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PRIVATE AND SOCIAL VALUES OF WETLANDS RESEARCH REPORTS

Potential Wetland Management Strategies – Murrumbidgee Floodplain Wagga Wagga to Hay

By S.M. Whitten and J.W. Bennett

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Abstract

Wetlands on the Murrumbidgee floodplain provide both private and social values. The nature and extent of these values is dependent on the biophysical status of the wetlands. Changes in land and water management can alter the biophysical status of the wetlands and hence the values they generate. In this research report, some potential future biophysical outcomes of alternative wetland management strategies are defined. These biophysical outcomes are compared against each other and against the alternative of what would occur if there were no changes to wetland management. The alternative outcomes provide a biophysical basis for the estimation of values held by private wetland owners and the wider community.

About the Private and Social Values of Wetlands Research Project

Wetlands generate values enjoyed by their owners and the wider community. Individual wetland owners manage wetlands for income generating purposes such as grazing and in some cases hunting and eco-tourism. These are private values from wetlands. Private owners, through the way they manage their wetlands, can change the availability of their wetlands for recreation or wildlife habitat that the community enjoys. These are social or community values of wetlands. In this project the trade-offs facing wetland owners and the community face when making decisions about how to use their wetlands are being examined. This information will help the community to achieve better use of wetland resources on private lands.

There are five main steps to achieving our main goal of better wetland resource use on private land:

1. *Model the changes in the physical attributes of wetlands resulting from alternative uses (biophysical modelling);*
2. *Estimate the community's value of the commercial (private) and non-market (social) outputs of alternative wetland uses (economic valuation);*
3. *Incorporate the value estimates into the biological modelling framework to establish the value trade-offs of alternative uses (bio-economic modelling);*
4. *Investigate alternative institutional frameworks that would give private wetland owners incentives to manage their wetlands in ways which maximise net community benefit; and,*
5. *Generalise the research findings to wetlands Australia wide.*

Two case studies in differing locations with differing mixes of alternative wetland uses and wetland values have been selected for analysis:

- *The Upper South East (USE) of South Australia; and,*
- *The Murrumbidgee River floodplain between Wagga Wagga and Hay in New South Wales.*

1 Introduction

The aim in this research report is to provide biophysical information for input into decisions about the area and level of protection afforded to wetlands on the Murrumbidgee River floodplain in New South Wales (NSW). Decisions about the level and protection afforded to wetlands will involve changes in wetland management. Changing wetland management changes the biophysical status of wetlands and leads to a different set of outcomes. It is the relationships between alternative management strategies and the resultant changes in the biophysical condition of wetlands that is the focus of this research report.

In the ‘Private and Social Values of Wetlands’ Research Reports 4 and 5 a range of wetland management strategies and outcomes were identified for the Murrumbidgee floodplain. In this research report, the changes in the biophysical status of the wetlands that result from adopting alternative management strategies are defined. The changes in the biophysical outcomes will be inputs in the next phase of the ‘Private and Social Values of Wetlands’ research project – economic valuation.

The methodology underlying the development of the management strategies is described in the next section. In Section three, a structure for presenting and comparing information about alternative management strategies and their outcomes is presented. The structure extends to the relationship between management strategies and the decision making process. In Section four, the assumptions underlying the strategies are detailed and each strategy is described. The strategies are all derived from a common starting point and are described in terms of changes to biophysical outcomes in the study area. The section concludes with a comparison of the biophysical outcomes of the strategies. The paper concludes with a brief discussion integrating the results of this research report within the research project. An appendix provides additional, more detailed information relating to the alternative management strategies and their biophysical outcomes.

2 Methodology

The alternative management strategies that are described in this paper are derived from the findings of previous studies of biophysical relationships on the floodplain. These studies identify current wetland management strategies and outcomes. These studies also suggest changes to wetland management and the likely changes to biophysical outcomes that would result. The major data sources used to define the biophysical relationships and/or to identify potential management strategies were:

- ‘A survey of hydrological changes to wetlands of the Murrumbidgee River’ (Briggs and Thornton 1994). This paper reports the information relating to wetland area, land tenure and hydrological management.
- Wetland ecosystems and landuse in the Murrumbidgee Catchment – Wagga Wagga to Hay and including Mirrool Creek (Whitten and Bennett 1998);
- Farmer perceptions of wetlands and wetland management on the Murrumbidgee River between Wagga Wagga and Hay and including Mirrool Creek (Whitten and Bennett 1999);
- A Survey of Graziers’ Land Management Practices on the Murrumbidgee River Floodplain (Jansen 1998); and,
- Other papers relating to particular management strategies by a number of authors (notably Sue Briggs and Alistar Robertson).

These sources are augmented by direct input from wetland researchers with expertise in the region and/or expertise with floodplain wetland management. It has also been necessary to make a number of assumptions regarding both the management strategies and their outcomes where information sources are limited. These assumptions are made explicit throughout the report.

The changes to biophysical outcomes resulting from management changes need to be described. The description should incorporate all attributes of the changes in outcomes that are valued by wetland owners and/or the wider community. The changes in outcomes should also measurable. By measuring the changes in outcomes a comparison of changes between strategies can be made. This comparison is part of the input to the economic valuation phase of the project. Six attributes (or measures) of the change in outcomes were chosen:

- Wetland area and status (quality);
- Forestry management practices in wetlands;
- Management and productivity of agricultural pasture;
- Area fenced to improve grazing management or eliminate grazing;
- Hydrological management of river flows; and,
- Impacts of wetland management on the fauna, flora and riverine environment.

Together these attributes are used in this research report to describe the likely ecological impact of adopting each management strategy.

Incentive mechanisms that might lead to particular management strategies being adopted are not discussed in this report. That is, a particular incentive mechanism is not linked to any potential strategies (although practical management strategies and potential incentives may be obvious). Once the values of alternative strategies have been estimated in the next phase of the project, analysis will focus on the most effective ways to achieve these strategies. That is, future analysis will focus on developing appropriate incentive mechanisms.

3. Biophysical and economic modelling

The aim of developing alternative strategies is to provide information that can be used in the estimation of the relative values of those strategies. In this section, a framework for the analysis of alternative strategies is developed using the concepts of analysis at the margin and analysis at future points in time given a specific set of assumptions. This framework describes the requirements to estimate the economic value that results from a change in outcomes.

3.1 Structured information for decision makers

At the margin

In this research report a number of potential biophysical outcomes of alternative management strategies are developed and reported. Each strategy involves an alteration of land and/or water management for a relatively small proportion of total wetlands on the Murrumbidgee floodplain. The alteration of land management practices can be broken into grazing, timber and water management changes.

Figure 1 shows the current grazing management of that proportion of the floodplain for which biophysical outcomes are altered by the strategies considered in this report. This area where change will occur is referred to as “the margin”.

Box 1: The margin

The margin is the area of land or quantity of water for which the management strategy is changed. The use of the concept of the margin allows analysis how much the area of land (or water) should be subject to a particular management strategy rather than whether such a management strategy should be practiced at all. That is, we can ask whether more or less of the floodplain should be grazed rather than whether any grazing should be practiced on the floodplain.

From Figure 1 it can be seen that the grazing management of a maximum of 36 percent of land in the Murrumbidgee floodplain changes under the strategies developed. Grazing management on the remaining 64 percent is not altered by the strategies developed. Currently the area where management changes are proposed consists of set stocking (16.0 percent of total area) and crash/rotational grazing (20.4 percent of total area).[1]

Similarly the concept of ‘at the margin’ can be applied to the management of wetlands for timber production or the management of water in the Murrumbidgee catchment. The potential strategies discussed refer to a relatively small proportion of total water diverted for irrigation in the catchment.

[1] The area includes buffer strips. Buffer strips are border areas around wetlands that are subject to changed grazing management.

Figure 2 shows the management of wetlands for timber production at the margin while Figure 3 shows the water usage at the margin.

