Cost of algal blooms

Final report

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GPO Box 2182
Canberra ACT 2601
Telephone: (02) 6257 3379
Facsimile: (02) 6257 3420
Email: public@lwrrdc.gov.au
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Authors: Atech Group
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Strathfield NSW 2135

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About this report

This report was commissioned by the Land and Water Resources Research and Development Corporation and the Murray-Darling Basin Commission as part of the National Eutrophication Management Program. For additional information, please contact either of the following:

Dr Richard Davis

National Eutrophication Management Program Coordinator

CSIRO Land and Water

GPO Box 1666

Canberra ACT 2601

Telephone: (02) 6246 5706

Facsimile: (02) 6246 5853

Email: richard.davis@cbr.clw.csiro.au

Atech Group Pty Ltd

28 Philip St

Strathfield NSW 2135

Telephone: (02) 9744 7644

Facsimile: (02) 9744 7645

Email: peterdempster@atechgroup.com.au

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Study team

Atech Group Pty Ltd

Dr Bob Banens

Ron Groenhout

Peter Cochran

Dr Laslo Nagy

Peter Dempster (Project Manager)

Ron Rosich

Wally Fink

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Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
ANCA	Australian Nature Conservation Agency
ANCOLD	Australian National Committee on Large Dams
AWRC	Australian Water Resources Council
AWWA	Australian Water & Wastewater Association
CMA	Catchment Management Authority
CVM	Contingent valuation method
DLWC	Department of Land and Water Conservation (NSW)
DNR	Department of Natural Resources (Queensland)
DNRE	Department of Natural Resources and the Environment (Victoria)
DPIWE	Department of Primary Industries, Water and Environment (Tasmania)
EIP	Environment Improvement Plan
ENVALUE	NSW EPA Environmental Valuation Database
EPA	Environment Protection Authority
EP	Equivalent person
GAC	Granulated activated carbon
LWRRDC	Land and Water Resources Research and Development Corporation
MDBC	Murray-Darling Basin Commission
MD2001	Murray-Darling 2001 Program
NHT	Natural Heritage Trust
NLP	National Landcare Program
NRP	National Rivercare Program
PAC	Powdered activated carbon
RSA	Read Sturgess and Associates: Consulting Economists
RWA	Rural Water Authority
SEQWB	South East Queensland Water Board
SoE	State of the Environment
STP	Sewage treatment plant
WQT	Water Quality taskforce
WTP	Willingness to pay

Executive summary

The objectives of this project were to:

- Identify the principal water user groups affected by freshwater algal blooms (cyanobacterial and other forms, but excluding blooms in estuarine or coastal waters) and the direct and indirect costs arising from these blooms.
- Quantify the direct and, as far as possible, the indirect costs of algal blooms to these water user groups.
- Identify areas where these costs are poorly quantified but likely to be large, and where there are opportunities to collect better data.

Based on discussions with resource management agencies in each state and territory, and review of such records as they were able to provide, it is apparent that algal blooms are a significant environmental issue for all states and territories other than Tasmania and the Northern Territory. Tasmania and the Northern Territory were excluded from further consideration in the study.

Principal water uses that are adversely affected by algal blooms

This report draws a basic distinction between extractive and non-extractive uses of water. The *non-extractive uses* that may be adversely affected by algal blooms include the recreational use of waterbodies by local residents and tourists (for swimming, boating and fishing), amenity uses by residents and tourists (water views and riverside walks), commercial fishing, and the so-called 'non-use' values. Non-use values include the value the community puts on the continued existence of waterbodies in their natural state and the existence of the flora and fauna that they support. The interests of non-extractive users can sometimes be cost-effectively protected by use of algicides, but it is generally not feasible to engage in instream 'water treatment' on the scale that would be required. These users rely mainly on environment protection activities to address their interests, for example, sewage treatment to reduce the quantities of algae-supporting nutrients that are discharged to rivers from point sources.

The *extractive uses* are defined as drinking water, water for commercial and industrial enterprises, and water extracted for aquaculture, stock watering and the irrigation of pastures and crops. These users are more likely to have cost-effective options for treating water that has been affected by algal blooms, whether it be a simple filtering process for protecting irrigation equipment or the use of activated carbon to deal with toxins in urban water supplies; however, their interests are also protected by investments in appropriate environment protection measures.

Order of magnitude estimate of the total costs currently incurred

Given the extreme difficulty of directly measuring many significant costs that are currently being incurred, particularly damage to non-use values and other costs incurred by non-extractive users, we decided to attempt an indirect estimate. To understand the method, consider that the response to algal blooms consists of short, medium and long-term measures.

Short-term measures include to:

- import drinking water
- erect warning signs
- treat farm dams with algicide.

Medium-term measures include to:

- develop groundwater resources
- improve water treatment
- relocate production.

Long-term measures include to:

- restore river flows
- establish effluent reuse schemes
- rehabilitate riparian land.

The current situation in Australia is that many of the short-term and medium-term measures have been implemented but there is still a long way to go in respect of the longer-term investments in environment protection. We should expect the total costs of algal blooms to fall significantly over time as the longer-term measures are adopted. For example:

- the costs of water treatment will fall as raw water sources improve;

- tourists will return to preferred recreational sites; and
- non-use values will be restored as the incidence of algal blooms declines.

Importantly, the benefits of future investments in environment protection take the form of reductions in costs that are currently being incurred. This suggests that current costs can be estimated in two steps.

First, we estimated the costs of the planned environment protection measures that can be attributed to algal blooms. Our conservative tally is approximately $120 million per year, comprising:

- the additional cost of sewage and stormwater management – $43 million per year;
- the additional cost of agricultural and industrial wastewater management – $33 million per year; and
- the additional costs of rehabilitating land and water resources, for example, restoration of riparian lands – $45 million per year.

Elements of these measures have been implemented and will have delivered some benefits already, that is, reductions in costs that would otherwise have been incurred. For the most part, however, these expenditures lie in the future or have yet to deliver substantial benefits.

The second step is to allow for the fact that the costs currently incurred are necessarily much larger than the anticipated costs of environment protection, for two reasons:

- There will be no investment in environment protection unless there is the prospect of reducing costs that are currently incurred.
- Since the anticipated investments in environment protection will not eliminate algal blooms, some of the costs currently incurred will still remain when those measures have been implemented.

We argue that the total costs of algal blooms can be reasonably put at twice the anticipated costs of environment protection – see section 3.2. Certainly the multiplier can be very conservatively put at 1.5. Having put the anticipated cost of environment protection at $120 million per year, we therefore put the current total cost of algal blooms at $180 million to $240 million per year.

We regard this as a conservative order of magnitude estimate. Our view is that it is difficult to make sense of planned environment protection activities unless algal blooms currently impose costs of this order of magnitude on the Australian community. That said, we have necessarily exercised considered judgment in putting the figure of $120 million per year on the additional costs of environment protection that will be incurred to deal with algal blooms.

Cost of algal blooms to principal water users

Table 1 summarises our estimates of the costs of algal blooms that are currently incurred by specific users. The joint management costs and the costs to extractive users have been directly estimated:

- The joint management costs are incurred by resource management agencies through contingency planning, monitoring and implementation of contingency management actions as appropriate, for example, dosing with algicides, notification of users (signage and media activities), provision of technical advice to users, and flushing. The cost estimates are based primarily on information collected by phone interviews with staff of resource management agencies.
- The cost to urban water supplies was collected by an exhaustive survey of urban water authorities. We collected information on the additional costs of investigations and assessments of algal problems, catchment monitoring and assessment, storage monitoring and assessment, water treatment and distribution, customer relations and administrative and training overheads. However, a substantial part of the total cost to urban supplies is an estimate ($20 million per year) of the cost of interruptions to the potable water supplies due to algal blooms.
- Each component of the costs to rural water supplies has been separately estimated, often drawing heavily on work done in recent years for a number of Victorian catchments.

Some of these costs will fall as appropriate investments in environment protection are undertaken.

The cost to non-extractive users has not been separately estimated. Nor does the study provide a further breakdown of cost for the various types of non-extractive use. The estimate is simply a residual, being the difference between the order of magnitude estimate of total cost and the sum of the joint management costs and the costs to extractive users. It is, however, commensurate with partial estimates of cost to non-extractive users that have been made for certain Victorian catchments.

Table 1: Cost of freshwater algal blooms by user group (Australia, late 1990s)

Type of cost		$m/year	
Joint management costs			**9**
Cost to extractive users			**95**
• Urban water supplies		35	
• Rural water supplies		60	
– *Stock and domestic water from farm dams*	*30*		
– *Stock and domestic water from rivers, storages and irrigation channels*	*15*		
– *Irrigation water supply*	*15*		
Cost to non-extractive users			**76–136**
Total			**180–240**

1. Introduction

The objectives of this project were to:

- Identify the principal water user groups affected by freshwater algal blooms (cyanobacterial and other forms, but excluding blooms in estuarine or coastal waters) and the direct and indirect costs arising from these blooms.
- Quantify the direct and, as far as possible, the indirect costs of algal blooms to these water user groups.
- Identify areas where these costs are poorly quantified but likely to be large, and where there are opportunities to collect better data.

Structure of the report

This report is organised in four further sections. Section 2 provides a summary of readily available information on the incidence of algal blooms in each of the states. On the basis of this information we decided to focus attention on NSW (including the ACT), Victoria, Queensland, SA and WA; that is, to ignore the relatively minor contributions of Tasmania and the NT to cost.

Sections 3 and 4 report our estimates of the costs of algal blooms. Section 3 provides an estimate of total cost, based on our assessment of the environmental protection expenditures that the community is willing to incur to reduce the incidence of algal blooms. Section 4 provides estimates of costs to specific user groups. We draw a basic distinction between costs associated with extractive uses of water and costs associated with non-extractive uses.

Extractive uses include:

- tap water for rural and urban households;
- water for commercial and industrial enterprises;
- stock watering; and
- irrigation of pastures and crops.

Non-extractive uses include:

- recreational use of water by local residents and tourists for swimming, boating and fishing;
- commercial fishing and aquaculture; and
- non-use values, being the value that the community puts on the continued existence of waterbodies in their natural state and the existence of the flora and fauna that they support.

Treatment of capital costs

Unless otherwise indicated, we have converted capital costs to their annual or ongoing equivalents by dividing them by 10. That is, the annual equivalent cost is assumed to be 10 per cent of the capital cost. This can be understood as an estimate of the rental cost of capital. For example, suppose you acquired a capital asset for $100, intending to rent that asset to users for an annual fee. That fee would need to cover two items:

- Assuming an interest rate of 5 per cent, a charge of $5 per year would be needed to cover borrowing costs.
- Assuming the asset depreciates at 5 per cent per year, a charge of an additional $5 would be needed to cover depreciation.

In effect, having started the year with a debt of $100 and a capital asset worth $100, at year's end there is a debt of $105 and an asset worth $95. The difference of $10 needs to be recovered from the user of that asset. It makes no difference if you have actually rented the asset to another party or employed the asset in your own business: $10 of capital services have been consumed during the year.

The assumption that capital items depreciate at 5 per cent per year is generally conservative. On some occasions, however, we have assumed even lower rates of depreciation – say, 3 per cent or zero depreciation – where a more conservative approach seemed appropriate.

2. Incidence of algal blooms

2.1 Method

Sources of information on the incidence of algal blooms were identified by the following means:

- Collection of State of the Environment (SoE) reports where available, that is, for NSW, Western Australia and South Australia. Queensland's first SoE report was scheduled for release in November 1999 and was not available in time for this study.
- Phone interviews with appropriate contacts in the environment protection and resource management agencies in each of the states.
- Analysis of such data and unpublished summaries as were made available to the study team – specifically, from NSW and Victoria.

2.2 Findings

2.2.1 New South Wales

This summary is based on the analysis of data supplied by the NSW Department of Land Water Conservation (DLWC) for the period October 1995 to August 1998. The database records notifications of algal alerts to the State Algal Coordinating Committee. (See appendix 1 for definitions of the three alert levels – low, medium and high – that have been adopted as a national standard.) We found that:

- DLWC's drinking water storages are frequently monitored and algal blooms are found to be a significant problem. Table 2 reports the incidence of weekly algal alerts as a proportion of the 149 weeks in the period October 1995 to August 1998.
  The storages are ranked according to the incidence of high level alerts. Note, for example, that Windamere Dam was subject to high algal alerts for two-thirds of the period. Four other storages experienced high algal alerts for 20 to 40 per cent of the period. On average, storages were subject to some level of algal alert for almost half of the period.
- Other water bodies – rivers and inland waters – are less frequently monitored than the DLWC drinking water storages; samples are taken only when a problem has been identified. Algal alerts were recorded for 197 such sites in the period October 1995 to August 1998. On average, these sites were subject to some level of algal alert for 7 per cent of the period. In 11 cases, the incidence of high algal alerts were in excess of 10 per cent of the period (see table 3).

DLWC has since terminated the centralised collection of data on algal alerts. Record-keeping arrangements are now determined independently by regional offices according to local needs.

The NSW Environment Protection Authority (EPA) has adopted phosphorus in rivers as its core indicator of eutrophication (NSW EPA, 1997, p233). It notes that:

- An increase in nutrient loads and eutrophication over time cannot be demonstrated objectively on the basis of existing water quality data, including data on algal blooms. Nevertheless, the intensification of agricultural activity in inland catchments supports the general impression that nutrient levels are increasing and blooms are becoming more frequent.
- Total phosphorus concentrations are high for 45 per cent of the sites monitored in NSW and exceed the limit recommended for freshwater aquatic ecosystems in about half of these.

2.2.2 Victoria

In the mid-1990s the Victorian EPA (1995a, pp3–4; pp8–11) summarised the information about algal blooms in Victoria as follows:

- Water supply authorities do most algal monitoring. They aim to optimise management responses by detecting blooms early. There was no system for systematically recording blooms before 1991.
- Algal blooms are less intensively monitored than other water quality parameters. Less than 1 per cent of the state's reservoirs had been monitored for periods that might provide a basis for determining the trend in algal blooms.
- A total of 355 blooms were recorded in the period 1928 to 1994, with about three-quarters of those recorded in the 1990s. Note that:
  - Many algal blooms have not been recorded and many records of algal blooms have not been identified.

- Because separate bloom events in a waterbody are recorded as only one bloom when they occur in the same season, there may have been many more than 355 individual bloom events.

