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VALUING ENVIRONMENTAL FLOWS FOR WETLAND REHABILITATION: AN APPLICATION OF CHOICE MODELLING IN THE MACQUARIE VALLEY

CASE STUDY: AUSTRALIA

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FOREWORD

This report was contributed as a national case study to an OECD project on the Applied Evaluation of Biodiversity, being carried out by the Working Group on the Economic Aspects of Biodiversity. It does not necessarily reflect the views of individual OECD Member countries or of the OECD Secretariat. It is published under the responsibility of the Secretary General.

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VALUING ENVIRONMENTAL FLOWS FOR WETLAND REHABILITATION: AN APPLICATION OF CHOICE MODELLING IN THE MACQUARIE VALLEY

by

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Executive Summary

The application reported in this case study involves the Macquarie Marshes, an ephemeral wetland on the Macquarie River in north-west New South Wales (NSW), Australia. Flooding in the Marshes has declined over the last 50 years and the use of irrigation has increased considerably in the Macquarie Valley since the construction of Burrendong Dam on the Macquarie River in 1967. The allocation of Macquarie Valley water to irrigation and away from the Macquarie Marshes has resulted from a fundamental imbalance in the market for water. The objective of the valuation exercise was the estimation of the non-use environmental values provided by the Macquarie Marshes. Specifically, the project sought to identify the monetary value the wider community has for improved environmental quality of the Marshes associated with the reallocation of water from irrigation agriculture to environmental flows for wetland rehabilitation.

Ecosystem or species studied: Wetlands and associated birdlife.

Valuation method used: Choice modelling.

Main lessons learned: The case study has demonstrated the potential of the Choice Modelling technique for estimating non-marketed values in the context of policies involving environmental impacts. The technique was shown to be capable of yielding estimates that are cost-effective to obtain because an array

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of values can be estimated from a single application. The flexibility to estimate values across a number of policy uses is also notable. For instance, through the decomposition of values into their component "implicit prices" policy makers are able to explore the potential of different policy options in achieving socially desirable outcomes.

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1. General Description[5]

Description of the ecosystem

The application reported in this case study involves the Macquarie Marshes, an ephemeral wetland on the Macquarie River in north-west New South Wales (NSW), Australia (see Fig. 1 and 2). The Macquarie Marshes were originally the largest wetlands in NSW, with an area of about 5000 km^2. They have now contracted to an area of around 2,200 km^2 . An 18,150 hectare Nature Reserve that is contained in the Marshes, is listed as a wetland of international importance under the Ramsar Convention, and is also listed by the National Trust of Australia (NSW) and the Australian Heritage Commission. The Marshes have a number of significant environmental values. They provide an important habitat for waterbirds and act as a filter that improves downstream water quality. They also provide high quality stock feed for sheep and cattle grazing enterprises.

Description of main impacts

Flooding in the Marshes has declined over the last 50 years. Kingsford & Thomas (1995) report that the area affected by large floods contracted by 40-50% between 1944 and 1993. This is primarily because of reduced flows into the Marshes. Kingsford & Thomas (1995) found that the area flooded in the Macquarie Marshes was significantly related to the total annual flow of water at Oxley (see Figure 2) over the previous 12 months during the period 1983-1993[6]. Reduced flooding also results from erosion of channels which has increased the amount of flow required before water will leave river channels and inundate parts of the southern Marshes. For example, in 1968 a flow of 300 ML/day was required to flood the reedbeds on Monkeygar Creek, whilst in 1992 a flow of 1000 ML/day was required to achieve the same result (Brereton 1993).

The frequency of high and medium floods reaching the Marshes has decreased (Brereton 1994; Kingsford & Thomas 1995) and the proportion of low flows has sharply increased (NSW EPA 1995). Furthermore, in summer the Marshes would previously have been dry 20% of the time, but now there is a continual low flow of about 300 ML/day, although this low flow is quite variable. Operational excesses and irrigation tailwaters cause this continual flow. This changed water flow regime has caused numerous environmental impacts:

- Native vegetation cover and health have declined and exotic species of plants have affected large areas in the Marshes.
- Waterbirds have declined significantly in the number of species, population and overall density.
- Native fish populations appear to have declined in abundance and diversity, while introduced species – particularly European carp (*Cyprinus carpio*) and gambusia (*Gambusia holbrooki*) – have increased in abundance.
- Water quality monitoring and flow data suggest that during low flow periods, water remains within channels and erosion of channel beds and banks occurs. As a result, total phosphorus, total nitrogen and suspended solids concentrations at downstream monitoring sites have often been greater than at the upstream monitoring sites.

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5 See Morrison, and Bennett (1997) for more details.

6 $\log(\text{Area,ha}) = -8.47 + 1.39 \log(\text{flow, ML/year})$ $R^2 = 0.859$, $p<0.001$

Identification of main sources of these impacts

The use of irrigation has increased considerably in the Macquarie Valley since the construction of Burrendong Dam on the Macquarie River in 1967. Irrigated agriculture is now one of the largest components of total agricultural production in the valley. A consequence of the increase in the use of water for irrigation is that the amount of water reaching the Macquarie Marshes has fallen substantially.

The increased use of on-farm storages has also resulted in lower flows of water reaching the Marshes. On-farm storages refer to dams away from the river and other structures that can be used to store water for irrigation.

As described in 1.2, the result of these changes to the flow regime has been a substantial decline in the condition and size of the wetland and its biota.

Identification of key objectives of the valuation exercise

In 1994 the Council of Australian Governments (COAG) agreed to the establishment of the COAG Water Reform Framework. The aim of the framework is to progress the efficient and sustainable reform of the Australian water industry. In 1995 the framework was subsequently tied to the National Competition Policy Agreement. Under this Agreement, implementation and continued observance of the COAG water reforms, along with similar reforms in the transport, gas and electricity sectors, is a requirement for States and Territories to receive the $16 billion in National Competition payments. The framework is to be implemented over the period to 2005/6. This case study covers some of the issues to be addressed by the framework including the allocation of water to the environment, clarification of property rights, public consultation and participation.

Few Australian rivers remain unaffected by human activities. Major human-induced changes in flow regimes have contributed to aquatic and riparian degradation. Balancing the needs of the environment - the flows required to maintain and restore healthy rivers - with water allocation for consumptive uses is a major task for Australian governments and communities. With achieving this balance in mind, the COAG Water Reform includes objectives that are concerned with the examination of the values and externalities associated with the alternative uses of water resources. One of the most significant outcomes to which these processes can contribute is the identification and allocation of adequate environmental flows in Australian river systems.