FIGURE 1: GRAZING MANAGEMENT AT THE MARGIN IN MURRUMBIDGEE FLOODPLAIN WETLANDS

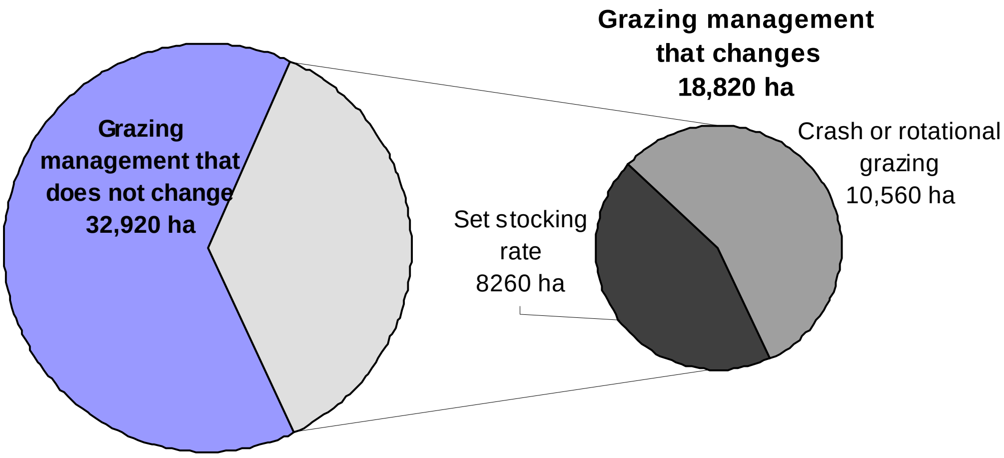


FIGURE 2: WETLAND TIMBER MANAGEMENT AT THE MARGIN

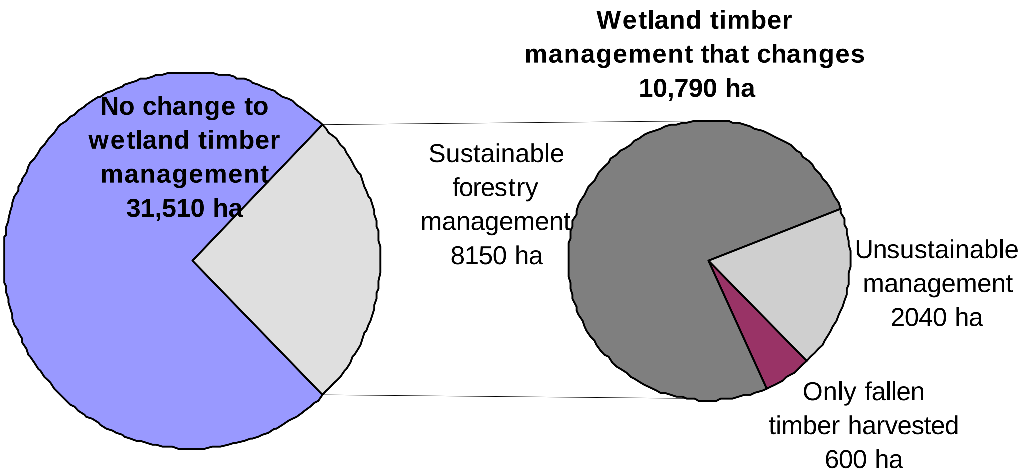
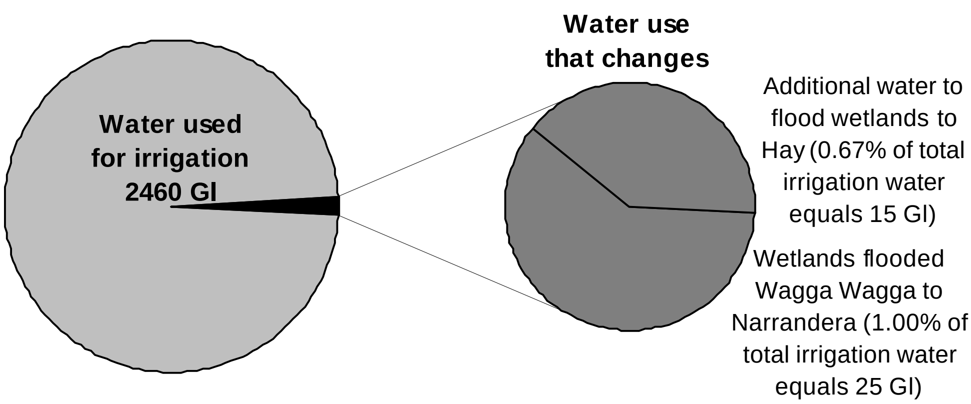


FIGURE 3: WATER USE AT THE MARGIN

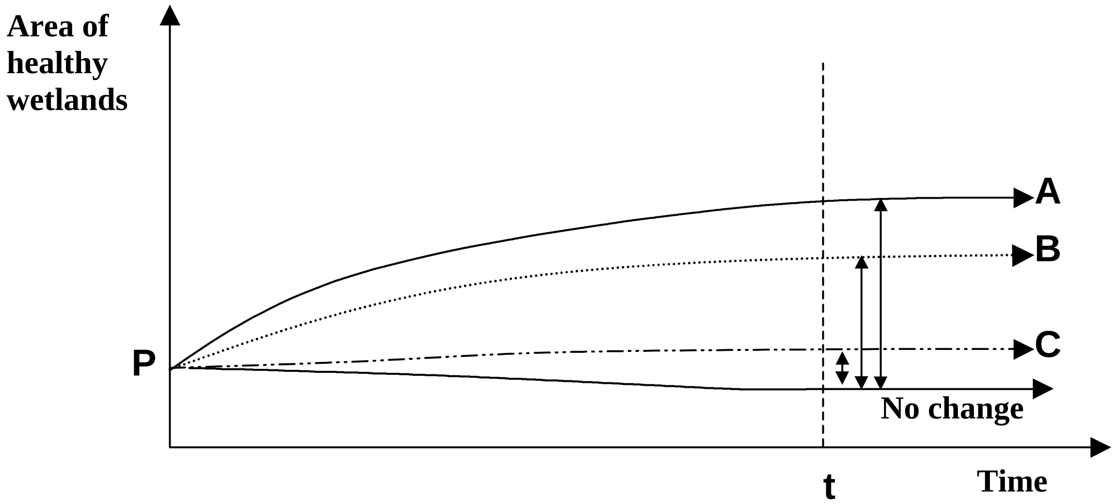


Hence the analysis in this paper focuses on the portion of the Murrumbidgee floodplain for which land and /or water management strategies change. It is this relatively small proportion of total land that is referred to as "the margin". The impacts of changing land and/or water management at the margin is not expected to impact on land areas. However the impacts are likely to extend to the Murrumbidgee River and immediate surrounds. Likewise, changes to management in "infra-marginal" land areas are not expected to affect strategies in the land "at the margin".

Analysis at future points in time

Each of the strategies discussed in this research report is developed from a common starting point. This point is the current biophysical state of the Murrumbidgee floodplain wetlands. That is, the alternative strategies lead to differing changes to the current biophysical conditions in the Murrumbidgee floodplain wetlands. In Figure 4 the current condition of one attribute of the marginal land areas – area of healthy wetlands -is indicated by point 'P'.

FIGURE 4: BIOPHYSICAL STRATEGIES AT FUTURE POINTS IN TIME



Depending on the management strategy employed in the future, the area of healthy wetlands may increase a lot (line A), increase somewhat (line B) or increase relatively little (line C). If management is left unchanged the future area of healthy wetlands could fall as represented by 'No change'.[2]

In assessing the alternative strategies, comparison should only be made against the 'no change' alternative at concurrent points in time. To compare strategy 'A', at time 't', against the current conditions 'P' is not appropriate. 'A' must instead be compared against what would happen if no change to wetland management occurred and against alternative strategies. That is, 'A' should be compared against the 'No change' strategy at point 't' and against other strategies at point 't'. Hence a 'no change in wetland management' strategy is explicitly developed in this research report in addition to outcomes arising from alternative management strategies. The comparison point in time 't' is defined as 2015 for the purposes of this study.

Once the outcomes of the alternative strategies are defined at future points in time, an assessment of the costs and benefits of moving to these strategies from the no change alternatives can be estimated. Comparing the costs and benefits of adopting alternative strategies provides a structure for decision making. The costs and benefits of moving to alternative strategies such as 'A', 'B', 'C' from the 'no change to wetland management' will be estimated in the next phase of the Private and Social Values of Wetlands research project.

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[2] Note that 'no change' refers to the management strategy employed and not the impact of that strategy.

3.2 The structure of the management options

The structure of the outcomes modelled

The outcomes are the result of changes to the management of grazing and timber production in and around wetlands and to hydrological management of Murrumbidgee River flows. The 'Private and Social Values of Wetlands' research project is focused on assessing values associated with wetlands. Hence only management changes that lead to changes in wetland values are defined. For example, a strategy of changing irrigation management is not considered except as it relates to wetland values.

Changes to wetland management can be considered in isolation or cumulatively. This distinction is important because the cumulative impact of multiple management changes will not be the same as the sum of the individual changes. This approach is illustrated in Figure 5 by reference to the alternative strategies defined in this paper.

The base, or comparative, outcome is defined as the 'no change to wetland management' strategy. Each outcome scenario is derived from one or more changes to the management that affects the wetlands. For example the 'grazing management' strategy arises from changes to the management of grazing in wetland areas and is built on the assumptions underlying the 'no change to wetlands management' strategy.

FIGURE 5: MANAGEMENT STRATEGIES FOR THE MURRUMBIDGEE FLOODPLAIN

No change to wetland management	**Hydrological management**	**Grazing management**	**Timber management**	**Water, timber and grazing management**
				Timber management
				Grazing management
	Hydrological management	Grazing management	Timber management	Hydrological management
No change to wetland management	No change to wetland management	No change to wetland management	No change to wetland management	No change to wetland management

Use of assumptions

Assumptions are used to simplify the development and limit the boundaries of the alternative strategies. In both cases, the validity of the assumptions used requires careful assessment. For example, determining the extent of the margin requires an assessment of whether the impacts of management change outside the margin are significant. Assuming incorrect marginal boundaries can lead to an incorrectly defined biophysical outcome and hence an under or over statement of net costs or benefits. Furthermore care needs to be taken both in the biophysical modelling phase, and in the valuation phase of the study, as to the potential cumulative impacts of multiple small errors on conclusions drawn. All assumptions used to develop the strategies and outcomes are detailed in Section 4.1.

4 Management strategies and biophysical outcomes

4.1 Assumptions and data sources

The assumptions and data sources used in this research report are detailed in this section. The assumptions are loosely divided into three groups:

i) Assumptions used to define the common starting point for developing all biophysical outcomes of the alternative management strategies;
ii) Assumptions used to define the 'no change in wetland management' strategy; and,
iii) Assumptions used to define alternative strategies and the resulting changes to biophysical outcomes.

Common starting point assumptions

The common starting point assumptions are built on the wetland areas defined in Briggs and Thornton (1994) in conjunction with the results of a survey of farmer wetland perceptions and management (Whitten and Bennett 1999). In Figure 2 the common starting point is referred to as 'P'. Assumptions used to define the common starting point underlie the alternative biophysical outcomes that are developed later in this paper. The assumptions and data sources are described below as they relate to the key descriptive attributes.

Attribute	**Assumptions / data sources**
Wetland area and status (quality)	The area of wetlands is based on Thornton and Briggs (1994). Wetlands included by Thornton and Briggs (1994) were restricted to areas greater than 1 ha (open water) and greater than 50m in width. The area of unmodified open water wetlands was tripled to adjust for small ephemeral wetland areas not included (an additional 1400 ha or a 3.2% increase in wetland area). Thornton and Briggs break wetland area into four categories based on hydrological status. Thornton and Briggs further subdivide these categories between the source

[3] Thornton and Briggs (1994, p3-4) subdivide the 'Hydrological Changes to Murrumbidgee Wetlands' as follows:

Category 1 = no control. The water regime is not locally manipulated.

Category 2a = Slight control. Water is pumped into the wetlands from the river, diverted into it by a weir, or enters during floods. The water is then pumped out of the wetland for irrigation, stock or domestic purposes. Water may or may not be retained in the wetland by a bank (regulator, earth or concrete wall). The water in the wetland may or may not retain its connection with the river, but the natural hydrology of the wetland overrides artificial control of its water regime. The wetland usually dries out (not necessarily annually) and its water level falls slowly (weeks to months) and predictably.

Category 2b = Slight control. Same degree of control as Category 2a but the wetland receives used irrigation water (tailwater).

Category 3a = Medium control. Same type of control as Category 2a, but greater degree. Control of the water level in part, or all, of the site overrides the natural hydrology of the wetland. Water levels may vary erratically over short periods (days to weeks) or more slowly (changing over weeks to months) and predictably. Surrounding river red gum floods in high rivers. The wetland rarely, or never, dries entirely.

Category 3b = Medium control. Same degree of control as Category 3a except the wetland receives irrigation tailwater.

Category 3c = Medium control. The wetland has been drained, or blocked off from the river. It receives water only in very high floods.

Category 4a = Heavy control. Same type of control as Category 3a but greater degree. All of the wetlands, including surrounding river red gum (if present), is subject to water level control. The wetland is either a weir pool or an off-river storage fed by a canal. It never dries up entirely, and the water level may go up or down erratically over short periods (days to weeks).

