minimum depth of 0.5 m (and maximum of 2 m), is needed to maintain and enhance growth of Spiny mudgrass (SKM, 2003a). Flooding shorter than approximately two months is not sufficient to replenish the seed bank. Grass species that are more sensitive to changes in water regime include perennial species such as the Water couch—a summer-growing species that requires spring or summer flooding between four and eight weeks of greater than 10 cm in depth (Roberts and Marston, 2000). Annual flooding provides the best conditions for such species.

Sedges and rushes

Sedges in the Hattah Lakes system vary in their water requirements for optimum growth. In general, most species require flooding of between two and six months, with a minimum depth of 0.1 m (SKM, 2003a). Common spike sedge has an optimum flooding duration of eight months. Most species of sedge found in the Hattah Lakes area require flooding in winter–spring for optimum growth but can tolerate flooding later in the season (summer). Annual flooding provides ideal conditions for germination and growth. There is little information on the maximum duration between floods that sedges and rushes are able to tolerate without damage to the seed bank and future recruitment (SKM, 2003a).

Wetland herbs (submerged and emergent macrophytes) and floodplain herbs

The design of water management strategies to meet the water requirements of wetland herbs is vital for the maintenance of biodiversity within the Hattah Lakes (SKM, 2003a) because of their roles as a food source and nesting material for birds and food source and habitat for aquatic invertebrates and fish. Knowledge of the water requirements for species occurring in the Hattah Lakes complex is only available for species from the emergent and submerged growth form categories.

Maintenance of the submerged herb Ribbonweed requires a water depth of between about 1 to 2 m, where turbidity less than 80 NTU (Roberts *et al.* 2000). Emergent Cumbungi and Phragmites do not commonly occur in Hattah Lakes (SKM, 2003a) because they require more permanent, stable water levels (Roberts & Marston, 2000). Even though the lakes contain water for many years once filled, the levels are variable, which does not suit these species (Treadwell, 2003).

Health of vegetation

Since European settlement the structure and composition of the vegetation around the Hattah–Kulkyne Lakes Ramsar site has been severely modified by domestic stock and native animal grazing, logging and the introduction of exotic flora and fauna (DSE, 2003). The impacts of reduced flooding frequency include dieback and reduced vigour of riparian River red gum, as well as affecting tree distributions (DSE, 1999; Wetlands International, 2004). There is no evidence of widespread dieback of flood-dependent vegetation around the lakes, although pockets of dieback, possibly due to length of inundation, rising groundwater and water stress between floods, have been recorded (P. Murdoch pers. comm., reported in DSE, 2003). The distribution of flood-dependent

woody vegetation may also be changing with evidence of regeneration of both River red gum and Black box (DNRE, 1996).

Grazing pressure has suppressed the regeneration of woody species and has resulted in reduced abundance of perennial taxa in the shrub and ground layers including the threatened Sand sida, Silky glycine, Upright adder's tongue, Hooked needlewood and the Prickly bottlebrush (DSE, 2003). Where grazing has been excluded, native perennial grasses are common and frequently form a large proportion of the understorey (Sluiter *et al.*, 1997). The remaining proportion of the understorey (up to 10%) is comprised largely of exotic flora.

A kangaroo management program was initiated within Mournpall Block of Hattah–Kulkyne National Park in 1990 and outside Mournpall Block in 1996. Since that time, reduced grazing pressure has allowed some regeneration of woody species and a suite of perennial subshrubs, herbs and grasses, including some rare or threatened plants, have been recorded within and outside the Mournpall Block (Sluiter *et al.* 1992; P. Murdoch pers. comm., reported in DSE, 2003).

4.2.4 Birds

The National Park contains 65 bird species, many of which are considered rare, threatened or endangered at either the state or national level. The Regent parrot has been specifically listed under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) (SKM, 2003a). The Regent parrot is known to be closely associated with River red gum forest. Therefore, the maintenance or restoration of River red gum should favour the establishment of the Regent parrot (Ian Sluiter pers. comm., as reported in SKM, 2003a).

The conservation status of the Hattah Lakes (Ramsar listing and inclusion on international migratory bird agreements) indicates that the area historically supported large numbers of colonially nesting waterbirds. The site provides important feeding, resting and breeding habitat for more than 47 waterbird species (DSE, 2003). In terms of carrying capacity, up to 288 Hoaryheaded grebes, 101 Freckled duck, 1,960 Pacific black duck, 2,550 Grey teal, 1,280 Pink-eared duck, 128 Black-fronted dotterel and 1,000 Australian pelicans have been counted at the lakes (ANCA, 1996).

A total of 18 waterbird species have been recorded breeding at the Hattah–Kulkyne Lakes Ramsar site (DSE, 2003). Of these species 16 are threatened in Victoria, eight are listed under the *Flora and Fauna Guarantee Act 1988*, two under the Bonn Convention, and one under CAMBA (DSE, 2003).

4.2.5 Fish

The main fish groups present in the Hattah Lakes system are flood spawners, main channel specialists and generalists, wetland specialists and low-flow specialists (SKM, 2003a). While some species prefer fast turbulent flows, others prefer the slower and less turbulent flow of pools, billabongs or deflation basin lakes (SKM, 2003a). Fish are only present in the system when the lakes are wet, so the fish assemblage is temporary. Macquarie perch were once recorded in the region but are now considered

extinct (Cadwallader, 1981). Freshwater catfish have also undergone a reduction in range (Clunie & Koehn, 2000). Flood spawners are a dominant component of the fish populations. Catfish are likely to be less influenced by a changed flow regime than by other factors such as sedimentation of spawning sites, habitat degradation, the effects of introduced species such as carp, and declines in water quality (Treadwell, 2003).