Environmental flows are critical for maintaining the health of the waters and rivers upon which ecosystems and industries depend. The timing, quantity and duration of flows and the quality of our waters are inexorably linked and depend upon the interactions between the catchment, floodplain, wetland, groundwater and stream. This case study specifically examines the values associated with environmental flows to the Macquarie Marshes and provides valuable information for the water reform processes.

Because of the competing nature of alternative uses of water in the Macquarie Valley, significant improvements in wetland quality are likely to occur only if there is a reduction in the amount of water allocated to irrigated agriculture. This will involve cost and benefits to the community. Information on the magnitude of these costs and benefits will assist decision-makers seeking socially optimal trade-offs involving the allocation of water between irrigation and wetland uses. While information is available in conventional markets for goods and services to estimate the cost to the community from reductions in agricultural production and many of the use benefits associated with improved wetland quality, little information is available on the non-market values of improved wetland quality. The key objective of this case study is to apply and develop a non-market valuation technique known as Choice Modelling to provide estimates of these wetland rehabilitation benefits through increasing environmental flows to the area.

2. Identification of causes and sources of pressures

2.1 Identification of sectoral activities and resulting pressures

The main economic activity in the Macquarie Valley is agriculture. The total area of crops and pastures in the Macquarie Valley in 1993 was 639,321 hectares (ha). About 14.5% of this area, or 93,000 ha, was irrigated. The irrigated agriculture sector is dominated by the production of cotton. Cotton production generates the highest total revenue of the irrigated crops in the Valley. Irrigated cotton uses more than 50% of regulated water in the valley and accounts for about 44% of total irrigated area (DLWC 1995). There are other irrigated crops such as cereals and wheat, oilseed, citrus, lucerne, pasture and fodder, vegetables and vines. Cotton is also the most valuable irrigated crop in the Macquarie Valley on a per hectare basis, with the gross margin for cotton reported to be $870/ha (NSW Agriculture 1994). The next highest gross margins are for irrigated summer cereal ($500/ha) and irrigated lucerne ($500/ha).

In Table 1, annual water allocations on the Macquarie River are reported. Approximately 30% of the water allocated for irrigation goes to four joint water supply schemes[7].

The use of on-farm storages for irrigation is also significant. DLWC (1995b) report that on-farm storage of water in the Macquarie Valley increased from 15,000 ML capacity in 1986 to an estimated 75,000 ML in 1995. These storages are often used to store water from floods originating downstream of Burrendong Dam, or from dam spills.

Table 1 **Annual allocation of regulated surface water on the Macquarie River and its effluents, September 1990**

Allocation	Macquarie River and effluents (ML/yr)	Percentage of total allocation
Town water supply	18,465	2.7%
Recreation	552	0.1%
Stock	2,356	0.3%
Industrial/Mining/Sand & Gravel	1,423	0.2%
Irrigation	598,758	88.6%
Horticulture, citrus, grape vines and other permanent plantings	3,188	0.5%
Domestic	1,332	0.2%
Macquarie Marshes Wildlife Allocation[8]	50,000	7.4%
Total	**676,074**	

Source: DWR (1991).

7 Narromine-Trangie Irrigators' Cooperative, Buddah Lakes Irrigators' Association, Tenandra Cooperative Society and Trangie-Nevertire Cooperative Limited.

8 In 1995 this was expanded to 125,000 ML p.a., comprising 75,000 ML of general security and 50,000 ML of high security water (DLWC & NPWS 1996)

As noted in Section 1, a consequence of increasing use of water for irrigation has been a reduction in the amount of water reaching the Macquarie Marshes and a change in the timing of flows that do reach the wetland.

The use of pesticides, notably endosulfan, in irrigated agriculture has also caused water quality concerns in the water reaching the Macquarie Marshes.

2.2 Identification of underlying causes of biodiversity loss

Missing markets or non-existent property rights

The allocation of Macquarie Valley water to irrigation and away from the Macquarie Marshes has resulted from a fundamental imbalance in the market for water. After the construction of the Burrendong Dam, water was made available to irrigators who applied for the available supply because of its potential to yield profit. No such profit motive existed for the supply of water to maintain the Macquarie Marshes ecosystem[9]. The benefits of protecting the wetland biodiversity are predominantly public goods and demands for these benefits could not be translated into bids for water that could compete against the bids derived from irrigated agriculture.

Information failure

At the time of the construction of the Burrendong Dam, little was known regarding the significance of the Macquarie Marshes as an ecological system. Furthermore, there was little understanding of the impact that irrigation would have on the wetlands. Over time, with increasing knowledge, there has been a growing public recognition of the importance of biodiversity protection in the Macquarie Marshes and hence a growth in demand for the public goods they supply. However, in the absence of any effective market vehicle whereby this demand could be effected, reliance has been placed on the public sector to ensure an allocation of water between irrigation and environmental protection uses that maximises community well-being. Water managers seeking this optimal trade-off also face challenges in identifying information on the values generated by irrigation and environmental protection. Irrigators are reluctant to reveal their financial positions for business reasons. However, it is comparatively straightforward for water managers to estimate irrigation generated benefits because market data relevant to the situation are readily available. Corresponding market data relevant to environmental protection are not available and so more complex non-market valuation techniques are required.

2.3 Identification of adverse incentives with negative impacts on biological diversity

Direct and indirect subsidies

The original intention of the government that initiated the construction of the Burrendong Dam was the development of irrigated agriculture in the Macquarie Valley and the minimisation of impacts associated with the flooding of towns in the lower Macquarie Valley such as Dubbo. The general goal was to generate prosperity that was free from the threat of drought and flood in the inland areas of NSW. In accord with this goal, water was supplied at a price well below marginal cost. There was no component in

9 It was only after the commencement of irrigation development that graziers in the Macquarie Marshes realised that their profit potential was highly dependent on the flows of water that had previously inundated the wetlands.

the price charged from the cost of infrastructure and even variable costs were not fully covered. Hence, water was supplied at a heavily subsidised price. It has only been in the last decade that water prices have approached marginal cost levels. The price charged has incorporated a component for "infrastructure provision" but has not however included a component to reflect the opportunity costs of environmental benefits foregone.