Category 4b = Heavy control. The wetland has been artificially created.

of the impact (water storage or irrigation drainage) and vegetation type (red gum or open water). The categories are described in the footnote below.[3]

Thornton and Briggs categorise wetlands as red gum or open water wetlands. A further category of 'deep wetlands' consisting of billabongs and floodplain creeks has been split out of Thornton and Briggs' categories. 'Deep wetlands' are important as they are near permanent and require additional protection from grazing and timber harvesting. 'Deep wetlands' are assumed to comprise all of the wetlands categorised with a suffix 'a' and 30% of wetlands categorised with a suffix 'b' by Thornton and Briggs (1994, see footnote 3).

Agricultural productivity

The grazing management currently pursued in wetland areas is drawn from the survey results of Whitten and Bennett (2000) (for private land) and discussions with NSW State Forests officers at Narrandera (for Crown Lands).

The current stocking rates are estimated as follows:

- Red gum grazing productivity is estimated as a weighted average of the wetland-stocking rate of all farmers with red gum wetlands.
- Open water is a weighted average of the wetland-stocking rate of floodplain farmers who own vegetated or non-vegetated open water wetlands.
- Deep wetlands productivity is assumed to be the same as the red gum rate.
- The current stocking rate for buffer strips that are fenced off and become unavailable for the existing grazing regime is from Jansen (1998).

Red gum forestry management

Red gum forestry management is based on Whitten and Bennett (2000) and discussions with NSW State Forests officers at Narrandera. It is split as follows:

- No timber harvesting on 63% of private land and 10% of crown land.
- Firewood or farm timber removed from 11% of private land.
- 26% of private red gum forests are managed for commercial timber production. This is arbitrarily split 13% sustainable or near sustainable incorporating habitat trees etc. and 13% without a sustainable management plan. 90% of State Forests red gum wetlands are commercially harvested with a sustainable management plan.

The current coarse woody debris[4] load on the floodplain is assumed to be approximately 20 tonnes per hectare (Mac Nally 1998, 1999).

Hydrological management

The current local hydrological management is defined for individual wetlands in Thornton and Briggs (1994). Hydrological management at a floodplain scale is defined by the River Management Committee Environmental Flows Rules controlling water harvesting at the major dams and releases for irrigation and environmental flows.

Under current water harvesting arrangements, the median number of flows greater than 35,000 Ml per day at Wagga Wagga has been halved since construction of Burrinjuck Dam while the seasonality of flooding events has shifted to later in spring.

The hydrological status of wetlands at a floodplain scale (as opposed to the degree of local manipulation) is split into too wet, too dry and unknown using Thornton and Briggs (1994) categories (see footnote 3 for more information). Thornton and Briggs Categories 1 and 3c are defined as too dry (due to reduced flooding as discussed above). Wetlands categorised 2a and 2b are defined as unknown, ie they are 'natural dominant' but may suffer the same fate as wetlands that are too dry. Thornton and Briggs wetland Categories 3a and b and 4a and b are defined as too wet.

Area fenced to remove grazing

All areas not currently grazed are fenced and assumed to be managed for conservation. The total area fenced is drawn from the farm survey results and is for red gum and open or vegetated water wetlands on the floodplain only. The starting proportions are 39% for red gum, 7% for open water and 5% for deep water.

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[4] Coarse woody debris are fallen timber that are slowly decomposing on the floodplain. Large coarse woody debris are those larger than 10 cm in diameter and more than one meter long.

Assumptions for 'no change to wetland management' strategy

The 'no change to wetland management' strategy is defined as no change to management of wetlands including no changes to the environmental flow rules currently applied. In Figure 2 the 'no change to wetland management strategy' is referred to as 'no change'. The strategy is based on the assumptions and information described above for the common starting point. The additional assumptions and information used to define the 'no change to wetland management' are defined below for each attribute.

Attribute	**Assumptions / data sources**
Wetland area and status (quality)	Wetland management is unchanged from 1999. The wetlands in the study area continue to degrade due to lack of (or too much) water, and/or inappropriate grazing and timber management.
Agricultural productivity	There is no change to grazing management or the resulting agricultural productivity.
Red gum forestry management	No significant change is made to red gum forestry practices with the exception that all timber harvesting is conducted on a sustainable resource basis. That is, the 13% of river red gum forests on private land currently harvested unsustainably will be harvested according to a management plan incorporating some conservation objectives.
Hydrological management	River management continues with no significant changes from current environmental flow rules.
Area fenced to remove grazing	No additional area fenced.

The biophysical condition of wetlands can be altered via the adoption of various alternative management strategies. Each alternative starts from the common starting point described above. Hence each is also based on the assumptions and information for the common starting point. A selection of the alternative management strategies is briefly described in the next sections. In each case a brief outline of the strategy is given before the additional assumptions or data sources are recorded for each attribute.

Assumptions for hydrological management strategy

The hydrological management strategy incorporates two changes to wetland management. At both the floodplain and local wetland levels, the hydrological management strategy involves the reintroduction of a flooding regime that would mimic pre-1913 patterns. The strategy can be divided into two levels, the first level affecting wetlands between Wagga Wagga and Narrandera and the second Wagga Wagga to Hay. The additional assumptions and information used to define this strategy are defined below for each attribute.

Attribute	**Assumptions / data sources**
Wetland area and status (quality)	The benefits are likely to result from the frequency and seasonality of small wetland flood events returning to approximately natural levels. Under the first level of this strategy, approximately one third of floodplain wetlands between Wagga Wagga and Narrandera only would benefit (that is approximately 8600 ha, of which 6300 are on private land). Under the second level of this strategy, approximately one third of floodplain wetlands between Wagga Wagga and Hay would benefit (approximately 17,200 ha of wetlands of which 12,600 ha are on private land).
Agricultural productivity	Agricultural productivity does not change.
Red gum forestry management	No significant change is made to red gum forestry practices.
Hydrological management	Management at the floodplain level: Once Burrinjuck dam exceeds 50% of capacity sufficient water can be released to create an artificial flood (a flow of 35,000 Ml for one full day at Wagga Wagga) that would flood approximately one third of floodplain wetlands (by area). The water would be purchased from irrigators and used according to a set of rules designed to improve the health of wetlands in the study area. The water could also be used to increase flood

	duration. The returned flooding would be sufficient to return the hydrological regime from droughted to approximately natural for the one third of the floodplain that would receive the additional floods. It is assumed that appropriate rules could be designed to approximately mimic seasonal flood events. Under the first level of this strategy water would be diverted at and below Narrandera eliminating floodplain wetland flooding below Narrandera. Under the 2nd level there would be no high flows pumping allowed until after Hay facilitating floodplain wetland flooding to Hay. Local wetland management: The area of wetlands affected by irrigation storage or drainage or levees is reduced and the degree of impact on these areas is reduced. This category of wetland areas accounts for 3% (1100 ha) of the total wetland area of which roughly one third (1% of total wetland area) would have improved management. Despite the relatively small area of wetlands, these areas are a significant proportion of deep-water wetlands (assumed approximately 30%) and may be disproportionately important ecologically.
Area fenced to remove grazing	No additional area fenced.

Assumptions for grazing management strategy

The grazing management strategy incorporates changes to the level and management of grazing. Grazing is removed from some wetlands while the impact of grazing on other wetland areas is reduced via changing management from set stocking to a rotational pattern incorporating ecological goals. In order to facilitate grazing removal or reduction some areas will require fencing. The additional assumptions and information used to define this strategy are defined below for each attribute.

Attribute	**Assumptions / data sources**
Agricultural productivity	It is assumed that regular grazing would be eliminated from approximately 10,560 hectares. A further 8260 hectares would change from set stocking to a rotational grazing pattern where grazing is less than 2 weeks in every three months or an equivalent management practice based on seasonal growth of wetland vegetation is adopted. There is little experimental data to quantify the productivity impacts of changing pastoral management from set stocking to rotational grazing. A case study (reported in Brouwer 1997a and 1997b) indicated that a significant increase in productivity resulted from implementing rotational grazing. Water supplies away from creeks were also improved and some revegetation occured. The increase in productivity over 11 years was approximately 50 percent. However, the location of the case study precludes transfer of result to the Murrumbidgee. Other studies (Roe and Allen (1993), Robinson and Simpson (1975) and Bishop and Birrell (1975) indicate little change in productivity as a result of rotational grazing. Hence changing pasture management from set stocking to rotational grazing is not assumed to alter significantly the productivity of areas where grazing is retained. The stocking rate for red gum wetlands is set using the NSW State Forests target rate at 2/3rds of a dse per ha. This is significantly lower than the current rate. Excluding grazing requires a buffer strip to be included. Buffer strips are included using the following ratios of area of buffer strip to wetland area protected: • River red gum area to buffer strip 20:1; • Open water wetland area to buffer strip 10:1; and, • Deep wetland area to buffer strip 5:1. Production from buffer strips is maintained if they are incorporated in a crash or rotation grazing strategy but lost if grazing is excluded. Overall agricultural productivity of floodplain wetlands (in dse) is expected to decline by approximately 29.9% (19,000 dse) under the grazing management strategy compared to ‘no change’ to wetland management. It is assumed that a small proportion of wetlands (5 percent) has lost their seed-bank and would need to be revegetated.

Wetland area and status (quality)	The impact of grazing on wetlands is reduced or eliminated via fencing wetlands and changing grazing management practices from set stocking to crash grazing where the period of grazing is minimised and the period between grazing in maximised. Separate water supplies reduce the impact where it is impractical to fence wetlands. The impact of changed grazing management and fencing is targeted towards wetlands that would deliver higher environmental values.
Red gum forestry management	No significant change is made to red gum forestry management practices. Reduction of grazing in red gum forests is expected to increase recruitment of red gums and may lead to higher timber productivity. Any productivity impacts are not expected to have an impact until beyond the fifteen-year time horizon.
Hydrological management	River management continues without significant change to current environmental flow rules.
Area fenced to manage grazing	At a minimum all areas from which grazing is excluded must be fenced. Some additional fencing may be required to manage grazing in and around wetlands. Hence, it is assumed that: • 50% percent of all red gum wetlands are fenced; • 50% of open water (no grazing plus half of rotational or crash grazed wetlands) are fenced; and, • 30% of deep wetlands (to exclude grazing in most areas rotation grazed) will require fencing separately. Average fencing rates per hectare protected are sourced as follows: • 10 ha per km for red gum based on Greening Australia data for the Murray and Murrumbidgee; • 20 ha per km for open water based on estimates calculated for the Upper South East of South Australia case study (Whitten and Bennett 1999); and, • 5 ha per km for deep wetlands based on fencing a 1km by 150m corridor around a deep wetland. Hence approximately 720 km of new fencing is required under this strategy.