When full, the Hattah Lakes support nine native fish species as well as three exotic species (as reported in *Mallee Catchment Management Authority Draft Integrated Water Management Plan*, Dr Oliver Scholz, pers. comm., MDFRC Lower Basin Laboratory, Mildura). Conservation status of native fish present is listed in DSE (2003):

- 1 Murray cod – may occur here – endangered in Vic., FFG Act listed;
- 2 Flat-headed galaxis – insufficient data;
- 3 Freshwater catfish – endangered in Vic., FFG Act listed;
- 4 Murray hardyhead – critically endangered in Vic., vulnerable in Australia, FFG Act listed;
- 5 Big-headed gudgeon – not threatened;
- 6 Western carp-gudgeon – not threatened;
- 7 Australian smelt – not threatened;
- 8 Golden perch – vulnerable in Vic., FFG Act listed;
- 9 Silver perch – critically endangered in Vic., FFG Act listed.

The Murray hardyhead has been specifically listed under the EPBC Act (SKM, 2003a). Murray hardyhead do show a preference for habitats dominated by macrophytes (Ben Gawne, pers. comm., as cited in SKM, 2003a). Therefore, the restoration of these habitats in the Hattah Lakes complex is likely to be beneficial to the long-term maintenance of this fish species within the region (SKM, 2003a).

The most abundant and diverse fish fauna in Hattah Lakes have been found to be associated with more permanent lakes that are frequently flooded (Souter *et al.*, 2000). Fish species richness and the ratio of exotic to native species abundance are correlated with the depth of lake inundation and the duration of the falling and rising limbs of present and past flood pulses (Puckridge *et al.*, 1997).

The changed hydrological regime is likely to have altered faunal habitat leading to lower recruitment rates within some fish and macroinvertebrate populations dependent upon certain flooding regimes (Cumming & Lloyd, 1993).

4.2.6 Macroinvertebrates

A major study of macroinvertebrates in the Hattah Lakes system by Souter (1996), Ward *et al.* (2000) and Souter *et al.* (2000) found habitat diversity and structure to be the most important factors in determining community structure, abundance and diversity. The macroinvertebrate fauna of the Hattah Lakes was also strongly correlated with flood frequency and drying time. Lake Kramen was found to be highly productive and diverse compared to the other lakes surveyed (lakes Hattah, Arawak,

Konardin, Bitterang and Mournpall). There was an overall pattern of declining species richness, but increasing productivity, the less frequently flooded the lake (Souter, 1996). In general, the project concluded that a diverse range of flooding frequencies throughout the Hattah Lakes will result in the greatest biological benefit, because lakes with different flooding frequencies support different biological communities and different ecological processes (Ward *et al.*, 2000). The relative condition of macroinvertebrates in the Hattah Lakes has not been reported.

4.2.7 Frogs

While the links between frogs and flow regime are poorly understood. It is highly likely that frogs benefit from increased flows (SKM, 2003a). Large breeding events are associated with big summer storms and floods, and frogs have been known to appear in the thousands when the lakes are flooded (Phillip Murdoch, pers. comm., as cited in SKM, 2003a). The relative condition of frogs in the Hattah Lakes has not been reported.

4.2.8 Water quality and algal blooms

DSE (2003) reported that water quality in the Hattah–Kulkyne Lakes Ramsar site, in terms of dissolved oxygen, pH and heavy metals (arsenic, cadmium, chromium, copper, lead, zinc), is generally good and complies with State Environment Protection Policy (SEPP) water quality objectives (EPA, 1985) and Australian and New Zealand Environment and Conservation Council water quality guidelines (ANZECC, 1992). Conversely, water quality in terms of nutrients (total nitrogen and total phosphorus) and chlorophyll-a is generally poor (Water ECOscience Pty Ltd, 1996 and Souter, 1996).

Nutrients are transported into the lakes during floods and other high streamflow events when the lakes are recharged with water from Chalka Creek. The increase in nutrient levels in the waters of the River Murray, primarily due to intensive land use within its catchment, has produced a nutrient enrichment in the Hattah Lakes system. As a result, the incidence and severity of algal blooms in the lakes have increased (DSE, 1999; Wetlands International, 2004).

The low-lying Hattah Lakes area is at risk of salinisation due to rising groundwater levels. The *Mallee Dryland Draft Salinity Management Plan* (MDCWG, 1993) predicts lakes Bitterang, Konardin, Yelwell and Hattah are all at risk of becoming salt-affected. Increases in salinity levels of the Hattah Lakes may threaten the habitat of fish and aquatic invertebrates, which in turn provide food for waterbirds. Raised salinity levels also favour certain blue-green algae, increasing the likelihood and severity of algal blooms (DSE, 2003).

4.2.9 Human use values

Commercial land use activities

Pastoralists first settled the Hattah Lakes area in 1838. Three pastoral groups began operation in 1847: Kidds Station; Gayfield; and Mournpall. Kidds Station occupied an area of 25,000 ha, while Gayfield or 'Kulkyne' occupied 26,000 ha including 32 km of

water frontage. The Mournpall pastoral group occupied 7,168 ha and, unlike the other two larger stations, relied upon lake water for stock and domestic water supply. Although banks and weirs were constructed to retain water, the Hattah area was not deemed suitable for larger scale irrigation development.

Timber resources in the Hattah area were used as a local source of wood for boats, houses and other construction needs. Although commercial forestry and timber production have never been established in the area, between 1924 and 1941 most of the mature trees in the region were harvested to supply fuel for a local pumping station. Harvesting of timber resources after this point was not significant enough to have an impact on forest area or forest composition (Bardwell, 1980).

Commercial land use activities are limited in the National Park. However, the mallee area supports part of the apiculture industry. Growth in this activity has increased in recent years. Growth in the number of apiarists was capped in 1989 until environmental concerns over the growth of the industry were reviewed (LCC, 1989).

Commercial-scale mining has not been undertaken in the Hattah area, although the *Mallee Parks Management Plan* has identified that gravel and sand extraction takes place on limited occasions to support local road maintenance (DNRE, 1996).

Recreation

Land (16,800 ha) was set aside as State Forest for the purpose of hunting of game in 1941. The Hattah–Kulkyne National Park was declared in 1980 with the amalgamation of the State Forests and a larger area.