- Blue-green algae account for about 84 per cent of recorded blooms.
- The most affected river basins are as follows:
  - *Northwest Plains River Region:* Run-off is very low. Streams form closed drainage networks, often run into terminal lakes and often form chains of interconnected pools. Most of the region is under cropping and dryland grazing.
  - *Murray Plains Region:* These basins drain northwards into the Murray River. Much of the region has been cleared and a large part of that is irrigated.
  - *Southern Lowlands and Urban River Region:* These basins contain a substantial proportion of Victoria's population and industry, including greater Melbourne, Geelong and the Latrobe Valley. The streams are the most modified and disturbed in the state.
- There is evidence of increasing nutrient loads in these river basins.

Table 2: Incidence of algal alerts in NSW DLWC storages, 1995–98

DLWC storage	Incidence of algal alerts (% of period October 1995 to August 1998)			
	Low	Medium	High	Total
Windamere	8.7	12.8	66.4	87.9
Toonumbar	11.4	16.1	38.9	66.4
Carcoar	18.8	19.5	32.2	70.5
Lostock	22.8	19.5	27.5	69.8
Burrinjuck	14.8	18.1	24.8	57.7
Wyangala	21.5	9.4	18.1	49.0
Copeton	33.6	12.1	13.4	59.1
Pindari	13.4	6.0	13.4	32.9
Chaffey	50.3	16.1	12.1	78.5
Burrendong	25.5	12.8	10.1	48.3
Split Rock	23.5	8.1	8.7	40.3
Glennies	16.1	4.7	8.1	28.9
Lake Cargelligo	4.7	10.7	8.1	23.5
Keepit	18.1	11.4	4.7	34.2
Glenbawn	16.1	10.7	0.0	26.8
Tantangra	2.0	6.7	0.0	8.7
Hume	0.7	0.0	0.0	0.7
Average	**17.8**	**11.4**	**16.9**	**46.1**

Table 3: Incidence of algal alerts in selected NSW waterbodies, 1995–98

Other waterbodies with an incidence of high algal alerts exceeding 10 per cent	Incidence of algal alerts (% of period October 1995 to August 1998)			
	Low	Medium	High	Total
Walka Water Works	0.7	1.3	86.6	88.6
Centennial Park Ponds	8.7	2.0	69.8	80.5
Hawkesbury-Nepean at Sackville	2.0	1.3	36.9	40.3
Dry Creek near Barooga	0.0	0.0	32.9	32.9
Rocky Creek Dam Swimming Hole	3.4	6.7	32.2	42.3
Lake Belvedere	0.0	0.7	30.2	30.9
Lismore Lake	8.7	15.4	23.5	47.7
Pejar Dam	1.3	8.7	21.5	31.5
Botany Wetlands	4.0	9.4	14.8	28.2
Sooley Dam	6.7	4.0	13.4	24.2
Macquarie River downstream of Burrendong	0.7	0.7	13.4	14.8

- Most recorded blooms were in lakes and reservoirs. This probably reflects the focus of monitoring activities. It is certain that blooms in streams, wetlands and sewage treatment ponds are significantly under-reported.

Victoria's Department of Natural Resources and the Environment (DNRE) has kept a record of blue-green algal blooms since 1991–92, comprising location, date, managing authority, type of waterbody, type of algae, toxicity and action taken. Note, however, that:

- Coverage is restricted to blooms that are reported to the DNRE and others of which DNRE has become aware.
- The list includes only blooms of 2,000 or more cells per millilitre and events where warnings were issued or water use was restricted.
- Separate blooms in a waterbody are recorded as only one bloom when they occur in the same season. (In other words, it is not really the number of blooms that are being reported but the number of waterbodies that are affected by blooms in a particular season.)
- For all but the latest year (1998–99), the record is available only in hardcopy form. Summary data have been compiled for the period since 1993–94.
- The record cannot be readily interrogated to determine the proportion of the time that waterbodies are subject to algal blooms.

Table 4 gives the number and types of Victorian waterbodies affected by recorded blooms. Table 5 shows the types of information being recorded. These four examples were drawn from the record for the 92 waterbodies that were affected by recorded algal blooms in 1998–99.

Table 4: Victorian waterbodies affected by recorded blooms, 1994–99

Year	Town water supply	Irrigation	Recreation	Other (domestic and stock, ornamental, industrial, wastewater)	Total
1993–94	7	27	21	3	58
1994–95	9	15	29	2	55
1995–96	4	25	19	1	49
1996–97	18	40	41	2	101
1997–98	16	36	25	6	83
1998–99	21	29	32	10	92

Table 5: Examples of algal management in Victoria, 1998–99

Waterbody	Managing authority	Type of waterbody	Number of times blue-green algae was detected in 1998–99	Action
Gum Lagoon	Goulburn Murray Water	Recreation, irrigation stock and domestic	19 (December to May)	Bloom isolated, water users notified, flows in and out stopped
Barwon River, Buckley Falls to Breakwater	Barwon Water	Recreation	14 (January to March)	Users notified, water to contact activities banned, warning signs erected, media notified
Tullaroop Reservoir	Goulburn Murray Water	Town water, irrigation, domestic and stock	27 (January to May)	Water users notified, warning signs erected, media release, off-take lowered, outflows reduced, switch to alternative supply
Gippsland lakes	DNRE, Gippsland Coastal Board	Recreation, industry	20 (February to April)	Water users notified, signs erected, contact recreation banned, taking of shellfish banned, fishing banned

2.2.3 Queensland

The Queensland Water Quality Taskforce (1992, pp17–20) reported that, until 1991–92, the state had been relatively free of blue-green algal problems. In part, this was attributed to:

- a summer rainfall climate, which means that turbid flushing flows usually occur during the higher-risk months; and
- the large number of towns and cities (200-plus) that draw their water supply from groundwater sources or can switch to groundwater as required.

Flexible supply arrangements – that is, variable off-takes and multiple storages – also reduce the practical consequences of the problem. The taskforce acknowledged that a dry season could result in blooms in any part of the state, but considered that only the south-east corner of the state shared the problems of NSW and Victoria.

Currently, the Queensland Department of Natural Resources (DNR) monitors 48 DNR reservoirs and weir pools (State Water Projects) across the state, at frequencies varying from weekly to monthly depending on their location and previous history of blue-green blooms. The program has been operating since October 1997. DNR maintains a database containing the results of all analyses to date, including the results of blue-green toxin analysis from specific storages. In addition to the DNR data, other agencies operating storages in Queensland have been sending information to form part of a weekly blue-green status report issued by DNR and published on the department's web site (http://www.dnr.qld.gov.au). These data are available back to November 1997. They list the storage, predominant blue-green algal taxa, current alert levels, and information on drinking water suitability and recreation hazard status.

The Queensland data was not made available for the purposes of this report. However we note that, in September 1999, the DNR web site listed 33 storages on algal alert out of a total of 48 (see table 6).

2.2.4 South Australia

The SA EPA obtains its data on the incidence of algal blooms from the SA Water Corporation; it does not systematically monitor for algae in inland waters elsewhere in the state. It was explained that:

- Most rivers and streams in SA do not have year round flows; it is only in the Murray River that algal blooms are a problem. However, waterholes in ephemeral rivers can still experience algal blooms.
- Nutrient reduction programs are directed mainly at the protection of the near-shore seagrass meadows that are being lost from the coastlines of Adelaide and the northern Spencer Gulf. (Part of the problem is the excessive growth of algae that attach themselves to seagrass leaves (epiphytes) and restrict the available light to the leaves.) The EPA has negotiated an environmental improvement program with SA Water to significantly reduce the discharge of nutrients to the marine environment – at a cost of approximately $210 million.

The available information about algal blooms in inland waters can be summarised as follows:

- In recent years SA Water has recorded a reduction in the incidence of *Anabaena circinalis* – a species of blue-green algae – at water supply off-takes along the River Murray. This is most probably due to the high turbidity and absence of persistent thermal stratification that accompanies above-entitlement flows. It is not due to reduced levels of nutrients entering the river.

Table 6: Algal alerts reported by DNR web site, September 1999*

Recreational status of 33 storages on alert		Drinking water status of 33 storages on alert	
• low level alert	24	• toxicity testing unnecessary	30
• medium level alert	4	• analysis pending	2
• high level alert	5	• treatment recommended	1
	33		*33*

** See appendix 1 for explanations of the guidelines adopted by the DNR for determining recreational and drinking water status.*

- SA Water also monitors for excessive algal growth in the metropolitan water storages and for the adverse impacts of excessive algal growth in the water treatment and distribution systems. These data are not particularly meaningful as environmental indicators; such growths are closely monitored and heavily treated when they appear. (The metropolitan water storages are not used for recreational purposes.)
- Lake Torrens is an artificial recreational lake in the middle of Adelaide. It was created about 100 years ago but recorded its first significant bloom, in fact its first ever bloom, in January 1998, coinciding with a major dredging operation. The bloom recurred in January 1999 and has caused the loss of significant recreational and amenity values.
- Waterfall Gully, which is a recreational resource in the Mt Lofty area, was the only other site that was mentioned to the study team as having a problem with algal blooms.

SA Water maintains more detailed records of algal blooms but these data were not available to this study.

2.2.5 Western Australia

According to the 1998 *State of the Environment Report* (WA Department of Environmental Protection, 1998) and supporting studies (Government of WA, 1997), the information on reported incidence of algal blooms in WA is limited to a small number of waterbodies. It can be summarised as follows:

- *Perth Metropolitan region:* Several lakes in the Perth Metropolitan region have shown signs that human activities have made them eutrophic or hyper-eutrophic, and large masses of green macroalgae in the Swan-Canning estuary indicate nutrient enrichment of the waterbody for some time. Incidents of potentially harmful phytoplankton blooms in the Swan-Canning and Avon Rivers were running at about six per year in the period 1978 to 1993. Potentially toxic blue-green blooms prevented recreational use of the Canning River for several months in 1994 and 1998.
- *South West Forests:* There are increasing signs of eutrophication in rivers draining agricultural land, including all rivers with a substantial amount of agricultural land in their catchments. There have been severe blue-green algal blooms in the Blackwood, Collie and other rivers in recent years.
- *Swan Coastal Plain:* Four of the seven estuaries on the Swan Coastal Plain – Peel Inlet, Harvey Estuary, Vasse Lagoon and Wonnerup Lagoon – are eutrophic and in poor condition. Two others are degrading. Increased flushing via the Dawesville channel – cut at a cost of more than $60 million in 1995 – have improved the condition of the Peel-Harvey.
- *Wheatbelt:* There is widespread evidence of eutrophication and algal blooms in the wetlands and river pools of the wheatbelt.
- *South Coast:* Estuaries, rivers and wetlands in the region show the symptoms of eutrophication, including algal blooms.

In its most recent update on algal blooms in the state, the WA Water and Rivers Commission (1999) reported:

> *Algal blooms have affected several rivers in the south west of the state this summer. Blue-green blooms have occurred in the Vasse, Avon, Serpentine and Canning rivers in recent months, in addition to a nuisance bloom in the Swan River. The Commission has issued public warnings in conjunction with the Health Department in areas where blue-green blooms could be potentially toxic to both humans and animals.*

2.2.6 Tasmania

Based on discussions with the Tasmanian Departments of Health and Human Services, and Primary Industries, Water and Environment (DPWIE), algal blooms are not a significant problem in Tasmania. The health department does not consider it to be an issue and no formal records are maintained by DPWIE. DPWIE advised that:

- Algae are sometimes a nuisance, particularly in farm storages, but direct costs are minimal.
- Tasmania's sole blue-green algal bloom on record occurred in an irrigation dam (Craigbourne) in 1997. There was some irrigator concern about possible loss of market garden produce but it was not a significant issue. The impact on tourism and recreation was minimal.
- There are ongoing green algal blooms in two water storages in the Central Highlands that are managed by a hydro-electricity company. Some monitoring and management costs are incurred; the water is also used for irrigation.

- The North West Regional Water Authority monitors for algae three times per year and has 10 years of data, in which time there have been no blooms.

2.2.7 Northern Territory

Algal blooms are not seen as a significant issue in the NT:

- Apart from Darwin and Katherine, drinking water is drawn from groundwater sources.
- Darwin is considered to have excellent drinking water. The absence of blooms in its storages is attributed to the combination of protected catchments and the fact that the NT's soils are generally leached, shallow and low in nutrients.
- Irrigation in the NT is almost entirely reliant on groundwater.

The NT's experience with blooms is limited to the following:

- The first inundation of new storages resulted in algal blooms that were treated with copper sulphate. These are once-only events associated with the release of nutrients from the freshly inundated soils.
- Algal blooms occur in the marine environment and the community sometimes mistakes these for oil slicks.
- Some work is being done on algal blooms in billabongs on the coastal flood plain, in particular to assess the impact of the pastoral industry relative to the natural incidence of algal blooms.

2.2.8 Australian Capital Territory

The Water Unit of Environment ACT has explained that Canberra's lake system has been designed to stop sediment and pollutants entering the river system so the quality of downstream water is protected. Large numbers of blue-green algae can form in those lakes in the warmer months. For example:

- Lake Tuggeranong experienced two blue-green algae blooms significant enough to close the lake for short periods in January and February 1998.
- Blue-green algae were also present in Point Hut Pond on a number of occasions, but levels were not high enough to close the pond to the public.
- Blooms also occur in Lake Burley Griffin, but that is the responsibility of the National Capital Authority.

In general, water quality in Canberra's lakes is improving as catchments stabilise after extensive development.

2.3 Conclusion

The survey of major water resource managers in each state has shown that the extent of the monitoring programs to detect algal blooms varies widely and the programs have been operating for different periods. In some cases the data have not been made available to the study.

The quality of the available data on algal blooms is such that its presentation does little more than set the scene for the report. The main practical implication is that Tasmania and the Northern Territory are excluded from further consideration; the incidence of algal blooms there is not significant.

3. Total cost of algal blooms

This section estimates:

- the additional costs of environment protection expenditure that will eventually be incurred in response to algal blooms; and
- the total costs of algal blooms that are currently being incurred by extractive and non-extractive users.

We link these two figures because we consider that the cost of algal blooms can be sensibly regarded as a multiple of the environmental protection expenditures that will be needed to respond adequately to algal blooms.