Assumptions for timber management strategy

The timber management strategy incorporates changes to area of timber harvested and the harvest management. Timber is no longer harvested from some wetlands while the impact of harvesting on other wetland areas is reduced via changing management to incorporate ecological goals. The additional assumptions and information used to define this strategy are defined below for each attribute.

Attribute	**Assumptions / data sources**
Red gum forestry management	The impact of logging in red gum forests is reduced by: • Eliminating timber harvesting in 8150 ha. • Eliminating commercial firewood collection in 600 ha. • Remaining logging only under sustainable practices (2040 ha changed from unsustainable). The management changes reduce the quantity of saw timber, residue or firewood available. The changes will lead (eventually) to an increase in the coarse woody debris load to over 50 tonnes per ha. Fifty tonnes per ha is an approximate threshold value for mammal populations in red gum forests (MacNally personal communication).
Wetland area and status (quality)	Altering logging management practices reduces the impact of logging on wetland areas via: • Reduced disturbance of red gum wetland areas; • Increased large coarse woody debris in and around wetlands and rivers (increased snags) leading to increased habitat for many fish and terrestrial animals and insects; and, • Increased retention of habitat trees (especially on private land) increasing waterbird breeding and roosting habitat.
Agricultural productivity	Agricultural productivity does not change.

Hydrological management	River management continues with no significant change to current environmental flow rules.
Area fenced to manage grazing	No additional fencing is required to alter red gum forestry management.

Assumptions for combined management strategies

The combined management strategies is the combination of the three individual strategies, hydrological, grazing and timber, discussed above. The strategies would be implemented in unison and are assumed to lead to a synergistic rather than additive response by wetlands. The additional assumptions and information used to define the combined strategies are defined below for each attribute.

Attribute	**Assumptions / data sources**
Wetland area and status (quality)	17,200 ha of wetlands benefit via approximately natural flooding frequency. Of this area, grazing and logging would be eliminated from approximately 10,300 ha and an additional 5100 ha would be subject to crash or set grazing and/or timber harvesting. The remaining 1800 ha would continue to degrade. Additional wetland areas with changed management would also benefit as discussed in the grazing and timber management strategies, however these areas would not benefit from hydrological management.
Agricultural productivity	Agricultural management changes as per the 'Grazing management' strategy. Additional flooding may lead to a small increase in productivity but the extent of this increase is not quantified and is therefore assumed to be zero.
Red gum forestry management	Managed as per the 'Forest management' strategy.
Hydrological management	Managed as per the 'Water management' strategy.
Area fenced to manage grazing	Fencing required is as per the 'Grazing management' strategy.

4.2 Summary of changes to outcomes

The biophysical outcomes of each of the alternative strategies are detailed in this section. The alternative outcomes are compared graphically against the 'no change in wetland management' strategy outcome. The graphical depictions indicate the change in landuse at the margin as discussed in Section 3.1. The outcomes are presented in terms of impact on grazing production, impact on timber production, impact on water available for irrigation, fencing requirements and ecological impacts (both in the wetlands themselves and the wider riverine environment). Greater detail regarding the biophysical outcomes is presented in Appendix 1.

No change in wetland management

The 'no change in wetland management' strategy involves no change to current water or land uses relating to wetlands. It represents the baseline for comparison with the outcomes of the alternative management strategies.

The impact of irrigation storage and use on floodplain wetlands is summarised in Figures 6 and 7. Figure 6 shows the current frequency of floods over 35,000 Ml per day at Wagga Wagga. As indicated above, a 35,000 Ml per day flow at Wagga Wagga is sufficient to flood approximately one third of floodplain wetlands by area. Figure 7 shows there are significantly more years with no flood compared to natural flow conditions due to storage of water for irrigation. Figure 7 below shows the seasonal impact of water extraction on floods over 35,000 Ml per day at Wagga Wagga. The impact is most pronounced between May and August but also apparent in February, March, April and September. The reduction in floods also reduces the length of time between repeat events (within a single year) hence reducing the chance for biota to breed and restock the river. A flood did not take place in May, June or July in about 25% of years between 1913 and 1998 (20 times) that would have naturally occurred. In most of these cases a late flood would have reconnected the wetlands to the river. Examining the full year (rather than May, June and July only) the impact is even more pronounced, in 31 years earlier floods were removed by irrigation storage (over 35% of years).

FIGURE 6: COMPARISON OF NATURAL AND ACTUAL FLOWS AT WAGGA WAGGA 1913-1996

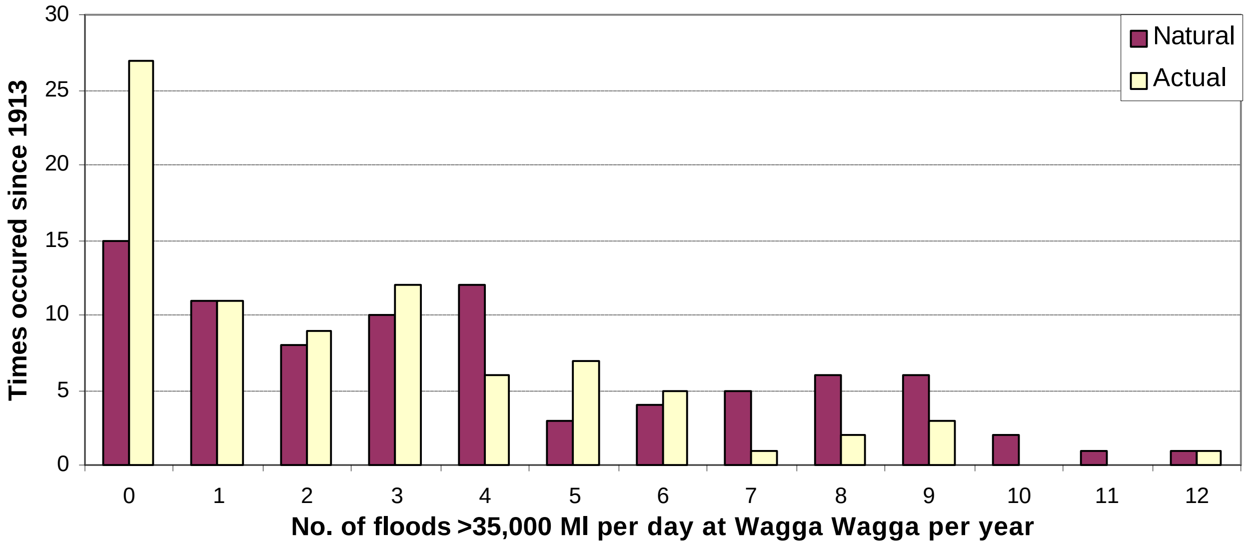
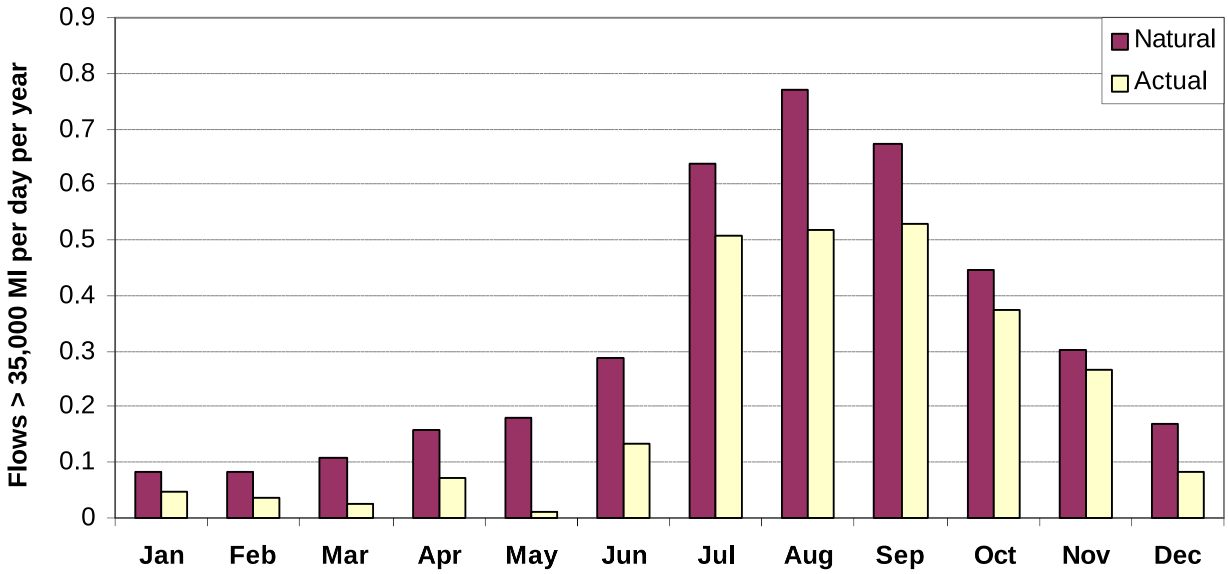


FIGURE 7: SEASONAL COMPARISON OF FLOWS >35,000 ML PER DAY AT WAGGA WAGGA



Landuse at the margin on the Murrumbidgee floodplain under the 'no change in wetland management strategy' is shown in Figures 8 (grazing landuse) and 9 (timber landuse). Current grazing landuse is split roughly evenly between set stocking rate and crash or rotational grazing strategies. Approximately 12 percent of wetlands are not grazed (although some may be grazed during drought periods). Sustainable timber harvesting dominates current red gum timber landuse at the margin. Figures 8 and 9 indicate that landuse is unchanged from the common starting point as illustrated in Figure 1.