The Hattah–Kulkyne National Park supports mostly recreational activities, given that commercial activities have largely ceased since the area was gazetted as a National Park in 1980. For a full description of recreational and tourist activities in the Hattah area, see the *Mallee Tourism and Recreation Strategy* (DCNR, 1993). The park attracts over 70,000 visitors annually who partake in a wide range of activities centred around some of the lakes including bushwalking, camping, driving, fishing, canoeing, swimming and nature study (DSE, 2003). Game hunting is not permitted in the Ramsar site.

European cultural heritage

Three cultural heritage sites found in the Hattah–Kulkyne National Park are listed in **Table 4.3**.

Table 4.3 – Registered cultural heritage sites in the Hattah–Kulkyne National Park. (Source: Modified from SKM, 2003a).

Register number	Name	Description
Register of the National Estate (Commonwealth)		
2/05/183/0007	Kulkyne station homestead	Nil. Destroyed by fire in 1982
Heritage Inventory Site		
H7328-001	Hattah–Kulkyne military internment camp	Remains of two main buildings and scattered debris
H7328-0002	Moonah Track and Wattle Track Charcoal pits	Three charcoal burning pits date to late 19th century/ early 20th century.

Indigenous culture and management

The Hattah–Kulkyne Lakes Ramsar site has been a focus for traditional Aboriginal society for thousands of years. The Lakes provided reliable sources of water as well as a rich and diverse supply of plant and animal resources for food, medicines, shelter, clothing and tools (DSE, 2003). Long and Edmonds (1997) provided an overview of Indigenous cultural heritage values and archaeological sensitivity in the National Parks. The management plan also provides detailed recommendations for the protection of Indigenous cultural heritage in the National Parks. SKM (2003a) provide a comprehensive review of Indigenous cultural heritage values in the Hattah Lakes complex.

Hattah Lakes is on the border of two groups of traditional owners, the Latji Latji group and the Jari Jari group. According to Clark (1990) the Latji Latji group occupied the southern Murray valley and northern mallee between the Hattah area and Wentworth, while the Jari Jari group occupied the southern bank of the Murray immediately upstream of the Latji Latji.

The reliable food source is believed to be the main reason for the dense tribal population in the Hattah Lakes region (and the Murray corridor in general) (Edmonds, 1994). Crayfish, shellfish, waterfowl and eggs are believed to have been the main food staples. The natural flooding regimes of the Lakes and River Murray provided Indigenous people with a reliable source of River mussel, which has resulted in the prevalence of middens around the lakes and along the riverbanks within the Hattah–Kulkyne National Park.

European settlement of the area resulted in a decline in tribal numbers, with the last remaining tribe members in residence of the Hattah area up until 1914, although real population decline and the disruption to traditional life began in the 1860s. The last documented burial of a tribe member was in 1914 at Lake Mournpall.

A cultural heritage assessment of the Hattah region was last carried out in 1993 (Edmonds, 1993). **Table 4.4** shows the frequency and type of significant sites in the

Hattah–Kulkyne National Park. Other sites of particular importance include shell middens that have been dated to 13,000 years BP. Late Holocene burials have been dated between 25,000 to 14,000 years BP (Luebbers, 1995).

Table 4.4 – Frequency and type of significant Indigenous sites located in the Hattah–Kulkyne National Park. Source: modified from SKM (2003a).

Site Type	Number
Scarred tree	578
Shell midden	113
Isolated artefact	61
Surface scatter	207
Burial/human remains	37
Isolated hearth	166
Exposure in bank	8
Total	984

4.2.10 Summary of knowledge of the condition of Hattah Lakes

The high conservation value of the Hattah Lakes has long been recognised, with 12 of the 18 lakes Ramsar listed. The area also has significant cultural heritage and recreation values. The main hydro-ecological feature of the Hattah Lakes is the large variation in permanency of the aquatic habitats ranging from episodically flooded lakes to almost permanent lakes. Despite its high conservation values, surveys have demonstrated some environmental changes in the Hattah Lakes. There is no evidence of widespread dieback of flood-dependent vegetation around the lakes, although pockets of dieback, rising groundwater and water stress between floods, have been recorded. The distribution of flood-dependent woody vegetation may also be changing with evidence of regeneration of both River red gum and Black box.

The Hattah Lakes historically supported large numbers of waterbirds, and currently provides an important drought refuge for waterbirds, reflecting the presence of permanent water within the wetland system. Fish are only present in the system when the lakes are wet, so the fish assemblage is temporary. Macquarie perch were once recorded in the region but are now considered extinct. Freshwater catfish have also undergone a reduction in range due to the combined effects of habitat and water quality degradation and introduced species such as carp. Carp may have been favoured by the regulated flow regime.

Various factors have impacted the health of the Hattah Lakes, including the altered flooding regime due to river regulation and internal hydraulic modification of flow paths. Under natural conditions, the majority of lakes in the Hattah Lakes complex would have been permanent. As a result of river regulation, the lakes now receive reduced inflows and are wet for shorter periods than occurred under pre-regulation conditions.

The extent of lake and floodplain inundation in response to floods of various magnitudes has been investigated, but additional analysis is required in order to more accurately and comprehensively model the hydraulic behaviour of the Hattah Lakes system.

The knowledge base for Hattah Lakes is extensive, as described in a large body of literature, but there is scope to improve on this. The various data on the ecological components of the lakes system (i.e., birds, fish, mammals, amphibians, macroinvertebrates, algae, vegetation) have not yet been compiled into a single database and summarised in terms of relevant and consistent measures of diversity, extent, abundance, and long-term trends.

The current knowledge of biophysical processes in the Hattah Lakes (as synthesised in SKM, 2003a) is adequate to specify environmental flows and works and measures that have a reasonable likelihood of achieving, or partially achieving, their objectives. Uncertainty can be reduced through improved knowledge of ecological processes, which can be achieved through hypothesis-driven investigations that will likely have specific data collection requirements.

4.3 Factors causing loss in environmental values

4.3.1 Hydrology

Local and internal hydraulic modification of flow paths

The climate of the Hattah Lakes system is semi-arid with an annual average rainfall of approximately 250 mm—October is the wettest month on average. Significant local rainfall can briefly fill the lakes, and it is an important source of water that helps to maintain vegetation between flood inundation events. However, the overall wetting and drying cycle of the Hattah Lakes is largely dependent on the pattern of inflows due to river flooding. There have been substantial changes to the hydrological regime of the Hattah Lakes system due to the regulation and modification of flow in the Murray River and structural and earthworks in the Chalka Creek (Cumming and Lloyd, 1993).