The underlying consideration is that investments in environment protection are responses to the collective needs of all users, including both extractive and non-extractive users. Users may water their crops or stock, or drink the water themselves; they may be involved in primary or secondary contact recreation; they may enjoy the amenity values of water bodies on visits or as local residents; they may fear the loss of markets if their region's 'clean and green' image is tarnished by algal blooms; or they may be non-users who need to know that certain environmental values are being preserved. But regardless of their individual needs and the additional costs incurred to meet those needs in the presence of algal blooms, their collective desire to tackle the underlying causes of algal blooms is expressed in actual or planned expenditures to protect the environment. Such expenditures may be taxpayer funded or extracted from individuals by applying the principal of 'polluter pays'.

To estimate the total costs that are currently incurred by all users it is necessary to:

- estimate the additional environment protection expenditures that will eventually be incurred to deal with algal blooms; and
- estimate the total cost of algal blooms by applying an appropriate multiplier.

We address the first requirement in section 3.1 and the second requirement in section 3.2.

3.1 Environment protection expenditures attributable to algal blooms

3.1.1 Introduction

We identified three broad areas in which additional costs are likely to be incurred in response to the problems posed by algal blooms, as follows:

- management of urban sewage and stormwater – see section 3.1.2;
- management of agricultural and industrial wastewater, for example, effluent from piggeries, dairies and food processing industries – see section 3.1.3; and
- rehabilitation of land and water resources – see section 3.1.4.

Section 3.1.5 gives a summary statement of these costs.

In defining these categories, we have been mindful of the classification scheme that the Australian Bureau of Statistics (ABS) has adopted in its most recent report on environment protection expenditure (ABS, 1999). In that publication, environment protection expenditures are classified according to the environmental media or the type of pollution or degradation, as follows for 1996–97:

- waste management – $2.5 billion;
- wastewater and water protection – $3.0 billion;
- ambient air and climate protection – $0.4 billion;
- protection of biodiversity and landscape – $1.5 billion;
- protection of soil and groundwater – $0.3 billion; and
- other, including noise and vibration abatement, research and development, and other joint expenditures that cannot be readily allocated to a particular domain – $0.8 billion.

The ABS would assign additional costs in our first two categories – management of urban sewage and stormwater, and management of agricultural and industrial wastewater – to the domain of 'wastewater

Table 7: Expenditure on wastewater management 1995–96 and 1996–97

	1995–96 ($m)	1996–97 ($m)
Current expenditure		
Final consumption spending	1,850.7	1,958.0
• *Household final consumption*	*1,729.4*	*1,749.9*
• *Government final consumption*	*121.3*	*208.1*
Intermediate consumption spending	385.9	439.6
• *Agriculture*	*6.7*	*11.8*
• *Manufacturing*	*135.3*	*142.9*
• *Mining*	*39.2*	*44.9*
• *Utilities*	*26.4*	*35.9*
• *Service industries*	*178.4*	*204.2*
Total consumption spending	2,236.6	2,397.6
Capital expenditure		
Wastewater management services	419.0	395.9
Agriculture	7.7	8.8
Manufacturing	116.9	128.1
Mining	69.6	44.7
Utilities	15.7	21.6
Service industries	61.4	21.5
Total capital formation	690.3	620.6
Total expenditure, current and capital	**2,926.9**	**3,018.3**

Source: ABS (1999)

and water protection'. The total cost of activities in this domain is about $3 billion per year – see table 7. These data include relatively minor amounts estimated for septic systems, but otherwise correspond closely to conventional definitions of point sources of pollution. Note also that the steady replacement of septic systems with sewerage systems has the effect of converting diffuse sources into point sources and enhancing treatment. To the extent that these investments are intended to reduce nutrient discharges, some part of the cost also needs to be counted as an investment in nutrient reduction.

The third area (rehabilitation of land and water resources) includes activities of the following kind:

- stream bank stabilisation and improved management of riparian zones, both of which help reduce discharges from diffuse sources; and
- protection and enhancement of aquatic ecosystems, with the effect of restoring natural sinks for nutrients and increasing populations of micro-organisms that graze on algae.

These activities provide a range of environmental benefits other than nutrient reduction. The ABS would assign the cost of these activities to two domains: protection of biodiversity and landscape, and protection of soil and groundwater.

Conservative nature of the estimate

If plans for responding to algal blooms are reasonably well advanced – which we think is the case – it seems reasonable to attempt an estimate of the environment protection expenditures that will eventually be incurred in response to algal blooms. That said, this method also presents considerable difficulties – in addition to the 'crystal ball' requirements:

- Investments in environment protection often serve multiple environmental objectives. For example, enhanced sewage treatment may not only reduce nutrients but also improve turbidity, microbiological quality, or other aspects of water quality. It is easy to attribute too much spending to algal blooms, ignoring the other drivers.
- Even measures that are aimed at algal blooms may be implemented for the benefit of extractive users rather than non-extractive users, or for some combination of the two.

In each case it is important to make conservative assessments of the costs of environmental protection measures that are or will be incurred.

3.1.2 Management of urban sewage and stormwater

Background

Until relatively recently it was accepted practice for effluent from sewage treatment plants (STP) to be discharged to inland streams with phosphorus concentrations in the range of 8 to 12 mg/L. (This is variously described as primary or secondary treatment.) That situation is changing. Based on discussions with resource management agencies in each of the states, we understand that over the next 5 to 10 years, STPs will either cease discharging to inland waters or, where discharge to land is not feasible, install treatment facilities to greatly reduce the discharge of nutrients. Appendix 2 gives an account of the policy directions being followed in each state. Overall, WA seems to have reacted earlier and more comprehensively to concerns about algal blooms.

The results of a recent survey of capital expenditure by water authorities (Australian Water & Wastewater Association, 1998, p3) suggests the scale of activity:

> *Investment on wastewater treatment plants…is of the order of $403M in 1997/98 and $565M in 1998/99. Non-metropolitan water utilities in New South Wales and Queensland will be the major investors in 1998/99…Across all states and territories, environmental regulations are the main driving force behind investment in wastewater treatment…Almost 70% of utilities expected to consider using biological nutrient removal technologies and over 80% expected to consider treating wastewater to a standard that would allow commercial reuse.*

In addition, all states are extending the coverage of sewerage systems (replacing septic tanks) and working to improve the management of urban stormwater. In WA, for example, the Water Corporation's Sewerage Infill Program will replace about 110,000 septic systems with sewerage services, over 10 years at a cost of $800 million. In 1997, NSW announced that $60 million would be provided over three years in the form of grants to address stormwater pollution throughout the state.

Cost of relevant environment protection activities

Urban sewerage systems

The cost of upgrading STPs to include phosphorus removal has been the subject of several investigations (Water Board, 1991; KME, 1993; NSW EPA, 1994). Drawing on these estimates we have characterised the required upgrade as reducing phosphorus content of effluent from 8mg/L to 0.5mg/L and put the cost at the levels given in table 8.

These costs are incurred if the STP continues to discharge to inland rivers. In many cases, however, the cost can be considerably reduced by opting for irrigation or by developing an appropriate scheme for effluent reuse. In some cases reuse schemes are so profitable that there is no net cost. However, informal advice from the Victorian EPA is that STPs save about half of the cost of upgrading if they are able to develop a reuse option. We therefore put the cost of adopting the land disposal option at 50 per cent of the costs given in table 8.

To estimate the total costs of improved management of sewage discharges to inland rivers, it is necessary to obtain information about the size distribution of STPs that discharge to inland waters and their actual or likely choice of disposal option. For NSW, the size distribution of STPs is available from the EPA web site (http://www.epa.nsw.gov.au/soe/97/figs/download/ch3f05.xls). We assume that all such STPs with a capacity exceeding 2,500 equivalent persons (EP) choose the land disposal option, with the exception of the plants at Albury, Canberra and those operated by Sydney Water Corporation in the Hawkesbury-Nepean system, which are known to have adopted nutrient removal. (The cut-off at 2,500EP reflects NSW's licensing arrangements – see appendix 2.) Table 9 reports the results. We put the total cost of ceasing the discharge of secondary treated effluent to inland rivers at $15.3 million per year, comprising $10.8 million for the additional cost of nutrient removal and $4.5 million for the additional cost of land disposal.

Table 8: Estimated cost of upgrading STPs to include nutrient removal ($ per kilogram of phosphorus removed)

Capacity (EP*)	Cost ($/kg P)	Capacity (EP)	Cost ($/kg P)	Capacity (EP)	Cost ($/kg P)
1,000	60	7,000	29	40,000	21
2,000	49	8,000	27	50,000	21
3,000	40	9,000	27	60,000	20
4,000	36	10,000	26	70,000	19
5,000	31	20,000	23	80,000	18
6,000	29	30,000	22	90,000+	17

** EP = equivalent person*

SA Water has been able to supply information of the same quality as that available from the NSW EPA. Only two plants meet the criteria for inclusion in our estimate of additional costs (Mannum and Murray Bridge); they now discharge to land. Using the same approach as for NSW, we put the additional cost at $0.1 million per year. Much rougher estimates were used for the other states, as follows:

- Victorians generate some 475,500 ML of sewage per year of which about 40,000 ML is discharged to inland streams (Victorian EPA, 1995b, p4). By comparison, 120,000 ML per year is discharged to inland streams in NSW. Accordingly we put the Victorian cost at one-third of the NSW cost, that is, $5 million per year.
- About 120,000 Queenslanders live in the urban areas in the Murray-Darling Basin, defined as centres with 4,000 or more people. This is about 30 per cent of the number of NSW residents living in similar circumstances – provided Canberra is excluded as not being representative of typical inland communities. Accordingly, we put the cost at 30 per cent of the costs incurred in the NSW portion of the Murray-Darling Basin (excluding Canberra), that is, $1.5 million per year.
- Regarding WA, informal advice from the Water Corporation and the Department of Environmental Protection indicates that about 20 STPs have ceased or will cease discharges to inland streams. They serve communities that range in size up to 20,000 persons. Based on comparisons with costs incurred by NSW communities in the same size range, we put the cost at $1.7 million per year.

These costs tally to $23.6 million per year (see table 11). It is important to note that many inland STPs throughout Australia have discharged to land for many years. They have not been included in the cost estimate since, presumably, these authorities found land disposal to be an attractive option before the discharge standards were tightened. Broadly speaking, we have attempted to estimate the costs that will be incurred from the mid-1990s onwards, and which can reasonably be regarded as responses to emerging concerns about nutrient levels and the incidence of algal blooms.

Sewerage infill programs

WA's Sewerage Infill Program provides the clearest evidence of costs that will be incurred to replace septic systems with sewerage systems, and where the program is to a significant degree a response to concerns about the discharge of nutrients to surface waters and the incidence of algal blooms. Under the program, the WA Government is spending $800 million over 10 years to establish the new sewerage schemes, averaging about $7,000 for each of the 110,000 properties that will be offered the conversion. In addition, property owners will incur the following costs:

- connection costs of about $1,000 per property;
- costs of decommissioning existing septic systems, which involves pumping out, breaking the concrete base, and filling them with sand; and

Table 9: Size distribution and treatment type of STPs discharging to inland rivers in NSW and SA

	Type of treatment expected to be adopted		
Capacity (EP)	**Land disposal**	**Nutrient removal**	**Total**
Less than 10,000	28	8	36
10,000–20,000	10	3	13
20,000–30,000	4	4	8
30,000–40,000	2	1	3
40,000–50,000	1		1
50,000–100,000	1	3	4
100,000+		2	2
Total	**46**	**21**	**67**

- ongoing charges for future operation and maintenance of the sewerage system.

There will be offsetting savings from the avoided costs of operating existing septic systems and of replacing those systems when they require renewal.

Our limited attempts to identify and obtain existing assessments of the net cost were unsuccessful. We therefore make the following assumptions:

- Property owners do not incur additional capital costs as a result of conversion; that is, the costs of connection and decommissioning are fully offset by future savings on the cost of replacing septic systems as they fall due for renewal.
- Property owners do not incur additional costs of operation and maintenance as a result of conversion; that is, sewerage charges of several hundred dollars per year are fully offset by savings in the costs of grease removal, effluent and sludge pump-out, and other forms of septic maintenance. We understand that this is a very conservative assumption, given the low cost of septic maintenance on WA's sandy soils.

On these assumptions, the only additional cost is the $800 million capital cost of the scheme. The annualised equivalent is $40 million per year at a minimum, being the interest charges on $800 million (5 per cent per annum of $800 million).

There are similar schemes in other states. For example, 150 villages in country NSW have been identified as needing sewerage services on health or environmental grounds and will attract grants of up to 75 per cent of the cost from the NSW Government. However, it is more difficult to attribute these investments to concerns about nutrients and the incidence of algal blooms. Other concerns are more prominent; in particular, microbiological contamination of waterways and on-site or local issues of amenity and public health.

WA's Water Corporation (1999) explains the situation as follows:

> *Historically, Western Australia has relied much more heavily on septic tanks than other States because the thinking of the day was that Perth's sandy soils were suitable for septic tank disposal.*
>
> *When the Infill Sewerage Program began, 25% of Perth properties and considerably higher proportions of some country towns were unsewered. In the case of the coastal city of Geraldton, for instance, 75% of properties relied on septic tanks.*
>
> *In a climate of growing concern over the threat to our groundwater reserves and the surrounding environment, and public health, the Infill Sewerage Program began in July 1994.*
>
> *Of particular concern were the unacceptably high levels of pollutants leaching into groundwater sources*

> *now becoming an increasingly important part of Perth's scheme water supply. High levels of nitrogen and phosphorous in the leached material were also contributing to algae growth in waterways and wetlands…Environmental and public health needs have driven the order of priority in the first four years of the Infill Sewerage Program – and will continue to be the main considerations.*
>
> *Areas most susceptible to septic tanks flooding and overflowing, particularly in winter, have been high on the list. In Perth, for example, low-lying properties near rivers and other wetlands in suburbs including Bayswater, Bassendean, South Guildford, Gosnells and Kelmscott have been among the first targeted for connection.*
>
> *In country areas, too, the threat posed by septic tanks to wetlands, waterways and other areas of particular environmental sensitivity has been the key factor in setting priorities. Towns such as Albany, Capel, Harvey, Waroona, Pemberton and Busselton have been high on the priority list and work is currently being undertaken in all these towns.*

Officers of the Swan River Trust and the Water and Rivers Commission have indicated that algal blooms have been a strong driver for the Sewerage Infill Program and that a significant part of the cost should be counted as a nutrient reduction activity designed to reduce the incidence of algal blooms.