FIGURE 8: GRAZING LANDUSE AT THE MARGIN UNDER THE 'NO CHANGE IN WETLAND MANAGEMENT' STRATEGY

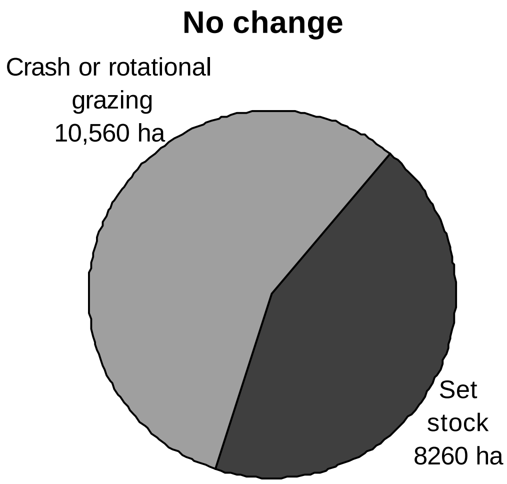
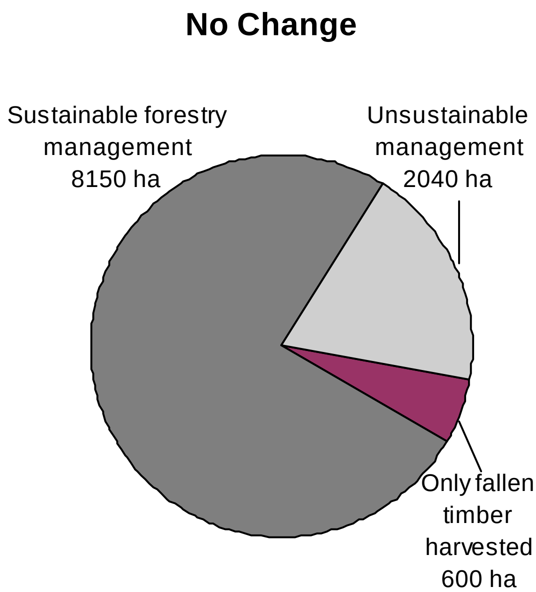


FIGURE 9: TIMBER LANDUSE AT THE MARGIN UNDER THE 'NO CHANGE IN WETLAND MANAGEMENT' STRATEGY



The ecological outcomes without any changes to wetland management can be summarised as follows:[5]

- Wetland vegetation and wetland health will continue to decline, wetland areas will continue to be invaded by terrestrial vegetation;
- The total number of water and woodland birds will decline as will the number of breeding events;
- Native fish populations will continue to decline – especially in wetlands and native fish will continue to be replaced by introduced species;
- Some terrestrial species may benefit but most are likely to decline in number as a result of decreased habitat diversity.

[5] The ecological impacts have been determined from consultations with wetlands scientists working in the region along with published documents where available.

The level of current ecological knowledge limits the accuracy of quantitative estimates. However, current best estimates indicate that by 2015 without any change to wetland management there will be:

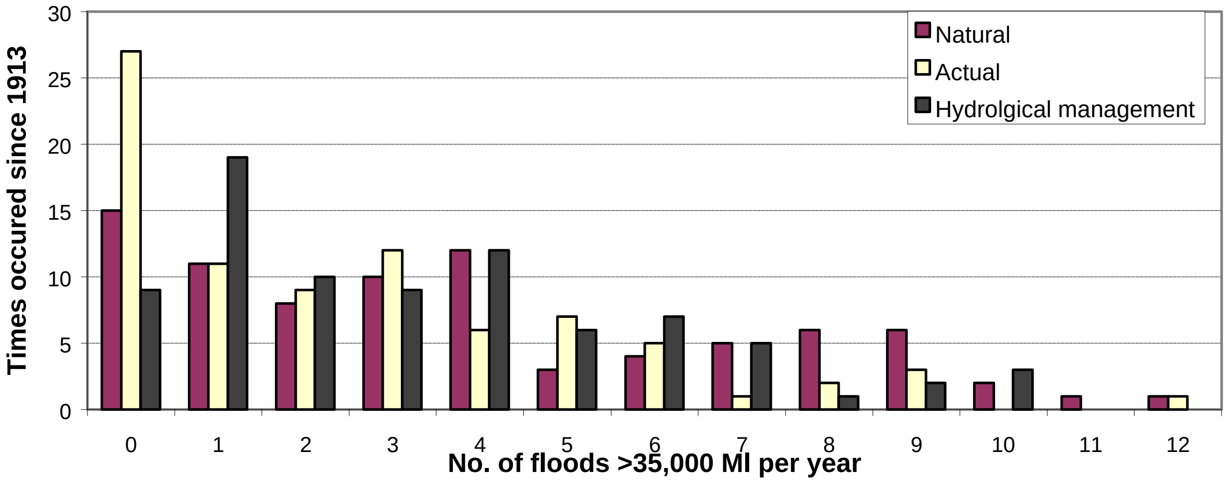
- 2300 hectares of healthy wetlands;
- Water and woodland bird numbers in the area will decline to 40 percent of historical levels; and,
- Native fish numbers will decline to 20 percent (or less) of historical levels.

Current levels were not explicitly identified but would not be significantly larger with the exception of woodland birds.

Hydrological management

The 'hydrological management' strategy would alter the management of water stored for irrigation from the Murrumbidgee River. Under this strategy the management of 41.7 Gigalitres of water currently stored and used for irrigation is used to improve the hydrological management of wetlands. Seventy Gigalitres would be required to create an artificial flood event with a 24-hour duration at Wagga Wagga. This translates to approximately 42,000 Ml (1.76% of average annual irrigation usage) that would have to be purchased from irrigators to facilitate the strategy.[6] The water would be used to increase the number of 'minor wetland flood events' via an artifical flood five years out of every six (on average). Alternatively the water could be used to increase flood duration where ecological benefits are significant. Potential flood frequency and seasonality is shown in Figures 10 and 11 by the 'hydrological management' bars.

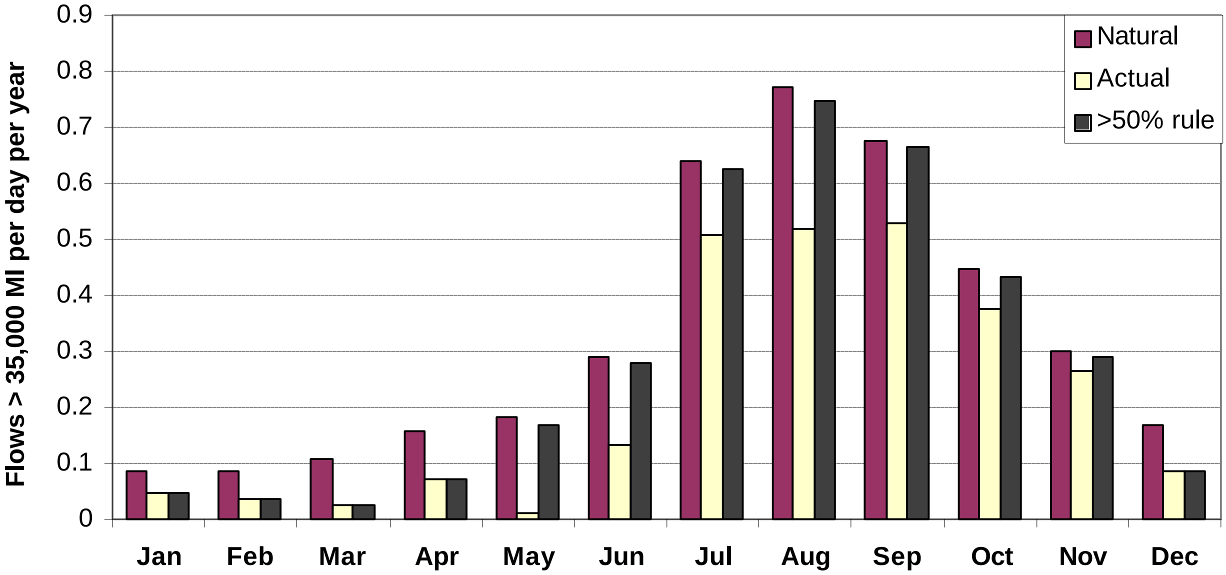
FIGURE 10: DISTRIBUTION OF MINOR FLOODS UNDER THE 'HYDROLOGICAL MANAGEMENT' STRATEGY



Minor wetland flood events are assumed to flood approximately one third of the flood plain wetlands (by area) between Wagga Wagga and Hay improving their hydrological status from droughted to approximately natural. It is assumed that appropriate rules could be designed to mimic a seasonal pattern close to natural as shown in Figure 11 (analysis shows sufficient water is available in the key months to facilitate such a rule from May to November). Analysis also shows that there has been a significant reduction in floods over 50,000 Ml per day at Wagga Wagga. These floods would have a somewhat different effect than small floods but these impacts are not assessed in this report.

[6] The difference between 70,000 and 42,000 Ml is through averaging the water requirement across six years (but only creating five floods) and assuming that only water not available to irrigators need be purchased. That is, if an artificial flood is released and the dam later fills then the water is not lost to irrigators and is not purchased from irrigators.

FIGURE 11: POTENTIAL MINOR FLOOD SEASONALITY UNDER THE 'HYDROLOGICAL MANAGEMENT' STRATEGY



Piggybacking a minor wetland flood event onto high irrigation flows early in the season would reduce the requirement to approximately 25,000 Ml but this reduces the effectiveness of the flood to between Wagga Wagga to Narrandera (within the case study area). Such a strategy would allow ecosystem needs in only this part of the river to be met and water would then be sold to irrigators.

The local wetland management portion of the strategy is designed to reduce the impact of using wetlands for irrigation storage, drainage basins or drought via levees. The total wetland area that changes management is approximately 1% (470 ha) of the total wetland area. These areas are returned from being too wet to a relatively natural hydrology. Despite the relatively small area of wetlands, these areas are a significant proportion of deep-water wetlands (assumed approximately 12%), and are likely to be disproportionately important ecologically.

Table 1 shows the difference between the outcomes of the 'hydrological management' strategy and those of the 'no change in wetland management' strategy using several descriptive attributes. Only the quantity of water diverted from the Murrumbidgee River for irrigation changes under this strategy. As a result of increased flooding and improved wetland management, wetland health would improve. Improved wetland health would result in reduced algal blooms, increased numbers of both wetland and woodland birds and increased frequency of waterbird breeding events. The species mix of water and woodland birds would not change as this is determined by breeding events outside of the study area. The number of fish that could be supported in the river and wetlands would increase. However, the overall carp population could also increase (but the proportion of the population would fall) due to the increased breeding opportunities provided by improved wetland management. Other wetland related fauna such as frogs and invertebrates would also benefit.

TABLE 1: DIFFERENCE BETWEEN 'WATER MANAGEMENT' AND 'NO CHANGE IN WETLAND MANAGEMENT'

Descriptive attribute	**Unit**	**Difference**	**Percentage difference**
Agricultural productivity	dse	0	0%
Timber productivity – sawn timber	m^3	0	0%
Timber productivity – Residue timber	m^3	0	0%
Fencing distance required	km	0	n.a.
Water diverted for irrigation	Ml	-41,700	-1.67%

In terms of quantifying these increases:

- the area of healthy wetlands could double to 5000 ha;
- the stocking capacity for native fish to 30% of historical levels;
- water and woodland birds number increase to 60 percent of historical levels; and,
- waterbird breeding events increase (but these rely on other cues besides flooding and increased breeding events would not significantly affect total waterbird numbers as these are determined outside the study area).

Native fish are referred to in terms of stocking capacity. This is because it is suggested that the current population is so low that they are unlikely to recover within the time frame without a restocking program.