The hydrology of the Hattah Lakes system has altered in response to the construction of locks and weirs along the River Murray, and the inlet channel, Chalka Creek, has undergone deepening and widening. A regulator on Chalka Creek at Messengers Crossing now delays flow recession from the lakes, which helps to increase the duration of inundation when floods do occur (DNRE, 1996) (**Figure 4.11**). Channels (with regulators) have been constructed between Lake Lockie and Lake Hattah and between Lake Hattah and Lake Little Hattah. Internal modifications first occurred in the early 1900s to ensure more reliable water supply to the Victorian Railways (Hattah railway station is just west of the Park). Subsequent alterations were also made to achieve a more permanent supply of water to the settlement of Hattah (SKM, 2003a). The history of internal modifications to the hydrology of the Hattah Lakes is provided in **Box 4.1**.

The most significant consequences of internal hydraulic modification of the Hattah Lakes system are:

- a reduction in the critical inflow for Lake Lockie from 48,900 ML/d to 36,700 ML/d (meaning that flow enters the system at a lower River Murray discharge, but also drains more quickly). Given that Lake Lockie provides inflow to a number of lakes during flood events, there is also a follow-on reduction in the critical flow to those lakes
- a reduction in the retention level of Lake Hattah (from 42.8 mAHD to 41.8 mAHD) which has allowed more water to drain out of the lake, and reduced the average depth of the lake (SKM, 2003a).



Figure 4.11 – Messengers Crossing Regulator in the Hattah Lakes system
(photo: Ben Dyer, MDBC)

Box 4.1 – Internal hydraulic modifications to the Hattah Lakes System. Source: SKM (2003a)		
Date	Modification	Effect on flows within Hattah Lakes
1908	Channel cut between Lake Lockie and Lake Hattah	Retention level of channel reduced by 0.69 m
1964	Earth bank constructed between Lake Hattah and Lake Little Hattah	Retention level between Lake Hattah and Lake Little Hattah increased from 42.11 mAHD to 43.58 mAHD
1966	Regulator constructed between Lake Hattah and Lake Little Hattah	Invert of regulator set at 41.7 m allowed Lake Hattah to drain almost completely. Retention level between Lake Hattah and Lake Little Hattah increased by 0.01 m to 43.59 mAHD.
1972– 1973	Natural bar removed at Messengers Crossing, and Chalka Creek channel expanded	Critical River Murray discharge for inflow to Chalka Creek reduced from 39,100 ML/d to 36,700 ML/d. Retention level reduced from 42.58 mAHD to 41.64 mAHD.
	Channel constructed between Lake Lockie and Lake Hattah. Bars constructed on northern and southern arms of Chalka Creek.	Critical River Murray discharge for inflow to Lake Lockie reduced from 48,900 ML/day to 36,700 ML/d.
	Regulator constructed along Chalka Creek at Messengers Crossing	Maximum retention level of 43.40 mAHD
1988– 1997	Soil removed along high points of Lake Lockie and Lake Hattah	Retention level of channel between lakes reduced by 0.3 mAHD
Current	Messengers Crossing reconfigured to allow greater inflows. Current practice is to close the regulator when flows out of the north arm cease.	Messengers Crossing regulator invert reduced by 0.2 m, with no evidence to indicate critical River Murray discharge for inflow has been reduced. Retention level unchanged.
	Gates between Lake Hattah and Lake Little Hattah removed	Retention level between lakes reduced to 41.7 mAHD. Allows Lake Hattah to almost drain completely.

Degree of change to flows due to river regulation

The Hattah Lakes are upstream of the Darling River confluence with the River Murray, and downstream of:

- major headworks storages on the River Murray (Hume and Dartmouth dams);
- three of the largest point diversions from the River Murray (Mulwala Canal, Yarrawonga Main Channel and National Channel [Torrumbarry]);
- the confluence of the River Murray and the Goulburn River;

- the confluence of the River Murray and the Murrumbidgee River; and
- the Ovens and Kiewa unregulated rivers.

Flows in this section of the River Murray follow a seasonal pattern similar to that experienced prior to river regulation, with maximum flows in winter and spring and minimum flows in autumn (Maheshwari *et al.*, 1995). However, River Murray headworks storage and diversions have resulted in an overall reduction of mean annual flow at Euston Weir to 50% of pre-regulation volumes. Flow regulation has also been associated with a reduction in the frequency and magnitude of small- to medium-sized floods to the lakes (Maheshwari *et al.*, 1995).

A comparison of the natural and current median monthly flows in the river zone of the Hattah Lakes is shown in **Figure 4.12**. In this context, current condition refers to flow as at 2002 operating conditions. This includes the operation of all weirs and locks and irrigation diversions. Natural conditions are simulated flow without locks, weirs and diversions and are an estimate of flow conditions pre-regulation.

The flow pattern in the River Murray downstream of Euston Weir has changed as the flows in spring are considerably less than under natural conditions. Under pre-regulation median conditions the lakes were wet, whereas under current median conditions the lakes do not get wet despite the reduced commence to flow threshold. The Hattah Lakes system under current conditions presents a trade-off between the frequency of wetting and the duration of wetting. While the frequency of events may have increased, the reduced 'commence to flow' threshold allows water to drain from the lakes faster than under natural conditions. The function of the regulator at Messengers Crossing on Chalka Creek is to reduce this problem.

