Rapid appraisal of the economic benefits and costs of nutrient management

August 2000

Prepared by

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for

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENT

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FOREWORD

The Victorian Government's Nutrient Management Program was developed in response to the increasing incidence of algal blooms and the deterioration of water quality in Victorian waterways. High levels of nutrients, in combination with other environmental factors, are a major cause of algal blooms. Protection of water quality is critical if Victoria is to meet the duel goals of healthy rivers and increased agricultural and food exports.

As part of the program, there are currently sixteen catchment-based nutrient management plans being developed and/or implemented across Victoria. These plans identify major nutrient sources within catchments and recommend actions to reduce the level of nutrients entering waterways.

Determining priority nutrient management actions within a catchment involves the need to undertake an economic analysis of the costs and benefits of those actions. Economic evaluations are critical to ensure that both regional communities and State Government invest in priority activities, those that give the best returns for the scarce resources invested.

These guidelines provide a methodology to undertake such economic evaluations. They focus on avoiding the costs of algal blooms (i.e. the benefits of the proposed nutrient program) and compare these to the costs of the nutrient actions themselves.

Read Sturgess and Associates commenced work on the guidelines in 1995, resulting in an unpublished draft methodology in 1996. The methodology was trialed in a number of catchments in 1997 and 1998, leading to the completion of this significantly revised methodology. I would like to acknowledge the efforts of Read Sturgess and Associates in developing and revising the methodology. The guidelines have also been developed with the cooperation and assistance of a number of stakeholders, including government agencies and catchment management authorities. I would also like to thank them for their input.

The application of these guidelines will assist communities and government agencies make sound investment decisions that will enhance the quality of Victoria's land and water resources.

PETER SUTHERLAND
Executive Director
Catchment & Water Division

ACKNOWLEDGMENTS

Many people have been involved in the production of these guidelines, principally the economic consultants Read Sturgess and Associates (particularly Mike Read).

Development of the first version of the guidelines was overseen by a steering committee consisting of Pat Feehan (Goulburn Murray Water [GMW]), Charles Thompson (then GMW), Terry A'Hearn (Environment Protection Authority [EPA]), and Stuart Critchell, Peter Vollebergh and Brendan Roughead (all Department of Natural Resources and Environment [NRE]).

Development of the revised version of the guidelines was overseen by a steering committee consisting of Pat Feehan (GMW), Phill Johnstone (then EPA), Veronica Lanigan (North East Catchment Management Authority), Peter Cottingham (Cooperative Research Centre for Freshwater Ecology), and Stuart Critchell, Heather Adams and Peter Vollebergh (all NRE).

Input and comments on the two versions of the methodology have also been sought and received from all catchment management authorities (including the Port Phillip Catchment and Land Protection Board), rural water authorities, NRE regional offices and other relevant NRE and EPA staff.

Finally, Carol Roberts and Peter Vollebergh (NRE) have undertaken final editing of the report and preparation for design and publishing.

CONTENTS

ABBREVIATIONS

AEAM	Adaptive Environmental Assessment and Management
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BGA	blue-green algae
BMP	best management practice
CMA	Catchment Management Authority
CMSS	Catchment Management Support System
CNMP	catchment nutrient management plan
DSE	dry sheep equivalent
EPA	Environment Protection Authority, Victoria
GIS	Geographic Information System
GMW	Goulburn Murray Water
ha	hectare
kL	kilolitre
ML	megalitre
ml	millilitre
N	nitrogen
NRA	National Registration Authority
NRE	Department of Natural Resources and Environment, Victoria
NTU	nephelometric turbidity unit
P	phosphorus
PPM	parts per million
RAM	rapid assessment methodology
RMUs	regional management units
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
VRTTS	Victorian Regional Travel and Tourism Survey
VWQMN	Victorian Water Quality Monitoring Network

SUMMARY

Purpose of these Guidelines

The Victorian Government's Nutrient Management Program was developed in response to the increasing incidence of algal blooms and the deterioration of water quality in Victorian waterways. High levels of nutrients, in combination with other environmental factors, are a major cause of algal blooms. As part of the program, catchment-based nutrient management plans are being developed and/or implemented by regional communities across most of Victoria.

These plans identify major nutrient sources within catchments and recommend actions to reduce the level of nutrients entering waterways. Determining priority nutrient management actions within a catchment involves the need to undertake an economic analysis of the costs and benefits of those actions. Economic evaluations are critical to ensure that both regional communities and State Government invest in priority activities, those that give the best returns for the scarce resources invested.

These guidelines provide a rapid appraisal methodology ('RAM') to undertake such economic evaluations of the costs and benefits of nutrient plans.

The guidelines are structured so that the body of the report provides an overview of the methods proposed for evaluating the benefits and costs of a proposed nutrient management plan. The appendices provide the detailed information necessary for those planning to undertake an evaluation.

Why Evaluate the Benefits and Costs of Nutrient Management?

In the evaluation of a nutrient management plan, the benefits of the plan are compared to the costs of implementing the plan (that is, a benefit–cost analysis; see Figure 1). However, the economic evaluation serves to achieve far more than a measure of the benefit–cost ratio for an overall plan. Namely, it should seek:

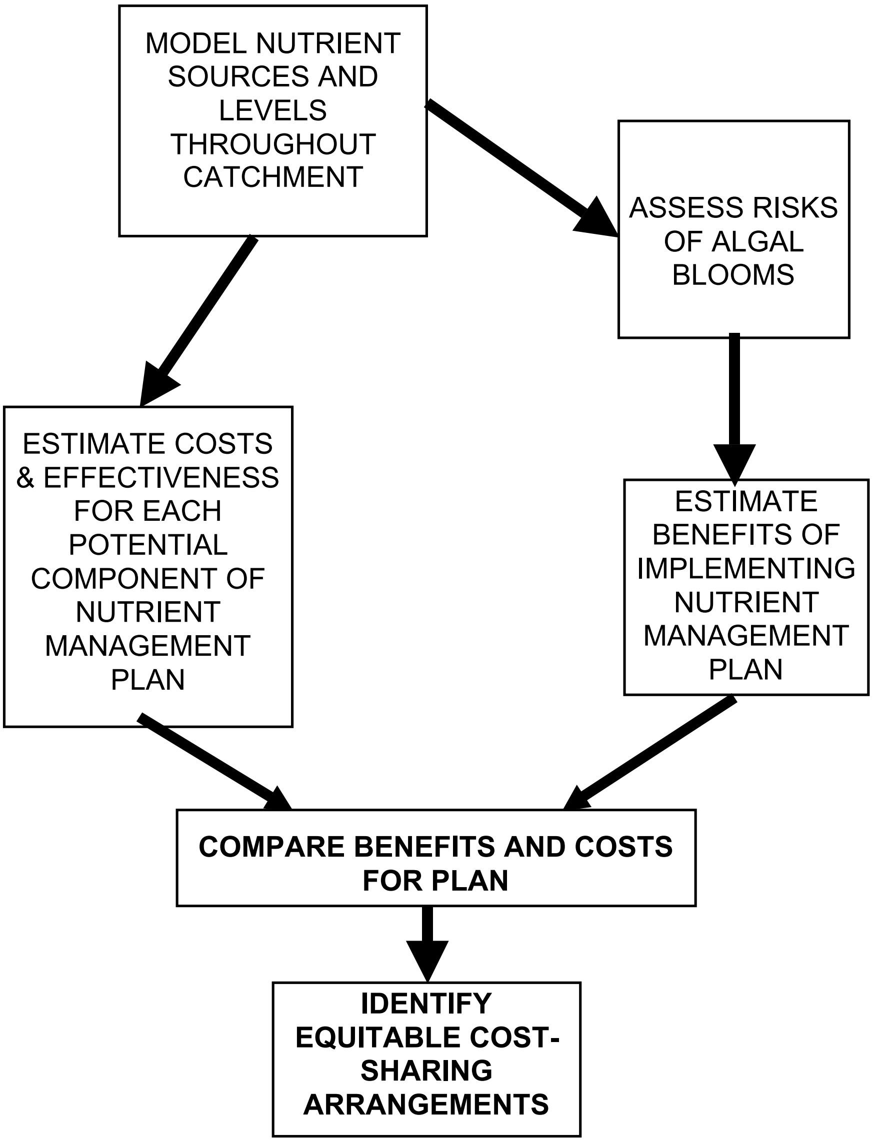
- ***to help formulate strategies for nutrient management***
  Identification and valuation of the likely benefits and costs of each potential nutrient management activity is vital in identifying priorities for strategies aimed at achieving healthy catchments;

- ***to help ensure informed decision making***
  Government and communities need to make choices about how they will spend their scarce dollars for natural resource management. In order to make rational and relevant decisions, it is important that they understand the costs and benefits of each component of a management plan;

- ***to help understand the uncertainties surrounding the benefits of management***
  The outcomes of nutrient management are rarely certain and analysis of the benefits of management helps to pinpoint the uncertainties; and

- ***to help devise equitable cost-sharing arrangements***
  Identifying and valuing benefits helps to reveal who benefits, and by how much, so assisting in the development of cost-sharing arrangements.

Figure 1 Framework for Economic Evaluation of Nutrient Management



Ideally the economic evaluation is undertaken as one of the early steps in formulating a management plan, rather than as a rubber stamp for a plan that has already been chosen without formal consideration of the economic benefits and costs.

Steps in Applying the Rapid Appraisal Method

For the purposes of this handbook, guidelines have been provided for the six main steps involved in the application of the RAM. These steps are:

1. modelling of nutrient sources and levels throughout the catchment (see Chapter 2);

2. assessing risks of blooms at each waterway/waterbody in order to estimate the incidence of blooms for each waterway and waterbody under present conditions (see Chapter 3);
3. estimating economic impacts of blooms under present conditions (see Chapter 4);
4. considering the effectiveness and costs for a range of activities to reduce nutrient loads (see Chapter 5);
5. comparing benefits and costs (see Chapter 6); and
6. assessing implications of benefit–cost analysis for cost-sharing (see Chapter 7).

The remainder of the summary presents an overview of the guidelines for undertaking the RAM and the economic framework which the RAM uses.

Modelling of Nutrient Sources and Levels

Modelling of nutrient concentrations and loads in the catchment should be undertaken to assist in the development of a nutrient management plan. The nutrient model is required to:

- establish the nutrient loads for each part of the catchment;
- assess the relative contribution of each nutrient source to the overall problem;
- assist in the selection of nutrient control options; and
- assist in the identification of stakeholders.

The nutrient modelling should identify all point sources and land uses that contribute nutrients to waterways and waterbodies.

The guidelines provide information on how this modelling has occurred in catchments throughout Victoria.

Assessing Risks of Algal Blooms

An estimate of the likely future incidence of blooms at a waterway or waterbody, with and without the proposed nutrient plan, is one of the most important pieces of information required for application of the RAM. It is necessary to consider the risks of blooms at all waterways and waterbodies within a catchment even though many may not have experienced algal blooms.

The guidelines assist with defining blooms and describe approaches to blue-green algae risk assessment throughout Victoria. Most commonly, these assessments have involved consideration of water quality (P, N, turbidity etc.), water velocity, water temperature and previous bloom history.

Types of Benefits Impacted by Algal Blooms

Impacts of poor water quality include restrictions on use for all those who enjoy values associated with the waterbodies and waterways; namely:

- those visiting waterbodies and waterways for recreation;
- farmers relying on stock water;
- farmers relying on domestic water;
- industrial users of water;
- urban users of water;
- irrigators;
- anglers and aquaculturalists; and
- environmental and amenity values.

In terms of how to evaluate all these water quality impacts, there are two important types of benefit:

1. values derived from use of the waterways and waterbodies. An algal bloom on a particular waterbody (lake, river, wetland, reservoir or irrigation channel), or high nutrient concentrations in diverted waters, can cause the human use of the waterbody to stop or to be reduced. Some of these use values have market prices, such as, the treatment of town water supplies or carting water and feed for livestock. The basic approach to valuation of these *market benefits* is one of simple multiplication of quantity times price.

2. non-use values of the waterways and waterbodies. Sometimes, and for a range of reasons, people may value a waterbody, or communities of flora and fauna it supports, because they exist even if those people never want to visit. One such reason might be a desire that the waterbody can be passed to future generations in the same state as it exists now. Algal blooms may reduce or destroy these values but non-use values are difficult to handle in a rapid appraisal, not just because they are unpriced but also because they are usually unique to the waterbody in question. Nevertheless, they must be acknowledged and, at times, may be important for some waterbodies threatened by blooms.

The focus of nutrient management plans in Victoria is mainly on the avoidance of toxic blue-green algal blooms, but there are other benefits derived from improvements in water quality which might be achieved through implementation of a nutrient management plan.

These guidelines cover most of the types of impacts that might arise from toxic algal blooms in many regions. However, there will often be other impacts specific to a particular region, and the analyst must seek to identify all impacts for the particular region being studied.

The guidelines also provide information about issues to consider when assessing economic impacts of blooms, including the importance of considering net economic values, the planning horizon of the evaluation, use of discount rates and uncertainty issues.

Costing Principles

The following important principles should be used in estimating costs for proposed nutrient management activities:

- include both capital and recurrent expenditure;
- present costs as discounted values or as annuities;
- recognise overhead costs for labour component; and
- recognise rates and timing of adoption.

Incremental Costs

'Incremental costs' of nutrient reduction represent the costs of avoiding a one kilogram increment of TP or TN, and provide a guide to the cost effectiveness of each potential nutrient reduction activity. This allows a ranking of the relative priorities which should be afforded to each type of activity.

In estimating the incremental costs for each activity, it is necessary to derive four important pieces of information:

1. location of point sources, or type of land use, in which to implement the activity;
2. percentage reduction of nutrient export that would be achieved by implementing the activity at those locations;
3. existing nutrient loads generated at those locations; and
4. costs of implementing that activity, expressed as an annuity.

The guidelines assist with the calculation of the incremental costs for nutrient management activities.

Comparing Benefits and Costs

Prior to commencement of a comparison between benefits and costs of nutrient management activities, the following information would already have been compiled:

- estimates of nutrient loads at each bloom site would have been obtained from the nutrients modelling. This would have involved specifying flows of nutrient from each sub-catchment or point source to particular bloom sites (see Chapter 2);
- estimates of the expected future incidence of toxic blooms, based on the recorded history of blooms at each site and a risk assessment undertaken for each site (see Chapter 3);
- estimates of the expected impacts of toxic blooms at each site (see Chapter 4); and
- estimates of costs of each potential management activity and the reduction in generation of nutrients that would result from each management activity (see Chapter 5).

The following additional steps are required to undertake the benefit–cost evaluation:

- specify relationship between reduction in nutrient loads at a particular site and the likely extent of reduction in frequency of blooms at that site (see Chapter 3);
- estimate the expected avoidance of damages from toxic blooms due to each management activity, by multiplying the estimated damages from each bloom (see Chapter 4) by the estimated reduction in frequency of blooms at each site. These cost savings represent the economic benefits of the nutrient management plan; and
- compare those benefits to the costs of each management activity.

Unfortunately there does not yet exist a fully adequate scientific understanding of the processes that lead to blooms, nor of the details of the relationship between nutrient levels and the incidence of those blooms. Given this lack of understanding, each region is encouraged to suggest its own approach to specifying a relationship between the reduction in nutrient loads at a particular site and the extent of reduction in frequency of blooms at that site. Regions are encouraged to consider the approaches taken in other catchments in the State to assist in determining which methodology best suits their catchment (see Chapter 6).

Presentation of Results

Government requires the following information to be compiled as part of the development of nutrient management plans for each region:

- costs of blooms occurring at each site;
- total costs of implementing each nutrient reduction activity;
- incremental costs of each nutrient management activity;
- total benefits from each management activity, expressed as the level of reduction in damages from toxic blooms;
- estimates of any other benefits, including possibly implications for environmental values, consumer welfare or regional economies;
- comparison of benefits and costs for each nutrient management activity, each expressed as discounted sums (using both 4 per cent and 8 per cent discount rates);
- benefit−cost ratio and net present value for each nutrient management activity;
- a clear statement of the assumed level of reduction in nutrient loads and estimated level of reduction in incidence of algal blooms;
- an estimate of the level of implied ratio of reduction in nutrient loads to bloom-reduction that would lead to a benefit−cost ratio of one; and
- appropriate cost-sharing between stakeholders for each nutrient management activity.

Cost-sharing Implications

Cost-sharing should be guided mainly by the Victorian Government's cost-sharing guidelines for nutrient management (NRE 1997). They are based on the premise of polluter pays, then beneficiaries pay, followed by the possibility of government investment. The benefit–cost evaluation assists in determining cost-sharing in nutrient management activities, by identifying nutrient contributors and beneficiaries.

1. INTRODUCTION

1.1 Purpose of these Guidelines

The Victorian Government's Nutrient Management Program was developed in response to the increasing incidence of algal blooms and the deterioration of water quality in Victorian waterways. High levels of nutrients, in combination with other environmental factors, are a major cause of algal blooms. As part of the program, catchment-based nutrient management plans are being developed and/or implemented by regional communities across most of Victoria.