Grazing management

Under this strategy, grazing is eliminated from 10,560 ha and the management of an additional 8,260 ha is altered to include conservation objectives. The change in landuse under the ‘grazing management’ strategy compared to the ‘no change to wetland management’ strategy is shown in Figure 12. A total of 18,820 hectares changes management under this scenario. The half of the floodplain wetlands targeted by this management strategy are 10% set stocked, 30% rotate or crash grazed and 60% not grazed or only grazed in drought. Management on the remaining half of floodplain wetlands is unchanged from present practices.

FIGURE 12: COMPARISON OF LANDUSE UNDER ‘NO CHANGE IN WETLAND MANAGEMENT’ AND ‘GRAZING MANAGEMENT’

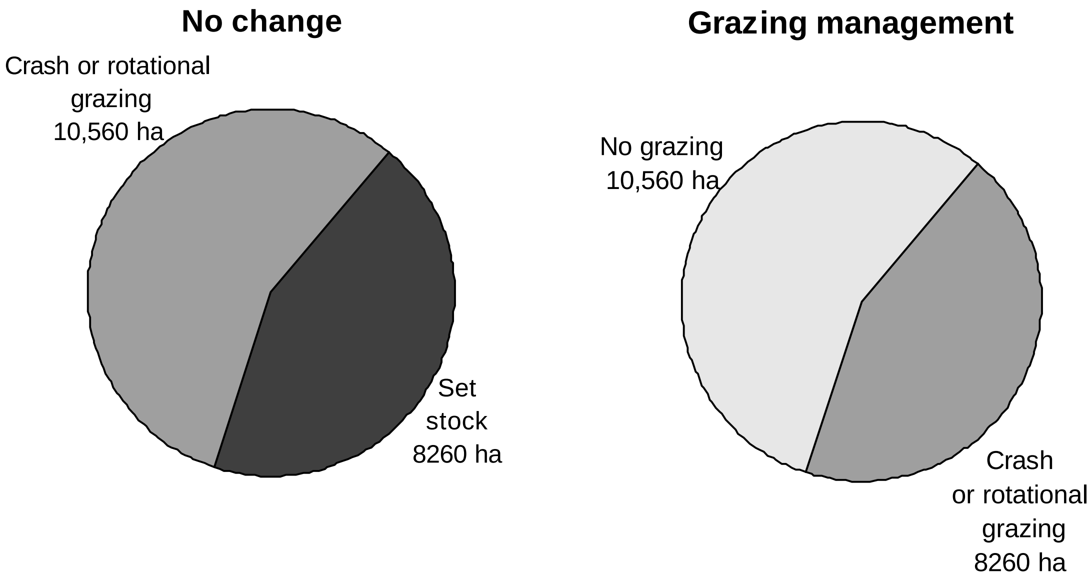


Table 2 shows the change in several outcomes between the ‘grazing management’ strategy and the ‘no change in wetland management’ strategy. In summary, total productivity is reduced and 720 km of fencing is required.

The ecological outcomes under this strategy are mixed. Some wetland vegetation will be restored. Terrestrial vegetation in buffer strips will also increase but would include significant weed populations (that may need control). Invasion of some wetlands by terrestrial species would continue. Woodland birds, terrestrial mammals, reptiles and invertebrates would all increase significantly (as a result of increased habitat diversity). The population of feral species (such as cats, foxes and pigs) would increase and require control. Within wetlands the incidence of algal blooms would decrease, the population of waterbirds would increase marginally and there would be some benefit to fish and frog species. The risk of fire in or around wetlands would also increase. The increases are quantified as follows:

- Healthy wetland areas increase to 9000 hectares;
- Water and woodland birds increase to 50 percent of historical levels; and,
- Native fish stocking capacity returns to 25 percent of historical levels.

TABLE 2: DIFFERENCE BETWEEN 'GRAZING MANAGEMENT' AND 'NO CHANGE IN WETLAND MANAGEMENT'

Descriptive attribute	**Unit**	**Difference**	**Percentage difference**
Agricultural productivity	dse	-15,539	-28.1%
Timber productivity – sawn timber	m^3	0	0%
Timber productivity – Residue timber	m^3	0	0%
Fencing distance required	km	720	42.0%
Water diverted from irrigation	Ml	0	0%

Timber management

The aim of this strategy is to reduce the impact of timber harvesting on floodplain wetlands. A total of 10,790 hectares changes management under this scenario. 8750 hectares is no longer harvested and 2040 hectares changes from unsustainable management to a sustainable management strategy. The proportion of river red gum floodplain wetlands targeted by this management strategy (50 percent of total area) are 90% not logged, 5% sustainable harvested and 5% with only fallen timber harvested (generally for on farm use). Management on the remaining half of the red gum floodplain wetlands is unchanged from present practices. Figure 13 shows the change in land use at the margin from the 'no change in wetland management' strategy to the 'timber management' strategy. Other parts of the floodplain wetlands do not change management.

FIGURE 13: COMPARISON OF LANDUSE UNDER 'NO CHANGE IN WETLAND MANAGEMENT' AND 'TIMBER MANAGEMENT'

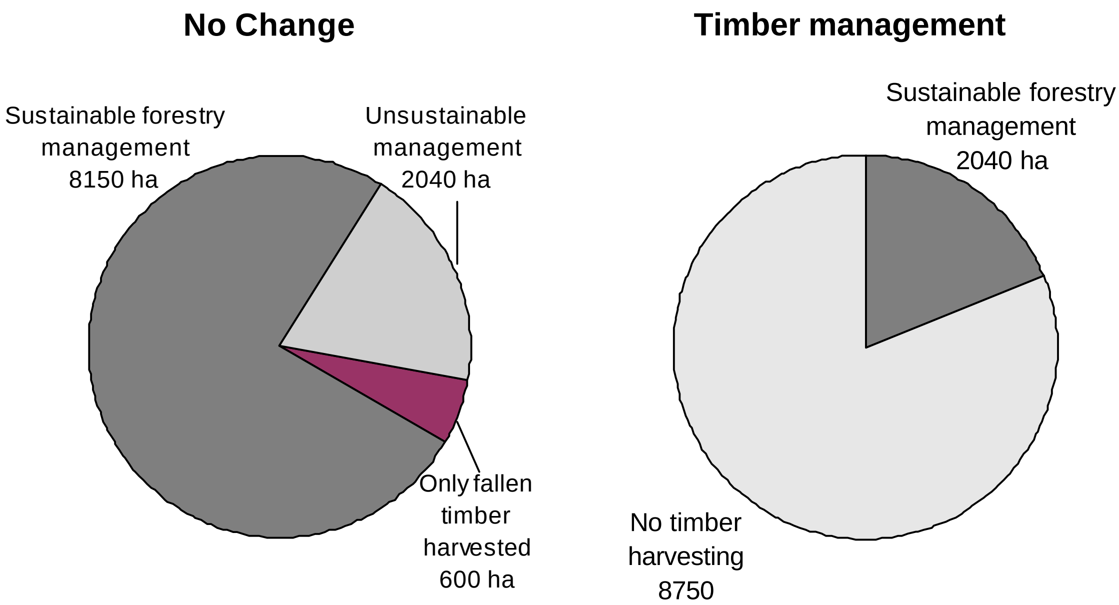


Table 3 shows the difference between the 'timber management' strategy and the 'no change in wetland management' strategy for several descriptive attributes. The ecological outcomes of this strategy implemented in isolation (that is without grazing management or water management) are limited. Increased snags and other coarse woody debris in wetlands and watercourses would increase resulting in increased habitat for fish in particular but also increased bird, reptile and invertebrate habitat (MacNally 1998, 1999). Woodland birds would benefit in the short term and waterbirds in the longer term. The benefits are quantified as follows:

- The area of healthy wetlands is unchanged;
- The increase in snags over the period might allow restocking of native fish to 25 percent of historical levels;
- Water and woodland bird numbers increase to 50 percent of historical numbers; and,
- Once the coarse woody debris load exceeds 50 tonne per ha native mammal species can be expected to benefit significantly (but the time to accumulate and the degree of benefit are not quantified).

TABLE 3: DIFFERENCE BETWEEN 'TIMBER MANAGEMENT' AND 'NO CHANGE IN WETLAND MANAGEMENT'

Descriptive attribute	**Unit**	**Difference**	**Percentage difference**
Agricultural productivity	dse	0	0%
Timber productivity – sawn timber	m^3	15,280	-43.9%
Timber productivity – Residue timber	m^3	31,156	-42.7%
Fencing distance required	km	0	0%
Water diverted from irrigation	Ml	0	0%

Combined management strategies

It is possible to conceive of four potential mixes of the three management changes indicated above (water and grazing, water and timber, timber and grazing, and water, grazing and timber). However, only the combination of all three strategies is defined in this report. This is because only a combination of all three strategies is sufficient to differentiate significantly the outcome from the stand alone management changes.

The combined strategy would employ the 'water management', 'grazing management' and 'timber management' assumptions as explained in the 'combined strategies' section above. Hence the one third of floodplain wetlands for which hydrological management are considered would have reduced grazing pressure, reduced timber harvesting impacts and a near natural flood regime (in terms of regularity of inundation). Closely surrounding areas (an additional 17 percent of the floodplain) would benefit from the implementation of the grazing and timber management strategies, but not the hydrological management strategy. The change in landuse that would result is shown in Figures 12 and 13. In summary, for the 50% of total floodplain wetlands where management changes are proposed:

- 60% (30% of all floodplain wetlands) would not be grazed or logged and two thirds would return to a near natural flood frequency;
- 30% (15% of all floodplain wetlands) would be subject to a rotational or crash grazing strategy incorporating some environmental goals, again two thirds of these would return to a near natural flood frequency. Some of these wetlands would also be subject to sustainable timber harvesting; and,
- The remainder would be subject to continued degradation.

Table 4 summarises the difference between the 'no change to wetland management' and 'combined' strategies. Total agricultural productivity of the wetland area is reduced by 29.9%, timber yield by approximately 43%, 41 Gigalitres[7] is diverted from irrigation and 720 km of fencing is required.

TABLE 4: DIFFERENCE BETWEEN 'COMBINED STRATEGIES' AND 'NO CHANGE IN WETLAND MANAGEMENT'

Descriptive attribute	**Unit**	**Difference**	**Percentage difference**
Agricultural productivity	dse	-15,539	-28.1%
Timber productivity – sawn timber	m^3	-15,280	-43.9%
Timber productivity – Residue timber	m^3	-31,156	-42.7%
Fencing distance required	km	720	42.0%
Water diverted for irrigation	Ml	-41,700	-1.67%

[7] Water diverted from irrigation would be purchased and does not comprise part of the current environmental allocation.