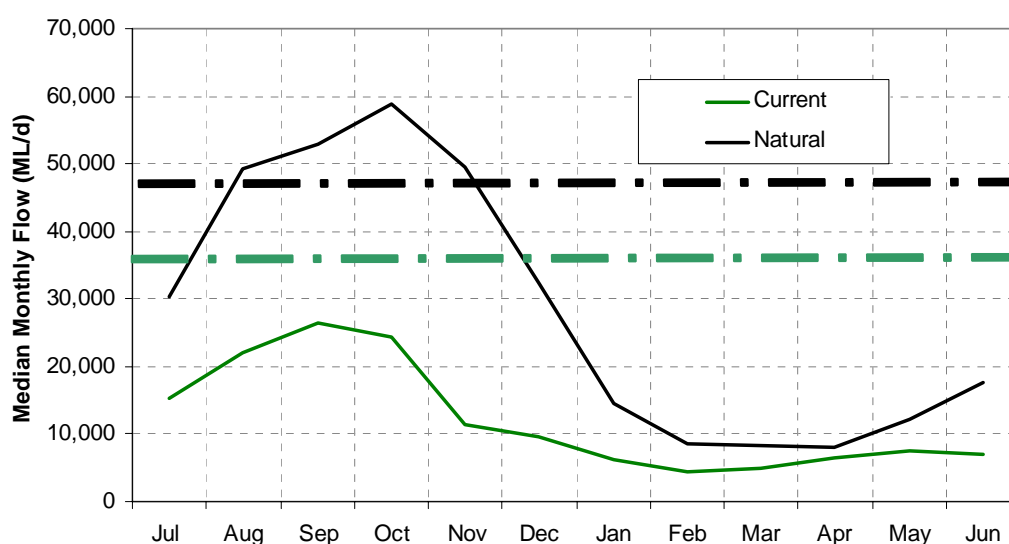


Figure 4.12 – Comparison of the natural and current median monthly River Murray flows passing downstream of Euston Weir. Dashed lines show the thresholds for inflow to Lake Lockie (the main feeder lake) under current (i.e., with the internal structural modifications) and natural conditions. Source: MDBC simulation model data.

A comparison of flood categories over the last 109 years under natural and current conditions at Euston Weir is provided in **Figure 4.13**. The contribution of flows to the system from the Murrumbidgee River at Balranald upstream of the junction with the River Murray is shown in **Figure 4.14**. Under natural conditions, the Lakes began to flood at a threshold of 48,900 ML/day and all of the lakes, with the exception of Lake Kramen, were flooded when the river reached 70,000 ML/d.

For flow gauged at Euston, under current conditions, the minimum threshold for inflow of water to the Lakes now occurs at 36,700 ML/d, which in principle would allow for more frequent flooding of the lakes. However, the frequency of flood events has been reduced by flow regulation, resulting in much less frequent inundation, with most flows failing to reach the inflow threshold (**Figure 4.12**). Also, the flood events that do occur are of reduced duration, and there has been an increase in the time between flood events. Flood events still occur over the July to December period, as they did prior to regulation. However, while under natural conditions August was a common start month for large flood events, lasting through to December, the larger floods now tend to begin in September or October (**Figure 4.13**).

The Murrumbidgee River is a potential source of water for filling the Hattah Lakes. Under regulated operation, discharge is typically maintained in the range 600 ML/d to 800 ML/day. In contrast, under natural conditions, flows at these low levels were rare (**Figure 4.14**). Under the regulated regime it is less likely that flows in the Murrumbidgee River will make a significant contribution to inundation of the Hattah Lakes.

NATURAL CONDITIONS
(average monthly flow ML/d)

CURRENT CONDITIONS
(average monthly flow ML/d)