These plans identify major nutrient sources within catchments and recommend actions to reduce the level of nutrients entering waterways. Determining priority nutrient management actions within a catchment involves the need to undertake an economic analysis of the costs and benefits of those actions. Economic evaluations are critical to ensure that both regional communities and State Government invest in priority activities, those that give the best returns for the scarce resources invested.

These guidelines provide a rapid appraisal methodology ('RAM') to undertake such economic evaluations of the costs and benefits of nutrient plans.

The guidelines are structured so that the body of the report provides an overview of the methods proposed for evaluating the benefits and costs of a proposed nutrient management plan. The appendices provide the detailed information necessary for those planning to undertake an evaluation.

The body of the report may suffice for some policy makers and funding agencies, who need only an overview of the methods proposed for evaluating the benefits and costs of a proposed nutrient management plan. The main report might even suffice for some of the technical and economic specialists who develop the nutrient management plan, as well as for some stakeholders. However, for others it will be essential to consult some of the appendices, which present background theory and details of methods and results from previous evaluations of nutrient management plans for a range of catchments in Victoria.

1.2 Why Evaluate the Benefits and Costs of Nutrient Management?

In the evaluation of a nutrient management plan, the benefits of the plan are compared to the costs of implementing the plan (that is, a benefit−cost analysis; see Figure 2). However, the economic evaluation serves to achieve far more than a measure of the benefit−cost ratio for an overall plan. Namely, it should seek:

- ***to help formulate strategies for nutrient management***
  Identification and valuation of the likely benefits and costs of each potential nutrient management activity is vital in identifying priorities for strategies aimed at achieving healthy catchments;

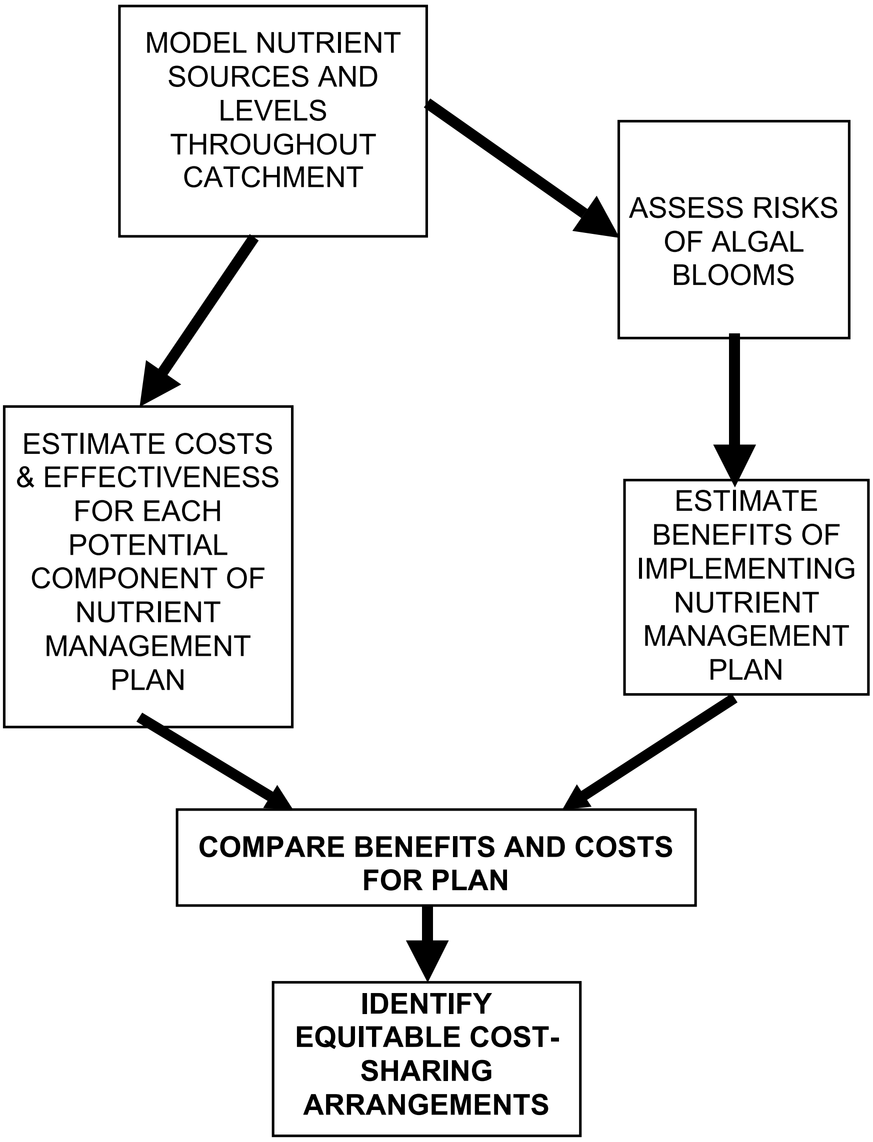
- ***to help ensure informed decision making***
  Government and communities need to make choices about how they will spend their scarce dollars for natural resource management. In order to make rational and relevant decisions, it is important that they understand the costs and benefits of each component of a management plan;

- ***to help understand the uncertainties surrounding the benefits of management***
  The outcomes of nutrient management are rarely certain and analysis of the benefits of management helps to pinpoint the uncertainties; and

- ***to help devise equitable cost-sharing arrangements***
  Identifying and valuing benefits helps to reveal who benefits, and by how much, so assisting in the development of cost-sharing arrangements.

Ideally the economic evaluation is undertaken as one of the early steps in formulating a management plan, rather than as a rubber stamp for a plan that has already been chosen without formal consideration of the economic benefits and costs.

Figure 2 Framework for Economic Evaluation of Nutrient Management



1.3 Types of Benefits Impacted on by Algal Blooms

Impacts of poor water quality include restrictions on use for all those who enjoy values associated with the waterbodies and waterways. This includes those visiting waterbodies and waterways for recreation, farmers relying on them for stock water and domestic water, industrial and urban users of water, irrigators, anglers and aquaculturalists, and environmental and amenity values.

The guidelines consider the economic impacts of algal blooms on each of these values. The avoidance and/or reduction of these impacts is the economic benefit from the nutrient management plan being evaluated.

1.4 Steps in Applying the Rapid Appraisal Method

The remainder of this handbook provides guidelines for the six main steps involved in the application of the RAM:

1. modelling of nutrient sources and levels throughout the catchment (see Chapter 2);

2. assessing risks of blooms at each waterway/waterbody in order to estimate the incidence of blooms for each waterway and waterbody under present conditions (see Chapter 3);

3. estimating economic impacts of blooms under present conditions (see Chapter 4);

4. considering the effectiveness and costs for a range of activities to reduce nutrient loads (see Chapter 5);

5. comparing benefits and costs (see Chapter 6); and

6. assessing implications of benefit–cost analysis for cost-sharing (see Chapter 7).

1.5 Ensuring Rapidity

The RAM provides information about the benefits and costs of nutrient management in a timely and cost-effective way. The key concepts of the RAM are:

- ***optimal ignorance*** *- knowing what facts are not worth knowing. It is the state of mind which endeavours to avoid information overkill; and*

- ***appropriate imprecision*** *- knowing that precise data are often unnecessary, and in the case of nutrient management may be impossible to obtain. Orders of magnitude and direction of change are often all that can be used in making decisions.*

There is little merit in estimating accurately one parameter in the benefit–cost analysis if other parameters can only be estimated in a very approximate manner. For example, the scientific relationship between nutrient loads and incidence of blooms is not well understood and hence estimates of the likely future incidence of blooms are generally not estimated readily.

The RAM is made both rapid and robust by emphasising that judgement is unavoidable, by structuring and standardising the form of the analysis, and by organising the processes of forming judgements. Economic evaluation of a nutrient management program using the RAM will always involve significant judgement by the catchment manager and the economist.

Some examples of the ways these principles can be applied in the rapid appraisal of the benefits and costs of nutrient management plans include:

- use interviews with key experts who are selected for their specialised knowledge and experience on the waterbody or type of damage under investigation;
- avoid strict sampling procedures and statistical niceties. Usually rough average values can be used. Use informal interviews and surveys rather than formal questionnaires and rigorously drawn samples of interviewees when attempting to estimate the effect of a bloom on, say, recreational activities on a given waterbody. Group discussions may also be useful in attempting to obtain a consensus;
- wherever possible base prediction of future effects and resulting damage on actual past events;
- make use of existing information and, where a sound case can be made, extrapolate the results from other studies. Such a process, known as 'benefit transfer', will be necessary for many attempts to value non-market benefits; and
- concentrate first on the evaluation of the market benefits. It may yield some interesting results which might permit the more difficult evaluation of non-market benefits to be avoided. Bear in mind that the monetary valuation of non-markets benefits is unlikely to yield highly accurate absolute values anyway.

Another useful way of thinking about, and using, the RAM is that it is analogous to the first (coarse) stage of a filtering process; that is, detail is sacrificed for speed of separation. In other words, the benefits of controlling blooms are analysed quickly, using a standardised method, so as to separate those which are clearly worthwhile investments from those which are not. Failure to demonstrate there are sufficient benefits to cover costs in this manner, however, does not necessarily mean that a proposal is not worthwhile. It may mean that evaluation of the proposal is complex and requires more detailed analysis or further research. In such situations, application of the RAM should indicate which of these conclusions is relevant.

As with most aids to practical decision making, the RAM is a mixture of science and judgement. Indeed, the current level of knowledge about the probability of occurrence of blooms of blue-green algae seems to be relatively low because blooms are extremely complex phenomena which require the simultaneous occurrence of many predisposing variables (see Appendix 1 for a schematic presentation of some of the many factors influencing the characteristics of blooms). As a result the predicability of the occurrence, extent and severity of blooms is low. Therefore, the economic evaluation of the benefits of controlling blooms is an endeavour in which the judgements of experts are crucial.

2. MODELLING OF NUTRIENT SOURCES AND LEVELS

Modelling of nutrient concentrations and loads in the catchment should be undertaken to assist in the development of a nutrient management plan. The nutrient model is required to:

- establish the nutrient loads for each part of the catchment;
- assess the relative contribution of each nutrient source to the overall problem;
- assist in the selection of nutrient control options; and
- assist in the identification of stakeholders.

The nutrient modelling should identify all point sources and land uses that contribute nutrients to waterways and waterbodies. The spatial details of the nutrient status within the catchment should be specified in a computer model that is capable of examining ‘what if’ scenarios about changes to nutrient concentrations and loads at any location in the catchment. This type of model provides crucial information for the economic analysis of changes in the nutrient status of the catchment.

Modelling is likely to be based on existing water quality knowledge for the catchment, as well as information about nutrient concentrations and export rates from other catchments. Details of the nutrient contribution from some point sources (e.g. wastewater treatments plants and industrial discharges) can be obtained from the Environment Protection Authority (EPA) which licenses those discharges. Point sources include:

- wastewater treatment plants;
- stormwater drains;
- irrigation drains;
- intensive animal production enterprises (pigs, poultry, fish farms, feedlots);
- construction sites;
- mining/extractive sites;
- industrial discharges; and
- septic tanks.

Non point sources include:

- in-stream and streambank erosion processes;
- off-stream gully erosion processes;
- roads;
- various types of forests; and
- various types of agricultural land uses.

Nutrient loads from non-point sources can be estimated either by:

- multiplying the expected nutrient concentration by runoff rate; or
- establishing nutrient export rates per hectare for specific diffuse sources; or
- establishing the proportion of total nutrient loads contributed for different sources.

In many instance there will not be good data describing the nutrient contributions for some types of land use, and some parameters will have to be based on judgements of subject matter specialists who are familiar with the catchment.

Nutrient export rates need to be developed for each catchment as they are likely to vary according to many factors including the sub-region in which the land-use occurs and other less predictable factors such as seasonal variations. For example, nutrient export rates vary between sub-regions due to variation in rainfall, the fertility and erodability of the land, and between land-uses due to variations in the disturbance to soils and industry inputs and outputs.

The literature reveals broad ranges for the relative nutrient contributions from most types of land-use. These guidelines do not present a wide review of the literature. However, examples of export rates used for the Glenelg Hopkins, Corangamite and Upper North East studies are presented in Appendix 2. NRE (in prep) presents a summary of export rates used in the modelling component undertaken for all catchment-based nutrient management plans being prepared around the State.

The modelling should be appropriate to the level of information available and the potential modelling frameworks available include:

- simple source and delivery models, probably specified in spreadsheets.
- the Catchment Management Support System (CMSS).
- Adaptive Environmental Assessment and Management models (AEAM).
- GIS models.

The modelling framework should be chosen to suit the skills and needs of nutrient managers in each catchment. Simple spreadsheet models are more flexible from the viewpoint of most managers and analysts involved in the process of developing nutrient management plans. However, as a generalisation, spreadsheet models are not appropriate for wide distribution to the wider community. CMSS and AEAM models on the other hand can represent easy-to-use models suitable for distribution to the wider community. There is additional expenditure required to produce CMSS or AEAM models and these should probably be considered only in situations where the nutrient models are likely to be used for education purposes or to assist with presentations to public forums.

Furthermore, the modelled loads or concentrations should be verified/calibrated against water quality monitoring data.

3. ASSESSING RISKS OF ALGAL BLOOMS

An estimate of the likely future incidence of blooms at a waterway or waterbody, with and without the proposed nutrient plan, is one of the most important pieces of information required for application of the RAM. Data describing the past incidence of blooms are useful in formulating scenarios about the future, but it is only relatively recently that close attention has been paid to the recording of details of algal blooms. Consequently, official records are likely to be dominated by waterways and waterbodies which have been experiencing blooms relatively frequently over the past decade or less, and those records are likely to under-estimate the incidence, over the longer term, of blooms at many waterways and waterbodies. For this reason it is necessary to consider the risks of blooms at all waterways and waterbodies within a catchment even though many may not have experienced algal blooms.

3.1 Defining Blooms

Scenarios about the future incidence of blooms should be considered for two types of blooms; namely:

1. minor blooms, where cell counts are greater than 2000 but less than 15,000 cells per mL; and

2. major blooms, where cell counts are greater than 15,000 cells per mL.

This distinction is important as the difference between cell counts of greater or less than 15,000 cells per mL largely determines the economic impacts of a bloom. This is because response plans require only increased monitoring of water quality for cell counts over the range 2000 to 15,000 cells per mL but, for cell counts greater than 15,000 cells per mL, require the cessation of the consumptive use of water and the implementation of measures such as distribution of information to the public and the erection of warning signs[1]. Consequently, the economic impacts for cell counts over the range 2000 to 15,000 cells per mL should be estimated based on the costs of increased monitoring of water quality; but that estimates of the economic impacts for cell counts greater than 15,000 cells per mL should be based the cessation of the consumptive use.

Scenarios for the incidence of blooms at each waterway and waterbody in the future cannot be determined solely from official records. The economic analysis should span 30 years and ideally data describing the incidence of blooms over the previous 30 years would be considered in formulating scenarios for the next 30 years. Unfortunately, as mentioned above, it is only relatively recently that close attention has been paid to the recording of details of blue-green algal blooms.

Furthermore, ecological factors may mean that the first occurrence of blooms at a particular waterway or waterbody may lead to an increased incidence of blooms in the future at the same waterway and waterbody. Consequently, blooms at waterways and waterbodies that have commenced a history of blooms over the relatively short period of record might be expected to experience more frequent blue-green algal blooms over future decades.

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[1] At the time of going to press, the ARMCANZ National Algal Manager was reviewing the suitability of the 20,000 cells/mL guideline for recreational use of waterbodies. It is suggested that the analyst using this cost-benefit assessment methodology check the current recommended guideline.

A two stage approach is suggested for predicting the number blooms at each waterway and waterbody:

1. assess risks of blooms at each waterway and waterbody; and
2. estimate incidence of blooms based on both recorded incidence of blooms and results of the risk assessment.

3.2 Approaches for Risk Assessment

The risks of algal blooms should be assessed for each waterway and waterbody. Careful judgement is required as there will be many factors influencing the incidence of blooms at a particular waterway and waterbody. For example, a perennial stream with a very high flow velocity throughout the year may not be conducive to the formation of blooms, even though other predisposing factors were present (e.g. high nutrient levels and high temperature). It may be judged that although those factors give rise to a high risk score, the characteristic of high velocity may in itself preclude the occurrence of blooms.

A risk assessment should be undertaken by scoring each waterway and waterbody with respect to a number of variables that influence the likelihood of blue-green algal blooms. For example, these might include:

- water quality ratings (e.g. TP, TN, TSS, turbidity, salinity);
- water velocity rating;
- water temperature rating; and
- previous bloom history.

Predicting the behaviour of the waterbody with and without a bloom may not be easy. It requires a reasonable understanding of the physical and biological processes which are, or may be, involved in producing algal blooms within the waterbody in question. The essence of the problem is to be able to predict the probability of occurrence for blooms of various sizes and severities. Blooms are difficult to predict and this will be of particular concern for waterbodies which have not yet experienced a bloom.