Urban stormwater

Efforts to improve the management of urban stormwater are still in their early stages. The common elements in stormwater initiatives taken by NSW, Victoria and Queensland are:

- statements of the roles and responsibilities of local authorities and state EPAs, including the responsibility of local authorities to prepare stormwater management plans;
- provision of model stormwater management plans designed to provide guidance to local authorities; and
- provision of best practice manuals or guidelines designed to support the planning process.

We note that stormwater education programs figure prominently in the nutrient management plans of the Hawkesbury Nepean Catchment Management Trust and of the catchment management authorities for the Glenelg Hopkins and North East regions of Victoria – see Read Sturges and Associates (1999) and Victorian DNRE (1998).

NSW has gone somewhat further than the other states. Its Urban Stormwater Management Program will provide $60 million over three years to:

- fund a stormwater education program ($2 million);
- assist councils to meet an EPA requirement to prepare stormwater management plans (50 per cent of cost); and
- subsidise the implementation of high-priority projects, for example, pollutant traps and wetlands to protect drinking water catchments – recent grants to inland centres include (the bracketed figure is the amount of the grant, which would be half of the project cost):
  - stormwater treatment wetland to protect Lake Albert at Wagga Wagga ($212,000);
  - a series of stormwater management practices at Deniliquin, including gross pollutant traps, sedimentation ponds and constructed wetlands to treat run-off entering the Edwards River ($337,000);
  - stormwater treatment wetland at Dubbo to reduce levels of urban stormwater pollution entering the Macquarie River ($500,000);
  - infiltration trenches, gross pollutant traps and a stormwater treatment wetland at Berrigan on the Murray River ($63,200);
  - stormwater treatment wetland at Tamworth to reduce pollutant loads to the Peel River ($307,500); and
  - stormwater wetland and gross pollutant trap at Gol Gol near Mildura on the Murray River ($88,000).

Ultimately, many hundreds of millions of dollars will need to be invested in urban stormwater management. Consider that:

- The $60 million being spent in NSW is regarded as little more than seed money designed to provide demonstration sites and force the pace of stormwater planning.
- A recent Victorian EPA report provides an estimate that it would cost $300 million to retro-fit the

existing drainage system within Melbourne Water's jurisdiction to install litter and sediment traps and other measures to improve water quality (Victorian EPA, 1999, p90).

- We interpret data from that same report (see Victorian EPA (1999), table 11) to indicate that, over time, urban communities would move to a situation where they spend an additional $700 per hectare per year to adopt best management practices for stormwater. The major item is renewal of the drainage system, where progress is governed by an 80-year asset replacement cycle. There are also significant ongoing costs of enforcement, education and awareness activities, improved waste management practices, extra street sweeping and drain cleaning. Assuming an urban population density of 30 persons per hectare, this suggests that plans are being organised based on the community willing to spend about $23 per person per year, albeit when existing assets fall due for replacement.

It is useful to compare that figure with amounts invested by selected inland urban areas under the NSW Urban Stormwater Management Program. The per capita amounts are in the range of $0.80 to $7.00 per year (see table 10). These amounts appear accurate if regarded as seed funding. Presumably, there are many other opportunities to improve stormwater management.

On this evidence we consider that, in the longer term, the cost of improved stormwater management can be conservatively put at $10 per person per year. The urban population in the Murray-Darling Basin and the Hawkesbury Nepean numbers two million. The total cost can therefore be put at $20 million per year at a minimum.

The management of urban stormwater is invariably listed as an issue when the problem of nutrient pollution is addressed, for example, in algal management strategy documents and nutrient control plans. Nevertheless, these costs will not be incurred solely in response to concerns about nutrient pollution and algal blooms. Stormwater also carries metals, litter, sediment and chemicals; its velocity is environmentally damaging; and its bacteriological quality can also be poor.

Costs attributed to algal blooms

Table 11 presents our estimates of the additional costs of urban sewage and stormwater that can be attributed to algal blooms, derived as follows:

- The first panel reports our estimates of the additional costs of environmental protection activities in respect of which concerns about algal blooms can be regarded as a significant driver.
- The second panel reports our assessment of the proportion of those costs that can be reasonably attributed to algal blooms. These are necessarily subjective but are based on review of relevant documentation and informal discussions with officers of state land and water management agencies and environmental regulators.
- The third panel is the product of the first and second panels. Overall we put the additional costs at about $40 million per year.

3.1.3 Management of agricultural and industrial wastewater

As reported in table 7, agricultural and industrial enterprises spend large amounts on wastewater and water protection activities – $664 million in 1996–97. Table 12 provides a more detailed breakdown of these

Table 10: Per capita costs of inland projects funded by the NSW Urban Stormwater Management Program

Urban centre	Population	Project cost ($)	Annualised cost ($/year)	Per capita cost ($/year)
Wagga Wagga	43,000	424,000	33,920	0.79
Deniliquin	8,000	674,000	53,920	6.74
Dubbo	30,000	1,000,000	80,000	2.67
Tamworth	32,000	615,000	49,200	1.54

Table 11: Costs of urban sewage and stormwater that can be attributed to algal blooms

	NSW	Vic	Qld	SA	WA	Total
1. Additional cost of nutrient reduction activities ($m per year)						
Sewage treatment/disposal	15.3	5.0	1.5	0.1	1.7	23.6
Sewerage infill	–	–	–	–	40.0	40.0
Stormwater management	16.5	2.2	1.1	0.2	–	20.0
Total	**15.3**	**5.0**	**1.5**	**0.3**	**41.7**	**83.6**
2. Proportion of costs attributed to algal blooms (%)						
Sewage treatment/disposal	75	75	75	75	75	75
Sewerage infill	–	–	–	–	50	50
Stormwater management	25	25	25	25	–	25
3. Additional costs attributed to algal blooms ($m per year)						
Sewage treatment/disposal	11.5	3.8	1.1	0.1	1.3	17.7
Sewerage infill	–	–	–	–	20.0	20.0
Stormwater management	4.1	0.6	0.3	0.1	–	5.0
Total	**15.6**	**4.3**	**1.4**	**0.1**	**21.3**	**42.7**

data, including additional detail for selected agricultural and manufacturing industries. Typical environment protection activities include:

- agriculture – flushing systems, collection drains, holding ponds for piggeries, dairies and cattle feedlots;
- manufacturing – changes of production processes to reduce the discharge of nutrients;
- mining – tailings dams; and
- services – on-site sedimentation ponds to control run-off from construction sites.

Table 13 shows our assessment of the costs that can reasonably be attributed to concerns about nutrient pollution of waterways and algal blooms. It is derived as follows:

- Column 1 reports total expenditure on wastewater and water protection activities, excluding ‘current market’ expenditure for all industries besides agriculture. This item is excluded because it consists largely of sewerage charges; additional costs of that kind were the subject of the previous section. Agriculture is the exception because it is considered that such charges would be minimal for agriculture.
- Column 2 provides conservative assessments of the proportions of these costs that can be reasonably attributed to algal blooms, having regard to the types of activities reporting costs in this category, the types of activities likely to be found in inland centres and the significance of nutrients in the waste streams from these activities.
- Column 3 is the product of columns 1 and 2. Overall we put the additional costs that can be attributed to algal blooms about $30 million per year.

3.1.4 Rehabilitation of land and water resources

The rehabilitation of land and water resources on a catchment scale includes a range of activities that can be regarded as one or more of:

- abatement measures aimed at reducing diffuse source pollution arising from soil erosion or agricultural run-off;
- measures that establish or maintain aquatic plants that increase the natural take-up of nutrients; and
- measures that will establish or maintain populations of the microorganisms that graze on algae.

Table 12: Expenditure on wastewater and water protection activities, 1996–97

	Current spending ($m)			Capital spending ($m)	Total spending ($m)
	Market	Internal	Total current		
Agriculture	9.1	2.7	11.8	8.8	20.6
vegetables	–	–	–	–	*4.2*
dairy farms	–	–	–	–	*4.3*
pig farms	–	–	–	–	*1.6*
Manufacturing	130.9	11.8	142.9	128.1	271.0
food & beverages	–	–	–	–	*40.0*
wood & paper	–	–	–	–	*7.6*
Mining	22.9	21.9	44.9	44.7	89.6
Utilities	13.7	14.5	35.9	21.6	57.5
Services	123.1	81.0	204.2	21.5	225.6
Total	**299.7**	**131.9**	**439.6**	**224.7**	**664.4**

Source: ABS (1999)

Table 13: Costs of agricultural/industrial wastewater and water protection activities attributed to algal blooms

	Total cost of environment protection* ($m/year)	Proportion of costs attributed to algal blooms (%)	Additional costs attributed to algal blooms ($m per year)
Agriculture	20.6	*40*	8.2
Manufacturing	140.1	*10*	14.0
Mining	66.7	*5*	3.3
Utilities	43.8	*5*	2.2
Services	102.5	*5*	5.1
Total	**373.7**	**–**	**32.9**

** Total excludes 'current market' expenditure for all industries other than agriculture.*

The Natural Heritage Trust (NHT) is the main vehicle for funding and promoting these types of activities. The following NHT programs are involved:

- The Murray-Darling 2001 Program addresses high-priority water quality and river health issues in the Murray-Darling basin. It aims to improve water quality by reducing the current salt and nutrient levels, and to restore the health of riparian land systems, wetlands and floodplains.
- The National Rivercare Program promotes activities that contribute to the sustainable management, rehabilitation and conservation of inland rivers outside the Murray-Darling Basin.
- The objectives of the National Landcare Program are to integrate catchment management, particularly land, water and related vegetation management, and to promote sustainable agricultural productivity.

Projected expenditures for three relevant programs are given in table 14. Several other smaller programs would also be partial responses to concerns about algal blooms but are excluded from consideration here; specifically, the National River Health Program, Waterwatch Australia, and the National Wetlands Program.

We also exclude costs associated with increasing environmental flows in Australian rivers. Such costs will be incurred in situations where increased flows are expected to reduce the incidence of algal blooms. However, the relevant consultative and decision-making processes are still in their early stages. Preliminary inquiries revealed that little information was readily available.

Table 15 reports our assessment of the costs that can reasonably be attributed to concerns about nutrient pollution of waterways and algal blooms. It is derived as follows:

- Row 1 reports annual average Commonwealth expenditure under the selected NHT programs.
- A suitable multiplier needs to be applied to Commonwealth expenditure in order to allow for the contributions of state governments and community volunteers, the latter usually in the form of in-kind services. At a minimum, the multiplier is three. In general terms, Commonwealth, state and community sources share the costs equally, one-third each. It has been suggested to us that the multiplier might be as high as 7 or 10 if state and community inputs were properly counted, including projects that do not succeed in attracting NHT funding. We adopt the relatively conservative multiplier of 3.5. This brings our estimate of average annual spending to $540 million per year – see row 3.
- Next, a suitably conservative judgment needs to be made about the proportions of these expenditures that can be reasonably attributed to algal blooms. We nominate the proportions given in row 5 and note the following:
  - Nutrients and algal blooms are given prominence in NHT documentation relating to MD2001.
  - NHT guidelines for applicants state that projects focusing on river health should propose to do one of the following: maintain or improve water

Table 14: Commonwealth expenditure on selected NHT programs

Description	1998–99 ($m)	1999–2000 ($m)	2000–01 ($m)	2001–02 ($m)	Total ($m)
Murray-Darling 2001 Program	40.4	43.1	48.7	32.6	164.8
National Rivercare Program	19.2	21.7	24.6	15.6	81.1
National Landcare Program	114.4	87.9	82.8	86.7	371.8
Total	**174.0**	**152.7**	**156.1**	**134.9**	**617.7**

Source: Budget 1999–2000: Ministerial Statements, chapters 5 and 6.

quality by preventing pollution (such as trapping sediments or nutrients), improving the management of discharges or controlling stock access to water; manage accelerated erosion or build up of river banks or beds; or contribute to healthy stream and riparian ecosystems.

– Nutrients and algal blooms are also significant issues in many river systems outside the Murray-Darling Basin, including various systems in Western Australia, the Hawkesbury Nepean in NSW, and the Fitzroy Basin in Queensland.

– Informally, state program managers acknowledged the significance of algal blooms as an issue (particularly in WA), although they were reluctant to express a view about the proportion of expenditures that could be attributed to algal blooms.

- The total cost under each program is the product of rows 3 and 4, and is given in row 5. The tally is $45 million per year.

We assume that these or similar programs will need to continue for many years beyond the current life of the NHT. (The NHT is currently funded to 2002.) Program managers indicate that current rates of spending could continue indefinitely. They believe the NHT has funded a considerable amount of assessment, educational and planning activity that creates the preconditions for on-ground works, but very large investments in on-ground works are still required. They beleive that environmental objectives cannot be attained in the longer term with lower rates of spending.

3.1.5 Summary of additional costs

Table 16 summarises the results given in sections 3.1.2 to 3.1.4. The tally of environmental protection expenditures across the three broad areas of activity is approximately $120 million per year. This is about 1.4 per cent of the $8.6 billion that Australians spend each year to protect the environment.

3.2 Multiplier and estimate of total cost

Thesvalue of this estimate of anticipated environment protection expenditures is in what it reveals about the costs currently incurred. If the Australian community is eventually to spend approximately $120 million per year on environment protection activities that can be attributed to algal blooms, the current cost of algal blooms must be at least $120 million. In fact the current cost will be considerably larger than $120 million per year.

There are two reasons to expect the current cost of algal blooms exceeds $120 million. First, the anticipated investments in environment protection will generate net benefits in the form of reduced incidence and cost of algal blooms. Those future gains are the partial reversal of costs currently incurred, such as:

- increased cost of water treatment;
- reduced agricultural productivity; and
- loss of non-use values.