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	YEAR (June)
45,500			64,200	47,100	33,000	23,400	14,100	9,700	9,200	15,300	25,600	18,910	32,500	57,900	50,900	40,700	16,300	8,700	6,300	5,200	4,200	4,200	7,100	13,100	18,910
37,400	46,800	41,100	35,800	181,200	33,800	29,800	7,900	5,400	8,300	19,800	33,500	19,930	24,300	19,800	28,200	19,100	14,200	20,500	4,200	3,300	3,200	4,900	6,200	10,500	18,910
53,000	65,700				50,900	22,300	19,600	12,100	22,200	38,600	39,200	18,910	24,300	44,400	43,300	54,200	63,000	15,600	8,800	4,800	6,400	10,800	16,700	25,000	18,910
51,400					27,000	13,400	12,000	9,100	11,000	16,500	15,500	18,910	18,910	41,600	58,900	63,700	62,000	42,300	8,800	3,900	5,000	7,300	8,400	6,700	18,910
30,200	37,000	43,400	64,500	37,900	15,300	9,700	6,000	7,100	8,300	15,200	18,300	18,910	15,400	16,200	28,600	30,800	7,200	4,600	4,000	4,300	4,600	5,900	7,100	6,400	18,910
27,100	32,500	26,300	35,600	24,500	13,400	11,500	19,700	10,200	7,500	5,500	5,900	18,910	10,600	9,400	8,800	6,900	5,700	7,000	4,000	4,300	4,300	5,900	4,900	3,300	18,910
16,800	27,300	37,700	53,000	37,100	13,200	5,300	3,400	10,900	5,200	5,600	16,800	18,910	7,000	9,000	20,400	7,400	6,000	4,500	4,500	4,000	3,800	4,000	7,200	6,000	18,910
29,700	30,400	45,200	44,600	32,800	31,400	10,500	5,700	5,700	4,800	13,800	23,300	18,910	12,500	16,200	15,400	8,300	6,600	5,800	5,100	5,300	4,700	6,400	8,700	8,500	18,910
45,200	45,400	41,000	24,100	22,600	14,600	5,900	4,800	4,100	13,500	24,400	30,000	18,910	25,500	15,500	10,000	4,500	5,300	9,300	7,000	7,000	8,500	10,600	11,500	12,700	18,910
39,400		69,800	68,500	51,100	19,200	8,100	5,000	3,700	5,900	8,400	17,000	18,910	28,100	34,300	38,800	23,700	12,000	10,300	6,200	4,700	4,600	6,900	7,500	5,900	18,910
21,800	20,300	33,400	53,700	34,800	41,400	8,900	5,300	3,800	4,600	4,100	10,700	18,910	35,700	48,900	49,500	29,000	8,200	7,700	5,800	4,700	5,800	4,700	4,700	4,800	18,910
15,000	11,200	8,000	13,100	9,900	5,700	7,700	3,400	3,800	6,900	13,400	18,500	18,910	5,300	4,800	6,300	5,400	5,100	5,600	5,300	6,400	6,100	6,100	7,600	7,200	18,910
32,000	46,500	36,000	44,700	42,600	23,500	19,700	18,900	10,100	6,100	11,000	12,600	18,910	22,100	23,200	16,400	16,000	7,700	6,800	6,500	5,300	4,500	5,300	6,000	5,100	18,910
26,800	49,400	46,800	49,300	42,400	37,300	9,200	5,200	4,100	4,400	6,700	13,200	18,910	18,400	28,600	22,700	13,400	12,600	5,800	4,900	4,100	3,800	7,300	6,400	7,300	18,910
33,600		64,600	41,300	45,400	44,000	15,000	5,300	7,900	13,200	18,500	32,100	18,910	22,900	44,000	17,600	9,900	8,800	6,200	4,500	4,700	7,100	5,200	5,300	14,300	18,910
47,800					62,500	32,600	13,900	7,900	7,400	10,400	14,200	18,910	33,700	46,800	47,200	67,400		16,800	6,200	4,600	4,300	5,300	7,700	5,600	18,910
16,800	25,400	40,600	31,900	26,400	20,200	14,500	6,600	5,100	3,700	5,000	11,700	18,910	5,900	11,300	10,500	6,700	5,600	6,200	5,500	4,200	3,700	6,000	5,400	4,400	18,910
20,100	29,800	33,200	44,600	37,000	15,900	5,600	4,400	6,300	5,800	19,100	36,300	18,910	8,600	10,700	14,400	10,300	6,700	5,000	4,500	4,100	4,900	6,900	11,500	19,900	18,910
59,800					43,800	16,500	6,900	6,200	5,300	5,000	4,100	18,910	35,700	48,900	49,500	29,000	8,200	7,700	5,800	4,700	5,800	4,700	4,700	4,800	18,910
23,700	36,700	34,900	65,200	34,900	18,300	24,600	30,900	25,100	13,700	19,000	17,000	18,910	14,300	16,800	23,800	34,800	14,800	10,500	7,300	12,800	10,100	7,400	8,300	17,700	18,910
51,700	56,100	54,700	36,200	18,200	10,900	8,300	4,600	3,300	3,500	4,400	3,100	18,910	35,200	32,100	13,900	6,800	4,600	5,500	4,100	4,000	4,400	5,100	4,400	3,700	18,910
14,100	27,400	34,000	36,800	52,200	26,900	25,200	12,400	8,400	13,500	23,200	22,000	18,910	7,700	11,600	17,200	23,700	5,800	9,100	5,800	4,900	6,100	7,600	9,000	5,900	18,910
12,800	30,200	38,000	38,200	36,700	23,900	9,400	5,400	4,000	8,300	9,600	14,300	18,910	17,500	9,400	9,300	8,000	5,300	5,200	4,300	3,800	4,800	5,500	5,900	4,800	18,910
28,500	18,100	13,800	11,500	5,300	3,200	5,000	3,300	2,200	4,500	13,700	17,100	18,910	4,800	5,200	6,800	5,000	4,600	9,000	7,900	9,400	8,800	7,800	7,100	18,910	
29,800	58,800	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600	30,900	36,000	35,000	15,200	7,700	8,900	5,700	4,200	6,400	6,700	4,900	18,910
29,500	64,000	49,300	69,200	49,300	43,500	13,200	7,100	7,100	5,400	6,900	3,300	18,910	22,600												

Combined effects of river regulation and lowered Lake Lockie inflow threshold on overall hydrology of the Lake Hattah system

Under natural conditions, the majority of lakes in the Hattah Lakes complex would have been permanent, with modelling of a 100-year time series by SKM (2003a) indicating that many lakes would have contained water for 98% of the time. As a result of river regulation, the lakes now receive reduced inflows and are wet for shorter periods than occurred under pre-regulation conditions. This has the potential to impact on vegetation communities and water bird breeding (SKM, 2003a). Some summary statistics on the change of flow regime in the Hattah Lakes are presented in **Box 4.2**.

Box 4.2 – Summary statistics on the change of flow regime in the Hattah Lakes.

Source (SKM, 2003a).

Reduced duration of flooding	The flooding behaviour of the Lakes system has been altered, both in terms of volume of water delivered to the lakes and the timing of its delivery. A reduction in the duration of flooding and inundation has occurred since regulation. For Lake Hattah, the depth of water retained in the lake has been reduced from 2.8 m to 1.8 m. This means that the average time taken for the lake to dry out after filling has reduced from 26 months to 17 months. Other lakes in the system have experienced a similar shift, with the depth of water retained in Lake Lockie being reduced from 1.2 m to 0.4 m. This has resulted in the average time to dry out being reduced from 12 months to two months.
Reduced frequency of flooding	The frequency, duration and volume of water delivered to the Lakes system has been significantly reduced through time. Modelling of natural and current conditions indicates that under current conditions, the number of floods in 100 years is 57 for Lake Hattah and 11 for Lake Kramen. Under natural conditions, the number of filling events in 100 years is 86 for Lake Hattah and 23 for Lake Kramen. It is important to note that Lake Hattah is one of the first lakes to flood, while Lake Kramen is one of the last (when a large flow event occurs).
Reduced annual volume	<p>The annual volume of water in the lakes is inversely proportional to the percentage of time that the lakes are dry. Modelling of natural and current conditions of the Hattah Lakes system indicates that for Lake Lockie, the proportion of the time that the lake is dry is 72% of the time under current conditions, compared to 9% of the time under natural conditions. Even though Lake Lockie is one of the first lakes to receive water, it has a low capacity and is relatively shallow. Other lakes in the system indicate a similar comparison between natural and current conditions. For example, under natural conditions, Lake Hattah is estimated to be dry 2% of the time compared to 25% under current conditions.</p> <p>As a result of modifications to the Chalka Creek channel, including the installation of regulators, the critical flow volume to achieve flooding between lakes has been reduced in most cases. For example, the critical flow between Lake Lockie and Lake Hattah has been reduced from 48,900 ML/d to 36,700 ML/d.</p>