Wherever possible, it is suggested that the analysts make use of information about real events and actual damage scenarios, for example, arguing from the effects of particular blooms which have occurred. Along with the experience of those involved in the management of the waterbody(ies), sources helpful in predicting future scenarios include: records held by government departments and water authorities; newspaper articles at the time; conference proceedings; knowledge gleaned from local business people or recreationists who have experienced the blooms; or specialist scientists.

The ‘without strategy’ scenario may be the current state of the waterbody. It must be remembered, however, that this may not always be appropriate if other forces are leading to change simultaneously (say, a trend towards further degradation, or a decline in the popularity of the waterbody as a site for recreation due to developments at a nearby substitute site).

From the viewpoint of estimating economic impacts from algal blooms, the incidence of blooms is most usefully expressed as the mean number of weeks of bloom duration per year, or the total number of weeks of blooms over the next 30 years.

3.3 Estimating Likely Future Incidence of Blooms

Predicting the likely future incidence of, or probabilities, with which blooms might occur is difficult. In the final analysis, this may be a matter for subjective assessment since past frequencies, even if known, may not be a guide to the future. Forming judgements about the 'with strategy' scenarios is obviously the main task of the technical analyst, assisted where necessary by key scientific experts.

Risk scores for waterways and waterbodies with a recorded history of blooms should be examined to determine some criteria for predicting the likelihood of blooms based on risk scores. Given that ecological factors suggest that the occurrence of blooms may lead to an increased probability of blooms in the future at the same waterway and waterbody, particular attention should be paid to waterways and waterbodies where official records, or anecdotal evidence, reveal a high incidence of blooms.

For example, Table 3-1 presents the scores which were assessed for Lake Modewarre and for the Gellibrand River in developing the risk assessment for each waterway and waterbody in the Corangamite catchment:

Table 3-1 Risk assessment for Lake Modewarre and Gellibrand River

Explanatory variable	Score for Lake Modewarre	Score for Gellibrand River
Water quality	4	4
Water velocity	4	1
Water temperature	3	3
Bloom history	4	1
Total score	**192**	**12**

Each variable was given an equal weighting and the overall risk scores were calculated as the product of the scores for each variable (e.g. for Lake Modewarre, the overall risk score was calculated as 4 times 4 times 3 times 4).

A useful approach is to examine the water quality and other relevant characteristics for those waterways and waterbodies with a history of blooms and to consider whether other waterways and waterbodies with those same characteristics might be expected also to bloom over future decades. For example, Lake Modewarre had a history of relatively frequent blooms. Consequently, for that region, a useful criterion might be that waterways and waterbodies with a risk score of, say, 200 or greater should be expected to bloom relatively frequently even if such events had not yet been recorded.

Managers should not necessarily constrain themselves to the variables, cutoffs and weightings that have been adopted in previous studies. Each catchment is different and the ecology of blooms is not understood fully. A range of approaches might be tried for waterways and waterbodies in the catchment and the results could be examined to see which approach had led to the most credible ranking of sites.

In presenting the results of the risk assessment, it is important to provide a table showing, for each waterway and waterbody, both the recorded incidence of blooms and the risk score assessed. Examples of risk assessments for a number of catchments are presented in Appendix 3.

Trend data should be examined wherever available. For example, a waterway or waterbody with a relatively low risk score might be judged as likely to commence a history of blooms in the future if water quality data revealed a steeply rising trend in the concentration of nutrients, particularly for the 'bio-available' forms of those nutrients. Similarly, evidence of a trend in land use or a proposed licensed discharge that was judged to increase the likelihood of blooms might constitute the basis for predicting that a particular waterway and waterbody was likely to commence a history of blooms in the future.

4. ESTIMATING ECONOMIC IMPACTS OF ALGAL BLOOMS

The economic benefits of a nutrient management plan are the difference between the economic value of water with and without the plan. The focus of nutrient management plans in Victoria is mainly on the avoidance of (sometimes toxic) blue-green algal blooms. The benefits of reducing the incidence of blooms are evaluated relative to what would happen if the present incidence of blooms continued. **That is, the benefits refer to the damage (costs) avoided by reducing the future incidence of algal blooms[2] due to the implementation of the nutrient management plan**.

For example, a bloom in the creek from which a farming community relies for its stock and domestic water would force the community to seek alternative supplies for the duration of the bloom. Avoiding the costs of obtaining those alternative supplies is the benefit of preventing a future bloom. As far as possible, benefits are measured in dollars so that they can be compared directly with the costs of nutrient management programs. All benefits which cannot be so measured must at least be identified (see Appendix 4).

The logical sequence of steps to estimate the impacts of a toxic blue-green algal bloom is to:

- collect details of the levels of all uses of the waterbody; then
- identify the classes of damage likely to be caused by the bloom, including both those that can be quantified in terms of market prices and those that cannot.

The approach recommended for the RAM is summarised below.

4.1 Issues to Consider when Assessing Economic Impacts

(i) The importance of considering net economic values

It is important to distinguish between:

- avoiding the loss of economic value; and
- avoiding the loss of economic activity.

The economic value of something is what people are prepared to pay for it (even if not required to do so), while economic activity concerns the flows of money and resources set in train as a result of the economic value.

From the viewpoint of Victoria/Australia, the costs of providing services to consumers must be offset against the expenditure by consumers. Oversimplifying, the net gain to the economy is \$35 when a restaurant prepares a meal for a family at a cost of \$65 and sells it for \$100. The amount of economic activity would be \$100, but the (net) economic value would be only \$35. Further, from the viewpoint of the nation/State, expenditure in a particular region would have many substitutes and such expenditure would only lead to a net increase in total expenditure in Australia if it would not otherwise have been spent in another region in Australia.

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[2] Most economic impacts would relate to **blue-green** algal blooms, but there are other types of toxic blooms. For example, a dinoflagelatte bloom in the Corangamite region (Lake Gnarpurt) resulted in the loss of 40-50 tonnes of eels during Spring 1999. The market value of the eels lost was approximately \$500,000. Similarly there can be economic impacts from non-toxic algal blooms.

Avoiding the loss of economic activity is likely to be most important in relation to tourism and the recreational use of a waterbody. As people use a waterbody for recreation they spend money on goods and services including petrol, accommodation, restaurants, walking shoes and fishing rods. By spending this money, jobs and buildings may be created and further spending induced by those who sell the goods and services. This activity is not the value of the waterbody but is brought into existence by the value of the waterbody. Loss of expenditure and jobs may be a loss to the region containing the waterbody, but it might not be a loss to the State since some recreationists may simply go elsewhere. Measuring the loss of economic activity caused by a bloom is useful for demonstrating the need for a regional cost share.

As a generalisation, evaluations from the viewpoint of the region will be more concerned with changes in economic activity while evaluations from the viewpoint of the broader Victorian/Australian economy will be more concerned with changes in (net) economic value.

(ii) Planning horizon and discount rate

Because the benefits accrue in the future and ultimately must be compared with costs which are outlaid both now and in the future, the present values of the benefits must be calculated using standard discounting procedures. The net benefit of the nutrient management program, or parts of it, is the difference between the present value of the aggregate benefit and the present value of the cost; and the benefit−cost ratio is the (discounted) ‘present value’ of the aggregate benefits divided by the present value of the costs.

Although some of the benefits may be very long term, a planning horizon of 30 years is suggested for the evaluation of benefits. This is roughly a generation interval and founded on the belief that each generation is doing a good job if it can plan for the next generation rather than attempting to look after many subsequent generations. Not only is 30 years about the time most actions taken for riverine management are likely to have attained equilibrium outcomes, but also the arithmetic of discounting means that little weighting is given to events beyond about 30 years.

In benefit-cost analysis, the process of discounting enables the direct comparison of amounts of money which accrue in different time periods. Discounting gives greater weight to initial costs and benefits, and less weight to those in the future. The present value of a future sum is lower the higher the discount rate[3].

‘Real’ discount rates (i.e. based on inflation-free interest rates) should be used, and at least two discount rates (say, four per cent and eight per cent), should be used to indicate the sensitivity of the results to this key parameter.

(iii) Uncertainty

All investment programs, particularly those concerned with the long time frames of nutrient management programs are subject to the uncertainty that things may not turn out as anticipated. In the face of such uncertainty, no form of analysis can ensure that the predicted outcomes will eventuate. The best which can be done with the information available at the time is to acknowledge uncertainty by specifying ranges, and to use wisely the analytical framework to make a good decision, that is, one that does most to further the nutrient management program’s aims.

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[3] For example, the present value of $100 to be received in 30 years from now is $55 at a discount rate of two per cent but only $6 at ten per cent. This is because $6 invested now at 10 per cent interest, or $56 invested now at 2 per cent interest, would both grow to $100 after 30 years.

In the context of the evaluation of nutrient management programs, possibly the best that can be done is to gain some understanding of what the benefits might be if the predictions made about future scenarios (such as, reduced visits by tourists) were incorrect and if the values attached to 'hard-to-value' items were different. For example, if the size of a particular type of benefit (say, preventing damage to wetlands) appears to have a strong influence on the overall benefits, it may be appropriate to test how sensitive the results are to changing the assumptions about the size or timing of that benefit.

This suggests that the procedures used in the evaluation exercise should employ some form of sensitivity analysis of key parameters, and that a range of estimates be used for uncertain parameters.

(iv) Valuing market benefits

Market benefits are those which can be valued by market prices. For example, the benefit of avoiding hand feeding of livestock can be readily valued since common forms of purchased fodder, such as wheat and hay, command prices in recognised markets. There are, of course, many examples of assets which, once in place, are seldom traded in a market (e.g. water treatment facilities and the fixed structures of irrigation systems. Nevertheless, avoiding damage to such assets or avoiding the installation of them is classed as a market benefit since the raw materials for those assets can be priced and relocation or installation costs determined.

The basic approach to valuation of market benefits is one of simple multiplication of quantity times price. The prices used may be actual prices or imputed prices. Imputed prices may take several forms, such as replacement value for physical assets or the prices of substitutes in the case of the interruption to supplies.

There are often a number of ways to avoid/reduce the damages from a bloom, and the cost estimate to be used should always be the **lower** figure. For example, the impacts on water supplies to a particular town might equally be avoided by carting in alternative supplies of bulk water by truck during the bloom, or by running existing filtration capacity. The latter is a much cheaper option and should be used as the estimate of costs to be avoided.

The need to ensure that minimum costs are used is particularly important for situations where the 'damages' that would be avoided would in fact be the expenditure associated with other measures that are already in place to prevent or reduce the physical impacts of blooms. Such (existing) preventative expenditures can be interpreted as minimum valuations of the damages that would result in the absence of the nutrient plan.

(v) Valuing non-market benefits

The total value of a non-market benefit is the total willingness to pay for it. The net value is this total minus the costs of providing it. These principles are the basis of several widely-used methods to value unpriced benefits, the best-known of which are the 'travel cost method' and the 'contingent valuation method'. However, neither of these methods is capable of rapid application. For a comprehensive review of these and related approaches, see Sinden (1994) and Commonwealth of Australia (1995).

The following are some methods which appear to lend themselves to the task of **rapidly** placing money values on the non-market benefits of controlling algal blooms, particularly those benefits associated with the recreational use of a waterbody and its environs. Each method requires different types of information and none of these methods will provide a precise estimate. The analyst should used every one of those methods for which the necessary information is available. Approaches include:

- replacement – cost method;

- interpretation of previous decisions from similar situations;
- transferring values from other studies; and
- threshold analysis.

Further information about valuing non-market benefits and economic value of environmental resources is in Appendix 4.

4.2 Types of Market and Non-market Benefits requiring Assessment

This section summarises the types of uses and values of waterbodies which are impacted upon by algal blooms and summarises the approach to estimating the economic impacts of blooms on these values.

(i) Impacts on recreation and tourism

The economic impact of an algal bloom on recreation is the difference between the value of recreation with and without the bloom. Estimating the economic impact of algal blooms on recreation involves three main steps:

1. determine the number of visitors and characteristics of recreational activities undertaken at the site in years prior to the bloom occurring;

2. determine the likely change in visitor numbers and recreational activities due to the bloom; then

3. estimate the net loss to the broader economy associated with the change in visitor numbers and recreational activities due to the bloom.

Details and examples of how to estimate the value of reduced recreation and tourism are presented in Appendix 5.

(ii) Impacts on urban water supplies

Algal blooms can impact on urban water supplies in a number of different ways, depending on what technical options are available for responding to the bloom. For example, impacts on a water authority might include the need to:

- use algicides quickly to treat an algal problem in a reservoir (note that the use of algicides is subject to specific regulatory controls – see Appendix 6);

- switch to alternative source of water if available, possibly with the need to impose water restrictions;

- use stand-by filtration capacity for toxin removal, possibly with the need to impose water restrictions; and

- cart in water and impose water restrictions.

The actual impact will depend on the options available for the particular supply system. For example, the impacts would depend on whether alternative sources of water were available, or whether high level filtration capacity had been installed prior to the onset of the bloom.

Details of the methods of estimating the economic impacts of blooms on urban water supplies and examples of estimates of the various types of impacts are presented in Appendix 6.

(iii) Impacts on farms and farming

The impacts of algal blooms on farms and farming will depend on the characteristics of the stock and domestic water supplies which are affected. For example, whether alternative sources of supply are available or whether farmers already treat or filter their water in some way.

The types of damage will vary depending upon whether the water affected is used for:

- drinking water for livestock,
- domestic water supplies for the farm, or
- irrigation water for pastures or crops.

The types of impacts might include the need to:

- use an alternative supply of water for livestock, crops or domestic use;
- cart supplies of water for livestock or domestic use;
- hand feed livestock in a holding area; and
- transport livestock to an agistment block.

Details of the appropriate approaches for estimating the impacts of algal blooms on various types of impacts on farm water supplies are presented in Appendix 7.

(iv) Impacts on management agencies

Algal blooms impose direct costs to water authorities, the Department of Natural Resources and Environment and other agencies responsible for their management. Costs include:

- increased water monitoring (algae and toxins);
- staff time (e.g. on response group, media/publicity/liaison with State Emergency Services, Displan);
- warning signs; and
- letter distribution (start and end of bloom).

The costs to water management agencies need to be determined for minor and major incidents. Minor incidents are defined as blooms at those waterbodies and waterways with only limited public access and which are not used as a major town water supply. The extent of increased monitoring and staff time would be considerably greater for major incidents, which would apply to blooms in waterways or waterbodies with substantial public access or with implications for town water supplies.

(v) Impacts on environmental values

Environmental values are taken to include such things as individual species of fish and wildlife and their habitats, the balance between species in a natural setting such as a stream or wetland, and the integrity of the stream or wetland. The value of an environmental asset may involve a mix of use and non-use values which are difficult to separate. A wetland, for example, may produce use values such as of bird watching, picnicking, duck shooting and as a photographic subject. In addition there may be non-use values because people value its existence even though they would never visit. The last type of value may arise because it is a nesting ground for particular species of waterbird. In a RAM, it may seldom be necessary to try to separate these values, rather the wetland is valued as a whole. Such values are clearly difficult to quantify. Section 4.1 (v) and Appendix 4 consider approaches to the valuation of environmental values.

However, in many circumstances helpful valuations will simply not be available, particularly, but not limited to, the case of small waterbodies which are not widely known outside the local community. **Therefore, threshold or breakeven analysis is likely to be the most used form of 'valuation' for environmental impacts associated with algal blooms.**

An important objective of the nutrient management plan for the Corangamite catchment was to minimise impacts on flora and fauna in streams and wetlands. One of the most valuable assets in the Corangamite region from the viewpoint of the State, national and international community might be the RAMSAR wetlands and other wetlands that are considered of State significance with respect to their natural values.

Using the nutrient model, consultants determined which mix of management activities in each sub-catchment would lead to a minimisation of the nutrient loads reaching the waterbodies in the Corangamite region that are considered of national and State significance with respect to their natural values. Using the same model, the consultants also determined which mix of management activities in each sub-catchment would lead to a maximisation of the benefit−cost ratio when only priced benefits were considered. The results of the comparison were then presented and questions were posed as to whether the costs of additional activities involved in the wetland-motivated mix would be justified by the additional improvement of water quality in important (mainly RAMSAR) wetlands.

(vi) Impacts on amenity values

Amenity is reduced for residents of houses with frontages to waterbodies and waterways during algal blooms. Blooms would reduce visual amenity as well as cause unpleasant odours and fears associated with the presence of toxins from blue-green algae. These factors have been shown to reduce the desirability of properties with frontages to waterbodies and waterways that are subject to blooms. Examples of estimates for this type of impact are presented in Appendix 8.

(vii) Other benefits

The benefits of reducing the incidence of blue-green algal blooms, discussed in the preceding sections, would in themselves represent an under-estimate of the total economic impacts of nutrient management. Firstly, water quality would often be degraded such that people reduced their level of water consumption or recreation at a particular waterbody or waterway even though blooms were not occurring. This chapter has examined only the impacts of poor water quality at the 'disastrous stage' when toxic blooms occur. Secondly, nutrient management activities would lead to improvements in water quality with respect to characteristics other than algal cell counts. Other water quality benefits which would be achieved by reducing nutrient loads in waterbodies and waterways include:

- reducing the risk of future deterioration of water quality;
- reduced water treatment costs; and
- benefits for residents and for improved image for regional economy.