3. Impacts on ecosystems

Impacts on genetic and species diversity

Vegetation

Brereton (1994) reports that the area of river red gums[10] in the Monkeygar and Bulgeraga Creek areas (the southern Marshes) has decreased form 21,277 ha in 1949 to 18,326 ha in 1991, a decline of 14%. In another study of an area within the southern Marshes, Brander (1987) estimated that the area of river red gums fell from 1407 ha in 1934[11] to 636 ha in 1981, a decline of about 55%. Waterlogging has killed some of these redgums, but the majority have been killed by reduced flooding and clearing. There has also been a reduction in black box, coolabah and poplar box since 1949 (actual reduction not reported) (Brereton 1994)

In the southern marshes there have been declines in the area of phragmites and cumbungi, however these areas have increased in a few areas within the northern marshes, because of ponding from constant low flow. Brereton (1994) reports that water couch, which is important feed for stock and waterbirds, has decreased in the Monkeygar and Bulgeraga Creek area by 40% between 1949 and 1991.

Exotic species have affected large areas in the Marshes. These include Lippia (*Phyla nodiflora*), which was initially used in the area as a substitute for grass in lawns, Noogoora burr (*Xanthium occidentale*), Bathurst burr (*Xanthium spinosum*) and roly poly[12] (*Sclerolaena quiquecuspis*). These species take over from water couch when there are reduced flows.

Waterbirds

Waterbird breeding events provide an indication of wetland health. NPWS & DLWC (1995) list four requirements for successful waterbird breeding events. These are the existence of living river red gums, flooding of sufficient volume (at least 250,000 ML at Oxley), flooding of sufficient duration (from 5.5-7 months, depending on the season) and flooding at a suitable time of year. As a result of changes in these parameters, the numbers of waterbirds breeding has declined (Johnson 1994). Limited empirical evidence is, however, available about the extent of the reduction.

Empirical evidence is available about the effect of reduced flooding on the changes in the numbers and diversity of waterbirds. Kingsford & Thomas (1995) examined the relationship between flooding and trends in waterbird populations in the Macquarie Marshes between 1983 and 1993. They surveyed approximately 25% of the area of the Marshes, as well as other control areas. A significant decline in the number of species and the density of waterbirds was found. Recent results show that there

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10 River red gums are important for the breeding of a number of waterbird species (NPWS & DLWC, 1995)

11 The study area in 1934 was 9200 ha and in 1981 it was 11,877 ha. Hence this is probably an underestimate.

12 Roly poly is a native plant.

has been a significant decline in the number of waterbirds in the Macquarie Marshes between 1983 and 1995 (Kingsford, pers. comm.). The number of waterbirds in the Marshes was also found to increase significantly with areas flooded (Kingsford & Thomas 1995).

Native fish populations

The native stocks of fish in the Macquarie Marshes appear to have declined in abundance and density, while introduced species – particularly European carp (*Cyprinus carpio*) and gambusia (*Gambusia hobrooki*) – have increased in abundance. As well as impacts from the introduction of European carp, the decline in native fish stocks may have been affected by streamflow regulation which has resulted in releases of colder water from Burrendong Dam, reduced flows entering the Marshes and reduced flow variability (Swales 1994).

There have been several fish surveys in the Macquarie Marshes, which suggest that native fish species have declined. Rankine & Hill (1979) report on a survey of four sites in the southern Marshes by NSW Fisheries[13]. Four species were caught: European carp, golden perch (*Macquaria ambigua*), freshwater catfish (*Tandanus tandanus*) and bony herring (*Nematolosa erebi*). The majority of fish were European carp. Swales (1994) reports the results of a survey of fish in the Marshes where native fish species were extremely low. Few golden perch and freshwater catfish, good numbers of bony herring, and no silver perch (*Bidyanus bidyanus*) were caught in (Swales 1994). Swales & Curran (1995) also report declining numbers of native fish. Beside two introduced species, five native species were recorded in a survey in 1995: golden perch, bony herring, rainbow fish (*Melanotaenia fluviatilis*), Australian smelt (*Retropinna semoni*) and western carp gudgeon (*Hypseleotris kluningere*). Silver perch and freshwater catfish were not recorded during this survey

Reptiles, amphibians and aquatic invertebrates

Aquatic invertebrates are an indicator of the diversity of wetland habitats. The Marshes have a rich diversity of invertebrates. Bray (1994) found 197 taxa, with the majority being insects. It was also found that channels with slowly flowing water, such as lagoons, tended to have much greater diversity. No data are available on how the diversity of invertebrates has changed due to increased regulation and consumptive use of flow.

Three species of frog (*Limnochynastes fletchers, L. tasmaniensis and Crinis sp.*) are associated with permanent water habitats in the wetlands (Brereton 1994). It was found that these species were less abundant in the southern Marshes where there was little flooding at the time of the survey compared to flooded semi-permanent wetland areas.

Impacts on ecosystem in general

Water quality

Water quality is monitored at two places upstream of the Macquarie Marshes: Bulgeraga at Oxley Road and the Macquarie River at Oxley Station. Downstream of the Marshes, water quality in the Macquarie River is monitored at Carinda. Water quality monitoring and flow data from these sites suggest that the Macquarie Marshes improves downstream water quality by filtering total phosphorus, total

13 Reported in Brereton (1993)

nitrogen and suspended solids under certain conditions (DWR 1994a, DLWC 1995a). Filtering occurs when flow levels are large enough for water to leave the channels within the Marshes and spread overland through vegetated areas. This typically occurs when the Northern Bypass Channel, which carries between 50-100 ML/day, is closed and when flow levels within the Marshes are several hundred megalitres per day or greater (DWR 1994a). During low flow periods, water remains within channels and erosion of channel beds and banks occurs. As a result total phosphorus, total nitrogen and suspended solids concentrations at Carinda have often been greater than at the upstream monitoring sites. There are sufficient high flow periods, however, for the Macquarie Marshes to reduce total phosphorus, total nitrogen and suspended solid loads in the Macquarie River (DLWC 1995a). DWR (1994a) estimated that the total phosphorus load at Carinda was about half the load at Oxley Station during 1993/94.

4. Impacts on economy and welfare: Rationale for the valuation method chosen and results

4.1 The valuation method

Valuation objectives

The objective of the valuation exercise was the estimation of the non-use environmental values provided by the Macquarie Marshes. Specially, the project sought to identify the monetary value the wider community has for improved environmental quality of the Marshes associated with the reallocation of water from irrigation agriculture to environmental flows for wetland rehabilitation.

Choice Modelling

The main stated preference technique used for estimating non-market values, the contingent valuation method, has several perceived deficiencies and/or limitations (Kahneman and Knetsch 1992; Diamond and Hausman 1994, McFadden 1994). As a result, economists have shown interest in the use of alternative stated preference techniques for estimating non-market values.