Changes in the frequency and duration of lake inflow events from the River Murray

An analysis of the change in flood frequency and duration for natural and current conditions was conducted using 109 years of modelled data. The results are indicative only, because the pattern of flooding has also been impacted by structures that control the movement of water within the Lakes system (**Box 4.1**), and it was not possible to

account for these effects in the modelling. **Table 4.5** provides results of the analysis of the percentage of time that flow thresholds are exceeded at Euston Weir, resulting in inflows into the Hattah Lakes system. Three flow thresholds were selected for analysis: 36,700 ML/d is the minimum discharge required for the lakes to begin filling under current conditions; 48,900 ML/d is the minimum discharge required for the same conditions to occur under natural conditions; and 70,000 ML/d was assumed to be a discharge which would result in the majority of the lakes filling (**Table 4.1**).

Table 4.5 – Percentage of time a flow event is exceeded using daily data for 109 years for modelled natural and current conditions at Euston Weir. Source: MDBC analysis.

Flow threshold	Natural Conditions % of time flow is exceeded	Current Conditions % of time flow is exceeded
36,700 ML/d commence to fill – current	NA	13
48,900 ML/d commence to fill – natural	22	NA
70,000 ML/d most lakes wet	12	4

The duration of a flood event is important for ensuring the success of bird breeding and seedling recruitment. The literature on the hydrological requirements of waterbirds in the River Murray system indicates that inundation for two months once every two to three years will maintain habitat and provide an opportunity for bird breeding. An analysis indicates that the frequency of sustained floods at the commence to fill level have reduced in frequency, and the larger flood events (that fill most of the lakes at more than 70,000 ML/d) have more than halved in their frequency under current conditions (**Table 4.6**).

Table 4.6 – Percentage of years when an event greater than the threshold flow occurs for at least 14 days duration; using daily data for 109 years, for modelled natural and current conditions at Euston Weir. Source: MDBC analysis. NA is not available, meaning it does not apply.

Flow threshold	Natural conditions % of years when a flood ≥14-day duration occurs	Current conditions % of years when a flood ≥14-day duration occurs	Percentage change
36,700 ML/d commence to fill – current	NA	51	–30%
48,900 ML/d commence to fill – natural	73	NA	
70,000 ML/d most lakes wet	54	23	–57%

For flood events exceeding 70,000 ML/day for at least 14 consecutive days (assumed to be 'large floods' in this analysis) the median interval between events was around one year (calculated value was 322 days) under natural conditions, compared to around two years (calculated value was 650 days) under current conditions. This means that the median time between major events that flood the entire Lake system has doubled under current conditions compared to natural. Similarly, the number of large flood events (greater than 70,000 ML/day) has been reduced from 77 in 109 years under natural conditions to 31 under current conditions.

When a flood event does occur (defined as a critical volume that results in onset of flow into one or more of the lakes), the duration of the event is significantly less under current conditions compared to natural conditions (**Table 4.7**). For events greater than 14 days duration, the median duration for the smaller flood events has been reduced from 82 to 62 days. The decrease in the duration for the larger events (more than 70,000 ML/day) has been less (11 days), but this represents a similar percentage reduction.

Table 4.7 – Median duration of events (of ≥ 14 days duration) for given flow thresholds using daily data for 109 years for modelled natural and current conditions at Euston Weir. Source: MDBC analysis. NA is not available, meaning it does not apply.

Flow threshold	Natural conditions Median duration (days)	Current conditions Median duration (days)	Percentage change
36,700 ML/d commence to fill – current	NA	62	NA
48,900 ML/d commence to fill – natural	82	NA	–24%
70,000 ML/d most lakes wet	43	32	–26%

4.3.2 Other factors

A past history of livestock grazing before the National Park was declared as well as excessive grazing pressure by rabbits, goats, Western grey kangaroos and Red kangaroos have degraded native vegetation and hence faunal habitat around the Hattah–Kulkyne Lakes Ramsar site (DSE, 2003). Other threats include nutrients, algal blooms and salinity.

Pest plants are of concern, particularly environmental weeds, because they reduce opportunities for regeneration of indigenous flora through competitive growth and by changing soil conditions required for successful germination and development. Flora species at greatest risk from weed invasion include those of highest conservation significance including the Garland lily and the Sand sida (DSE, 2003).

Large numbers of carp enter the Hattah–Kulkyne Lakes Ramsar site from the Murray River via Chalka Creek (DSE, 2003). The feeding strategy of carp can result in increased water turbidity and the destruction of submerged aquatic vegetation that provide food and shelter for native fishes and habitat for waterbirds (Barnham, 1998). Muddying the water makes the environment unsuitable for many of the aquatic biota that naturally thrive in the lakes (DSE, 2003).

Feral pigs cause localised soil disturbance, spread weeds and disturb understorey vegetation. Pigs also forage for tortoise and waterfowl eggs that have been laid around the perimeter of the lakes (DSE, 2003).

Some recreational activities also pose a threat to some of the values of the Hattah–Kulkyne Lakes Ramsar site (DSE, 2003). High visitation has led to problems associated with fire, damage to native vegetation, firewood collection, soil erosion and compaction. Firewood collection causes significant environmental damage through the destruction of habitat of many small, ground-dwelling animals (DSE, 2003). Disturbance by visitors during bird breeding season may pose a potential threat to the survival of threatened species such as the Freckled duck, Blue-billed duck, Spotted bowerbird and Whitebellied sea-eagle (DSE, 2003).

Hattah Lakes are located in northern Victoria where high fire danger conditions occur throughout summer. Wildfires, inappropriate fuel reduction burning and fire suppression operations have the potential to reduce the site's values (DSE, 2003). Changes to natural fire regimes can adversely affect the diversity of flora and its dependent fauna. Fire frequency, intensity and season can have a major influence on the floristic composition of grassy woodland communities and grassland communities, which are the predominant vegetation types surrounding the Hattah–Kulkyne Lakes Ramsar site (DSE, 2003).