Reducing the risk of future deterioration of water quality

Where trend information indicates that water quality is presently deteriorating, then there is a place for the development of hypothetical scenarios to test how the results of the analysis would change if conditions were to deteriorate further in the absence of nutrient management.

Reduced water treatment costs

With respect to water treatment costs, each case should be considered on its merits and the potential savings would be determined mainly by the particular levels of suspended solids and turbidity, and on the type of water treatment in place.

Improvements in water quality, particularly colour and turbidity, is a common benefit from any river management activities that reduce sediment loads in surface waters that are used for urban water supplies. The two major components would be savings in chemical use at water treatment plants and a reduction in the need to scour water mains.

For example, North East Region Water Authority treats water from the Ovens River at Wangaratta. Turbidity levels are typically below 5 NTU for about 50 per cent of the year. It is estimated that during those times of low turbidity, the chemical costs of treatment are about $5 per ML. When turbidity exceeds 5 NTU, it is estimated that the quantities of chemicals (alum, soda ash and lime) are tripled. This suggests a cost saving of $10 per ML for activities which lead to turbidity levels being reduced below the threshold of 5 NTU at the Wangaratta treatment plant (Read Sturgess and Associates and Rendall McGuckian 1998).

Benefits for residents and improved image for regional economy

Residents of catchments appreciate good water quality. Further, any incidence of algal blooms at popular tourism sites, farms or on food processing companies, could have a disastrous effect on the image of the region as a tourism destination or as a producer and processor of ‘clean foods’ (notably meat and dairy products). Similarly, blooms in town water supplies could have health impacts for the human population.

The additional expenditure required to improve and protect water quality may pale into insignificance relative to the value of tourism in the region, or the value of food products being produced each year. Experience has shown that tourists and export markets for food products are unforgiving, and that it takes a water quality catastrophe in only one short period to lead to a sustained withdrawal of support from tourists and markets beyond the region.

There is no basis for predicting the probability of a given set of water quality problems leading to such a catastrophe, but indicative scenarios might be formulated for the purposes of demonstrating the order of potential costs involved.

Importance of considering each case on its own merits

These guidelines have attempted to cover most of the types of impacts that might arise from algal blooms in many regions. However, there will often be other impacts specific to a particular region, and the analyst must seek to identify all impacts for the particular region being studied. For example, impacts on herbicide efficacy were considered in an evaluation of the Wimmera nutrient management plan and impacts on eel farming were considered for the Corangamite nutrient management plan.

5. ESTIMATING COSTS OF NUTRIENT MANAGEMENT ACTIVITIES

5.1 Costing Principles

The following important principles apply in estimating costs for proposed nutrient management activities:

- include both capital and recurrent expenditure;
- present costs as discounted values or as annuities;
- recognise overhead costs for the labour component; and
- recognise rates and timing of adoption.

(i) Include capital and recurrent expenditure

In estimating the cost of activities, two types of costs must be considered; namely, capital costs and recurrent costs. Capital costs are once-off costs that are incurred typically at the beginning of an investment, such as the cost required to establish an improved pasture. The establishment costs will include preparing the ground for sowing, applying herbicides and sowing the seed. Recurrent costs are the annual on-going costs required to maintain the investment, such as by applying fertilisers and managing weeds and pests.

The occurrence of capital and recurrent costs makes it important that an appropriate discount rate is applied to enable the present values of various investments to be calculated and compared (see below).

Some impacts or changes can affect both the capital stock of a resource and the recurrent flow of goods from that resource. In economic terms the value of the stock is the (appropriately discounted) value of the future flow of goods from that resource, so care must be taken not to count changes to both since this would be double counting. For example, if some agricultural land would be lost through erosion, then either economic value of the lost agricultural production each year, or the (once-off) capital value of the land, is an appropriate measure of that loss, not both.

(ii) Present costs as discounted values or as annuities

In benefit−cost analysis, the process of discounting enables the direct comparison of amounts of money that accrue in different periods, such as capital and recurrent costs. Discounting gives greater weight to initial costs and benefits and less weight to those in the future. Discounting future costs using standard discounting procedures calculates the **present value** of the costs.

In a similar way, when benefits accrue in the future, the present value of these benefits must be calculated and compared with the present value of costs. When the present value of benefits are greater than the present value of costs then an investment or activity is economically feasible.

Discounted costs can be presented as present values or alternatively as an equivalent annual value. In calculating a present value, it is necessary to sum the discounted costs from different periods. The following example (see Table 5-1) shows an investment involving an initial capital cost of $200.00 and subsequent recurrent costs of $20 per year. Applying a discount rate of 8 per cent, the present value is $251.55, which is less than the arithmetic sum of the cash flow.

Table 5-1 Example calculation of discounted sums

Year	Cost	Present value
0	$200.00	$200.00
1	$20.00	$18.52
2	$20.00	$17.15
3	$20.00	$15.88
Total	**$260.00**	**$251.55**

Alternatively, the present value can be expressed as an **annual equivalent** or **annuity**, which are the constant yearly amounts that are equal in value to a once-off present value. For example, the annual equivalent for the present value shown in the example above is $75.95. Stated differently, the present value of $251.55 is equal to four equal payments of $75.95 when discounted at 8 per cent. The advantage of using annual equivalents is that many of the benefits are calculated as annual impacts.

(iii) Recognise overhead costs for the labour component

When including the costs of labour for employees of large businesses or organisations. It is necessary to include **overhead costs** and staff **on-costs** in addition to salaries. Staff on-costs include allowances for long service leave, Workcover, superannuation and payroll tax and are equal to approximately 110 per cent of direct salary costs. This is based on guidelines for costing Government activities, which have been provided by the Commonwealth Department of Finance (1991) and Victorian Department of Treasury (1993). The two sets of guidelines suggest different levels of overheads and these RAM guidelines have taken an average of the two (see Table 5-2).

Table 5-2 Guidelines for attributing overhead costs to salaries in the public sector

Type of overhead	Overhead costs as % of direct salary costs	
	Commonwealth Department of Finance (1991)	Victorian Department of Treasury (1993)
Non-working days	n.a.	n.a.
Operating expenses (stationary, postage, telephone, furniture, light &power, computer services and incidentals)	48.2	40.0
Legal services	1.6	n.a.
Office rental	23.5	23.5
Corporate overheads (accounting, management, other corporate services)	53.5	30.1
Total	**126.8**	**94.5**

(iv) Recognise rates and timing of adoption

The results of benefit-cost analysis can be extremely sensitive to assumptions about the rate at which adoption of a new technology or investment occurs. The problems with poor adoption are exacerbated in the rural sector where the demographics of the community and the absence of large operating profits tend to slow potential adoption. The adoption rate chosen should be challenging, but achievable.

The rate at which an investment is adopted reflects the rate at which costs should be included in the benefit−cost analysis. The adoption rate will also determine the rate at which benefits are achieved subject to any lag period.

5.2 Incremental Costs

‘Incremental costs’ of nutrient reduction represent the costs of avoiding a one kilogram increment of TP or TN, and provide a guide to the cost effectiveness of each potential nutrient reduction activity. This allows a ranking of the relative priorities which should be afforded to each type of activity.

In estimating the incremental costs for each activity, it is necessary to derive four important pieces of information:

1. location of point sources, or type of land use, in which to implement the activity;

2. percentage reduction of nutrient export that would be achieved by implementing the activity at those locations;

3. existing nutrient loads generated at those locations; and

4. costs of implementing that activity, expressed as an annuity.

Estimates of incremental costs can then be calculated by dividing the costs of implementing the activity by the reduction of nutrient export (TP or TN) that would be achieved by implementing that activity.

In themselves, the incremental costs are a useful filter, for use at an early stage in development of nutrient management plans to develop a ‘short-list’ of activities for further consideration. However, estimates of incremental costs in themselves are insufficient to provide a guide as to the extent of implementation of each activity. The latter can be judged only after consideration has been given to the benefits from implementation of each activity at each location. For example, **an action with a relatively high incremental cost may have a positive benefit−cost ratio upstream of a high priority waterbody**.

For example, in evaluating actions within the proposed nutrient management plan for the Loddon catchment, it was found that some actions with relative high incremental costs can have a high benefit−cost ratio because those actions lead to a substantial reduction in nutrient loads upstream of a high priority waterbody.

Appendix 9 provides further information on the calculation of incremental costs for nutrient management activities.

6. COMPARING BENEFITS AND COSTS OF NUTRIENT MANAGEMENT ACTIONS

Prior to commencement of a comparison between benefits and costs of nutrient management activities, the following information would already have been estimated:

- nutrient loads at each bloom site would have been obtained from the nutrient modelling. This would have involved specifying flows of nutrient from each sub-catchment or point source to particular bloom sites (see Chapter 2);
- the expected future incidence of toxic blooms, based on the recorded history of blooms at each site and a risk assessment undertaken for each site (see Chapter 3);
- the expected impacts of toxic blooms at each site (see Chapter 4); and
- costs of each potential management activity and the reduction in generation of nutrients that would result from each management activity (see Chapter 5).

The following additional steps are required to undertake a benefit−cost evaluation:

- specify relationship between reduction in nutrient loads at a particular site and the likely extent of reduction in frequency of blooms at that site;
- estimate the expected avoidance of damages from toxic blooms due to each management activity, by multiplying the estimated damages from each bloom (see Chapter 4) by the estimated reduction in frequency of blooms at each site. These cost savings represent the economic benefits of the nutrient management plan; and
- compare those benefits to the costs of each management activity.

6.1 Relationship between Nutrient Levels and Blooms

The major benefits of nutrient management should be estimated as the reduction in costs associated with a reduction in the incidence of toxic blooms. Conceptually, this is calculated simply for each nutrient management activity as:

[the reduction in frequency of blooms]

MULTIPLIED BY

[economic impacts of one bloom]

However, in order to estimate the reduction in frequency of toxic algal blooms that would be achieved for each nutrient management activity, it is necessary to specify a relationship between reduction in nutrient loads at a particular site and the extent of reduction in frequency of blooms at that site. However, there does not yet exist a fully adequate scientific understanding of the processes that lead to blooms, nor of the details of the relationship between nutrient levels and the incidence of those blooms.

There are published acknowledgments that there is a link between nutrient loads and the frequency or severity of algal blooms. For example, Harris (1994) observed that:

> *. . . an increase in the frequency of the occurrence of blooms of a cyanobacteria in inland waters is largely the result of nutrient enrichment by human activity although some blooms may be entirely natural in origin . . . It can be predicted that reductions in the external load of nutrients will cause*

> *. . . a reduction in the severity of nuisance blooms. Phosphorus loading reductions are the key control factor . . .*

While it has been widely acknowledged that that there is a link between nutrient loads and the frequency or severity of algal blooms, the details of the likely relationship(s) are not known.

Given this lack of understanding, each region is encouraged to suggest their own approaches to specifying a relationship between the reduction in nutrient loads at a particular site and the extent of reduction in frequency of blooms at that site. Regions are encouraged to consider the approaches taken in other catchments in the State to assist in determining which methodology best suits their catchment. Examples of approaches adopted in Victorian nutrient management plans in defining a relationship between reductions in nutrient loads and the incidence of blooms are presented in Appendix 10.

Furthermore, regions should investigate the outcomes of the latest available technical studies between the links between nutrient levels and the frequency and severity of blue-green algal blooms when determining the methodology to be used. For example, at the time of publication, the Cooperative Research Centre for Freshwater Ecology and the Department of Natural Resources and Environment were considering developing a nutrient-algae response framework specifically aimed at assisting water resource managers quantify the relationship between nutrient loads, nutrient availability and algal growth.

In order to assist Government with comparing the evaluations of proposed nutrient management plans from different regions, there is a need for that relationship to be explained carefully. Each region should also state clearly the assumed level of reduction in nutrient loads and estimated level of reduction in incidence of algal blooms. This then allows an estimate of the implied ratio of reduction in nutrient loads to bloom-reduction which would give a benefit–cost ratio of one. This enables Government to make comparisons between regions with respect to that break-even ratio. The break-even ratio can be calculated simply as:

assumed level of reduction in incidence of algal blooms

DIVIDED BY

assumed level of reduction in nutrient loads

DIVIDED BY

benefit–cost ratio estimated for the proposed plan.

6.2 Estimate the Expected Avoidance of Damages

An estimate of the expected avoidance of damages can be calculated by multiplying the estimated damages from each bloom by the estimated reduction in frequency of blooms at each site. These cost savings represent the economic benefits of the nutrient management plan.

The nutrient modelling (see Chapter 2) should be specified in a computer model that is capable of examining ‘what if’ scenarios about changes to nutrient concentrations and/or loads at any location in the catchment. Generally, it is assumed that all nutrients will move down waterways, eventually to the end of the catchment. Retention of specified proportions of nutrient flows at particular points (i.e. nutrient ‘sinks’) can be specified. This type of model can be used to estimate how nutrients generated in each sub-catchment will affect the levels of nutrients at each bloom site in the catchment. This then allows the identification of the reduction in nutrient loads at each site which would be achieved by reducing nutrient loads at another site. This is crucial information for the economic analysis of changes in the nutrient status of the catchment.

The estimated reduction in frequency of blooms at each site can then be multiplied by the estimated damages from each bloom at that site. The sum of such cost savings represent the economic benefits of the nutrient management plan.

6.3 Benefit–Cost Analysis

For each nutrient management measure being evaluated, the following information must be presented:

- estimate of tangible benefits and costs as well as incremental costs;
- benefit–cost ratio and/or net present value based on tangible benefits and costs; and
- monetary valuation of environmental impacts or non-monetary score for environmental impacts or qualitative description of environmental impacts.

In some cases, it would be appropriate to show the results of a threshold analysis indicating the scale of physical impacts, and/or intangible benefits, required to justify particular levels of expenditure.

The prime decision rule in benefit–cost analysis is that a program or project should, subject to budget constraints, be accepted if the present value of benefits exceeds the present value of its costs, that is, the program's 'net present value' is greater than zero. The benefit–cost ratio of a program is calculated by dividing the present value benefits by the present value of its costs:

benefit–cost ratio = present value benefits / present value costs

A program with a benefit–cost ratio greater than one is acceptable because the present value of benefits exceeds the present value of costs. A benefit–cost ratio of 1.3 indicates that $1.30 present value of benefit is received for each $1.00 present value of cost. The benefit–cost ratio is a useful adjunct to the net present value but it should not be used as the sole decision rule because it may give a misleading ranking if the projects differ in size. Standard spreadsheet packages all include simple-to-use functions to calculate present values, net present values and annuities.

Activities should be prioritised according to their ranking with respect to:

1. net present value and benefit–cost ratio; and
2. environmental impacts.

Unfortunately, there is no objective basis for assigning weightings to each of these criteria.

6.4 Presentation of Results

Government requires the following information to be compiled as part of the development of nutrient management plans for each region:

- costs of blooms occurring at each site;
- total costs of implementing each nutrient reduction activity;

- incremental costs of each nutrient management activity;
- total benefits from each management activity, expressed as the level of reduction in damages from toxic blooms;
- estimates of any other benefits, including possibly implications for environmental values, consumer welfare or regional economies;
- comparison of benefits and costs for each nutrient management activity, each expressed as discounted sums (using both 4 per cent and 8 per cent discount rates);
- benefit–cost ratio and net present value for each nutrient management activity;
- a clear statement of the assumed level of reduction in nutrient loads and estimated level of reduction in incidence of algal blooms;
- an estimate of the level of implied ratio of reduction in nutrient loads to bloom reduction that would lead to a benefit–cost ratio of one; and
- appropriate cost-sharing between stakeholders for each nutrient management activity.

6.5 Examples of Benefit–Cost Applications in Victoria

Several benefit–cost assessments have been undertaken in Victoria for nutrient management plans using the methodology described in these guidelines. Several were formal case studies to assist in the development of the methodology. They can be consulted by analysts to gain an increased understanding of the 'real life' operation of the methodology.

At the time of publication, studies have been completed in the following catchments:

- Upper North East (Read Sturgess and Associates, 1998a);
- Ovens (Read Sturgess and Associates and Rendell McGuckian, 1998);
- Goulburn Broken (Read Sturgess and Associates, 1998b);
- Corangamite (Read Sturgess and Associates, 1998c); and
- Glenelg Hopkins (Read Sturgess and Associates, 1999).

7. ASSESSING IMPLICATIONS OF BENEFIT–COST ANALYSIS FOR COST-SHARING

Cost-sharing negotiations should proceed only after a proposed management project has passed the benefit–cost test. There is little point arguing about sharing of costs for inefficient projects. The benefit–cost methodology for ranking projects essentially tells us whether or not a particular project is likely to increase community welfare. This is the critical first step and should not be overtaken by undue emphasis on how the project should be paid for, and by whom. The benefit–cost analysis will also assist in identifying the stakeholders between whom costs should be shared.