One alternative is choice modelling[14] (see Bennett and Blamey, forthcoming). In choice modelling questionnaires, respondents are presented with a series of choice sets, each containing, usually, three or more resource use options. Each option in the choice sets is described using a common set of attributes. The options vary by taking on different levels. These levels systematically vary across options according to an experimental design (see Bunch, Louviere and Anderson 1993, Lazari and Anderson 1994). Similar to other stated preference techniques, in a choice modelling questionnaire there is a description of the study site, details of the proposed changes and a series of socio-economic and attitudinal debrief questions.

One of the advantages of this technique is that it is possible to determine, separately yet simultaneously, the importance of economic, social and environmental factors in a valuation exercise (Swallow, Opaluch and Weaver 1992).

In choice modelling applications, non-monetary factors such as environmental quality and employment opportunities, as well as monetary factors such as an income tax levy can be included as attributes of the options in a choice set. This makes it possible to determine the relative importance of these attributes to people in making their choices. Because monetary and non-monetary attributes are included, choice modelling results can be used to estimate the value of the non-monetary attributes.

14 Also know as choice experiments.

Another advantage of choice modelling is its incentive compatibility properties. The concept of incentive compatibility was used by Randall and Hoehn (1987) in order to compare the potential of different response formats for strategic understatement of willingness to pay. Randall and Hoehn (1987) concluded that the dichotomous choice contingent valuation format, in which respondents choose whether they are willing to support a proposal at a fixed cost, has strong incentive compatibility properties (i.e. respondents will be truthful in their answers). In order to reach this conclusion, two assumptions were made: (1) that the policy will be implemented if a plurality of citizens approves it (i.e. majority rule); and (2) the respondent is *uncertain* about how other citizens will vote. Given these assumptions, each individual is believed to compare the cost of the proposal with their estimate of the Hicksian compensating surplus that they would receive from the change. If the surplus is higher that the cost then they would support the proposal. This is an optimal strategy because if the project does not go ahead they will suffer utility loss. These properties also hold for choice modelling applications where respondents evaluate several generic options in a choice set. Given uncertainty about the actions of others and majority rule, the optimal strategy is also for respondents to indicate which alternative provides them with the greatest net-benefit.

Implementation procedures

Questionnaire Development and Description

The questionnaire used for this case study was developed using the results from eight focus groups and a pre-test (see Morrison, Bennett and Blamey 1997a). The focus groups were used to determine the attributes that should be included in the choice sets, and to refine a draft questionnaire. A pre-test of 50 respondents was undertaken in June 1997 in Sydney, the capital city of NSW. On the basis of the pre-test, minor modifications to the questionnaire were required.

In the questionnaire, respondents were told that there were three broad options available for the management of the Macquarie Marshes: to continue the current situation, to increase water for the wetlands, or to increase water for irrigation. The scenario presented to respondents was that it would be possible to purchase water for the wetlands from farmers on the existing water trading market. This would mean that the sale of water rights would be voluntary and farmers would be compensated for giving up the right to water. The rationale given for farmers being willing to sell water is that the funds received would allow them to install more water efficient irrigation equipment and that some farmers may choose to revert to dryland farming. Respondents were told that the Government did not have sufficient money to purchase the water from existing revenue and that it would be necessary to charge households in New South Wales a one-off levy on water rates in 1998.

Respondents were then presented with six choice sets showing various options for the Macquarie Marshes, the first of which was an example (see Table 1). The options in the choice sets were defined using five different attributes: water rates, irrigation related employment, wetlands area, frequency of waterbird breeding and endangered and protected species present[15]. Respondents were told that five sets of possible options had been prepared and were then asked for their preferred choice from each set of options. Finally, before answering the choice sets, respondents were requested to keep in mind their available income and other things on which they may need to spend money. They were also reminded that other environmental projects may cost them money in the future.

15 The attribute levels used in the choice sets were: water rates (\$0, \$20, \$50, \$150), irrigation related employment (4400 jobs, 4350 jobs, 4250 jobs), wetlands area (1000 km², 1250 km², 1650 km², 2000 km²), frequency of waterbird breeding (every 4 years, every 3 years, every 2 years, every year) and number of endangered and protected species present (12 species, 15 species, 20 species, 25 species).

Table 2 **Example of Choice Set from the Macquarie Marshes Questionnaire**

Outcome	Option 1: Continue current situation	Option 2: Increase water to Macquarie Marshes	Option 3: Increase water to Macquarie Marshes
Your water rates (one-off increase)	No change	$20 increase	$50 increase
Irrigation related employment	4400 jobs	4350 jobs	4350 jobs
Wetlands area	1000 km²	1250 km²	1650 km²
Waterbirds breeding	every 4 years	every 3 years	every year
Endangered and protected species present	12 species	25 species	15 species

- ❑ I would choose option 1
- ❑ I would choose option 2
- ❑ I would choose option 3
- ❑ I would not choose any of these options because I would prefer more water to be allocated for irrigation.

Survey Logistics

A "drop-off, pick-up" procedure was used, thus avoiding the potential of interviewer bias. The questionnaires were distributed in Sydney on the weekend of the 11th and 12th of October 1997 by nine interviewers. Three attempts were made to pick up each completed questionnaire, and after this a mail back option was provided. Response details are listed in Table 2.

Table 3 **Survey statistics**

Number of questionnaires distributed (1)	416
Final (useable) data set (2)	218
Number of houses with nobody home (3)	693
Number of rejections (4)	304
Response rate 1	76.4%
Response rate 2	44.2%
Response rate 3	22.5%

Note: Response rate 1 is based on the number of surveys distributed i.e. [2÷1]; response rate 2 is based on the number of surveys distributed and the number of rejections i.e. [2÷(1+4)]; response rate 3 includes the number of surveys distributed, rejections and people not home i.e. [2÷(1+4+3)].

The socio-demographics of the respondents to the survey are shown in Table 3. The socio-demographics of the sample are close to the Sydney average, except for income. In part the difference can be explained by the inclusion in the Sydney average of several regional centres surrounding Sydney that have lower average in come levels. It is possible, though, that part of the difference is due to some respondents not reporting their income, which is a common problem with stated preference surveys, or sampling bias.