The ecological changes as a result of the combined strategies are larger than those described above due to a synergistic response. The number of species would not change as this is determined by events outside the study area. Wetland and buffer strip vegetation would return to healthy levels albeit with an increased weed population in buffer strips. The population of water and woodland birds, fish, frogs and terrestrial vertebrate and invertebrate species would all significantly increase. There would also be a corresponding increase in feral species that would require control (possibly including carp). There would also be a minor improvement in riverine water quality but this would not be sufficient to change usage patterns or costs. The ecological improvements are loosely quantified as follows:

- the area of healthy wetlands increases to 13,500 hectares;
- the population of water and woodland birds returns to 70 percent of historical levels; and,
- the stocking capacity of native fish returns to 40 percent of historic levels.

4.3 Comparison of strategies

A summary comparison tabulation of the alternative strategies is provided in this section. The summary tabulation is provided in two formats:

- A comparison of differences between the outcomes of the potential management strategies and those of the ‘no change in wetland management’ strategy;
- A comparison of the potential biophysical management strategy outcomes at the aggregate level.

Comparison with ‘no change in wetland management’

A comparison of the ‘no change in wetland management’ strategy against the alternative strategies described is provided in Table 5. The percentage change is also shown in Table 5. The comparison includes the change in landuse and the impact on descriptive attributes. For example, the ‘grazing management’ strategy shows grazed wetland area falling area rising resulting in lower productivity, increased fencing required.

TABLE 5: DIFFERENCE BETWEEN ‘NO CHANGE IN WETLAND MANAGEMENT’ AND OTHER STRATEGIES

Descriptive Attributes	**Unit**	**Water management**	**Grazing management**	**Timber management**	**Combined strategies**
Water purchased from	Ml	41,700	0	0	41,700
irrigation	*(%)*	*(1.7)*	*(0.0)*	*(0.0)*	*(1.7)*
Set stocking rate	ha	0	-8259	0	-8259
	(%)	*(0.0)*	*(-38.1)*	*(0.0)*	*(-38.1)*
Rotational or crash	ha	0	-2296	0	-2296
grazing management	*(%)*	*(0.0)*	*(-9.6)*	*(0.0)*	*(-9.6)*
No grazing	ha	0	10,555	0	10,555
	(%)	*(0.0)*	*(172.4)*	*(0.0)*	*(172.4)*
No logging	ha	0	0	8745	8745
	(%)	*(0.0)*	*(0.0)*	*(42.5)*	*(42.5)*
Fallen timber harvesting	ha	0	0	-596	-596
	(%)	*(0.0)*	*(0.0)*	*(-18.0)*	*(-18.0)*
Sustainable timber	ha	0	0	-6111	-6111
Harvesting	*(%)*	*(0.0)*	*(0.0)*	*(-42.6)*	*(-42.6)*
Unsustainable timber	ha	0	0	-2039	-2039
harvesting	*(%)*	*(0.0)*	*(0.0)*	*(-50.0)*	*(-50.0)*
Total productivity	dse	0	-15,539	0	-15,539
	(%)	*(0.0)*	*(-28.1)*	*(0.0)*	*(-28.1)*
Sawn timber yield	ha	0	0	-15,280	-15,280
	(%)	*(0.0)*	*(0.0)*	*(-43.9)*	*(-43.9)*
Residual timber yield	ha	0	0	31,156	31,156
	(%)	*(0.0)*	*(0.0)*	*(-42.7)*	*(-42.7)*
Fencing required	km	0	718	0	718
	(%)	*(0.0)*	*(42.0)*	*(0.0)*	*(42.0)*

Note: Data in this table may differ slightly from data in figures and text due to rounding.

Aggregate comparison of biophysical strategies

Whereas Tables 5 indicates differences for each descriptive attribute Table 6 reports indicators for each attribute.

TABLE 6: ATTRIBUTE TOTALS BY STRATEGY

Physical management description	No Change (ha)	Hydrological management (ha)	Grazing management (ha)	Timber management (ha)	Combined management (ha)
Hydrology					
Too Wet	1540	1069	1540	1540	1069
Too Dry	46,871	31,325	46,871	46,871	31,325
Unknown *	193	193	193	193	193
Approx natural	0	16,017	0	0	16,017
Total	*48,604*	*48,604*	*48,604*	*48,604*	*48,604*
Grazing					
Set Rate	21,690	21,690	13,432	21,690	13,432
Rotation	23,916	23,916	21,619	23,916	21,619
No grazing	6124	6124	16,679	6124	16,679
Total ^	*51,730*	*51,730*	*51,730*	*51,730*	*51,730*
Total production (dse)	*55,395*	*55,395*	*39,856*	*55,395*	*39,856*
Timber harvesting					
No logging	20573	20573	20573	29319	29319
Fallen timber	3306	3306	3306	2710	2710
Sustainable	14336	14336	14336	8225	8225
Unsustainable	4078	4078	4078	2039	2039
Total red gum wetland area	*42294*	*42294*	*42294*	*42294*	*42294*
Sawn timber (m^3)	34,790	34,790	34,790	19,509	19,509
Residue (m^3)	72,885	72,885	72,885	41,729	41,729
Other attributes					
Fencing (km)	1687	2406	1687	1687	2406

* Unknown are the wetlands that are ‘natural dominant’ in Thornton and Briggs (1994).

^ The total area subject to potential management change is larger than the total wetland area as it includes buffers strips around wetlands.

5 Discussion and conclusions

A range of alternative potential management strategies and their outcomes has been presented for the Murrumbidgee River floodplain wetlands between Wagga Wagga and Hay in this paper. The strategies are designed to reveal the biophysical impacts on wetlands from changes to the management of wetlands or water management in this area. The biophysical outcomes for wetlands differ significantly across the range of potential strategies defined.

As the level of biophysical values provided by wetlands changes, the values provided by the wetland ecosystems are also hypothesised to change. The values are likely to change in several ways:

1. The total (aggregate) value generated from wetland ecosystems will change under alternative strategies.
2. The mix of private and social values generated by wetlands under alternative strategies will change. For example reducing grazing pressure in wetlands is likely to increase community values while reducing private values.

Hence changes in value to both the community and private wetland owners must be taken into account.

The next phase of the research project will involve estimating the change in value to both the community and wetland owners. The change in value comprises a cost and a benefit component. Costs are mainly associated with the cost to wetland owners of changing management to achieve the alternative potential biophysical strategies. Benefits are provided to both the community and private wetland owners (see Whitten and Bennett 2000, 1998 for example). The costs of achieving each strategy include capital costs, ongoing costs and costs due to foregone opportunities. Benefits are more difficult to estimate and relate to both use and non-use values of wetland areas. Comparing the costs and benefits provides a decision framework for determining whether a particular strategy will be pursued.

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Appendix 1 Detailed description of biophysical outcomes

Additional details describing the strategies defined in Sections 4.1 and 4.2 above are provided in this Appendix. The study area comprises floodplain wetlands between Wagga Wagga and Hay. Floodplain wetlands are defined as those areas that retain water following flooding. The extent of the floodplain is defined as the approximate height of the 1974 flood following Thornton and Briggs (1994). Where areas are unchanged from the 'no change to wetland management' strategy, there is no discussion. For example grazing management is unchanged except as part of the 'grazing management' strategy and the 'combined management' strategy.

A1.1 Common starting point biophysical conditions

The year 2000 is used as the starting point for the analysis. Some data are sourced from periods prior to 2000 including basic wetland data (1994) and wetland use data (mainly from Whitten and Bennett 1999). These data are not expected to have changed substantially between collection and present.

Wetland area and hydrological management – common starting point

Wetland area is based on Thornton and Briggs (1994). These data do not include open water wetlands less than one hectare or less than fifty metres in width. Hence the data were adjusted upwards by 1520 hectares. Thornton and Briggs (1994) specify red gum and open water wetlands. A third class of 'deep water' wetlands was split from these, as such wetlands are relatively permanent and function in differing ways to shallow wetlands. The split between crown land and freehold land was also provided in Thornton and Briggs (1994). Table A1.1 shows wetland types and tenure.

TABLE A1.1: COMMON STARTING POINT WETLAND AREA AND TENURE (2000)

Wetland Type	**Freehold land ha**	**Crown land ha**	**Total area ha**
Red gum	30,896	11,397	42294
Open water	1973	535	2508
Deep wetlands	2790	1013	3802
Total	35,658	12,946	48,608

Source: Thornton and Briggs (1994), adjusted for an assumed 1520 hectares of small wetlands that were not included.

These wetlands can also be split according to whether they are too wet, too dry and a small area of wetlands for which modified use has made them difficult to classify (unknown). The starting wetland areas are shown in Table A1.2.

TABLE A1.2: COMMON STARTING POINT WETLAND AREA AND TENURE (2000)

Wetland Type	**Too wet Ha**	**Too dry ha**	**Unknown ha**
Red gum	14	42280	0
Open water	214	2252	43
Deep wetlands	1313	2340	150
Total	1540	46871	193

Source: Wetlands classified as 'category 1 = no control' and (category 3c = medium control, drained or levied) by Thornton and Briggs are classified as 'too dry', categories 3a, 3b, 4a and 4b are all classified as too wet and categories 2a and 2b as 'unknown'. See Footnote 3 for more details.

Grazing management and productivity – common starting point

Current grazing management was estimated from Whitten and Bennett (1999) for freehold land and discussions with NSW State Forestry Officers for crown lands. Grazing management estimates by area are reported in Table A1.3 and productivity in A1.4.

TABLE A1.3: COMMON STARTING POINT GRAZING MANAGEMENT (2000)

Grazing management strategy	**Red gum wetlands (ha)**	**Open water wetlands (ha)**	**Deep wetlands (ha)**
Set stocking rate	17,763	1103	1521
Rotational or crash grazing	19,455	1304	1711
No grazing	5075	100	570
Total	42,294	2508	3802

Source: Areas as for Table A1.1, split by Whitten and Bennett (1999) and discussions with NSW State Forests Officers.

TABLE A1.4: COMMON STARTING POINT GRAZING PRODUCTIVITY (2000)

Grazing management strategy	**Red gum wetlands (dse)**	**Open water wetlands (dse)**	**Deep wetlands (dse)**
Set stocking rate	20,355	613	1743
Rotational or crash grazing	22,294	725	1961
No grazing	0	0	0
Total	42,649	1338	3704

Source: Whitten and Bennett (1999) and discussions with NSW State Forests Officers.