Cost-sharing should be guided mainly by the Victorian Government's cost-sharing guidelines for nutrient management (NRE 1997) which state:

> *The development of cost-sharing arrangements for nutrient management activities should be based on the premise that no-one has a right to cause damage to waterways and everyone has a duty of care to ensure that their activities have a minimal impact on waterways.*
>
> - *The prime responsibility for paying the cost of a nutrient management activity rests with the individual, industry or authority that is responsible for the related nutrient contribution.*
> - *Beneficiaries of nutrient management are encouraged to share in the cost.*
> - *Government may share in the cost to facilitate the uptake of nutrient management so that broader environmental, economic and social objectives are met (that is, for the public benefit).*

It is evident from the above statement that the question of rights and the potential for external diseconomies underpins the Victorian Government's cost-sharing policy for nutrient management.

Three sources of funding can be considered:

1. private entities or local agencies whose actions are causing the degradation that is giving rise to the need for the implementation of the plan (i.e. the 'polluters pay');
2. private entities or local agencies who would benefit from the implementation of the plan (i.e. the 'beneficiaries pay'); and
3. Government.

7.1 Polluters Pay

It has been a long-standing code of human conduct that if you make a mess you clean it up. This notion has been enshrined in the 'polluter-pays' principle for environmental protection. With respect to water quality, polluters are those who cause damage to the physical, biological or chemical characteristics of the waterbodies and waterways. Demanding that polluters pay is often society's policy of first choice because it is regarded as being the fairest and most equitable policy. It is also the most efficient policy when the principle can be applied to stop pollution before it occurs, or to control it within acceptable limits.

Therefore, where the polluter-pays principle is appropriate and the polluters can be identified and their pollution measured, monitored and levied, it is sensible that that **polluter-pays principle should take precedence over the beneficiary-pays principle** for sharing the funding of management measures. To do otherwise runs the risk that the pollution may continue unabated.

The principle may be made operational in a variety of ways, including:

- a tax to discourage pollution;
- requirements for those causing damage to a river to pay for fixing it up; or
- requirements to pay compensation to affected parties after causing a polluting event.

The polluter-pays principle, therefore, is a principle which provides an economic disincentive to pollute (Read Sturgess and Associates1984 and OECD 1989). While full adherence to the polluter-pays principle would require that the polluters bear the full cost of pollution control measures, a degree of flexibility has arisen in application of the principle. In some circumstances, if the cost to the polluter of full adherence is very high, 'compatibility' with the principle may be all that is required.

There are difficulties in applying the polluter-pays principle which concern the identification of the polluters. It may be readily applicable when the source of pollution can be traced to a particular user of the waterbodies and waterways (so-called point-source pollution), such as wastewater treatment plants. It is much more difficult to apply when there are high costs of identifying the polluters and monitoring the damage they cause. This is particularly the case for 'non-point' pollution arising from broadacre activities.

7.2 Beneficiaries Pay

The main convention by which commercial affairs are conducted is that the 'user' or 'beneficiary' of some service pays for that service. By paying prices which reflect the social value of these goods and services, an economically efficient allocation of resources can be ensured. Governments and public authorities have come to realise that it is important for the efficient use of scarce resources that the services provided by public authorities also be paid for by the users or beneficiaries of those services. Thus, the beneficiary-pays principle has been adopted by many authorities for determining who should meet the costs of the works undertaken as part of land and water planning.

A distinction can be made between direct and indirect beneficiaries (see for example, MDBC 1996), but it is appropriate that both groups pay. That is, even if the benefits are indirect or intangible, those enjoying the benefits *should also contribute*. This includes those whose use of a river and its environs is non-consumptive. An example would be recreational anglers who, unlike irrigators, do not pay any charges for the use of increased quantities of water of improved quality, but benefit from the improved quality because the habitat for a sport fishery is improved.

7.3 Government Pays

Government contributions to the funding of on-ground works can be justified in situations where there would be too little investment in nutrient management if it were left entirely to the free market. The reasons for this proposition are:

- the polluters are blissfully unaware of the effects of their actions on other parties ('externalities');
- enjoyment of the benefits cannot be restricted to a particular group of private entities (that is, the benefits represent 'public goods'); and

- the costs of collecting contributions from each private beneficiary or polluter would be too large relative to the contributions required from those entities (that is, the ‘transaction costs’ are excessive when collecting contributions from the private entities).

7.4 Application of Cost-Sharing Principles

The following steps are required in order to allocate responsibility for funding each nutrient management activity:

- identify those who are continuing to contribute nutrients in a manner that is contrary to prevailing laws, regulations and government policies. Charge those contributors the full cost of the components of the plan which is necessitated by that continued nutrient contribution;
- identify all the beneficiaries of the remaining components of the nutrient management plan (i.e. not funded by nutrient contributors);
- measure the benefits they receive;
- charge the beneficiaries the full cost in proportion to the benefits received; and
- consider which nutrient management activity remains unfunded by contributors and beneficiaries and examine whether it is appropriate for Government to provide some or all of that funding so that broader environmental, economic and social objectives are met.

Unfortunately, this simple mechanistic process could only be put in place if all benefits were priced in markets, that is, they were excludable goods. Seldom, if ever, will this be the case for the benefits of nutrient management. Suppose, for example, that a management program produces a mix of public benefits (say, improvement of a wetland) and private benefits (say, avoiding water restrictions). *If the dollar value of public benefits cannot be determined, the proportion of total benefits accruing as public and private goods cannot be determined*. Therefore, the beneficiary-pays principle cannot be implemented readily. In such cases negotiation will be required.

The economic evaluation should assist in identifying nutrient contributors and beneficiaries from nutrient management. Consequently, it should also assist in identifying appropriate private, regional, State and national cost-sharing.

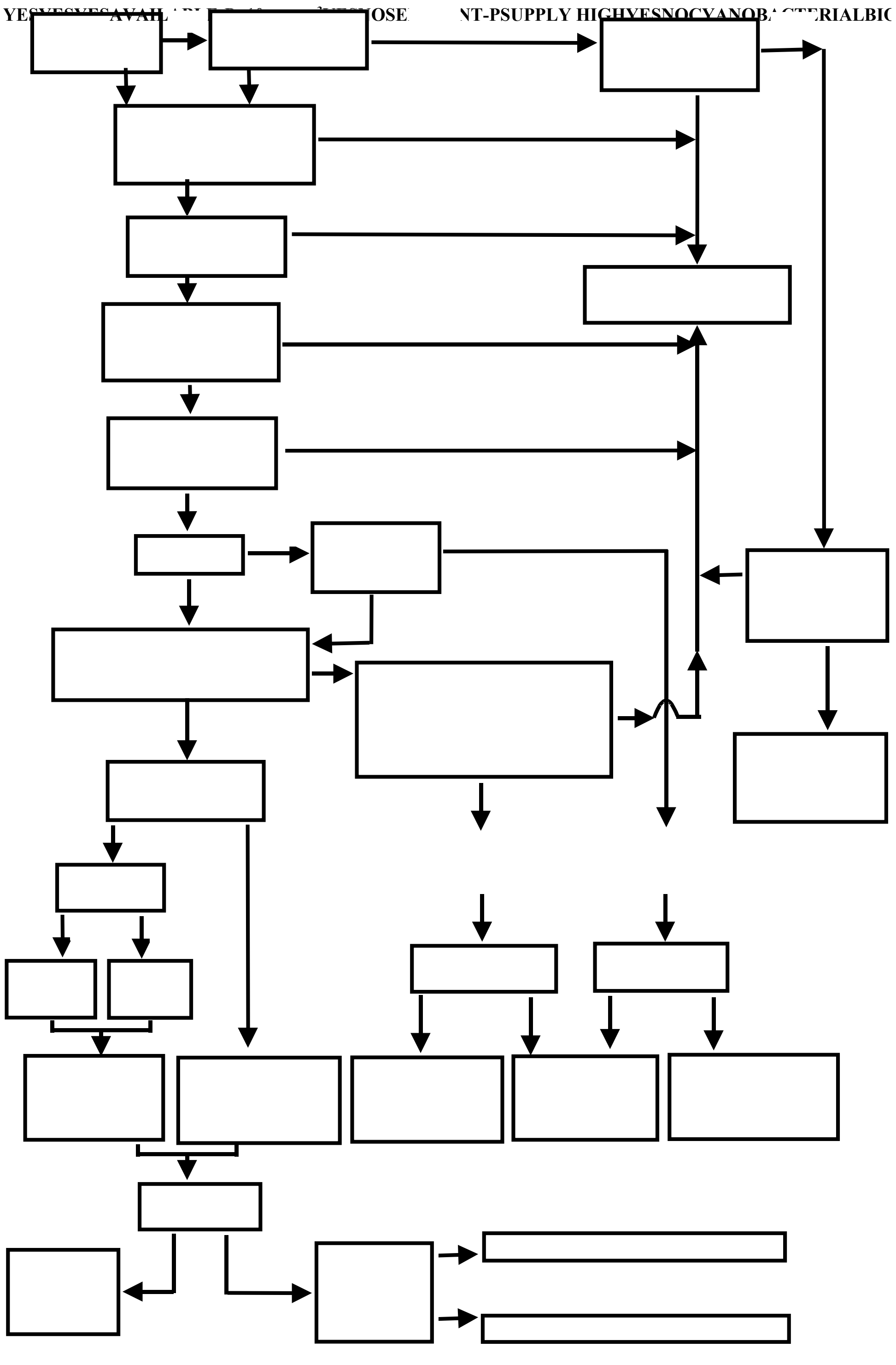
NRE (1997) provides further information about cost-sharing in nutrient management plans being developed and impleented in Victoria.

APPENDIX 1 FACTORS INFLUENCING THE CHARACTERISTICS OF ALGAL BLOOMS

A complex interaction of factors can influence the development of algal blooms. Such factors include:

- availability of nutrients (particularly nitrogen and phosphorus) within the water column and from sediments;
- bioavailability of nutrients, i.e. how accessible the nutrients are for algal growth;
- water temperature;
- impacts of phytoplankton grazing;
- stratification of the waterbody and its mixing regime;
- water turbidity and light availability; and
- effects of wind.

These factors are summarised in the flow chart on the following page.



(Source: Oliver, R. L. and Ganf G. G. (2000),’Freshwater Blooms’ in Whitton, B.A. and Potts, M. (eds): *The Ecology of Cyanobacteria*, Kluwer Academic Publishers, Netherlands.)

APPENDIX 2 EXAMPLES OF NUTRIENT EXPORT RATES

Technical literature reveals broad ranges for the relative nutrient contributions from most types of land use and these guidelines do not present a wide review of this literature here. However, examples of export rates used for the Upper North East, Goulburn Broken, Corangamite and Glenelg Hopkins economic evaluations (Read Sturgess and Associates 1998 a, b & c and 1999 respectively) are presented in this appendix.

Export rates have generally been estimated by examining actual levels of nutrients in streams through sub-catchments with a uniform land use and attributing the implied export rates per hectare of sub-catchment to that predominant land use. For example, refer to the export rates adopted for the Corangamite and Goulburn Broken catchments in Tables A2-1 and A2-2 respectively. NRE (in prep) presents a summary of export rates used in the modelling component undertaken for all catchment-based nutrient management plans being prepared around Victoria.

One possible weakness of that approach is that it may obscure the fact that while the landcover for a particular sub-catchment may be, say, predominantly dryland pasture, it might be that the majority of nutrients are being contributed by erosion of streambanks and/or gullies and/or roads that dissect that sub-catchment. In some cases it may be pertinent to identify such processes as separate sources of nutrients. To this end, a slightly different approach was adopted for the Glenelg Hopkins and Upper North East economic evaluations. For those catchments, the relevant Steering Committee's provided their best guesses as to the likely contribution of nutrients from those sources (see Tables A2-3 and A2-4).

Table A2-1 Export rates for non-point sources estimated for the Corangamite Catchment (expressed as ranges) (Source: Read Sturgess and Associates 1998c)

Land use	TP export rate (kg/ha)	TN export rate (kg/ha)
Remnant vegetation & forestry – hardwood	0.01 – 0.05	0.20 – 0.50
Forestry – softwood	0.05 – 0.10	1.00 – 1.50
Horticulture	0.60 – 2.00	5.00 – 15.00
Pasture – dryland	0.10 – 0.30	0.60 – 1.40
Pasture – irrigated	0.30 – 0.70	0.90 – 3.50

Table A2-2 Export rates for non-point sources estimated for the Goulburn Broken Catchment (Source: Read Sturgess and Associates 1998b)

TP export rates used for dryland areas

Land use	TP export rate (kg/ha/yr)
Pasture	0.11
Cropping	0.1
Horticulture	0.4
Irrigation	0.2
Forest	0.06

TP and TN export rates used for irrigated areas (kg/ha/year)

Land use	Irrigation season		Non-irrigation period	
	TP	TN	TP	TN
Perennial pasture	5.24	13.1	0.3	0.8
Annual pasture	1.22	3	0.15	0.4
Crops	1.77	6.7	0.12	0.5
Vegetables	1.62	8.1	0.15	0.8
Fruit - surface drainage	0.23	4.5	0.04	0.8
Fruit - subsurface drainage	0.18	90.9	0.02	7.6

Table A2-3 Relative contributions of sediments for non-point sources other than agricultural runoff for the Upper North East Catchment (Source: Read Sturgess and Associates 1998a)

Sediment source	Relative contribution of sediments from each source (base case)	
	Cleared catchment	Forested catchment
Stream banks & in-stream processes	55%	35%
Gullies offsite from perennial streams	25%	25%
Roads	10%	20%
Sheet erosion	10%	20%

Table A2-4 Relative contributions of nutrients for non-point sources estimated for the Glenelg Hopkins Catchment (Source: Read Sturgess and Associates 1999)

	% of total contribution of TP to surface waters					
	Glenelg		Hopkins		Portland Coast	
Phosphorus source	Agricultural	Forested	Agricultural	Forested	Agricultural	Forested
Stream banks & in-stream processes	30%	25%	30%	25%	25%	20%
Gullies offsite from perennial streams	40%	15%	35%	15%	30%	15%
Roads and logging	10%	40%	10%	40%	5%	40%
Run-off	15%	15%	20%	15%	30%	15%
Groundwater	5%	5%	5%	5%	10%	10%

	% of total contribution of TN to surface waters					
	Glenelg		Hopkins		Portland Coast	
Nitrogen source	Agricultural	Forested	Agricultural	Forested	Agricultural	Forested
Stream banks & in-stream processes	10%	20%	20%	20%	20%	20%
Gullies offsite from perennial streams	20%	20%	20%	20%	10%	20%
Roads and logging	10%	40%	0%	40%	10%	40%
Run-off	40%	10%	40%	10%	40%	10%
Groundwater	20%	10%	10%	10%	20%	10%

APPENDIX 3 EXAMPLES OF BLUE-GREEN ALGAL BLOOM RISK ASSESSMENTS FOR A NUMBER OF VICTORIAN CATCHMENTS

This appendix provides examples of the methodologies used for different Victorian catchments in assessing blue-green algae risk in waterways. The assessments were made specifically to assist with cost–benefit analyses required for the development of nutrient management plans.

The general approach was to assign a score to a range of criteria, such that the total score was a measurement of the risk of a bloom. The higher the score, the higher the risk. The criteria most commonly used were water quality (P, N & turbidity), velocity/flow, temperature and previous bloom history.

In summary, the variables most commonly used were:

- water quality rating:
  - mostly TP; also TN (Corangamite) and turbidity (Upper NE);
  - mostly using OCE (1988) classifications;
  - sometimes the threshold was simply > 1 mg TP/l (= OCE 'degraded');
  - other times using the full OCE range;
  - mostly median values from VWQMN data;
- water velocity rating:
  - used discharge figures as a surrogate for velocity;
  - specified in terms of < or > the 25th/30th percentile (Campaspe, Loddon, Corangamite); or
  - specified in terms of actual flows (Goulburn Broken, Ovens; don't know basis for calculation, presumably the flows given are based on given percentiles ?); or
  - Upper NE didn't use flow at all, but considered retention time (4-5 days minimum);
- water temperature rating:
  - measured what temperature was at 75th percentile;
  - most used < 10° as the lowest rating and > 20° as the highest, but different range between (Goulburn-Broken, Corangamite, Upper NE); Loddon used > 12.5 °;
  - some CNMPs simply used seasons: 'summer'/ 'winter' as the temperature surrogate (Ovens, Campaspe); and
- previous bloom history:
  - used by Upper NE, Corangamite and Goulburn Broken;
  - 'no blooms' = lowest rating to 'blooms regularly/every year' = highest rating.

A3.1 Corangamite

In the Corangamite catchment, the risk of a blue-green algae bloom occurring was scored based on a combination of the following factors:

- water quality;
- water flow;
- water temperature; and
- bloom history.

A score was assigned for each of these factors as follows:

Water quality (median values based on OCE 1988 guidelines). The score was assigned to whichever of N or P gave the highest score.