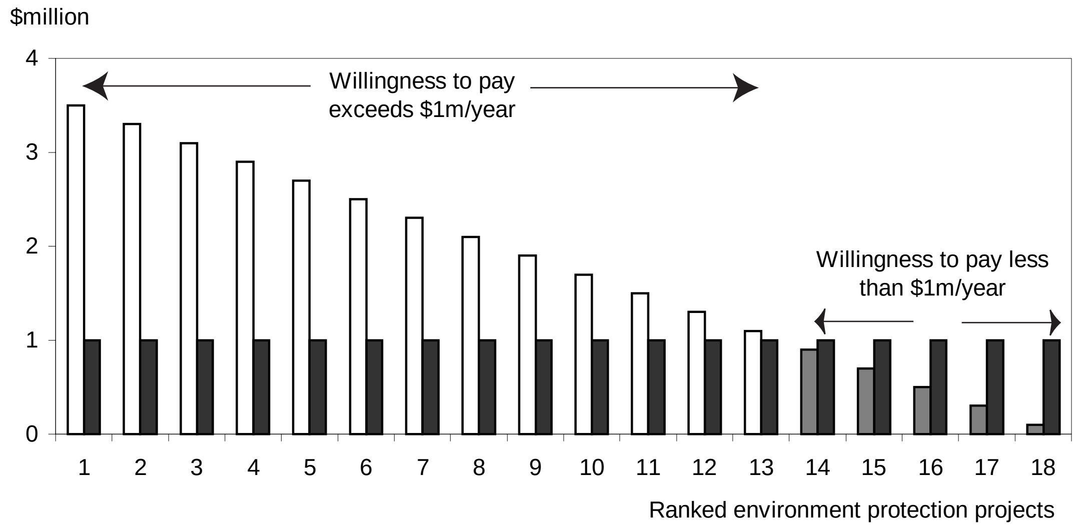
Table 15: Costs of rehabilitating land and water resources that can be attributed to algal blooms

	Murray-Darling 2001 Program	National Rivercare Program	National Landcare Program	Total
1. Commonwealth expenditure ($m per year)	41.2	20.3	93.0	154.4
2. Multiplier (to account for state and community contributions)	3.5	3.5	3.5	–
3. Total expenditure ($m per year)	144.2	71.1	325.5	540.8
4. Proportion of costs attributed to algal blooms (%)	15	10	5	–
5. Costs attributed to algal blooms ($m per year)	21.6	7.1	16.3	45.0

Table 16: Anticipated environment protection costs that can be attributed to algal blooms

Area of environmental protection activity	NSW	Vic	Qld	SA	WA	Total
Urban sewage and stormwater	15.6	4.3	1.4	0.1	21.3	42.7
Agricultural and industrial wastewater	–	–	–	–	–	32.9
Rehabilitation of land and water resources	–	–	–	–	–	45.0
Total	**–**	**–**	**–**	**–**	**–**	**120.6**

Figure 1: Willingness to pay for environment protection projects



Second, whatever environment protection activities are actually undertaken, they will not totally eliminate algal blooms. Both extractive and non-extractive users will continue to bear costs that cannot be fully reversed. For example, resource management authorities will continue to incur some monitoring costs; environment protection activities might have little effect on the incidence of algal blooms in farm dams; and in some cases it may be more cost effective to retain sophisticated water treatment facilities than to thoroughly protect the water supply catchment.

Figure 1 illustrates the relationship between the total costs of algal blooms currently incurred and the future cost of anticipated environment protection activities. It is constructed as follows:

- Suppose that environment protection proposals that are specific to algal blooms in a particular catchment can be characterised as a series of projects, each of which has an annualised cost of $1 million. For illustrative purposes, 18 such proposals are identified in figure 1; the black bars represent these costs.
- For a particular project to proceed the catchment community needs to be willing to pay at least $1 million, that is, to see the prospect of avoiding at least $1 million dollars of damage to extractive and non-extractive values as a result of the project. The net benefit of a project to a community is the amount by which willingness to pay exceeds $1 million.
- In figure 1, the 18 projects are ranked from left to right according to the community's willingness to pay for each project. Willingness to pay declines for two reasons. First, the more effective measures are adopted first, which means that, at the margin, each additional investment of $1 million has less impact on the discharge of nutrients and the incidence of blooms. Second, the community will put a higher value on the elimination of blooms in some

situations than in others, for example, depending on the number of potential visitors to recreation sites.

- Figure 1 shows 13 projects having a willingness to pay that exceeds the cost of $1 million per year. Ideally, these projects proceed; the remaining five projects are abandoned.

In this example the situation *before* implementation of the 13 projects is that the catchment community incurs a total cost of $31.4 million per year, being the sum of the amounts that the community is willing to pay across all possible projects. This is the sum of the white and grey columns in figure 1. *After* implementation, the cost to the community will be reduced to $15.5 million per year, comprising $13 million per year for environment protection activities *plus* $2.5 million per year in respect of residual algal problems. (The grey columns in figure 1 represent the latter component.)

The multiplier in this case is 2.4, that is, the ratio of $31.4 million to $13 million. However, this example merely explains what we mean by the multiplier; it does not establish the actual size of the multiplier.

Proposed multiplier

We consider that the multiplier can be reasonably put at 2 and very conservatively put at 1.5. See appendix 3 for a detailed explanation. Accordingly, the total cost of algal blooms can be put in the range of $180 million to $240 million per year. It may be considerably higher.

3.3 Conclusion

We have reviewed actual and anticipated environment protection expenditures that can be reasonably attributed to algal blooms and estimate that these expenditures can be expected to reach at least $120 million per year. It is difficult to make sense of these expenditures unless the current costs of algal blooms are of the order of $240 million. These costs can be very conservatively put at $180 million. We therefore put the current cost of algal blooms in the range of $180 million to $240 million per year.

This section reports our estimates of the cost of algal blooms to specific user groups, including joint management costs that are incurred on behalf of two or more user groups. The material is organised under the following headings:

- joint management costs – section 4.1;
- urban water supply – section 4.2;
- rural water supply (domestic, stock and irrigation) – section 4.3; and
- costs to non-extractive users – section 4.4.

4. Cost of algal blooms to specific user groups

This section reports our estimates of the cost of algal blooms to specific user groups, including joint management costs that are incurred on behalf of two or more user groups.

4.1 Joint management costs

4.1.1 Definitions

Once algae-affected water enters the off-takes of urban and rural extractive users, it necessarily becomes the problem of those users. This section deals with the costs incurred by the agencies that manage water resources *before* that point is reached. These agencies undertake the higher level (above off-take) functions of:

- operating major dams and irrigation systems that supply water to multiple rural users and/or urban water authorities, including monitoring, alert notifications and appropriate management of algal blooms 'above' the off-take (for example, algicide dosing of water storages); and/or
- assisting the managers of lesser systems to deal with algal blooms as and when they occur, for example, by organising additional monitoring and alert notifications, or by providing technical advice.

We define the relevant agencies in box 1.

It is important to note that, while the distinguishing feature of these agencies is that their operations do not extend below the off-take points of urban water authorities and rural users, the reverse is not always true.

In particular, the activities of many local water authorities extend above the off-take point to include the monitoring and management of lesser storages and, less frequently, the catchments of those storages. Any additional algae-related costs of that kind are treated as costs of urban water supplies (see section 4.2).

Box 1: Water management agencies

Victoria

Department of Natural Resources and the Environment; Goulburn-Murray Rural Water Authority (RWA); Gippsland and Southern RWA; Casey's Weir and Major Creek RWA; First Mildura Irrigation Trust; Sunraysia RWA; Wimmera-Mallee RWA

NSW (including ACT)

Department of Land and Water Conservation; Sydney Catchment Authority; Murray Irrigation Limited; Murrumbidgee Irrigation; Jemalong Irrigation; Coleambally Irrigation

Queensland

Department of Natural Resources (State Water Projects); South East Queensland Water Board

Western Australia

Water and Rivers Commission

South Australia

Department of the Environment, Heritage and Aboriginal Affairs

Murray-Darling Basin Commission

The specific activities to be costed are:

- contingency planning;
- monitoring of waterbodies for excessive algal growth;
- notification of users (signage and media activities) when algal alert levels are breached and response to customer complaints and inquiries; and
- implementation of contingency management actions as appropriate, for example, by dosing with algicides, closure of reservoirs to recreational use, adjustment of off-take points, switching to alternative sources of supply, interruptions to supply, or flushing.

4.1.2 Findings

Table 17 summarises our findings. A brief description of sources follows.

Cost of monitoring and notifications

We put the cost to NSW at $0.5 million per year, derived as follows:

- Based on discussions with irrigation companies, each company is spending some tens of thousands of dollars each year to monitor algal growth and to issue warnings as appropriate. Assuming $25,000 each for four irrigation companies, the total is $100,000 per year.
- Between them, the DLWC and the Sydney Catchment Authority monitor about 30 storages for excessive algal growth. Assuming an annual cost of $10,000 per storage – for monitoring and appropriate notifications to users – the total cost is $300,000.
- Discussions with the coordinators of the eight Regional Algal Coordinating Committees in NSW indicated that these coordination activities involve approximately 50 people at an average cost of about $2,000 each, plus ad hoc sampling at a cost of about $10,000 per committee. The total is $180,000 per year.

We conducted phone interviews with all but one of the Victorian RWAs and questionnaires were completed by three of the RWAs. Based on that information, the cost to Victoria is put at $0.5 million per year, most of which is incurred by the Goulburn-Murray RWA.

Overall we put the cost to Queensland at $0.7 million per year, derived as follows:

- The Queensland Department of Natural Resources (DNR) monitors approximately 50 dams and weirs and provides appropriate notifications to users. It has recently established a web site that reports the algal alert status of its storages and on behalf of other resource managers who choose to use the service. DNR estimates the additional costs (monitoring and notification) that can be attributed to algal blooms at $250,000.
- The South East Queensland Water Board (SEQWB) manages three storages independently of DNR. SEQWB estimates its additional costs at $1.36 million in once-off expenditures and $290,000 per year on ongoing costs. The annualised equivalent is $0.4 million per year ($290,000 plus 10 per cent of $1.36 million). These costs relate to: lake modelling and destratification design; installation and operation of a destratification unit; algal research; inflow monitoring; biological monitoring; algae sampling and toxin testing; and sediment investigations.

DNR is examining its management options for algal blooms at the present time. There is some prospect of millions of dollars being spent on destratification and other capital works and there is some ongoing work to investigate the potential of biomanipulation techniques.

On the basis of our discussions with the SA Department of the Environment, Heritage and Aboriginal Affairs, the department does not incur significant algae-related costs, at least in respect of inland waters. SA Water undertakes the relevant monitoring activities; these costs are reported in section 4.2. We put the cost to SA at zero.

The WA Water and Rivers Commission has reported large annual costs of monitoring for algae – $3.1 million per year – and has confirmed that figure in subsequent discussions. We have added reasonable additional costs for the cost of notifications to give a total figure of $3.5 million per year.

Contingency planning

All authorities that we interviewed had conducted some form of contingency planning and had determined their response to algal blooms. Based on information provided by the Goulburn-Murray RWA, we consider that the Australia-wide cost of these exercises can be reasonably put at $5 million. An equivalent annualised

Table 17: Joint costs of resource management

Cost of monitoring and notifications ($m)					Contingency planning ($m)	Cost of water used to flush algal blooms ($m)	Total ($m)
NSW	Vic	Qld	SA	WA			
0.5	0.5	0.7	0.0	3.5	0.5	3.0	**8.7**

figure is $500,000 per year, including ongoing costs of providing technical support and maintaining an appropriate skills base.

Loss of water

There are two possible scenarios for water loss. Either water is released from storage to flush downstream rivers or storages, or water cannot be released from a particular storage because of concerns that it will infect downstream rivers or storages. In both cases, irrigators and other rural users may suffer reduced access to water supplies. To assess the practical significance of these possibilities, we conducted phone interviews with relevant staff from the Murray-Darling Basin Commission, NSW DLWC and Queensland DNR. The Goulburn-Murray RWA also addressed the issue in its response to our questionnaire.

It was generally considered that the likely costs would be small. The thinking was that, given the multiple opportunities to re-regulate flows that have been released from upstream storages, particularly in the Murray-Darling Basin, overall losses to the system as a whole would be small – certainly hundreds of thousands rather than millions of dollars. The Goulburn-Murray RWA was an exception: it put costs at $2.6 million per year.

Overall we put the cost of reduced water supplies at $3.0 million per year.

It is important not to confuse these costs with the cost of restoring environmental flows in Australian rivers. The latter may be increased partly in response to concerns about algal blooms and a cost would thereby be incurred on account of algal blooms. We define this type of activity as environmental protection; ideally, such costs would be included in the estimates provided in section 3. As explained there, however, the processes for restoring environmental flows are not sufficiently advanced to allow reasonable cost estimates to be provided.

4.2 Urban water supplies

4.2.1 Method

The public water authorities were our main focus. (These include small systems that supply small villages that would not otherwise be recognised as urban areas.) In four states and territories we attempted a complete census of all such authorities, using a combination of phone interviews and a follow-up questionnaire (see appendix 4) where appropriate. This is straightforward where there is only one provider of public water for the entire state, as is the case in SA, WA and the ACT. It is somewhat more demanding in Victoria where public water supplies are provided by 19 metropolitan and regional water supply authorities. We contacted each Victorian authority by phone and dispatched questionnaires when adequate responses could not be provided during the phone interview; 8 out of 11 of these were returned. Follow-up was limited to one reminder call.

This comprehensive approach was not feasible in NSW and Queensland, where water supply is organised for the most part by local governments. Instead we asked the resource management agencies – DLWC in NSW and DNR in Queensland – to nominate the water authorities that they knew to experience problems with algal blooms. We then added other major authorities to compile a list of 32 NSW authorities and 10 Queensland authorities (see box 2).

We managed to contact all but two of these authorities by phone and dispatched questionnaires when adequate responses could not be provided during the phone interview; seven out of eight were returned from Queensland and 16 out of 19 were returned from NSW. Follow-up was limited to one reminder call.

Apparent gaps in individual returns were filled by the study team on the basis of comparisons with similar costs reported by other authorities.