Table 4 **Socio-demographics of the respondents**

Variable	Sample average	Sydney average
Age (>17 years)	44.3 years	43.9 years
Sex (% male)	55.8%	49.2%
Children (%)	72.1%	67.0%*
Own house (%)	71.3%	67.4%
Education (% > year 12)	74.6%	77.4%
Income	$54,680	$46,184 (household)
Employed full or part time (%)	65.7 % (> 18 years)	59.3 % (> 15 years)[*,#]

* State average
# The % employed > 18 years was not available
Source: Australia Bureau of Statistics 1996 Census data

Description and analysis of results[16]

Two different multinomial logit models were estimated using the data from the Macquarie Marshes survey. Definitions of the variables used in these models are presented in Table 4.

Table 5 **Definitions of variable**

Variable		Mean value
C1	Alternative specific constants for option 2	—
C2	Alternative specific constants for option 3 and 4.	—
INCOME	Respondent's household income	$54,680
CHILD	Dummy variable showing whether respondents have children	0.72
VISIT	Dummy variable representing whether a respondent is intending to visit the Marshes in the future	0.46
PRODEV	Dummy variable showing that a respondent is pro-development	0.10
PROGRE	Dummy variable showing that a respondent is pro-environment	0.36
RATE	Water rates	—
JOBS	Irrigation related employment	—
AREA	Wetlands area	—
BREED	Frequency of waterbird breeding	—
ENDSPECIES	Number of endangered and protected species present	—

16 See Morrison, Bennett and Blamey (1999) for more details.

Model 1: A basic model.

There are four utility functions derived from the multinomial logit model. Each represents the utility generated by one of the four options. Option 1 is the status quo, options 2 and 3 are options whereby more water would be allocated to the Marshes and option 4 involves a reduction in water to the Marshes.

$V_1 = \beta_1.RATE+\beta_2.JOBS+\beta_3.AREA+\beta_4.BREED+\beta_5.ENDSPECIES$

$V_2 = C1+\beta_1.RATE+\beta_2.JOBS+\beta_3.AREA+\beta_4.BREED+\beta_5.ENDSPECIES$

$V_3 = C1+\beta_1.RATE+\beta_2.JOBS+\beta_3.AREA+\beta_4.BREED+\beta_5.ENDSPECIES$

$V_4 = C2$

There are two alternative specific constants (C1 and C2) in this model. These alternative specific constants capture all of the systematic but unobserved information about why respondents chose a particular option. The alternative specific constants for options 2 and 3 (the increase water to the Marshes options) were constrained to be equal because a generic format and an experimental design that was close to orthogonal were used to develop the choice sets.

For the first three utility functions, utility is determined by the levels of the five attributes in the choice sets (RATES, JOBS, AREA, BREED, ENDSPECIES). Hence the model provides an estimate of the effect of a change in any of these attributes on the probability that one of these options will be chosen. For the fourth utility function only an alternative specific constant is included. This is because no attributes were used to define the fourth option in any of the choice sets.

The results of this model are shown in Table 5. The coefficients for all of the attributes in the choice sets are significant at the 1% level and all have the a *priori* expected sign. The results indicate that positive non-use values exist for both environmental and social outcomes (i.e. respondents valued the environmental attributes of wetland protection and they also valued the non-use benefits of jobs created by irrigation development). The overall model is also significant at the 1% level, as shown by the chi-squared statistic. The explanatory power of the model is relatively high, with an adjusted rho squared of 19.6%[17].

17 Rho-squared is similar to R^2 in conventional regression analysis. It is equal to one minus the ratio of the unrestricted log-likelihood over the restricted log likelihood. Hensher and Johnson (1981) comment that "values of rho squared of between 0.2 to 0.4 are considered extremely good fits so that the analyst should not be looking for values in excess of 0.9 as is often the case when using R^2 in ordinary regression."

Table 6 **Multinomial logit models 1 and 2**

	Model 1	**Model 2**
C1	-0.30* (0.19)	-1.59*** (0.30)
C1 * INCOME		0.79E-5*** (0.22E-5)
C1 * CHILD		0.62*** (0.20)
C1 * PROGRE		1.36*** (0.18)
C1 * VISIT		0.64*** (0.19)
C2	5.53 (2.91)	5.82* (3.46)
C2 * PRODEV		2.42*** (0.31)
RATES	-0.12E-1*** (0.81E-3)	-0.13E-1*** (0.21E-2)
RATES * CHILD		-0.35E-2* (0.21E-2)
RATES * VISIT		0.42E-2** (0.20E-2)
JOBS	0.17E-2*** (0.65E-3)	0.19E-3*** (0.78E-3)
AREA	0.56E-3*** (0.13E-3)	0.55E-3*** (0.15E-3)
BREED	-0.31*** (0.51E-1)	-0.29*** (0.58E-1)
ENDSPECIES	0.50E-1*** (0.97E-2)	0.54E-1*** (0.11E-1)
Summary statistics		
Log-likelihood	-1756.497	-1184.993
χ^2 (constants only)	362.050	493.480
rho2	0.197	0.277
Rho2 adjusted	0.195	0.275
Iterations completed	6	6
Observations	1577 (0 skipped)	1183 (394 skipped)

Note: * Significant of the 10% level; ** significant of the 5% level; *** significant of the 1% level

Model 2: A model with socio-economic and attitudinal interactions

In order to test the accuracy of the assumption of independently and identically distributed (IID – Gumbell) errors in this basic model, a mother logit model was estimated. A likelihood ratio test was conducted to test whether the multi-nominal or mother logit is the true model. This test showed that the basic model suffers from violations of the IID assumption at the 5 percent significance level. There are various reasons why this may have occurred. One possibility is the existence of random taste variations (i.e. heterogeneous preferences amongst respondents). If this is the cause it may be possible to minimise the violation by including socio-economic interactions in the model.

In model 2 several socio-economic and attitudinal variables are included in addition to the attributes from the choice sets. The use of both socio-economic and attitudinal variables as independent variables is justified under the hypothesis that attitudes and socio-economic characteristics are separate factors influencing behavioural intentions and behaviour (Lynne, Shonkwiler and Rola 1988)[18]. The specification for this model is as follows:

$V_1 = \beta_1$.RATE+β_2.RATES*CHILD+β_3.RATES*VISIT+β_4.JOBS+β_5.AREA+β_6.BREED+β_7.ENDSPECIES
V_2=C1+C1.INCOME+C1.CHILD+C1*PROGRE+C1*VISIT+β_1.RATE+β_2.RATES*CHILD+β_3.RATES*VISIT +β_4.JOBS+β_5.AREA+β_6.BREED+β_7.ENDSPECIES
V_3=C1+C1.INCOME+C1.CHILD+C1*PROGRE+C1*VISIT+β_1.RATE+β_2.RATES*CHILD+β_3.RATES*VISIT +β_4.JOBS+β_5.AREA+β_6.BREED+β_7.ENDSPECIES
V_4=C2+C2*PRODEV

Socio-economic and attitudinal variables can be included in multinomial logit models in two different ways[19]. The first way is by interactions with the attributes in the choice sets. In this model, one socio-economic and one attitudinal variable (CHILD and VISIT) are interacted with RATES. These interactions show how the variables CHILD and VISIT modify the effect of RATES on the probability of choice.