N or P rating	degraded	poor	moderate	good	excellent
Score	5	4	3	2	1

Water flow

Summer flow ML/day at 25th percentile	no flow	< 10	< 50	< 100	> 100
Score	5	4	3	2	1

Water temperature

Water temperature at 75th percentile	> 20	< 20	< 18	< 15	< 10
Score	5	4	3	2	1

Bloom history

	blooms every year	blooms some years	elevated cell counts but no blooms recorded	no elevated cell counts or recorded blooms
Score	4	3	2	1

These scores were then multiplied together to give the overall risk score.

The Corangamite Water Quality Working Group investigated whether particular weightings on the water quality, water temperature and flow would improve the correlation between a risk score based on those three criteria with the observed bloom history at each site. When equal weightings were assigned to each of those criteria results in a statistical correlation coefficient of about 46 per cent.

A simple linear programming model was then used to specifically test every conceivable mix of weighting's and, broadly speaking, the observed level of correlation was seen to reduce when unequal weighting's were applied. They then investigated using different cut-off levels of velocity and temperature for determining the scores at each site. They found that the observed level of correlation dropped when they tried different cut-offs. They also used the 90th percentile temperature instead of the 75th percentile, and also found that this reduced the level of correlation. Therefore their results suggested that the risk scores adopted represent the best available given the data available.

A3.2 Goulburn Broken

In the Goulburn Broken catchment, the risk of a blue-green algae bloom occurring was scored based on a combination of the following factors:

- water quality;
- velocity of water flow;
- water temperature; and
- bloom history.

A number of sites were selected within and external to the catchment to apply the assessment. Selected sites were chosen on the basis of perceived importance of impacts or risks of blooms and the availability of data.

For sites in the catchment, each of these factors has been given a ranked score according to the following criteria:

Water quality (TN and TP)

OCE classification	excellent	good	moderate	poor	degraded
Score	1	2	3	4	5

Summer flow velocity (daily flow is used as a measure of flow velocity)

Summer flow ML/day	> 5000	> 500	> 100	< 100
Score	1	2	3	4

Water temperature

Temperature °C	< 10	< 15	< 20	> 20
Score	1	2	3	4

Bloom history

	no blooms	elevated cell counts	some blooms	regular blooms
Score	1	2	3	4

Data used to derive the score were as follows:

- water quality – 50th percentile concentrations for TP and TN as reported in the VWQMN 1994 annual report (Hunter and Hedger 1995) and assessed against the OCE criteria;
- summer flow velocity – local knowledge and consideration of summer flows in the water body (flow is taken to be indicative of flow velocity);
- temperature – the 75th percentile temperature as reported in the VWQMN Annual Report (taken to be indicative of summer water temperature); and
- bloom history – from Cottingham (1994) and data on hand in the GMW office.

Scores for each parameter were multiplied to give an overall rating of 'risk of a blue-green algae bloom.'

A3.3 Ovens

A blue-green algae risk index rating was calculated for the lower Ovens River (i.e. the Ovens River to Lake Mulwala reach). The index was calculated for each month during the modelled period (1977 to 1993). This index provided a relative measure of the potential for development of blue-green algal blooms, under any modelled scenario.

Key factors included in the index were season, flows and nutrient concentrations, for all of which trigger levels would need to be reached before any algae risk was registered. Turbidity and ecological condition were additional factors.

The index was calculated as follows. The maximum score possible (highest risk) is:

Total Phosphorus concentration

	low < 0.05 mg/L	medium 0.05 to 0.1 mg/L	high > 0.1 mg/L
Score	0	1	2

Total Nitrogen concentration

	low < 0.05 mg/L	medium 0.05 to 1.0 mg/L	high > 1.0 mg/L
Score	0	1	2

Flow (e.g. for the Ovens River at Wangaratta)

	adequate > 500 ML/day	low 100 to 500 ML/day	insufficient < 100 ML/day
Score	0	1	3

Season

	winter/spring	summer/autumn
Score	0	1

Turbidity/Suspended solids

	low < 20 NTU or < 40 mg/L	medium 20 to 30 NTU or 40 to 60 mg/L	high > 30 NTU or > 60 mg/L
Score	0	1	2

Ecological Condition (from Native Fish Index)

NFI score	good > 10	moderate 5 to 10	poor < 5
Score	0	1	2

A3.4 Upper North East

In the Upper North East catchment, the risk of a blue-green algae bloom occurring was scored based on a combination of the following factors:

- water quality (both nitrogen and phosphorus levels);
- turbidity;
- water temperature;
- bloom history; and
- potential sources of algae

The following criteria were used to rank each of the sites:

Water Quality data from the VWQMN 1995 annual report (Hunter and Loone 1996) were used. The data was assessed against the OCE (1988) guidelines.

As outlined in the OCE guidelines, the median (50th percentile) total nitrogen and phosphorus values were compared against the guideline value.

N or P rating	degraded	poor	moderate	good	excellent
Score	5	4	3	2	1

Where data were unavailable (as was the case at historical monitoring sites) a judgement was made about the rating based on factors such as land use and assessments made of the environmental condition of the streams, as outlined in Department of Water Resources (1990).

Turbidity (as a measure of light) data from the VWQMN annual report, and the Murray Darling Basin Commission were used. The 75th percentile as used, i.e. the point below which 75% of the readings lie. The lower the turbidity the higher the risk.

Turbidity reading	**Plain**	> 30	< 30	< 20	< 17.5	< 15
	Valley	> 22.5	< 22.5	< 15	< 12.5	< 10
	Mountain	> 12.5	< 12.5	< 10	< 7.5	< 5
Score		1	2	3	4	5

Water temperature data from the VWQMN 1994 annual report (Hunter and Hedger 1995) were used.

The 75th percentile was used, i.e. the point below which three-quarters of the reading (i.e. the 75th percentile was used as being indicative of summer periods).

Water temperature at 75th percentile	> 20	< 20	< 15	< 10
Score	4	3	2	1

Previous Bloom History (data sourced from NRE, North East Region Water Authority, MDFRC and Benalla Veterinary Laboratory)

	blooms every year	blooms some years	recorded elevated cell counts	no recorded blooms
Score	4	3	2	1

Potential sources of algae are very important when assessing a site for the possibility of a bloom occurring. This means that a water storage with a retention time of about 4-5 days is at risk of algal blooms and therefore sites downstream of a storage must also be at risk of algal blooms. The retention of water allows blue-green algae sufficient time to grow up to a nuisance level.

Therefore, when assessing a section of stream, consideration was given as to whether or not a storage existed upstream. If a storage did exist, the site downstream was rated as having the same or slightly less risk as the storage.

For each site the scores of each factor were multiplied together to give an overall rating of algal bloom risk. That is:

> *Risk score* = water quality score* turbidity score* water temperature score* water velocity* previous bloom history + consideration of storage upstream.

A3.5 Loddon

In the Loddon catchment, the risk of a blue-green algae bloom occurring was scored based on a combination of the following factors. A point was added to the score for each of the following conditions met:

- TP > 0.1 mg/L ('degraded' in OCE classification)
- temperature exceeds 12.5°C (translated to time of year); and
- river flow is less than 30% of median monthly flow.

A3.6 Campaspe

In the Campaspe catchment, the risk of a blue-green algae bloom occurring was scored based on a combination of the following factors:

Parameter	Condition	Score
TP	> 0.1 mg/L	1
	< 0.1 mg/L	0
Flow	< 25th percentile	1
	> 25th percentile	0
Season	summer	1
	winter	0
Maximum score		**3**

Data used to develop the index was taken from the ANZECC (1992) guidelines and from unpublished data (Water Ecoscience personnel).

A3.7 LaTrobe Thomson

To determine the likelihood of blooms in Lake Wellington, chlorophyll *a* levels were measured and related to observed P levels:

> Chlorophyll *a* levels are used as the main indicator of risk of algal blooms and the chlorophyll *a* objectives form the basis for the target phosphorus concentrations in the lake and the input loads of phosphorus. Before a target nutrient loading can be derived, objectives for chlorophyll *a* need to be determined. The objectives adopted will need to result in a significant reduction in the risk of algal blooms and be realistic . . . Target chlorophyll *a* levels of 0.008 mg/L for the annul median and 0.005 mg/L for the summer/autumn median have been chosen . . . (EPA 1995)

In other words, the risk of blooms in Lake Wellington is ‘known’, at least as indicated by chlorophyll *a* levels (the report notes problems with relating these levels to bloom occurrence; however it is beyond the scope of these guidelines to discuss this issue).

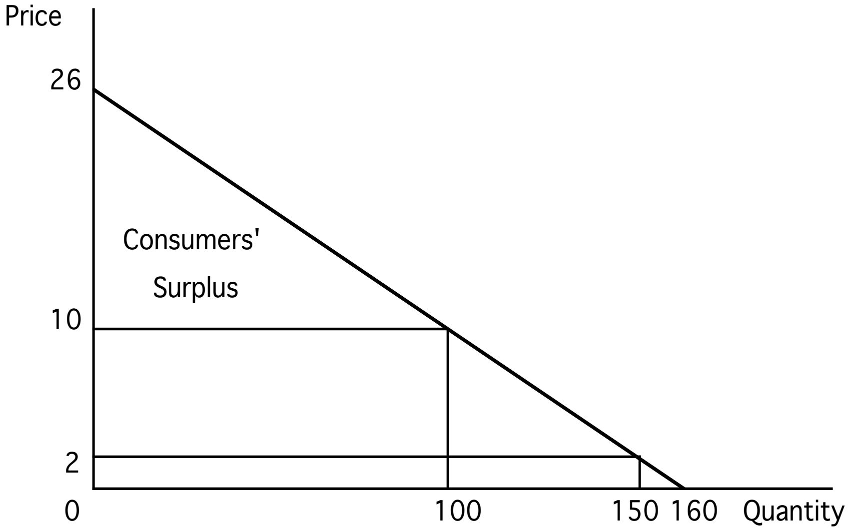
APPENDIX 4 VALUING NON-MARKET BENEFITS

A4.1 Demand Theory and the Economic Value of Environmental Resources

The economic value of a good or service provided by a waterbody is determined by the maximum amount consumers are willing to pay for that good or service. Changes in value as the quantity of the good or service changes are traced out by the demand schedule (see below). The notion of a demand schedule is understood by many people. However, some attributes of the schedule are often overlooked in everyday usage and some useful measures of consumer welfare can be obtained from the schedule.

A demand schedule (or curve) shows the amounts of a good that would be purchased at various prices during some specified period of time (say, one year), **all other things held constant**. If price is measured on the vertical axis of a graph and the quantity purchased on the horizontal axis (as in Figure A4-1), the curve is generally downward-sloping – a greater quantity is purchased during the specified time period the lower the price. If one is interested only in the relationship between price and the quantity purchased, the other things which must remain constant so as not to confuse the relationship include incomes, tastes and the prices of other goods. Thus, for example, it is to be expected that the demand curve for lamb will be higher (shifted to the right) if incomes rise, if people become less interested in eating pork or if the price of beef rises.

Figure A4-1 Demand schedule showing consumer surplus



The demand curve observed for the entire market is, of course, built up from the demand curves expressed by individuals. One reason the demand curve is thought to slope downwards is due to the so-called ‘law of diminishing marginal utility’. Simply stated, this law says that as more units of the good in question are consumed, the value of each succeeding one decreases. Or, stated another way, a consumer's willingness to pay for the tenth orange purchased in the specified time period will be lower than for the ninth orange which will be lower than the eighth orange and so on. If the demand curves for the given good were known for all individuals these could be added horizontally to obtain the market demand curve. That curve will have negative slope due to all individuals displaying diminishing utility and because new consumers enter the market and existing consumers purchase more as price decreases.

The market demand curve can be used to express the value to the community of any quantity of the good or service. Total willingness to pay for a given quantity is nearly always greater than what people actually have to pay. The balancing item of value is called **consumers' surplus**. This can be demonstrated with the aid of Appendix Figure 4-1. At a price of $10 per unit, 100 units would be exchanged in the market during the relevant time period. Total revenue from the sales (price times quantity), part of the total value to the community and which is transferred from consumers to producers, would be $1000. This is equivalent to the rectangle under the demand curve that extends from the origin to the price/quantity coordinate of 100 and 10. The remaining triangular area under the demand curve, for the quantity 0 to 100, is called the consumers' surplus because it represents the value in excess of what they had to pay. Those consumers who were prepared to pay any price higher than $10 per unit to obtain the quantity they wanted have gained a benefit – a surplus in value – because they only had to pay $10 per unit. The idea of consumers' surplus can be likened to getting a bargain. Indeed, getting a bargain means paying less than one would be willing to pay and, by the nature of a demand curve, some consumers always get bargains. Those consumers can now spend the money so saved on other things. Consumers' surplus is not only a legitimate form of economic value but one of the most important forms which must be counted in the economic analysis of public policy.

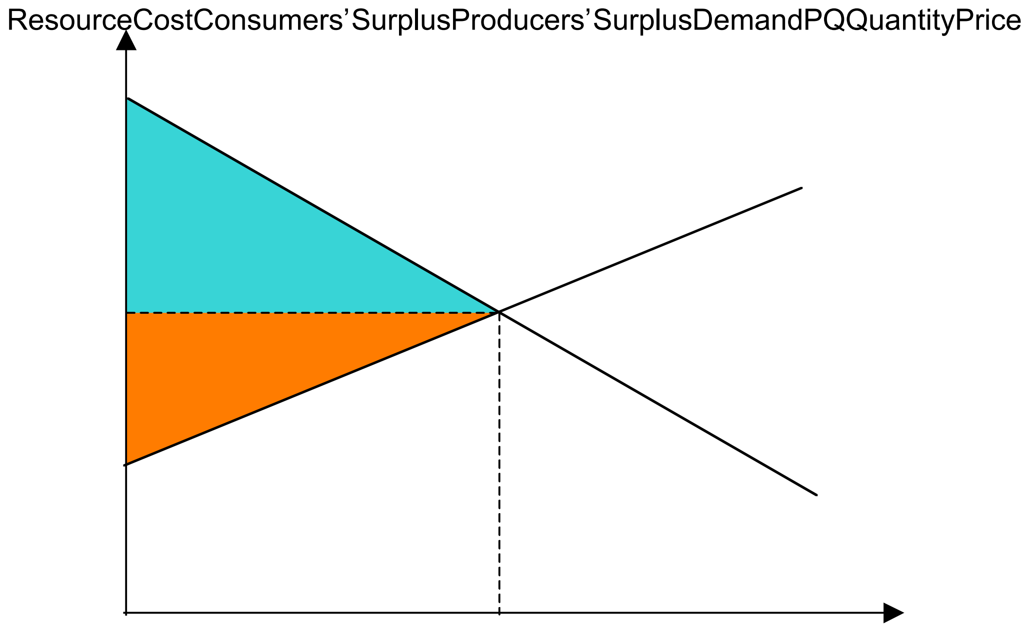
Expenditure in the market is sometimes considered to be a reliable guide to total value of a good or service. The reason this view is mistaken can be demonstrated if the demand curve in Figure A4-1 is redefined so that it is the demand curve for an individual rather than the aggregate demand curve. The total value (measured in money) of the good to the individual is the whole area under the demand curve. A consumer who buys 100 units at the market price ($10/unit) spends $1000 and gains a consumer's surplus equal to the triangular area under the demand curve but above the price of $10. If the market price falls to $2/unit, the consumer's **total valuation does not change** but now she buys 150 units, spends only $300 and gains a much larger consumer's surplus. Expenditures, therefore, do not reveal the real worth of an activity, service or commodity, namely, what people would be prepared to pay over and above their cash outlays. The large numbers which can be generated by expenditure surveys, exciting as they may be, are not the right measure of value.

It is of paramount importance when applying demand theory to the valuation of environmental resources to realise that economic value and demand are not created because prices exist. Value and demand exist for every good and service in society, **whether or not markets and prices exist**. Markets and prices arise from the aggregate behaviour of consumers and producers of a good or service when rights to that good or service are well-defined, enforceable and exclusive. When these characteristics are present, the prices established by transactions aid considerably in revealing the maximum that consumers are willing to pay for units of the good or service. But it must always be remembered that demand or willingness to pay must be present before markets can emerge.

Resource costs are involved in the production of manufactured goods or services and underlie the concept of the supply curve. If some real resource, such as labour or capital, is used in the production of a manufactured good the cost of doing so is the economic value which is given up by not producing something else. The cost of resources, therefore, is often referred as **opportunity cost** since their cost is the value of lost opportunities. It should be noted, however, that when the markets for resources are competitive, market prices for the resources are a good guide to the economic value of the goods and services that would otherwise have been produced by those resources. As the price which producers are offered for the commodity in question rises, more of the commodity is produced by using more resources. Because more of other things are given up the cost is higher but it is made worthwhile by the higher price. As is well known, the equilibrium price and quantity are discovered in a competitive market by the intersection of the demand curve and the supply curve (Figure A4-2).

The net economic value from a manufactured good or service is the shaded area in Figure A4-2, that is, as the difference between the gross economic value (area under the demand curve) and the resource costs (area under the supply curve). It is seen in Figure A4-2 that the price line (P) actually divides the net economic value into two segments. The upper segment is the consumers' surplus while the bottom segment is termed the **producers' surplus**. Producers' surplus is the aggregate return to all producers over and above the resource (opportunity) costs. It is measured by subtracting total resource costs from total revenue.