Box 2: NSW and Queensland water authorities studied

NSW (including ACT)

ACT Electricity & Water; Armidale City Council; Ballina Shire Council; Balranald Shire Council; Bathurst City Council; Berrigan Shire Council Broken Hill Water Board; Central Darling Shire; Central Tablelands Water; Deniliquin Shire Council; Dubbo City Council; Glen Innes City Council; Griffith City Council; Hay Shire Council; Hunter Water Corporation; Inverell Shire Council; Lismore City Council; McLean Shire Council; Murray Shire Council; Orange City Council; Parry Shire Council; Rous Water; Rylestone Shire Council; Severn Shire Council; Shoalhaven City Council; Sydney Water Corporation; Tamworth City Council; Tenterfield Shire Council; Wakool Shire Council; Wagga Wagga City Council; Wentworth Shire Council; Yass Shire Council

Queensland

Brisbane Water; Bundaberg City Council; Caboolture Shire Council; Caloundra Maroochy Shire; Gladstone Water Board; Gold Coast City Council; Kingaroy City Council; Rockhampton City Council; Toowoomba City Council; Townsville Water Board

4.2.2 Findings

The results of the survey are presented in table 18. Note:

- WA Water Corporation reported total once-off and ongoing costs; the composition of its additional costs is not available.
- The total annualised cost to the water authorities in the survey is approximately $10 million per year

There are good reasons to expect that this is a conservative estimate of the additional costs, as follows:

- We were either unable to contact or unable to obtain useful information from several water

Table 18: Additional costs reported by public water authorities

	NSW	Vic	Qld	SA	WA	Australia
Once-off costs ($'000)						
Investigations & assessments	1,204	960	740	500	–	3,404
Catchment monitoring and management	134	30	160	500	–	824
Storage monitoring and management	467	12,02	550	250	–	13,288
Water treatment and distribution	9,026	2,776	1,590	8,700	–	22,092
Customer/user relations	11	2	7	0	–	20
Administration, training, overheads	12	30	25	0	–	67
Sub-total	10,854	15,819	3,072	9,950	1,000	40,695
Ongoing costs ($'000/year)						
Catchment monitoring and management	270	87	244	0	–	601
Storage monitoring and management	323	180	414	665	–	1,582
Water treatment and distribution	1,157	271	392	160		1,980
Customer/user relations	49	9	7	20	–	85
Administration, training, overheads	178	39	42	20	–	279
Value of lost production	525	225	37	0	–	787
Sub-total	2,501	810	1,136	865	100	5,413
Annualised cost ($'000/year)	**3,587**	**2,392**	**1,444**	**1,860**	**200**	**9,483**

authorities that were identified as likely to have algae-related problems. About 10 per cent of the non-metropolitan authorities fall into this category. (All metropolitan and state-wide authorities provided useable information.)

- Significant numbers of water authorities that incur additional costs have not been identified, certainly in Queensland and to a lesser extent in NSW. Queensland DNR is aware of gaps in its database, since authorities report the results of algal monitoring activities to DNR on a voluntary basis. For example, DNR does not receive reports from any authorities north of Rockhampton.
- It is apparent from our discussions with operators, and the content of returns that operator understanding of the issues varies from very good to quite poor. The quality of information provided suffers if respondents are not fully aware of the range of possible impacts on their operations.
- It is also apparent that some authorities are less willing or less able to deal with the problem. Their customers live with a consequent loss of water quality. Costs are incurred but not directly by the water authorities. On average, water authorities reported that their management responses to algal blooms were about 80 per cent effective.
- There is a significant problem of loss of corporate memory due to apparently high staff turnover. It was often the case, particularly in the more remote areas of NSW and Queensland, that operators did not know the algal history of the authority and could not reliably report a sensible average over good and bad years. This is a significant issue given that algal blooms impose high costs at relatively infrequent intervals – say, 1 in 10 years.
- There is a major discrepancy between the survey returns on the cost of algae-related interruptions to water supply and Victorian estimates of the cost of such interruptions in five catchments and along the Murray River. The former is only $800,000 per year and is a national figure; the latter tally is $8 million per year and relates to part of Victoria. We consider that the survey return is an underestimate, due mainly to a poorly worded question. The questionnaire asked about the loss of revenue when water restrictions were imposed by a water authority that is otherwise unable to cope with algal blooms. Water restrictions, however, are not generally imposed in that situation. Water is still supplied, if only to provide a fire service, but customers are advised not to use the water inside their homes and sometimes not even in their gardens. The community then incurs the cost of carting replacement supplies and loss of amenity. Based on the Victorian estimates, the national cost of interruptions to normal supplies might be conservatively estimated at $20 million per year.
- Finally, the reason that many water authorities do not have problems with algal blooms is that their catchments are heavily protected, for example, by the exclusion of all productive activity that might pollute drinking water storages. The land that is locked up in this way represents a substantial investment, part of which might reasonably be attributed to the algal blooms that would otherwise result.

To remedy the apparent deficiencies in the survey returns for Queensland, we interviewed a major supplier of activated carbon to water authorities in the eastern states. Based on a cursory review of recent sales, we were told that the market for activated carbon in Queensland is about $1 million per year. This compares with the survey return of about $400,000 for the ongoing costs of water treatment in Queensland.

We have not attempted to estimate the value of land that is locked up in drinking water catchments in order to prevent algal blooms. It is not an asset that is generally reported in the balance sheets of water authorities and we consider that respondents to the questionnaire would generally find it impossible to assess the counterfactual situation – that is, less catchment protection and more algal blooms.

Considering these factors, we put the cost of algal blooms to urban extractive users of water at about $35 million per year. The composition of this cost is shown in table 19.

Table 19: Cost of algal blooms to urban extractive users

	$m/year
1. Survey return	9.5
2. Double the survey estimate of Queensland costs	+1.4
3. Add 25 per cent to account for less than fully effective management of algal blooms	+2.7
4. Add $20 million as estimate of the cost of interruptions to the supply of potable water (but not actual water restrictions)	+20.0
Total	**33.6**

4.3 Rural water supplies

Rural users obtain their water from farm dams, surface waters, irrigation channels and groundwater. Only groundwater is free of costs associated with algal blooms. We consider the remaining three in turn.

4.3.1 Stock and domestic water from farm dams

Farmers incur the following costs in response to algal blooms on farm dams:

- monitoring costs;
- algicides;
- exclusion of stock by fencing or other means;
- carting of water;
- loss of feed or cost of replacement feed; and
- stock losses.

Our approach to estimating the total of these costs has been to:

- obtain an estimate of the total number of farm dams in Australia, extracted from Australian Bureau of Agricultural and Resource Economics (ABARE) farm surveys;
- review estimates of the cost per farm dam, extracted from various cost-benefit analyses of nutrient reduction strategies that have been completed for Victorian catchments; and
- multiply the total number of dams by a suitably conservative estimate of the cost per dam.

Number of farm dams

Table 20 reports ABARE's estimates of the number and value of farm dams in Australia. Note the following exclusions:

- Farm dams are defined to exclude structures that are not designed to harvest water, for example, 'earth tanks' and 'turkey nests'. These structures are used to store water that is pumped from rivers, dams or groundwater, and may be no more than watering points.
- Several significant industries fall outside the scope of the ABARE farm surveys, including horticulture, viticulture, cotton specialists and sugar.
- Sub-commercial (hobby) farms are also excluded from the survey.

We considered whether to exclude farm dams in the high-rainfall zone that forms the greater part of the coastal belt and the adjacent tablelands of the three eastern mainland states, small areas in eastern SA and south western WA and the whole of Tasmania. On the evidence of the situation in Victoria, however, there is no reason to suppose that dams in the high-rainfall zone are less likely to incur these costs. We therefore take ABARE's estimates at face value – approximately 375,000 farm dams worth about $2.0 billion.

Average cost of algal blooms per farm dam

The average cost of algal blooms has been estimated for typical conditions found in several Victorian catchments – see Read Sturgess and Associates (1998a, chapter 5; 1998b, chapter 5; 1999, chapter 2) and Victorian DNRE (1998, vol 2, chapter 3). We extracted the

Table 20: ABARE estimates of the number and value of farm dams

	Number of farm dams			Value of farm dams ($m)		
	Irrigator	Dryland	All farms	Irrigator	Dryland	All farms
Broadacre, pastoral zone	1,008	28,968	30,111	6.6	226.6	234.7
Broadacre, wheat-sheep zone	65,017	135,160	200,517	390.8	669.7	1,067.4
Broadacre, high-rainfall zone	16,332	100,913	117,417	164.0	369.8	554.2
Dairy	15,008	13,567	28,557	86.2	52.3	137.7
Total	**97,366**	**278,608**	**376,602**	**647.48**	**1,318.3**	**1,994.0**

following estimates of the average costs in each catchment:

- Ovens catchment – $55 per dam per year
- North East region – $14 per dam per year
- Glenelg Hopkins region – $140 per dam per year
- Goulburn Broken catchment – $150 per dam per year.

The main differences between the catchments were not in the cost of actual blooms but in the incidence of blooms. The estimates exclude monitoring costs, algicides and stock losses. In other respects, however, the authors of these studies acknowledge that the estimates may be somewhat generous. There is great uncertainty about these costs. In our few discussions with farmers, we found they were inclined to dismiss algal blooms as a fact of life and, given the associated costs were unavoidable, did not regard them as worthy of much consideration.

Overall, we consider that the average cost of algal blooms in farm dams can be put in the range of $50 to $100 per dam per year.

Total cost

Applying that average cost to the 375,000 farm dams in Australia, we put the total cost in the range $20 million to $40 million per year and nominate $30 million per year as the mid-value.

4.3.2 Stock and domestic water extracted from rivers, storages and irrigation channels

For stock and domestic users, blooms in surface waters impose costs in much the same way as blooms on farm dams, except that farmers avoid the monitoring costs and it is generally not feasible to treat surface waters with algicides. Hence the main costs are:

- exclusion of stock by fencing or other means;
- carting of water;
- loss of feed or cost of replacement feed; and
- stock losses.

According to the Victorian studies referred to in the previous section, a bloom in surface waters can be regarded as a more severe version of a bloom in a farm dam. That is, the costs are considered to be somewhat higher when a farmer is denied the use of a river or storage than when a farmer is denied the use of a farm dam. However, we have not been able to obtain national estimates of the number of farmers who draw water for stock and domestic purposes from rivers and storages, comparable to the estimates for farm dams obtained from ABARE.

We have therefore proceeded by comparing the Victorian estimates for the cost of blooms in rivers and storages with the cost of blooms in farm dams.

The results are reported in table 21. On these limited data, the total cost of blooms in rivers and storages is about half the total cost of blooms in farm dams; however, the variation is extreme – the ratio ranges from 13 per cent in the Ovens catchment to 200 per cent in the Goulburn Broken catchment.

We put the total cost of blooms in rivers and storages at $10 million to $20 million per year, being half of the total cost of blooms in farm dams as determined in the previous section. We nominate $15 million per year as the mid-value.

Table 21: Total cost of blooms in rivers and storages relative to costs in farm dams (Victorian estimates)

	Ovens catchment	North East region	Goulburn Broken catchment	Total
Total cost of blooms in farm dams ($m)	7.14	0.16	1.68	8.98
Total cost of blooms in rivers and storages ($m)	0.96	0.13	3.56	4.65
Ratio of cost in rivers and storages to the cost in farm dams (%)	13.4	81.3	211.9	51.8

Table 22: Derivation of estimated cost of algal blooms in irrigation water

	Area of irrigated pasture and crops in Australia ('000 ha)	Average cost per hectare during blooms ($/ha/day)	Incidence of blooms (average days/year)	Total annual cost ($m/year)
	Column 1	Column 2	Column 3	Column 4
Pasture	1,136	3.00	2–4	7–14
Crops	872	1.50	2–4	2.5–5
Total	**2,008**	**–**		**10–20**

4.3.3 Irrigation water supply

Table 22 sets out our estimate of the cost to irrigators of algal blooms in supplies of irrigation water, again drawing heavily on the Victorian studies. The steps are:

- Column 1 – Estimates of the area of irrigated pasture and crops in Australia are based on ABS data (ABS, 1996, tables 2.20 and 2.21).
- Column 2 – These estimates of the cost per hectare are drawn from the Victorian studies. In respect of irrigated pasture, the main cost is considered to be the loss of pasture feed as graziers postpone the grazing of areas irrigated by algae-affected water. In respect of irrigated crops, there is no loss of production but there are increased costs in the form of:
  - adjustment of irrigation off-takes to minimise impacts of algal blooms (labour cost);
  - extra power and water for filter backwashing; and
  - unblocking pressurised irrigation systems, particularly low-level sprinkler systems (labour cost).
- Column 3 – It is generally expected that most of the costs will be incurred during severe blooms that occur once in, say, 10 or 15 years. Production will not be interrupted for a few days every year but for a few weeks every 10 years.
- Column 4 – The product of columns 1, 2 and 3.

Accordingly, we put the total cost to irrigators at $10 million to $20 million per year, with $15 million per year as the mid-value.

Arguably, farmers behave somewhat less cautiously in their use of algae-affected water than their customers would prefer and thereby avoid some of the costs that would be incurred under best practice management.

We take the view that the cost to the community is not thereby avoided. Consumers take a risk that they would prefer to avoid.

4.3.4 Summary – rural water supplies

We put the total cost to rural extractive users at $60 million, comprising:

- stock and domestic water from farm dams – $30 million;
- stock and domestic water from rivers, storages and irrigation channels – $15 million; and
- irrigation supplies – $15 million.

4.4 Costs incurred by non-extractive users

The non-extractive use of water comprises:

- commercial fishing;
- recreational use of a waterbody by local residents and by tourists – for swimming, boating and fishing;
- amenity values enjoyed by local residents and by tourists – water views or walks; and
- so-called 'non-use' values, being the value that the community puts on the continued existence of waterbodies in their natural state and the existence of the flora and fauna that they support.

Some attempts have been made to estimate the cost of algal blooms to non-extractive users; these are reviewed in section 4.4.1. Other pointers to the size of these costs are reviewed in sections 4.4.2 and 4.4.3. Our conclusions are argued in section 4.4.4.

4.4.1 Review of existing studies

Walker and Greer

Walker and Greer (1992) estimate $9.4 million for losses in tourism and recreation benefits due to blue-green algal blooms at three sites in NSW in 1991–92. Their study was a direct response to the extensive algal bloom in the Barwon-Darling River in December 1991. The cost was found to be:

- $6.7 million in a section of the Hawkesbury-Nepean River;
- $1.5 million in towns along the Darling River; and
- $1.2 million in two DLWC storages.

However, these estimates are not a reliable guide to the loss of economic benefits, for several reasons:

- To a large extent the losses incurred are reductions in the gross revenues of caravan parks, hotels and other enterprises that service tourists and recreational activities. Such reductions in gross commercial takings can greatly overstate actual economic losses, since no account is taken of the corresponding reduction in the cost of providing services when trade is slow.
- Because 1991–92 was an exceptional year for algal blooms in NSW, the study will have overestimated typical reductions in gross revenue.
- The study is based on a highly selective sample and provides no information about the representativeness of the sample or the size of the population that it represents. That is, the study does not provide a multiplier that can be applied to determine comparable losses for the state as a whole.
- Given subsequent changes in management regimes, the study would not describe current conditions.