The second method used to include socio-economic and attitudinal variables is through interactions with the alternative specific constants[20]. In this model, four variables (INCOME, CHILD, PROGRE and VISIT) are included as interactions with the alternative specific constant for options 2 and 3 (C1) and one variable (PRODEV) is interacted with the alternative specific constant for option 4 (C2). These interactions show the effect of various attitudes and socio-economic characteristics on the probability that a respondent will choose either option 2 or 3, or option 4.

Theory provides some guidance in terms of the expected signs of several of the above variables. PROGRE would be expected to have a positive sign as respondents with a pro-environmental orientation would be more likely to choose options 2 or 3 more frequently. VISIT would be expected to have a positive sign as respondents who intend to visit the Marshes in the future may have positive option value (see Bishop 1982). INCOME would have a positive sign if respondents with higher income should have a greater capacity to pay. PRODEV would also have a positive sign if respondents with a pro-development orientation favoured option 4 with its further development of the Marshes area and the creation of more jobs. The sign for CHILD is, however, ambiguous. Bequest motives would be expected to induce higher willingness to pay, yielding a positive coefficient; however, households with children may have lower disposable income, thereby lowering willingness to pay.

The results for this model are shown in the final column of Table 5. The four variables (INCOME, CHILD, PROGRE and VISIT) interacted with the alternative specific constant for options 2 and 3 are significant at the 1 percent level. Consistent with expectations, these interactions show that respondents were more likely to support either options 2 or 3 if they (1) had a higher income; (2) had children; (3) had a pro-environmental orientation; and (4) were intending to visit the Macquarie Marshes in the future.

18 There is some debate surrounding the use of both attitudes and socioeconomic factors as explanatory variables (see Blamey, Common and Quiggin 1995; Rolfe and Bennett 1996a). There appeared to be little evidence of multicollinearity in this model.

19 All variables were initially interacted with both the attribute variables and the alternative specific constants, and were deleted if they were insignificant.

20 Because of the interactions with the alternative specific constants, socioeconomic variables can only be included for J-1 alternatives.

The interaction between the constant for option 4 and PRODEV is also significant at the 1 percent level. As expected, this interaction indicates that respondents are more likely to choose option 4 (less water to the wetlands) if they have a pro-development orientation.

Also included in Model 2 are variables based on the attributes from the choice sets, and two interactions with the RATES variable. Similar to Model 1, all of the choice set attributes are significant at the 1 percent level. This confirms the result of model 1, that it is possible to have non-use values attached to environmental as well as economic outcomes. One of the interactions with RATES (VISIT) is significant at the 5 percent level and the other interaction (CHILD) is significant at the 10 percent level. These interactions show that willingness to pay for improved wetlands quality is higher: (1) if respondents are planning to visit the Macquarie Marshes; and (2) do not have children. The negative sign for CHILD is of note given that the interaction with the alternative specific constant was positive. These two different results indicate that while respondents with children are more likely to choose either options 2 or 3, their willingness to pay is generally lower. This is consistent with the hypothesis that while respondents with children are likely to have bequest motives, they also likely to have a lower capacity to pay.

The overall model is significant at the 1 percent level and the explanatory power is also high. Compared to model 1, the explanatory power of the model has increased to 28 percent.

In order to test for the accuracy of the assumption of IID error terms a mother logit model was estimated. The likelihood ratio test indicated that at the 5% significance level the multinomial logit model was the true model. Hence the inclusion of socio-economic and attitudinal variables was sufficient to minimise the violation of the IID assumption. This suggests that the main cause of the IID violation in the first model was the existence of random taste variations.

Estimation of Willingness to Pay

Point estimates of the willingness to pay for a change in one of the attributes in the choice sets can be found by estimating implicit prices. Implicit prices are the marginal rates of substitution between the attribute of interest and the monetary attribute. This is equal to the ratio of the coefficient of one of the non-monetary attributes and the monetary attributes. In other words, the implicit price for wetland area is: $IP_{AREA}=\beta_{AREA}/-(\beta_{RATES})$. Estimates of implicit prices for each of the non-monetary attributes in the choice sets are reported in Table 6. Confidence intervals for the implicit prices have been calculated using the Krinsky and Robb (1986) procedure[21]. While Model 1 was earlier found to be problematic, these results show that the existence of violations of the IID error assumption in the basic model did not have a large effect on the estimates of implicit prices.

21 The Krinsky and Robb (1986) procedure involves randomly drawing a large number of parameter vectors from a multivariate normal distribution with mean and variance equal to the β vector and variance-covariance matrix from the estimated multinomial logit model. Implicit prices are then estimated using each of the parameter vectors that are drawn from the normal distribution and confidence intervals can be calculated. To estimate the confidence intervals reported here, 100 draws were taken. See Parsons and Kealy (1994) for another application of this procedure.

Table 7 **Estimates of Implicit Prices ($A1997)**

	Model 1		Model 2	
	Mean	**95% Confidence Interval**	**Mean**	**95% Confidence Interval**
JOBS	0.13	0.12-0.14	0.14	0.13-0.15
AREA	0.046	0.044-0.048	0.040	0.038-0.042
BREED	24.62	23.80-25.45	21.82	20.98-22.67
ENDSPECIES	4.04	3.86-4.21	4.16	4.00-4.32

These estimates indicate that, for example, respondents were willing to pay 13 cents for an extra irrigation related job preserved and about $4 for an additional endangered species to be present in the wetlands. These estimates are based on a ceteris paribus assumption i.e. all other parameters are held constant except the attribute for which the implicit price is being calculated. Implicit prices can also be used to calculate the relative importance respondents place on each of the non-monetary attributes. For instance, the results from Model 2 indicate that, relative to increasing the frequency of waterbird breeding, respondents would make the following trade-offs between the non-monetary outcomes:

> Breeding frequency increases by 1 year = 154 jobs = 545 km² of extra wetland area = 5 extra endangered or protected species present.