Figure A4-2 Demand and supply schedules



In the case of environmental resources the situation is somewhat different but the principles remain the same. A river or a lake can used to provide recreational services, such as fishing or a pleasant environment in which to walk. The consumer of any recreational activity is, of course, part of the production process that creates the supply of the activity in question. That is, one day of fishing requires the input of one day of the consumer's time along with the necessary equipment, travel and the natural resources of the river or lake. The owners of the river or lake (government acting on behalf of society in general) can alter it, say by landscaping, so that the supply of recreational services is altered. Real resources (labour and capital) are involved in making such an alteration. Presumably, these alterations to supply will be made if the net value (value of the service minus the cost of provision) is positive. Even without altering the supply of the service, some water bodies, for example reservoirs, will need maintenance and once again the owners of the reservoir will undertake the maintenance if the net economic value of doing so is positive.

Most natural waterbodies, such as the Gippsland Lakes, are in fixed supply but for the reasons outlined above, the recreational services they can produce are not. Government and private investment in the form of roads, camping and picnic areas, river management, walking tracks, and the exclusion of distracting activities help to determine the quantity of recreational services provided by the waterbody.

A4.2 Willingness to Pay and Willingness to Accept Compensation

The guidelines have discussed the underlying value of any good or service, including those of waterbodies, in terms of a person's willingness to pay (WTP) for the good or service. The obverse of WTP is willingness to accept (WTA) compensation to give up the good or service. One would expect that these two valuations should not be markedly different. If you want a cake you indicate your WTP for it and this should be about the same amount of money that you would be prepared to accept from someone else to give up the cake (your WTA). In practice, however, this appears not to be the case. People often attach a greater weight to losses than to commensurate gains. This has been shown to apply not just to unpriced items but also trivial priced items (Knetsch 1993).

Many valuations of environmental assets are considered relative to some situation in which the asset is lost or damaged and the WTP to prevent damage is regarded as equivalent to the WTA compensation for the loss. If, however, WTP and WTA are found to differ markedly for environmental goods and services, there is a problem for the valuation of environmental assets. Not only will it lead to poor predictions of behaviour but assessment of values on the basis of WTP measures would undervalue the assets. This issue has yet to be resolved. In the meantime, it needs to be noted that any values which might be attached to unpriced values associated with water bodies and their catchments might understate their true value if the community were to contemplate the loss of those values.

A4.3 Valuing Non-market Benefits

The following are some methods which appear to lend themselves to the task of **rapidly** placing money values on the non-market benefits of controlling algal blooms, particularly those benefits associated with the recreational use of a waterbody and its environs. Each method requires different types of information and none of these methods will provide a precise estimate. The analyst should used every one of those methods for which the necessary information is available.

(i) Replacement-cost method

The cost of replacing an unpriced asset or service, which would be damaged by a bloom, can be a useful measure of benefit. An area of wetland may be endangered by algal blooms but perhaps it could be replaced, or an equivalent area provided. The cost of this replacement is a measure of the benefit of the wetland. Avoiding the costs to a management authority, or other agency, of replacing the values of the wetland are a measure of the benefits of controlling algal blooms. The key assumption is that the replacement costs are able to be calculated and that they are not greater than the value of the asset which would otherwise be destroyed.

(ii) Interpretation of previous decisions

Occasionally, a decision to spend or save money in a similar situation elsewhere can be interpreted to value a non-market benefit. The level of past expenditure to achieve similar benefit characteristics, in similar risk situations, and in similar economic circumstances, can be used as an estimate of the value of any type of resource. For example, the Big Tree is a river red gum at Guildford near Castlemaine which is classified by the National Trust. It is close to high voltage power lines which present a fire risk. The (then) State Electricity Commission organised an expenditure of $8600 specifically to shift a power pole to remove the risk. This method of valuation, using values from past decisions in similar situations, is discussed fully in Sinden and Worrell (1979). When the similarities are strong, the method is useful.

(iii) Transferring values from other studies

Values for non-market goods and services can sometimes be inferred from the results of existing valuations for similar resources in other locations. The validity of a 'benefit transfer' approach has been scrutinised by Smith (1992) and Desvouges, Naughton and Parsons (1992). The latter authors suggest four criteria that must be satisfied before values are transferred from an original study to the appraisal of interest:

- the original study must be based on adequate data;
- the original and new locations must offer similar recreational opportunities to a similar spectrum of households;
- the benefits to be valued at the new site must be similar to those valued at the original site; and
- the original study must contain regression analysis of value (measured by willingness to pay) as a function of socio-economic and environmental variables.

The essence of these criteria is that the studies should be sound, that the sites satisfy the common-sense requirement that they be 'comparable' and that there be sufficient information to allow systematic adjustment for differences between sites. It seems reasonable that transferring use values from one site to another is likely to have greater validity than transferring non-use values. One might hypothesise that the value attached to a particular recreational activity, such as freshwater fishing, represents a 'core' value which may vary according to the type and quality of the environment in which it is undertaken. The angler who chooses a particular spot on, say, the Murray River does so from a reasonable number of substitute sites.

In contrast, not only is the actual determination of non-use values in a site-specific exercise more controversial than for use values, but the non-use values may be heavily dependent on the uniqueness of the site. In other words, some might argue that transferring values from a similar site to the Gippsland Lakes is impossible because the Gippsland Lakes are unique.

There are few site-specific estimates of willingness to pay for the non-market goods and services of waterbodies in Victoria. One study which is rich in valuations of the use values of river attributes and river-based recreation is that of the Ovens and King Catchment conducted by Sinden (1990). Sinden collected data from 658 groups during eight summer weeks during 1989-90. The groups were selected to provide a systematic sample in terms of sites, time of day, day of week, and times during the season. About 25 groups were surveyed at each of 20 sites, to give a statistically adequate sample at each site and a good overall coverage. The original study, therefore, seems to have been based on sound and adequate data.

Sinden's (1990) study performs well on the various criteria for benefit transfer. It is, therefore, a useful source of values for some types of attributes and activities associated with some of the types of waterbodies likely to be affected by algal blooms. The main impediment to the use of these values is that they are now over ten years old.

(iv) Threshold analysis

In some situations, particularly where environmental or amenity values are important, the task of obtaining any estimate of benefits may appear too daunting. However, if one adopts the approach that any formalisation of benefits is better than none, some simple procedures could be employed. For example, suppose a wetland (or river reach) would be protected from algal blooms by installing sediment traps at a once-off cost of $80,000, equivalent to an annual payment of $7000. Assume that the wetland (or river reach) will be seen by V people who speed by on the highway each year, and it has no other benefits. The benefits to the community are, in fact, valued at (V x the individual willingness to pay). Preventing an algal bloom will only be economically desirable if the benefits to the community exceed $7000 per year. Let the current value of the community be worth $0.50 per individual viewer. A program to protect the wetland (or river reach) from blooms would be economically desirable if (V x $0.50) exceeds $7000. By rearranging we can say the program is desirable if V exceeds 14,000 (calculated as 7000/0.50). The only unknown is V -- the number of viewers. The only judgement needed now is whether V is likely to exceed the breakeven number of viewers, calculated here as 14,000. If so, the program is justified because benefits exceed costs.

As a last resort, all the difficult-to-value-benefits from controlling algal blooms could be listed and the decision-makers might be encouraged to consider their own interpretations of the public's valuation of those benefits. That is, the estimation of net benefits can be re-worked as a question or statement for the decision-maker. Suppose, for example, that a measure to prevent a bloom would have a cost of $X million and the main benefit would be the protection of a wetland or lake of national significance. Few people would ever see this wetland or lake but it will be retained. Instead of assuming that the benefits exceed the costs of control (or do not exceed the costs), a question can be posed for judgement. **Is the protection of this natural asset worth $X million?** Photographs may also have a role to play in this process by providing indicative evidence of any non-use values and possible changes in those values, see for example, photographs of the Darling River and the Gippsland Lakes during serious blooms.

A4.4 Examples of Studies that have Estimated the Economic Value of Environmental Resources

Sappideen (1993) used a contingent valuation procedure to value the bundle of use values embodied in the Sale wetlands. These attributes included supporting important colonies of water birds, game hunting, camping and bushwalking. Sappideen bundled these together as 'environmental amenities' and obtained values for the bundle from the viewpoint of the general community and from the viewpoint of specialist hunters of game birds. These values were obtained in the context that the wetlands are under threat from encroaching salinity. For the general community, he found an average willingness to pay (as an admission fee) of $2.58 per visit. This value may be useful for benefit transfer to comparable wetlands under threat from algae. Sappideen did not value the non-use attributes of the wetlands but found that people regarded as important the option to visit in the future, the conservation of existing values and the availability of the wetlands to future generations.

A useful figure for gauging the importance of the riverine environment is Sinden's (1990) finding that visitors to the Ovens and King rivers were able to express a value for the 'naturalness' of the environment in which they undertook recreational activities. The degree of naturalness of the bed and banks of a stream can be assessed on a numerical scale using a procedure devised by the (then) Department of Conservation and Environment (1990). Sinden found that the recreational value could be altered by about $8 for a unit change on the scale of naturalness of the environment. For further discussion of these values and the application of them in the context of physical damage to streams can be found in Read Sturgess and Associates in association with Ian Drummond and Associates (1992, Section 9.2.4).

Hill (1994) used contingent valuation methods to determine the value that the (NSW) public might place on improved water quality in the Darling River. In December 1991, the Darling-Barwon river system experienced the world's largest recorded bloom which stretched for 1000 km. Hill's study is interesting in that it showed that people across the whole State, including residents of Sydney, were willing to pay to improve the quality of the river system.

As might be expected, however, people close to the river were prepared to pay most. Hill did not attempt to separate use and non-use values so that the valuation obtained is an estimate of total economic value. It might be expected that the use-value component was higher relative to the non-use component the closer the respondents were to the river. An open ended question provided a median estimate of willingness to pay (what 50 per cent of the population would pay) of $20 as a once-off payment to improve water quality. Aggregated to Sydney alone, this would represent a once-off payment of $26 million. Some consideration might be given to transferring Hill's estimates to other major river systems or other waterbodies of State or national importance.

APPENDIX 5 ESTIMATING IMPACTS OF ALGAL BLOOMS ON THE VALUE OF RECREATION AND TOURISM

The economic impact of an algal bloom on recreation is the difference between the value of recreation with and without the bloom. Estimating the economic impact of algal blooms on recreation involves three main steps:

1. determine the number of visitors and characteristics of recreational activities undertaken at the site in years prior to the bloom occurring.

2. determine the likely change in visitor numbers and recreational activities due to the bloom.

3. estimate the net loss to the broader economy associated with the change in visitor numbers and recreational activities due to the bloom.

A5.1 Determining Visitor Numbers

Published estimates of visitor numbers for particular sites will not generally be available. Therefore, it will be necessary to undertake surveys to derive estimates for particular sites. Informal interviews with a small number of persons who would regularly observe visitors at the particular site will generally suffice. An alternative approach is to use accommodation guidebooks when such surveys are not possible.

(i) Using original surveys

More often than not in estimating the number of visitors at a particular site, it will be necessary to derive original estimates. Ideally, this would be done by undertaking a survey over a full year. This could be done, for example, by counting vehicles using electronic counting devices[4]. However, such a survey would not be rapid. A more realistic approach for a rapid appraisal would involve once-off interviews with persons who regularly observe visitors throughout the year at the particular site.

It is the authors' experience that such interviews rarely succeed if it is simply asked: 'How many visitors do you observe over a given period of the year?'. It is much more fruitful to style the interview so as to seek information about the number of visitors likely to be observed in a 'typical day'. The consultants have found considerable success in asking the following questions about five periods of the year:

1. How many visitors would you expect on a typical day during the summer holiday period?

2. How many visitors would you expect on a typical day during the Easter holiday periods?

3. How many visitors would you expect on a typical day during any other defined holiday period?

4. How many visitors would you expect on a typical weekday outside of holiday periods?

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[4] Counting vehicles in itself does not provide estimates of visitor numbers. It is necessary also to have detailed observations in order to 'calibrate' a model for interpreting the vehicle counts. For example, it is necessary to know how many people arrive on foot, the average number of persons in a vehicle, the average length of stay and the number of times that a particular vehicle is likely to pass the counting device.

5. How many visitors would you expect on a typical Saturday or Sunday outside of holiday periods?

For each of those periods, seek information about:

- the breakdown between day visitors and those who have visited the site as part of an overnight stay away from home; and

- the breakdown between visitors who reside within and outside the local region.

It then becomes a simple matter of multiplying the number of visitors expected on a typical day during each of those periods by the number of days corresponding to each of those periods.

(ii) Using accommodation guidebooks

The authors have devised a method for estimating numbers of overnight visitors to particular sites for situations where even an informal survey cannot be undertaken. Such situations might include large geographic sites where a bloom could affect visitation to a large area and many towns, for example, a large lake or river system. The approach involves determining the number of beds/sites available at motels, hotels, holiday flats/units and camping grounds at the particular site of interest. Assumptions are then made about occupancy rates and the proportion of visitors who would use waterbodies and waterways.

The example below was used in estimating the number of visitors to some sites in the Corangamite region. Overnight visitor numbers were based on the total number of accommodation beds and camping sites located adjacent to each waterway unit (RACV 1997). The number of beds/sites were then multiplied by average occupancy rates, then by average group sizes.

> Occupancy rates have been based on the average values in Victoria, as reported by Bureau of Tourism Research (1992):
>
> | | |
> |---|---|
> | Motels and Hotels | 52 per cent |
> | Caravan parks | 24 per cent |
>
> These represent the average proportion of rooms/sites with visitors, but on average there is more than one person per site/room. Average groups sizes were based on results of the ABS (1995) survey of tourist accommodation:
>
> | | |
> |---|---|
> | Motels and Hotels | 1.4 persons per room |
> | Caravan parks | 3.1 persons per site |
>
> A range of plus and minus 20 per cent around the resulting estimate of overnight visitors for the Desktop Approach was then applied.

Tourism Victoria's (1995) regional travel and tourism survey (VRTTS) of the Western Geelong/Barwon regions asked travellers to nominate the major activities undertaken during their trips to the region. The following information from the survey was relevant to how water quality might affect recreation for visitors to the region:

- swimming was a major activity for 24 per cent of visitors;
- sailing/boating was a major activity for 3 per cent of visitors;
- fishing was a major activity for 13 per cent of visitors;

- water-skiing was a major activity for 1 per cent of visitors; and
- sightseeing was a major activity for 52 per cent of visitors.

By assuming that one-third of sightseeing activities involved locations by waterbodies and waterways, this information might be construed to suggest that 57 per cent of visitors went to waterbodies and waterways (24 plus 3 plus 13 plus 1 plus 17 per cent). However, this may be an over-estimate on two counts. Firstly, the VRTTS sample included people who nominated more than one major activity. Secondly, the VRTTS estimates would include water-based recreation in the sea at coastal resorts along the Otways Coast.

Lacking any better information, a range of 20 to 30 per cent was adopted for the Desktop Approach. This was influenced strongly by the other observation of the VRTTS that only 59 per cent of visits were primarily for pleasure (the remaining visits were primarily for visiting friends/relatives and for business).

The VRTTS revealed that there were five overnight visitors for every day visitor, where 'day visitors' are restricted to those travelling 50 km or more to reach their destination. In the Desktop Approach an estimate of the number of day visitors from outside the region was arrived at by multiplying the estimated number of overnight visitors by a ratio based on that finding of the VRTTS. A range of 0.2:1 to 0.4:1 was adopted for this ratio in order to acknowledge the level of accuracy implied.

In the Desktop Approach the number of day visitors from the local region was then estimated by multiplying the estimated number of day visitors from outside the region by a ratio of 2:1. This was based mainly on a number of informal surveys by Read Sturgess and Associates which have revealed that recreation at waterbodies and waterways in Victoria is often characterised by a substantial number of day visitors from the local region; that is, visitors who would travel less than 50 km to reach the waterbody.

A number of the potential bloom sites were waterbodies and waterways situated in urban centres, and are popular locations for walkers, joggers and visits to playgrounds by local residents who typically walk to the waterbody and stay only for a very short time, often less than one hour. This class of visitor would also include local residents who visit during meal breaks. Another class of visitor that stays at a waterbody for only a very short periods comprises people who 'stopover' for a break from driving.

For the purpose of this report, all these visitors who stay for only a very short time are referred to as a 'walker'. This group is important since, at some waterbodies in urban centres, the average number of 'walkers' may far outweigh the number of other visitors who by contrast have come purposely to the waterbody for a longer visit of some **hours** in duration.

For the Desktop Approach, walkers for waterbodies and waterways in rural settings were ignored, but the number of walkers per year at all waterbodies in urban settings was estimated as 300 per cent of the urban population that lives within the urban centre. That is, an average of three short visits per year per person.