Hill

Hill (1994) also conducted a study in the wake of the algal blooms on the Barwon-Darling River in late 1991. It reports the results of a phone survey designed to assess the willingness of NSW residents to pay for improved water quality in the Darling River. A key finding was that, at the very least, 50 per cent of the population would be willing to make a once-only payment of at least $20 to ensure that the river water would be suitable for swimming, boating and fishing. Aggregated for Sydney residents alone, this is a once-off payment of $26 million. This equates to about $30 million in current dollars and would amount to an annual payment of $1.5 million.

This is not a large amount in terms of the costs of addressing the causes of algal blooms. Higher estimates were forthcoming when the question was asked in a different way. Given the sensitivity of the results to the manner in which the question was asked, it is not possible to rely on these estimates.

Cost benefit assessments of nutrient management strategies in Victorian catchments (1998 and 1999)

Tables 23 and 24 present the results of a series of investigations of the costs and benefits of nutrient management strategies in several Victorian catchments and along the Murray River. These data have been collated from Adams (1998), Read Sturgess and Associates (1998a; 1998b; 1999) and Victorian DNRE (1998).

These are bottom-up assessments of the impact of algal blooms. Rapid assessment techniques were used to assess:

- the number of algal blooms of varying degrees of severity in specific parts of the catchment, taking the longer-term average over good and bad years;
- unit costs (per bloom) for various types of water users; and
- the impact of proposed nutrient reduction plans on the incidence of blooms and the dollar benefits that are then expected to accrue to water users.

Table 23 reports estimates of costs incurred in three catchments in the absence of any nutrient reduction activities; these estimates represent the current state of play. Taken together, non-extractive users in the three catchments incur costs of about $15 million per year. Two of these catchment reports also identify beneficial nutrient management actions, being stormwater education programs, STP upgrades, control of gully erosion, stream stabilisation, best management practices for forestry operations and the land disposal of silt from a hydro station. The cost benefit assessments are as follows:

- In the Upper North East region, beneficial actions would cost $4.7 million per year, yield $2.6 million per year in net benefits (over and above the costs) and virtually solve all algal bloom problems in the region.
- In the Glenelg Hopkins catchment management authority (CMA) region, beneficial actions would cost $278,000 per year, yield $479,000 per year in net benefits, but leave about 60 per cent of the region's algal problems still in the 'too hard basket'.

Table 24 reports reductions in the cost of algal blooms that (unspecified) nutrient reduction programs are expected to achieve. At a minimum, these bring the

Table 23: Annual costs of algal blooms in selected Victorian catchments

Type of benefit	Glenelg Hopkins CMA region		Upper North East region		Corangamite region	
	$'000	%	$'000	%	$'000	%
Management costs	52	2.7	117	1.6	1,029	14.0
Urban water supplies	173	9.0	223	3.0	515	7.0
Domestic and stock water	1,054	54.8	380	5.1	147	2.0
Irrigation water supplies	38	2.0	40	0.5	74	1.0
Eel production	313	16.3	–	–	956	13.0
Recreation and tourism	139	7.2	548	7.3	3,749	51.0
Amenity for foreshore residents	156	8.1	599	8.0	882	12.0
Downstream benefits in Murray River	–	–	5,606	74.6	–	–
Total	**1,925**	**100.0**	**7,513**	**100.0**	**7,350**	**100.0**
Joint management costs	52	2.7	117	1.6	1,029	14.0
Costs to extractive users	1,265	65.7	4,524	60.2	735	10.0
Costs to non-extractive users	608	31.6	2,872	38.2	5,586	76.0

Victorian tally of annual costs to non-extractive users to about $25 million per year, comprising:

- Glenelg Hopkins CMA region – $608,000 per year;
- Upper North East region (excluding benefits to Murray River) – $1,147,000;
- Corangamite region – $5,586,000;
- Ovens catchment (excluding benefits to River Murray) – $5,346,000;
- Goulburn Broken catchment – $5,346,000; and
- Murray River – $7,051,000.

Importantly, these studies have not attempted to quantify some potentially significant losses. First, the damage to non-use values is not quantified. The authors consider that this is a significant omission, given the high value that the community puts on the health of wetlands and rivers – as revealed in assessments of related environmental issues. Second, the methodology is limited in the sense that it is based on observed changes in recreational and tourist activity in the presence of an algal bloom, that is, the temporary rises and falls in these activities. It may be, however, that the longer-term history of algal blooms has adversely affected the reputation of these regions to the point where there has been a more permanent reduction in the level of activity. These losses are incurred even in the absence of algal blooms.

4.4.2 Significant gap between the estimate of total cost and estimate of cost to extractive users

There is a considerable gap between our estimate of the total costs of algal blooms and our combined estimate of joint management costs and costs to extractive users:

- We put the former at $180 million to $240 million per year – see section 3.
- We put the latter at $104 million per year, comprising $9 million in joint management costs, $35 million in costs to urban water supplies and $60 million per year to rural water supplies – see sections 4.1–4.3.

In other words, the cost to extractive users does not explain the scale of the investments in environment protection. Consider also that environment protection measures would generate relatively few savings in the form of reduced joint management costs or costs of algal

Table 24: Expected annual benefits from nutrient reduction programs

Type of benefit	Murray River		Ovens catchment		Goulburn Broken catchment	
	$'000	%	$'000	%	$'000	%
Management costs	472	2.1	13	1.9	1,000	4.5
Urban water supplies	1,877	8.2	365	10.9	4,500	20.0
Domestic and stock water	9,372	40.9	965	44.9	6,500	35.8
Irrigation water supplies	4,140	18.1	10	15.2	3,500	18.3
Recreation and tourism	5,879	25.7	110	22.6	2,000	14.2
Amenity for foreshore residents	1,172	5.1	29	4.6	1,500	7.2
Downstream benefits in River Murray	–	–	7,445	–	6,000	–
Total	**22,912**	**100.0**	**8,937**	**100.0**	**25,000**	**100.0**
Joint management costs	472	2	166	2	1,124	4
Costs to extractive users	15,389	67.2	6,341	71	18,530	74.1
Costs to non-extractive users	7,051	30.8	2,430	27	5,346	21.4

blooms on farm dams. These investments in environment protection need some other explanation. The obvious explanation is that there are also large costs to non-extractive users, of the order of $80 million to $140 million per year, that is, the difference between the estimate of total costs and the estimate of costs to extractive users.

There are two other possible explanations for the gap. First, we may have overestimated the costs of environment protection that can be reasonably attributed to algal blooms. We endeavoured to be conservative at each stage but must allow that others might look at the same data, conduct the same interviews, and reach quite different conclusions about the total costs of algal blooms. Second, we may have underestimated the cost to extractive users. That is, an overly conservative approach to the estimation of such costs may create the appearance of a significant gap between total costs and the costs to extractive users.

4.4.3 Other evidence

We examined the *1997 State of the Environment Report* for NSW (NSW EPA, 1997) to obtain additional perspective on the relative importance of costs to extractive and non-extractive users. The main points are:

- Algal blooms are given particular prominence as threats to recreational water quality, inhibiting both primary and secondary contact recreation. They also reduce water clarity and accumulate along shorelines to the detriment of aesthetic values. Discussion of algal blooms is confined to the chapters on eutrophication and recreational water quality.
- Algal blooms are not mentioned as specific threats to wetlands, riverine corridors, fisheries or biodiversity. Other factors are given greater prominence in each case.
- Improved water treatment is seen as the main response to concerns about drinking water quality. While improved catchment management is mentioned in this context, environmental protection receives considerably less prominence than improved water treatment.

On this evidence, lost recreational and associated aesthetic values are the major sources of concern about algal blooms.

Water authorities consistently reported that the closure of storages to recreational users during algal blooms – or simply the erection of warning signs – was a sensitive issue. In WA in particular, it was emphasised that water storages were major recreational assets in some regions.

4.4.4 Conclusion

We put the cost to non-extractive users at $80 million to $140 million per year, based on the following considerations:

- It is difficult to explain the scale of the environmental protection effort in the absence of significant costs to non-extractive users.

Table 25: Summary statement of costs of algal blooms

Type of cost		$m/year	
Joint management costs			**9**
Cost to extractive users			**95**
• Urban water supplies		35	
• Rural water supplies		60	
– *Stock and domestic water from farm dams*	*30*		
– *Stock and domestic water from rivers, storages and irrigation channels*	*15*		
– *Irrigation water supply*	*15*		
Cost to non-extractive users			**76–136**
Total			**180–240**

- A national figure of $80 million to $140 million per year is commensurate with the (partial) Victorian estimate of $25 million per year.

4.5 Summary

Table 25 summarises our findings. The joint management costs and the components of the costs to extractive users have been separately estimated. The total cost has also been separately estimated. The cost to non-extractive users has been derived as the difference between the total cost and the sum of the joint management costs and the costs to extractive users.

References

Adams, H. (1988), *Draft Corangamite Region Nutrient Management Plan*, Victorian DNRE, May.

Australian Bureau of Statistics (1996), *Australian Agriculture and Environment*, Cat. no. 4606.0.

Australian Bureau of Statistics (1999), *Environment Protection Expenditure: Australia, 1995–96 and 1996–97*, Cat. no. 4603.0.

Australian Water & Wastewater Association (1998), *Capital expenditure on water and wastewater treatment plants in Australia: 1996–1999*, Australian Water & Wastewater Association, Sydney.

Australian Water Resources Council (1987), *1985 Review of Australia's Water Resources and Water Use*, Australian Government Publishing Service, Canberra.

DLWC (1996), *1994/95 NSW Water and Sewerage Performance Comparisons*.

Government of WA (1997), *State of the Environment Reference Group Draft Working Papers for Western Australia*, Government of WA.

Hill, CM. (1994), 'Water Quality Improvement in the Darling River: a contingent valuation study', Occasional Paper, NSW Department of Water Resources, Water Policy Division.

KME (1993), *Economic Environmental Modelling System for Water Quality Management – Pollution Abatement Costs*, Kinhill, Metcalf & Eddy.

NSW EPA (1994), *Using Economic Instruments to Control Pollution in the Hawkesbury Nepean*.

NSW EPA (1995), *An Environment–Economic Model for the Hawkesbury Nepean*.

NSW EPA (1997), *New South Wales State of Environment Report*.

Queensland Water Quality Taskforce (1992) *Report on freshwater algal blooms in Queensland*, Queensland Water Quality Taskforce, Brisbane.

Read Sturgess and Associates (1998a), *Goulburn Broken Water Quality Strategy: Benefits from reducing the frequency of algal blooms in Goulburn-Broken catchment*.

Read Sturgess and Associates (1998b), *Economic benefits from reducing the frequency of algal blooms in the Ovens catchment: final report*.

Read Sturgess and Associates (1999), *Rapid appraisal of benefits and costs of nutrient management in the Glenelg Hopkins CMA region*.

Victorian DNRE (1998), *Benefits and costs from reducing frequency of algal blooms in Upper North East region*, Volumes 1 and 2.

Victorian EPA (1995a), *Algal bloom and nutrient status of Victorian inland waters*, Government of Victoria.

Victorian EPA (1995b), *Managing sewage discharges to inland waters*, Government of Victoria.

Victorian EPA (1999), *Protecting the environmental health of the Yarra catchment waterways*, Government of Victoria.

WA Department of Environmental Protection (1998), *State of the Environment Report: 1998*, Government of WA.

WA Water and Rivers Commission (1999), *The Water & Rivers Commission*, <http://www.wrc.wa.gov.au>.

WA Water Corporation (1999), *Infill Sewerage Program – The Challenge*, <http://www.watercorporation.com.ua/infill/challenge>.

Walker, C. and Greer, L. (1992), 'The Economic Costs Associated with Lost Recreation Benefits due to Blue-Green Algae in New South Wales: Three Case Studies', in Hassall and Associates, *Blue-Green Algae: Final Report of the New South Wales Blue-Green Algae Task Force*, Department of Water Resources, Parramatta.

Water Board (1991), *Technical feasibility report to upgrade sewage treatment plants in the Hawkesbury Nepean catchment*, Nutrient Reduction Program, Draft Report.

Appendix 1: Water suitability guidelines for management of algae

National alert level framework

The national alert level framework provides for three alert levels for the purposes of monitoring, bloom management and public communication. These are briefly presented in table 26

Table 26: Alert levels for bloom management

Alert level	Cell concentrations (cells/mL)	Response actions
Alert Level 1	500–2,000	– Identify the algal type – Establish early bloom conditions – Initiate low-level monitoring
Alert Level 2	2,000–15,000	– Progression of bloom into potentially hazardous category – Comprehensive monitoring – Media releases, public notices – Storage operation alterations
Alert Level 3A (Toxic)	> 15,000	– Bloom established as toxic – Frequent toxicity testing – Water supply alternatives may be required – Higher level of public awareness
Alert Level 3B (Non-toxic)	> 15,000 cells/mL	– Bloom established as non-toxic – Operations aimed at minimising taste and odour problems – Continued medium-level monitoring

These categories are aimed mainly at establishing standard procedures for water supply storages. In the case of non-water supply waterbodies, actions are aimed more towards increased public awareness and risk management.

Queensland guidelines

Provisional drinking water guidelines

In the absence of current drinking water guidelines for Cylindrospermopsin and Saxitoxins, the drinking water suitability guideline levels in table 27 have been based on the accepted guidelines for Microcystin-LR.

Table 27: Drinking water guidelines

Suitability status	Guidance level	Recommended action
Suitable	<1 µg/L Cyanobacterial Toxin or Negative Mouse Bioassay Result	Suitable as potable supply water after conventional water treatment, without specific treatment for cyanobacterial toxins.
Treatment recommended	>1 µg/L Cyanobacterial Toxin or Positive Mouse Bioassay Result	Suitable as potable supply water after conventional water treatment, including appropriate treatment for the removal of cyanobacterial toxins.

Provisional guidelines for cyanobacteria in bathing waters

The guidelines in table 28 are based on World Health Organization guidelines for safe practice in managing bathing waters which may produce or contain cyanobacterial cells or toxins.