Implicit prices, however, do not provide estimates of compensating surplus. Estimating the overall willingness to pay for a change from the current situation requires more substantial calculations. This is because the attributes in the choice sets do not capture all of the reasons why respondents might choose to increase the amount of water allocated to the wetlands. To estimate overall willingness to pay it is necessary to include the alternative specific constant. To illustrate this process, estimates are provided for four alternative scenarios. The current situation and four scenarios are as follows:

Current situation	Wetlands area is equal to 1000 km², Waterbird breeding every four years, Twelve endangered and protected species present, and Irrigation related employment i.e. equal to 4400 jobs.
Scenario 1:	Wetlands area increases to 1400 km², The frequency of waterbird breeding increases to every three years, The number of endangered and protected species present increases to sixteen, and There are no employment effects.
Scenario 2:	Wetlands area increases to 1400 km², The frequency of waterbird breeding increases to every three years, The number of endangered and protected species present increases to sixteen, and Irrigation related employment falls by 100 jobs.
Scenario 3:	Wetlands area increases to 1800 km², The frequency of waterbird breeding increases to every two years, The number of endangered and protected species present increases to twenty, and There are no employment effects.

Scenario 4: Wetlands area increases to 1800 km²,
The frequency of waterbird breeding increases to every two years,
The number of endangered and protected species present increases to twenty, and
Irrigation related employment falls by 150 jobs.

Estimates of compensating surplus are calculated for both models using equation 6:

$$CS = -1/\beta_M * (V_C - V_N)$$

Where β_M is the marginal utility of income (assumed to be equal to the coefficient for rates $-\beta_{MRATES}$); V_C represents the utility of the current situation, and V_N represents the utility of the new option.

To use this equation to estimate compensating surplus it is first necessary to calculate the utility associated with the current option and the alternative option being considered. Under model 1, this is achieved for the current option utility by substituting the model coefficients and the attribute levels for the current option (i.e. V_1):

$$V_C = \beta_{RATES}*RATES+\beta_{JOBS}*JOBS+\beta_{AREA}*AREA+\beta_{BREED}*BREED+\beta_{ENDSPECIES}*ENDSPECIES$$

$$= -0.12E-1*0+-0.17E-2*4400+0.5E-3*1400+-0.31*3+0.50E-1*16$$

$$= 7.38$$

The value of the utility of the alternative option is estimated in a similar way, except that the coefficient for the alternative specific constant for options 2 and 3 is included and the attribute levels associated with the changed scenario are used. For scenario 1:

$$V_N = C1+\beta_{RATES}*RATES+\beta_{JOBS}*JOBS+\beta_{AREA}*AREA+\beta_{BREED}*BREED+\beta_{ENDSPECIES}*ENDSPECIES$$

$$= -0.30+-0.12E-1*0+-0.17E-2*4400+0.56E-3*1400+.031*3+0.50E-1*16$$

$$= 7.82$$

The compensating surplus for the change from the status quo to the new scenario is then estimated by calculating the difference between these two values, and then multiplying this by the negative inverse of the coefficient for rates. For the change to scenario 1:

$$CS = -1/(-0.12E-1) * (7.38 - 7.82) = -\$36.10$$

The negative sign indicates that to maintain utility at level V_C, given an improvement in wetland quality, income must be reduced by $36.10. Hence, the willingness to pay per household for an improvement in wetland quality from the status quo to scenario 1 is equal to $36.10.

Estimates of willingness to pay for the four scenarios are presented in Table 7. These are marginal estimates, showing willingness to pay for a change from the current situation. When estimating willingness to pay using the Model 2, all of the attitudinal variables were set to their mean levels, and Sydney averages were used for the socio-economic variables. Note that Model 1 suffers from violations of the IIA property and that Model 2 is the preferred model.

The importance of including employment effects when calculating willingness to pay for an environmental improvement is evident from these willingness to pay results. While the existence values for improved environmental quality outweigh the existence values for rural employment, including employment effects reduces willingness to pay by about 20-30% in the scenarios presented here. Note that Scenarios 1 and 2, and Scenarios 3 and 4 differ only in terms of employment effects.

Table 8 **Estimates of household willingness to pay**

	Model 1	**Model 2**
Scenario 1	$36.10	$48.75
Scenario 2	$22.36	$34.04
Scenario 3	$94.73	$102.62
Scenario 4	$67.25	$73.19

These per household estimates can be aggregated to determine the willingness to pay of the wider community to achieve the four scenarios for improved environmental quality at the Macquarie Marshes. Similarly, the modelling results described above can also be used to value a range of other scenarios resulting from different water allocations. Water managers could then utilise these value estimates, and estimates of the value of any changes in agricultural production, to determine which scenarios are likely to have the greatest net benefits for the community.

4.2 The role of information and uncertainty in the design and implementation process

A particular strength of the Choice Modelling technique is its ability to yield a functional relationship between policy affected parameters — the attributes — and the impact on social welfare of a policy change. This is in contrast to a Contingent Valuation application where a single estimate of value derived from a specific policy change is provided. The Choice Modelling application therefore provides decision makers with the opportunity to explore the sensitivity of value across a range of potential policy options on the basis of one survey. This can be particularly advantageous when there is uncertainty regarding the bio-physical and social outcomes of proposed policy changes. Decision makers can use the Choice Modelling results to undertake sensitivity analysis of attributes which are subject to uncertainty.

5. Design of policy responses based on valuation results

The case study application of Choice Modelling has had general and specific impact. In the general sense, the estimates of environmental, non-use, values have increased the recognition given to these values by policy makers and their advisers. Two NSW Government agencies provided direct financial support for the research (NSW Environment Protection Authority and NSW Natural Parks and Wildlife Service). Both organisations have used the project results in their development of policy generally. The NSW EPA has gone on from the project to commission a study aimed at estimating the environmental values of NSW river systems (Bennett, Morrison and Harvey 2000). In partial response to this consequential rise in general awareness of environmental values, policies relating to the determination of environmental flows in rivers have been, and continue to be, revised.

At the Commonwealth level of government the results of this case study and other similar work continues to be incorporated in policy development on achieving more efficient allocation of resources for both consumptive and environmental purposes. The recently announced natural resource management action plan will implement ‘targets and standards for natural resource management, particularly water quality and salinity, with the States and Territories, either bilaterally or multilaterally, as appropriate. The targets and standards should include salinity, water quality and associated flows, and stream and terrestrial biodiversity based on good science and economics’ (Commonwealth of Australia 2000).