Timber management – common starting point

Current management of timber harvesting from red gum wetlands was estimated from Whitten and Bennett (1999) for freehold land and discussions with NSW State Forestry Officers for crown lands. Coarse Woody debris data is from MacNally (1998, 1999). Timber harvest management estimates by area and production are reported in Table A1.5. Fallen timber only refers to harvest of fallen branches and dead trees for firewood on a commercial basis or live timber for farm use. Sustainable harvest requires a management plan including conservation objectives while unsustainable harvest management generally has either no management plan, or an inadequate management plan.

TABLE A1.5: COMMON STARTING POINT TIMBER MANAGEMENT (2000)

Timber harvest management	**Red gum wetlands (ha)**	**Sawn timber yield (m^3)**	**Residue timber yield (m^3)**
No logging	20,573	0	0
Fallen timber only	3306	0	3306
Sustainable management	14,336	28,672	57,344
Unsustainable yield	4078	6117	12,235
Total	42,294	34,790	72,885

Source: Whitten and Bennett (1999) and discussions with NSW State Forests Officers.

Area fenced – common starting point

The area of wetlands fenced is a crucial factor as this allows alternative and conservation specific management strategies to be adopted. Hence, fencing is likely to be an important cost of altering strategies. The area of wetlands and remnant vegetation currently fenced has been estimated from Whitten and Bennett (1999) and is reported in Table A1.6. The area fenced includes a buffer strip as defined in Section 4.1.

TABLE A1.6: WETLAND AREA CURRENTLY FENCED (2000)

Wetland type	Area (ha)	Distance (km)
Red gum	16,410	1641
Open water	166	8
Deep wetlands	190	38
Buffer strip area	875	Included
Total	17,641	1687

Source: Estimated from Whitten and Bennett (1999).

A1.2 'No change in wetland management' biophysical conditions

There are no significant changes to wetland management envisaged under the 'no change in wetland management' strategy. Hence floodplain wetlands are expected to further degrade as a result of grazing, timber and water management practices. The management strategies by area are expected to continue as described in Section A1.1 and are not reproduced here.

A1.3 'Hydrological management' strategy

The only changes expected under the 'Hydrological management' strategy are to wetland health, hydrological management and ecological outcomes. All other attributes are not expected to change. Wetland health and hydrological management are discussed together below before discussing ecological outcomes.

Wetland health and hydrological management

The 'water management' strategy comprises two key components:
1. Improved wetland management at the individual wetland scale; and,
2. Increased environmental flows and improved flow management.

Improved wetland management at the individual wetland scale involves returning approximately 365 hectares of deep wetlands that are currently too wet to a natural or near natural hydrological regime. Specifically this would involve pumping from the Murrumbidgee River directly and piping to farmers (rather than using wetlands as storages), removal of artificial blockages to flow and recycling of irrigation drainage water prior to entry into wetlands.

Increased and improved hydrological management is defined by Figures 10 and 11. Improved management involves purchasing sufficient water to create an artificial flood approximately five out of six years. Flow rules would be designed to achieve natural or near natural flood frequency and duration. The artificial flood would affect approximately one third of floodplain wetlands (by area) between Wagga Wagga and Hay.

As indicated these wetlands can also be split according to whether they are too wet, too dry and a small area of wetlands for which modified use has made them difficult to classify (unknown). The wetland area for each under the 'water management' strategy is shown in Table A1.7.

TABLE A1.7: 'HYDROLOGICAL MANAGEMENT', WETLAND HYDROLOGICAL STATUS (2015)

Wetland Type	Too wet Ha	Too dry ha	Unknown ha
Red gum	0	28,191	0
Open water	89	1551	43
Deep wetlands	980	1583	150
Total	1069	31,325	193

Source: adapted from Table A1.2.

Hydrological management - ecological outcomes

Most ecological outcomes are likely to improve under this strategy. Algal blooms are likely to decline in wetlands. The restoration of early season floods will increase plant diversity and overall wetland vegetation. There may be a small positive impact on river red gum recruitment. Woodland birds and waterbirds are likely to increase along with increased frequency of waterbird breeding. The species mix of waterbirds and woodland birds within the study area is unlikely to change as these are determined by factors outside the study area (this is the case for all management strategies). The population of small fish in particular is likely to increase but the carp population may also increase. Frogs will also benefit from this strategy.

A1.4 Grazing management strategy

The only changes expected under the 'grazing management' strategy are to grazing management in wetlands, the agricultural productivity arising therefrom, area fenced and ecological outcomes. All other attributes are not expected to change. Hence only grazing management and productivity, area fenced and ecological outcomes are discussed below.

Grazing management and productivity

There are two main changes to grazing management envisioned under this strategy:

1. Grazing is removed from approximately 10,560 hectares; and,
2. The management of 8260 hectares is changes to include wetland health targeted conservation objectives.

Grazing management estimates by area are reported in Table A1.8 and productivity in A1.9. Where grazing is eliminated or where grazing management changes, the area that changes management includes a buffer strip.

TABLE A1.8: 'GRAZING MANAGEMENT' MANAGEMENT BY AREA (2015)

Grazing management strategy	**Red gum wetlands (ha)**	**Open water wetlands (ha)**	**Deep wetlands (ha)**	**Buffer strips (ha)**
Set stocking rate	10,966	677	951	808
Rotational or crash grazing	18,186	1154	1046	1234
No grazing	13,111	677	1806	3802
Total	42,294	2508	3802	

Source: Table A1.3 adapted for changes to grazing management.
Note: The 808 hectares indicated as a 'set stocking rate buffer strip' is the area that would change management if the area currently set stocked were to change management.

TABLE A1.9: 'GRAZING MANAGEMENT' GRAZING PRODUCTIVITY (2015)

Grazing management strategy	**Red gum wetlands (ha)**	**Open water wetlands (ha)**	**Deep wetlands (ha)**	**Buffer strips (ha)**
Set stocking rate	10,966	339	951	4038
Rotational or crash grazing	15,931	577	856	6169
No grazing	0	0	0	0
Total	26,927	915	1806	

Source: Table 1.4 adjusted for changes to grazing management.

Grazing management – area fenced

In order to alter management in wetland areas it is necessary to exclude stock to facilitate the improved management. The tool for stock exclusion is fencing. Table A1.10 shows the area and distance of fencing required under this management strategy.

TABLE A1.10: 'GRAZING MANAGEMENT' WETLAND AREA FENCED (2015)

Wetland type	**Area (ha)**	**Distance (km)**
Red gum	21,147	2115
Open water	1254	63
Deep wetlands	1141	228
Buffer strip area	1411	Included
Total	24,952	2406

Source: Table A1.6 adjusted as per fencing assumptions.

Grazing management - ecological outcomes

Reduced grazing pressure will lead to reduced turbidity and algal blooms in wetlands (that is improved water quality). The improved water quality will increase the use values associated with wetlands as well as the ecological values. Wetland vegetation would significantly improve as a result of this outcome but would also include significant weed populations (it is assumed that weeds that are an ecological problem can be controlled). A small proportion of wetlands (assumed to be 5%) would require revegetation. Woodland bird numbers would increase significantly (as a result of the gradual return of an under-story) and there would be a small increase in waterbirds (invertebrate feeders). Fish and frogs would benefit from this strategy as well. There would be an increased fire risk associated with the increased vegetation when grazing is withdrawn from some areas. The habitat diversity would increase significantly increasing the diversity of these areas including mammals and invertebrates. Feral species populations (especially pigs, foxes and cats) would increase and require control.

A1.5 Timber management strategy

The timber management strategy focuses on the management of timber harvesting in red gum wetlands. The strategy aims to reduce logging and, where logging continues, to reduce the impact of logging on the environment via sustainable forest management practices. The strategy also focuses on the harvesting of coarse woody debris, both in conjunction with logging and for firewood alone. This strategy only impacts on timber harvesting and ecological outcomes hence these are the only attributes discussed below.

Timber management strategy – red gum forest management

There are three main components to this strategy relating to current harvesting practices and conservation aims. The first component is to reducing overall timber harvest from red gum wetlands hence reducing the area of forest subject to disturbance. The second component is to implement sustainable forest management practices in areas that continue to be harvested. The final component is to largely eliminate harvest of fallen timber. The changed timber management practices are shown in Table A1.11.

TABLE A1.11: 'TIMBER MANAGEMENT' STRATEGY OUTCOMES (2015)

Timber harvest management	**Red gum wetlands (ha)**	**Sawn timber yield (m^3)**	**Residue timber yield (m^3)**
No logging	29,319	0	0
Fallen timber only	2710	0	2710
Sustainable management	8225	16,451	32,901
Unsustainable yield	2039	3059	6117
Total	42,294	19,509	41,729

Source: Table A1.5 adjusted for changed timber management.

Timber management - ecological outcomes

The timber management strategy would increase the number of snags in the river along with other coarse woody debris. Hence the habitat area for fish, lizards, snakes, birds and spiders would also increase (Mac Nally 1998, 1999). Mac Nally (personal communication) indicates that once a threshold of 50 tonnes per hectare is reached mammal populations will also benefit significantly. While the very long-term impact would be increased hollows, this is well beyond the time horizon of the study. Woodland birds are likely to benefit in the short term.

A1.6 Combined management strategies

The physical changes as a result of implementing the combined management strategies are defined by Sections A1.3 for wetland area and hydrological management, A1.4 for grazing management and fencing area and A1.5 for timber management. The change in the ecological outcome is defined below.

Combined management strategies - ecological outcomes

The combined strategies would lead to a synergistic response and hence an outcome greater than the sum of the outputs described above. Fish, frogs, waterbirds, woodland birds and wetland vegetation would all benefit in excess of the above descriptions. As indicated the number of species would not change as this is determined by events outside of the case study area. Carp, feral mammal species and weeds all remain a problem. There would also be a minor improvement in riverine water quality (but not of significance for water uses).

Previous Research Reports in the Series

Whitten, S.M. & Bennett, J.W. (1998). *Wetland Eco Systems and Landuse in the Upper South East of South Australia,* Private and Social Values of Wetlands Research Report No. 1, University College, The University of New South Wales, Canberra.

Whitten, S.M. & Bennett, J.W. (1998), *Farmer Perceptions of Wetlands and Wetland Management in the Upper South East of South Australia*, Private and Social Values of Wetlands Research Report No. 2, University College, The University of New South Wales, Canberra.

Whitten, S.M. & Bennett, J.W. (1999). *Potential Upper South East Regional Wetland Management Strategies*, Private and Social Values of Wetlands Research Report No. 3, University College, The University of New South Wales, Canberra.

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Whitten, S.M. & Bennett, J.W. (2000). *Farmer perceptions of wetlands and wetland management on the Murrumbidgee River between Wagga Wagga and Hay including Mirrool Creek*, Private and Social Values of Wetlands Research Report No. 5, University College, The University of New South Wales, Canberra.