Table 28: Bathing water guidelines

Hazard status	Guidance level or situation	Health risks	Recommended action
High	Cyanobacterial scum formation in contact recreation areas or > 100,000 cells total cyanobacteria /mL, or > 50 µg/L chlorophyll-*a* with dominance of cyanobacteria.	Short-term adverse health outcomes such as skin irritations or gastrointestinal illness following contact or accidental ingestion. Severe acute poisoning is possible in worst ingestion cases.	Immediate action to prevent contact with scums. Signs to indicate high alert level – warning.
Moderate	20,000–100,000 cells total cyanobacteria/ml or 10–50 µg/L chlorophyll-*a* with dominance of cyanobacteria.	Short-term adverse health outcomes, for example skin irritations, gastrointestinal illness, probably at low frequency.	Signs to indicate moderate alert level – increased health risk for swimming and other water contact activities.
Low	< 20,000 cells total cyanobacteria/mL, or < 10 µg/L chlorophyll-*a* with dominance of cyanobacteria.	Short-term adverse health outcomes unlikely.	Signs to indicate cyanobacteria either absent or present at low levels.

Appendix 2: Trends in the management of urban sewerage and stormwater systems

New South Wales

Under the provisions of the Protection of the Environment Operations (General) Regulation 1998, STPs in NSW pay a pollution fee that is partly based on the quantities of nutrients discharged to surface waters. The fee varies with the type of activity, the weight assigned to the pollutant and the environmental sensitivity of the region in which the activity occurs. In respect of nutrient pollution, the critical zones are defined as the Hawkesbury Nepean catchment plus all catchments west of the Great Dividing Range, excluding the Snowy. These are the areas of greatest concern in respect of algal blooms. The DLWC and EPA consider that these arrangements will effectively require water authorities to either organise for the discharge of effluent to land or, where this is not practical, implement tertiary treatment. The transition is expected to occur over the next 5 to 10 years.

Victoria

Guidelines for the management of sewage discharges to inland water were published by the Victorian EPA in 1995 (Victorian EPA, 1995b, pp8–9). They identify sewage effluent as the major source of bio-available nutrients in streams under base flow conditions and which favour excessive algal growth, including blue-green algae. Water authorities were advised that new treatment plants should incorporate tertiary treatment if reuse was not practical, and existing plants should upgrade within five years if continuing to discharge to waterways. Tertiary treatment was defined as 0.5 mg/L for total phosphorus and 10 mg/L for total nitrogen. It was considered that the 50 per cent cost increase of moving from secondary to tertiary treatment was reasonable given the state of the waterways and the practicability of reuse for many communities.

Subsequent debates about costs and benefits were resolved in 1997 when the Victorian Government made a ‘stroke of the pen’ decision requiring that all STPs meet these requirements by 2001 except where the cost increases were prohibitive, that is, increasing by a factor of two. For the vast majority of inland STPs this meant that wastewater would be disposed to land and that reuse options had to be developed. The State Government has provided assistance as part of a $410 million package for the upgrade of water treatment plants and STPs. The STP share of this money is likely to be in the range of $100 million to $200 million. On a dollar to dollar basis, that puts the total cost of the STP upgrade at $200 million to $400 million.

Queensland

STPs in Queensland are individually licensed at a regional level under the state’s Environment Protection Act. The Act provides only that a range of considerations be taken into account; it does not impose particular limits on sewage discharges to inland waters. However, discussions with the EPA and local authorities indicate that Queensland is moving in the same direction as NSW and Victoria but with somewhat less urgency. One or two larger authorities are implementing tertiary treatment; the remainder are seeking to delay the transition until existing STPs come to the end of their normal commercial lives. The likely scenario is for the transition to gather pace within five years.

South Australia

The EPA licenses STPs and generally requires the licensee to monitor discharges and to develop an environment improvement plan aimed at reducing or eliminating discharges to surface waters. The EPA’s Annual Report for 1997–98 notes that policy for the protection of inland waters was being developed and would encourage ‘…better use of wastewater by waste avoidance or elimination, minimisation, reuse and recycling; waste treatment to reduce potential impacts; and finally disposal.’ SA Water has confirmed that its STPs are either being upgraded to tertiary treatment or converted to land disposal.

Western Australia

Discharge requirements for STPs in WA are decided on a case-by-case basis, taking account of the sensitivity of waterways and community perceptions of environmental risk. Informal advice from the Water Corporation and the Department of Environmental Protection is that, under these arrangements, 10 or 20 inland STPs have made the transition to land disposal in the past several years. Nutrients and algal blooms are considered to be the ‘number one’ drivers for this program, although water conservation and the reduction of pathogen risks in recreational waters are also important considerations.

Appendix 3: Method for estimating the total cost of algal blooms

Figure 2 presents a long-term view of the cost of algal blooms. We distinguish three periods:

- The period before point A is associated with increasing incidence of algal blooms and increasing costs to extractive and non-extractive users. This stage ends when the problem becomes sufficiently well recognised and understood that governments and communities resolve to do something about it.
- Remediation occurs in the period between A and B. It is characterised by new investments in environment protection and a commensurate reduction in the costs to extractive and non-extractive users.
- A new equilibrium between economy and the environment is restored in the period beyond B.

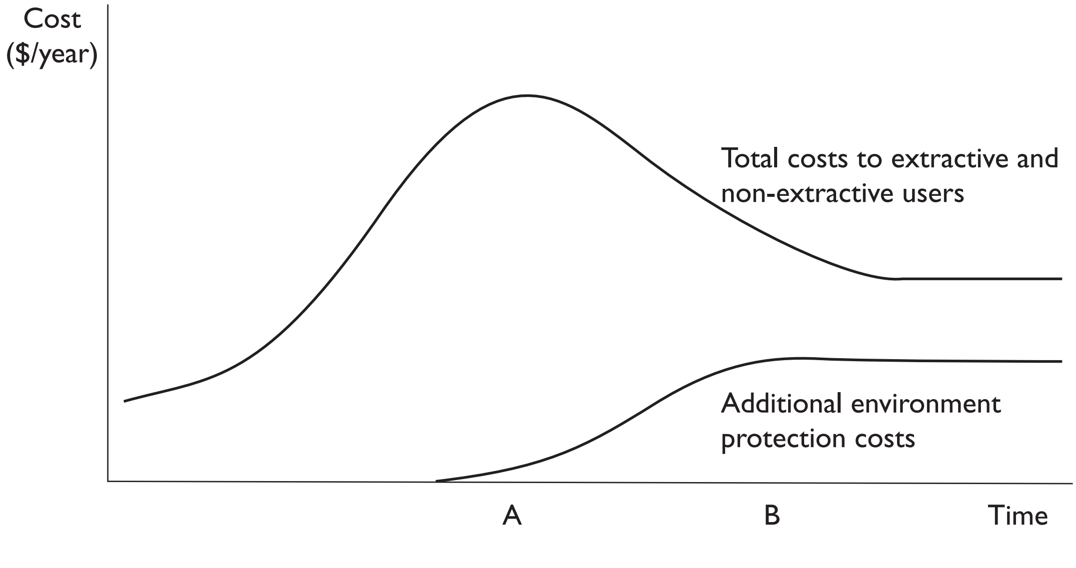
Very little of this profile is understood. It seems reasonable, however, to assume that point A corresponds to the 1980s and 1990s. The problem has been widely recognised and actively addressed, but there is a long way to go before we reach point B.

The key issue for this study is the magnitude of total costs at the present time. A significant portion of those costs, the costs to non-extractive users, cannot be directly observed, but collective concerns about those costs are reflected in actual and planned investments in environment protection. Our tally of the additional costs that will be incurred at point B is $120 million per year. We know that the total costs currently incurred must exceed the additional environment protection costs; otherwise the proposed investments in environment protection make no sense. But what is the ratio between the two?

Figure 1 shows a conventional analysis of this relationship. In that figure *additional environment protection expenditures* are presented as a range of projects that will each cost $1 million per year indefinitely (the black bars). The *total cost currently incurred* is represented as a willingness to pay for those projects, ranked from highest to lowest. Importantly, the total cost is the cumulative sum of the white bars and the grey bars in figure 1. The former indicate projects that should proceed, since the willingness to pay exceeds the cost; the latter should not proceed.

Figure 1 is constructed on the simplifying assumption that the willingness to pay schedule is linear, that is, willingness to pay declines by a constant amount from project to project. One can imagine various relationships between the total cost of algal blooms and the additional costs of environment protection (see panel A of figure 3, where the total cost of algal blooms is represented by the area of the triangle and the additional costs of environment protection are represented by the area of the rectangle). It is readily shown that the area of the rectangle can be no more than half of the area of the

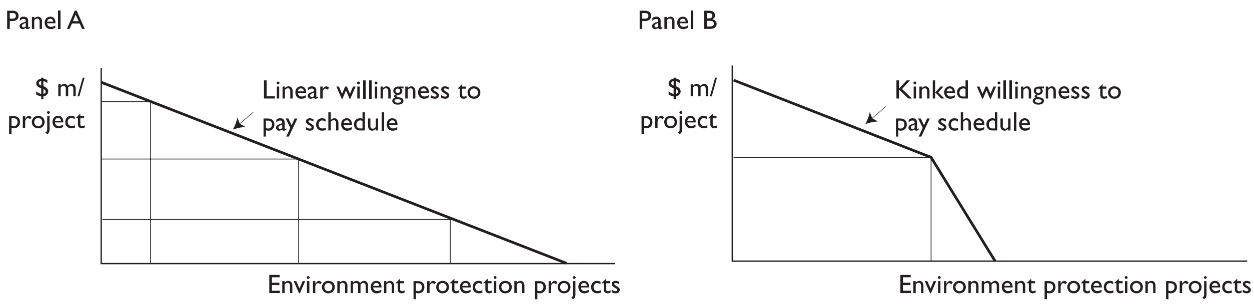
Figure 2: Costs of algal blooms over the long term



triangle. (To prove mathematically, consider that a linear willingness to pay schedule can be represented by the equation $y = a - b.x$; the area of the triangle is $a^2/(2.b)$; the area of the rectangle is maximised when $x = a/(2.b)$ and $y = a/2$; and that maximum area is $a^2/(4.b)$.) It follows that, if the willingness to pay schedule were approximately linear, the total cost of algal blooms could be conservatively put at twice the cost of environment protection measures. For the purposes of section 3.2 the multiplier would be 2.

It is possible to draw the willingness to pay schedule in such a fashion that the cost of environment protection absorbs a much larger portion of the community's willingness to pay. For example, panel B of figure 3 shows a willingness to pay schedule that is kinked in such a way that the schedule is flat for the early projects (leaving little net benefit) but steep for the remaining projects (reducing the residual algal problem). We therefore allow for the possibility that circumstances may conspire in such a way that the costs of environment protection are large relative to the costs currently incurred. We nominate 1.5 as a very conservative multiplier.

Figure 3: Possible relationships between the cost of environment protection and the willingness to pay for environment protection



Appendix 4: Survey questionnaire

Cost of algal blooms to water authorities: a survey

1 Identification

Name of water authority:		
Name of person who completed the survey:		
Position:		
Phone:	Fax:	Email:

2 Reporting date

If you are in the process of significantly upgrading your capacity to manage excessive algal growth, please answer this survey from the perspective of the authority after that upgrade is complete. Indicate the reporting date here - August 1999 or some future date.

Reporting date is:

If you choose a future date, it is important that you answer all subsequent questions as if you had arrived at that future date.

3 Costs of investigations and assessments

In the last 5 years, what has the authority done to investigate the causes and effects of blooms, and to develop, trial and assess management options, including community consultation? What has it cost to undertake these assessments?

Brief description of investigative and assessment activities:	Estimated cost $

4 Type of algal blooms

Please indicate the significance of blue-green algae as a percentage of the algal problems experienced by the water authority.	%

5 Checklist of costs of algal blooms

Please tick the box for any of the following management options or cost increases that have been implemented or incurred by the water authority, provided these costs have been incurred at least partly in response to algal blooms or the threat of algal blooms.

- Catchment management (nutrient reduction strategies) ❑
- Destratification (please circle - mechanical or aeration?) ❑
- Hypolimnetic aeration or oxygenation ❑
- Variable off-take ❑
- Mechanical harvesting or floating booms ❑
- Dredging ❑
- Back-up water supply ❑
- Chemical dosing of storage (please circle - algicides, algistats, alum, gypsum) ❑
- Dissolved air flotation ❑
- Activated carbon (please circle - PAC, GAC or biological) ❑
- Ozone treatment ❑
- Additional or alternative disinfectant ❑
- Back-up storage or treatment capacity ❑
- Additional monitoring ❑
- Additional training ❑
- Additional customer or user complaints ❑
- Community education and warnings (eg, signage, media releases) ❑
- Increased administrative overheads ❑
- Any other cost increases (please specify) ❑

6 Cost of management strategies at nominated reporting date

Please estimate the cost of the management strategies that you have implemented in response to algal blooms and briefly describe the measures involved. Informed estimates of costs will do; we do not need an 'accounting' level of accuracy. **Important:**

- **For once-off capital costs, please estimate the replacement cost at current prices.**
- **For on-going costs, estimate average costs across good and bad years for blooms.**
- **Avoid 'double-counting' any costs already reported as costs of investigation.**
- **If certain strategies have been adopted partly for reasons other than algal blooms, report only that part of the cost that can be reasonably attributed to algal blooms.**

Brief description of management strategies or costs	Once-off costs ($)	On-going costs ($/year)
Catchment monitoring and management (please specify)		
Storage monitoring and management (please specify)		
Water treatment and distribution (please specify)		
Customer/user complaints, warnings, etc (please specify)		
Administration, training and other o/heads (please specify)		

7 Reduced production during algal blooms

On average, how much water does the authority produce per year? (ML/year)	
Given the management strategies that have been implemented, how often do you expect water restrictions to be imposed as a result of algal blooms? (eg, two times per year, once every five years). Avoid answering 'never' unless you are confident that you can manage any algal bloom that may occur in the future without imposing water restrictions.	
Taking the average over good and bad years, what production do you expect would be lost due to water restrictions caused by algal blooms? (ML/year)	
What is the approximate value (lost revenue) of that lost production? ($/year)	

8 Effectiveness of management response to date

Roughly, what percentage of algal problems that you have been able to fix, including problems created for recreational users and tourists. %

9 Cost of this survey (optional)

How many person-hours were required to complete this survey?

Thank you. Please return the survey to Peter Dempster:

Atech Group Pty Ltd	Ph: (02) 9744 7644	Fax: (02) 9744 7645
28 Philip Street, Strathfield NSW 2135	Email: peterdempster@atechgroup.com.au	