Specifically in the Macquarie Valley, the results of the study are expected to be used in the development of a water management plan for the Macquarie Marshes. Benefit-cost analyses of potential policy options have been informed by the estimates reported here. A further Choice Modelling application designed to determine the environmental value enjoyed by residents of the Macquarie Valley as a result of the rehabilitation of the Macquarie Marshes has also been undertaken (Morrison 2000).

While it is difficult to state precisely the extent to which the case study had an impact on revisions to environmental flows and the further development of water markets, it is clear that it formed a component of the pressure for more policy development to be directed to this issue.

6. Policy relevant conclusions

The case study reported here has demonstrated the potential of the Choice Modelling technique for estimating non-marketed values in the context of policies involving environmental impacts. The technique was shown to be capable of yielding estimates that are cost-effective to obtain because an array of values can be estimated form a single application. The flexibility to estimate values across a number of policy uses is also notable. For instance, through the decomposition of values into their component “implicit prices” policy makers are able to explore the potential of different policy options in achieving socially desirable outcomes.

The decomposition facility also has implications for the use of Choice Modelling applications as the source of value estimates that can be used for “benefit-transfer” exercises. Because Choice Modelling value estimates are functional relationships between attributes and values, their potential for adjustment to suit policy situations where conditions are somewhat divergent from the source study is enhanced. For instance, consider a case where a policy is being developed for wetland “X” that is a different size and has different species diversity characteristics to the Macquarie Marshes. The Choice Modelling application reported here could be used as a source of benefit estimates for the wetland X case with only minor adjustment to the scenario information fed into the estimation model. This flexibility is not available from contingent valuation applications where single value estimates are produced. The application also demonstrated the use of Choice Modelling to estimate non-use values associated with social factors. The hypothesis of Portney (1994) that non-use values can be provided by attributes other than those associated with the environment is supported by the study’s results. This result adds to the potential for Choice Modelling applications to support decision making which has at its core the principle of ecological sustainable development. The requirement to assess economic, environmental and social impacts is made more achievable through the application of Choice Modelling to investigate the trade-offs that people are willing to make across the three types of impacts.

The use of Choice Modelling in this application has also made clear some of the challenges facing those choosing to use the techniques. The complexity of the choice tasks in a Choice Modelling application places significant cognitive burden on the participating respondents. The design of a Choice Modelling questionnaire therefore requires a great deal of attention. The impacts of design features on value estimates will also require examination. These are challenges which are worth addressing give the advantages demonstrated by the technique relative to other stated-preference methods.

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Figure 1 **The Macquarie Valley**

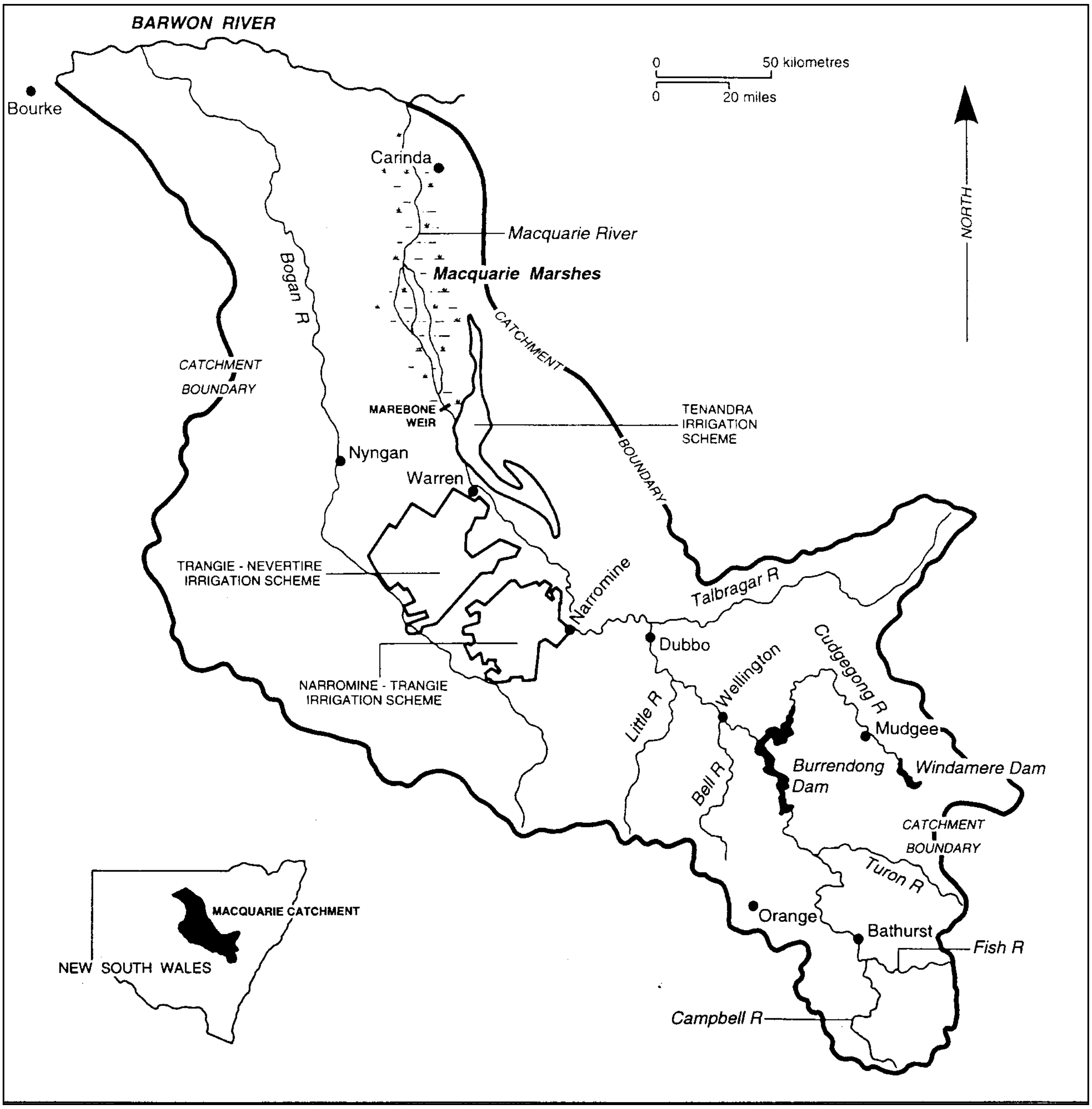

Figure 2 **The Macquarie Marshes**