Based on current understanding, DSE (2003) rated altered water regimes, pest plants, pest animals and grazing the most serious threat to the Hattah–Kulkyne Lakes Ramsar site's environmental values and ecological character (**Table 4.8**).

Table 4.8 – Level of risk to Ramsar values at the Hattah–Kulkyne Lakes Ramsar site. Source: DSE (2003).

Risk	Priority
Altered water regime	●●●
Resource utilisation	●
Salinity	●●
Pollution	●
Grazing	●●●
Pest plants	●●●
Pest animals	●●●
Recreation	●
Fire	●

- Higher priority risk – risks that currently or may potentially result in significant loss of the site's environmental values and ecological character.
- Medium priority risk – risks that currently or may potentially result in moderate loss of the site's environmental values and ecological character.
- Lower priority risk – risks that currently or may potentially result in minor loss of the site's environmental values and ecological character.

These various threats to the health of the Hattah Lakes have been recognised for some time. Management plans have been developed at various levels, and a number of site management strategies have been developed in response to the analysis of risks to the values (DSE, 2003). The following section examines opportunities to address flow-related threats.

4.4 Opportunities to meet objectives for this site

4.4.1 Introduction

The Hattah Lakes is located downstream of significant water management headworks and diversions and it is also affected by regulation within the lakes system itself. The area has also been affected by grazing and introduced species. Hydrological options for improving the ecological condition of the lakes fall into two categories: increasing the frequency and duration of flooding through allocating additional water; and structural works that more efficiently capture and retain water. The ecological condition of the lakes could also be improved through control of grazing by rabbits and kangaroos.

4.4.2 Use of environmental water

Environmental water allocation would provide an opportunity to increase the frequency of watering, and reduce the length of dry spells at the Hattah Lakes. Additional water could be used to increase the number of lakes that fill by increasing the magnitude of existing flood peaks in the river. This could be facilitated by releases from Euston Weir. Gippel (2003) reported on an attempt to manipulate Euston Weir during the October

2000 flood to fill the Hattah Lakes. For example the December 2000 flood enabled the weir pool operation and the natural flood to be used to inundate the lakes. Another possibility for increasing the frequency of flow to the Lakes system could be to source water from the Murrumbidgee or Goulburn rivers.

In considering any future watering options for the Hattah Lakes, it should be noted that only very large floods result in complete inundation of all of the lakes. Smaller floods that have a recurrence interval of every several years are of the magnitude that floods from 30% to 50% of the Lakes. Utilising these smaller flood events that occur relatively frequently will be just as important as managing the less frequent larger flood.

4.4.3 Structural and operational measures

There is potential for improving the health of the Hattah Lakes system through structural and operational measures that make better use of existing inflows into the lakes. Water could be retained for longer in the lakes to improve conditions for recruitment and growth of flood dependent plants and for bird-breeding events.

A detailed study of potential water management options, including the locations for regulators to manipulate the water regime and increase duration of inundation at lakes, has recently been conducted by SKM (2003a). Twelve potential options for water management were evaluated. The favoured option comprised the construction and operation of four regulators within the lakes complex. Two regulators could be positioned in the southern arm of the lake chain (between lakes Little Hattah and Hattah, and lakes Bulla and Arawak). The remaining two regulators could be positioned in the northern arm of the lake chain (between lakes Yerang and Mournpall, and lakes Mournpall and Konardin).

The regulators could be kept open until the lakes are filled by a flood event, whereupon they could be closed. The regulators could remain closed until the next flood event, and opened if the level of the flood exceeds the water level in the lake (David Sheehan, Sinclair Knight Merz, pers. comm., 2003). Potential adverse impacts of the regulators might include increased groundwater levels, and trapping of biocides and pollutants, and these should be monitored (SKM, 2003a). These factors would need to be considered in operating rules if such structures are built.

There have been suggestions for deepening Chalka Creek in order to provide flows to the Hattah Lakes at lower river discharges. However, recent analysis has indicated that this option is unlikely to achieve significant environmental benefits (SKM, 2003a). Installing a pump station at Chalka Creek to pump water into Chalka Creek and the Hattah Lakes is also an option. It would allow an increase in flood frequency as well as duration and magnitude, (SKM, 2003a).

The structural and operational works and measures already considered or identified to improve flow management within the Hattah Lakes include (MDBMC, 2004):

- identification of ecological objectives and their water requirements;

- identification of options for water management which will provide a range of water regimes representing pre-regulation conditions and will meet the ecological objectives;
- upgrade the regulating structure between lakes Hattah and Little Hattah;
- feasibility studies into all priority options, including construction of regulators between lakes Bulla and Arawak, Yerang and Mournpall, Mournpall and Konardin;
- investigation into feasibility of pumping water into the lakes system to address the ecological objectives.

4.4.4 Links between ecological objectives and management opportunities

The proposed opportunities for managing flows in the forest aim to reverse or partially reverse the effects of River Murray flow regulation and internal hydraulic modifications by providing a range of water regimes representing pre-regulation conditions. This will help meet the objective of restoring healthy examples of all original wetland and floodplain communities. Large floods exceeding 70,000 ML/d are required to inundate all of the lakes and such floods are too large to be significantly modified by management actions. So the expected outcomes of the actions under the First Step Decision are with respect to smaller floods that have a recurrence interval of every several years and have a magnitude that can flood around 50% of the Lakes. Floods of this magnitude (which have decreased in frequency and duration under regulation) are the major target of flood enhancement efforts. Thus, the expected outcome is restoration of the aquatic vegetation zone in and around at least 50% of the lakes.

The structural and operational works will enable water that floods into the lakes (through natural and/or enhanced natural floods) to be retained for longer to improve conditions for recruitment and growth of flood dependent plants. The likelihood of successful bird-breeding events (for colonial waterbirds, some of which are threatened) will increase through longer-lasting inundation events.

The most abundant and diverse fish faunas have been found to be associated with more permanent lakes that are frequently flooded. So, frequent and longer-lasting flooding will provide opportunities to enable increased population size and frequency of successful breeding events of the fish species present, some of which are listed as endangered.