A5.2 Reduction in Number of Visitors Due to a Bloom

In undertaking an economic evaluation of the impacts of blooms, the analyst should rely on experience with past blooms. The authors have obtained estimates of the reduction in visitor numbers from previous blooms at four locations; namely, for Lake Mokoan which has bloomed in most years since 1990, for blooms at Lake Boga in the summers of 1993/94 and 1994/95, for the bloom in the Gippsland Lakes in the summer of 1987/88 and for the blooms at Lake Colac in the summer of 1993/94. The proportion of visitors who ceased to visit a particular site during a bloom appears to depend mainly on the following factors:

- the mix of visitors from the local region and visitors from outside the region;
- the mix of recreational activities, particularly since this determines the proportion of visitors who would otherwise enter or use the water;
- the extent of restrictions placed by the managing authority on recreation during the bloom (e.g. whether the water body or stream is closed, and if so over what proportion of the water body/stream the closure extends);
- the extent of publicity of those restrictions;
- the proximity of other waterbodies/streams/channels that offer close substitutes for the recreational activities at the particular site; and
- the distance from large centres of population.

It appears that the most important factor might be the mix of visitors from the local region and visitors from outside the region. The duration and size of reduction in visitor numbers was particularly high at Lake Boga and Gippsland Lakes, likely to be because tourism at those locations is dominated by visitors from outside the region who would typically stay for one to two weeks and who would plan such a major holiday well in advance.

By contrast, Lake Colac is used mainly by local residents of Colac who would not have to plan their visits well in advance. It is suggested that the number of visitors from outside the region would be reduced by about 70 per cent during the bloom and for about half a year subsequent to the bloom, but that the number of visitors from the local region would be reduced by only about 50 per cent and only for a much shorter period. Therefore, lower impacts for local residents have been adopted in these guidelines because they could readily respond to changing water quality.

In applying those percentage reductions to the annual number of visitor numbers at each site, it would be appropriate to adjust the number of visitors to account for the fact that blooms are most likely to occur in the (higher temperature) months of January – April when recreation at waterways and waterbodies is more prevalent (e.g. 70 per cent of annual visitation to waterbodies and waterways would typically occur in that 120 day long period).

Table A5-1 presents details of the duration and extent of reduction in visitor numbers used for evaluation of the Corangamite region nutrient management plan.

Table A5-1 Assumed change in visitor numbers in the Corangamite region due to algal blooms (Source: Read Sturgess and Associates 1998c)

	Duration of period, during & subsequent to bloom, for which no. of visitors is reduced (days)		**Reduction in no. of visitors during that period (%)**	
	Low	**High**	**Low**	**High**
Impact on outsiders	160	240	55	85
Impact on locals	25	40	40	60

A5.3 Estimating Economic Value of Tourism and Recreation

A benefit–cost analysis is concerned with net economic values. Estimates of tourist expenditure are often used by organisers of major events, but they are **not** relevant to benefit–cost analysis. Benefit–cost analysis is concerned with economic value which represents net gains to the economy (see section 4.1(i)). It requires large and specialist economic studies to attempt to quantify the net value of tourism at specific sites, but it is possible to gain some indicative values from other sites where tourism values have been assessed in specialist economic studies; an approach that has been termed ‘benefit transfer’.

There have been many estimates of the **net economic values** of tourism and recreation in Australia and elsewhere, most often derived by seeking the amount that visitors would be willing to pay for particular recreation experiences (see for example, Herath and Jackson 1994; Read Sturgess and Associates 1994; Sappideen 1993; Sinden 1990). The following unit values for economic values associated with recreation, shown in Table A5-2, are recommended for use with the RAM.

Table A5-2 Recommended economic values associated with recreation

Recreational activity	Economic value per visit ($)	
	Low	High
Walkers	0.50	1.00
Local residents for day trips	2.00	4.00
Day visitors from outside region	4.00	8.00
Overnight visitors	10.00	15.00

APPENDIX 6 ESTIMATING IMPACTS OF ALGAL BLOOMS ON URBAN WATER SUPPLIES

Algal blooms can impact on urban water supplies in a number of different ways, depending on what technical options are available for responding to the bloom. For example, impacts on a water authority[5] might include the need to:

- use algicides quickly to treat an algal problem in a reservoir (note that the use of algicides is subject to specific regulatory control – see below);
- switch to alternative source of water if available, possibly with the need to impose water restrictions;
- use stand-by filtration capacity for toxin removal, possibly with the need to impose water restrictions; and
- cart in water and impose water restrictions.

The actual impact will depend on the options available for the particular supply system. For example, the impacts would depend on whether alternative sources of water were available, or whether high level filtration capacity had been installed prior to the onset of the bloom.

A6.1 Use of Algicides

Algicides are toxic substances that kill the algal cells forming a bloom. The use of such toxic materials is subject to specific regulatory controls from both chemical management and environment protection perspectives. Under the chemical control requirements of the National Registration Authority (NRA), algicides must be registered for use and their application must comply with the conditions specified on the product label. Few algicides are registered for use in potable water supplies. Some water authorities have been granted temporary permits from the NRA for the use of generic Copper Sulfate as an algicide pending their application for registration of the material.

Victorian State environment protection policies (e.g. SEPP Waters of Victoria) include specific requirements to ensure that toxicant levels in the environment are not harmful to aquatic biota. Consequently, application of an algicide that results in persistent elevation of toxicant levels in a waterbody or its underlying sediment constitutes pollution.

Algicide use where it would lead to the elevation of toxicant levels in the environment (i.e. within waterways or waterbodies with beneficial uses other than water supply) that exceed the environmental objectives of State environment protection policy is not permitted. The application of algicides is, therefore, effectively restricted to dedicated storages within water supply systems.

It should also be noted that some algicides may be persistent in underlying sediments long after their application to a waterbody. There is a possibility that repeated heavy application of such algicides could result in sediments exceeding the toxicity criteria for contaminated sites. It is unlikely that the community would tolerate this situation, particularly within potable water supply systems.

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[5] The guidelines refer to ‘the water authority’ throughout this section, but could equally be referring to domestic water supplies managed by water authorities or private diverters.

It is advisable that algicide application within a water supply system be undertaken in a manner that minimises the use of the chemical to obtain effective control. In many cases this can be achieved by selective targeting of algal concentrations, early in the development of a bloom, rather than broadscale application across a storage area.

A6.2 Assessment of Types of Damages Caused by Blooms to Urban Water Supplies

The following series of questions are proposed to help determine which types of 'damages' might occur with a particular bloom, and hence how to estimate the impacts for urban water supplies for that particular bloom. The order of the questions is premised on three assumptions namely:

- use of alternative supplies that were not contaminated would be preferable to removing algal toxins with existing high level filtration systems;
- water authorities would not want to cart in alternative supplies except as a last resort (owing to the high costs to the authority); and
- water authorities would not want to impose restrictions unless absolutely necessary (owing to high costs to customers).

(1) Can the affected supply be successfully and quickly treated with algicides[6]?

If so, then estimate impacts as the costs associated with using algicides.

Otherwise go to (2).

(2) Does authority have an alternative source of water to meet total demand?

If so, then estimate impacts as the additional costs associated with using that alternative source.

Otherwise go to (3).

(3) Does authority have standby filtration capacity to meet full supply?

If so, then estimate impacts as the costs associated with using that filtration.

Otherwise go to (4).

(4) Does authority have sufficient unaffected supplies to meet restricted supply levels?

If so, estimate impacts as the costs associated with imposing restrictions.

Otherwise go to (5).

(5) Does authority have an alternative source of supply to meet restricted supply?

If so, then estimate impacts as the costs associated with using that alternative source plus the costs of imposing restrictions.

Otherwise go to (6).

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[6] In accordance with legal requirements as previously described.

(6) *Does authority have standby filtration capacity to meet restricted supply?*

If so, then estimate impacts as the costs associated with using that filtration plus the costs of imposing restrictions.

Otherwise go to (7).

(7) *The authority has no option but to cart in water and impose water restrictions.*

Estimate impacts as the costs of carting in water plus the costs of imposing restrictions.

A6.3 Examples of Estimates of the Impacts of Blooms on Urban Water Supplies

This section contains examples of estimates of the impacts of blooms on urban water supplies. Values quoted were current at January 1997.

(1) *Situation where the affected town water supply can be successfully treated with algicides*

Glenrowan reservoir has bloomed on a number of occasions, but the blooms have been treated with copper and it has not been necessary to take any other actions as blooms have been cleared within the withholding period of two weeks. Glenrowan has smaller storages that enabled supply during those fortnight periods.

The only costs were dosing with copper at a cost of $1100 plus the insignificant costs of distributing the copper by using the authority's own personnel and boat for about three hours, a total impact of about $1300 for a particular bloom.

Tarago reservoir bloomed during March/April 1991 and was treated successfully with copper.

Tarago has a capacity of 37,580 ML and the reservoir could be dosed at about 2 litres of Cupricide per ML, but it is likely that only the top metre would require treatment. This would cost about $53,000 ($7 per litre Cupricide) plus $1800 for the hire of a light plane to spread the copper, a total impact of about $55,000 for a particular bloom.

(2) *Situation where town water authority has alternative source of supply to meet total demand*

Cohuna township purchases bulk supplies from Goulburn-Murray Water (GMW) which are drawn from Gunbower Creek and piped to the town's treatment plant. In the event that Gunbower Creek bloomed, GMW could make supplies available from an irrigation channel. However, a temporary pipeline would have to be laid from the channel to the treatment plant. Cohuna would not have to pay any additional amount for the water from another irrigation channel as it would be purchasing the Gunbower Creek water from GMW at the same price anyway. GMW has estimated that the cost of a temporary pipeline would be about $12,000, which would be the total impact on town water supplies for a particular bloom, regardless of duration. A separate valuation of other impacts (e.g. on recreational activities in Gunbower Creek would also be required).

(3) *Situation where town water authority has standby filtration capacity to meet full supply*

Inglewood and Bridgewater have a shared town water supply and have recently installed GAC filtration with capacity to meet total demand at time when the Loddon

River blooms at the authority's point of offtake. With an average daily summer demand of 1.1 ML, and a filtration cost of $28 per ML the impact would be $30 per day for the duration of the bloom or $450 for, say, a 15 day bloom.

Shepparton has installed PAC filtration with capacity to meet total demand at times when the Goulburn River blooms at the authority's point of offtake. With an average daily Summer demand of 75 ML, and a filtration cost of $20 per ML the impact would be $1500 per day for the duration of the bloom or $22,500 for, say, a 15 day, bloom.

(4) *Situation where town water authority has sufficient unaffected supply to meet restricted supply*

Springhurst experienced a bloom in its main reservoir for two months during 1994 and copper treatment failed, but the authority was able to switch to its own standby bore and meet restricted demand. The costs associated with the bloom have three components:

- Copper treatment would have cost about $350 for the total treatment.
- Bore pumping costs would have been about $15 per ML (for a 30 meter lift) or about $150 for the two months (60 days and restricted demand over summer of 0.16 ML per day).
- Water restrictions which led to halving of water usage; namely, a loss of use of 10 ML. At a water price of $0.70 per kL, this loss would be valued at $7,000. Further, a garden damage cost of $200 per household on average for such a long period of restrictions was assumed, or a total of $18,000 across the authority's ninety customers.

On this basis the total impact was estimated as about $25,000 ($270 plus $150 plus $7000 plus $18,000).

(5) *Situation where town water authority has standby filtration capacity to meet restricted supply*

Maryborough has installed PAC filtration to meet half supply at times when the authority cannot draw water from Tullaroop and Evansford due to blooms. A hypothetical bloom of 15 days is considered. The total impact of a bloom would have two components:

- Operation of the standby PAC filtration capacity. With a restricted demand of 3.5 ML per day (average daily summer demand of 7 ML), and a filtration cost of $20 per ML the impact would be $70 per day for the duration of the bloom or $1050 for, say, a 15 day, bloom.
- Water restrictions which led to halving of water usage; namely, a loss of use of 3.5 ML per day. At a water price of $0.70 per kL, this loss would be valued at $2450 per day or $36,750 for, say, a 15 day bloom. Further, a garden damage cost of $20 per household for such a short bloom was assumed, or a total of $100,000 across the authority's 5000 customers.

On this basis the total impact was estimated as about $140,000 ($1050 plus $36,750 plus $100,000) for a hypothetical bloom with a duration of 15 days

(6) *Situation where authority has no option but to cart in water and impose water restrictions*

The water supply for the township of **Yarrawonga** draws water from Lake Mulwala and cannot readily switch to alterative supplies. Yarrawonga has a water treatment plant (dissolved air flotation) which is fairly efficient at removing algal cells, but it has no filtration system capable of removing algal toxins. A hypothetical bloom with duration of 15 days is considered. The impacts of a bloom would have two components:

- Water carting costs. At present a bloom in Lake Mulwala would require Goulburn-Murray Water to impose restrictions and cart water in. With an average daily demand of 6 ML during summer, it is likely that 3 ML of water would be required to meet restricted demand each day. At a price of $10,000 per ML, this would cost $30,000 per day, or $450,000 for a 15 day bloom.
- Water restrictions which led to halving of water usage; namely, a loss of use of 3 ML per day. At a water price of $0.70 per KL, this loss would be valued at $2100 per day or $31,500 for, say, a 15 day bloom. Further, a garden damage cost of $20 per household for such a short bloom was assumed, or a total of $50,000 across the authority's 2500 customers.

On this basis the total impact was estimated as about $500,000 ($450,000 plus $50,000) for a hypothetical bloom with a duration of 15 days.

This analysis considers only impacts associated with town water supplies in Yarrawonga and ignores the impacts associated with reduced recreational activities on Lake Mulwala.

APPENDIX 7 ESTIMATING IMPACTS OF ALGAL BLOOMS ON FARMS AND FARMING

The impacts of algal blooms on farms and farming will depend on the characteristics of the stock and domestic water supplies which are affected, for example, whether alternative sources of supply are available or whether farmers already treat or filter their water in some way. The types of damage will vary depending upon whether the water affected is used for:

- drinking water for livestock;
- domestic water supplies for the farm; or
- irrigation water for pastures or crops.

A7.1 Process for Determining Costs of a Bloom to a Farm

The following series of questions is provided to simplify the determination of the cost of a bloom in waterways and waterbodies which supply water for drinking or irrigation on a farm. Further detailed information to assist with estimating the actual costs is provided in section A7.2

(i) Drinking water for livestock

(1) Do stock have access to the affected waterbody?

If yes, estimate costs of excluding stock from it and proceed to (2) to identify additional costs associated with an alternative supply of water for the stock.

(2) Do farms have alternative sources of water that can be accessed?

If so, estimate the costs of temporary connection to that source, such as alternative irrigation channel, bore, town supply or creek.

Otherwise go to (3).

(3) Is carting water by tanker feasible?

If so, estimate the impact as the costs of carting water for livestock.

Otherwise go to (4).

(4) If options (1), (2) and (3) are not available or only suit a proportion of total stock.

Assess impact as the loss of value of stock which must be sold and eventually replaced.

(ii) Domestic water supplies for farms

(1) Do farms have alternative sources of water that can be accessed?

If so, estimate the costs of temporary connection to that source (proceed as for drinking water for livestock).

Otherwise go to (2)

(2) Alternative sources not available.

Estimate the impact as the cost of carting water for domestic supplies.

(iii) Irrigation water for pastures

(1) Do farms have alternative licensed sources of water that can be accessed?

If so, estimate the costs of temporary connection to that source (proceed as for drinking water for livestock).

Otherwise the current recommendation is that about 14 days should elapse between irrigation with contaminated water and grazing. Estimate this as the reduction in pasture growth which would result due to the lack of grazing period during the resting period. If this is infeasible, go to (2).

(2) Do most farms have a dryland block available for grazing?

If yes, calculate the impact as the cost of transport for the appropriate number of livestock to and from the block plus the cost of any additional handfeeding for the estimated duration of the bloom.

Otherwise go to (3).

(3) Do most farms have access to agistment?

If yes, calculate the impact as the cost of transport for the appropriate number of livestock to and from the agistment area, plus the cost of agistment, plus the cost of any additional handfeeding for the estimated duration of the bloom.

Otherwise go to (4).

(4) Handfeeding of stock is necessary.

Estimate the impact as the cost of hand feeding for the appropriate number of livestock for the estimated duration of the bloom.

(iv) Irrigation water for crops

For most purposes, irrigating crops with contaminated water is unlikely to have any significant impact. The impact may include education and warning programs.

A7.2 Estimating Damages Caused by Blooms on Farms

This section assists in estimating the costs associated with blooms which affect farm water supplies.

(i) Impacts of contaminated drinking water for livestock

Preventing access to contaminated water

The neurotoxins and hepatotoxins produced by various species of blue-green algae can be toxic to livestock if ingested in sufficient quantity or they can produce liver damage and loss of production. Therefore, livestock should not drink water which is likely to be contaminated by algal toxins.

Where technically feasible, the water supply should be stopped, drained or stock should be excluded from the affected water. If fencing is necessary and feasible for grazing livestock, the length of the perimeter of the exclusion zone should be determined and fencing costed at the cheapest form available depending on whether the exclusion needs to be temporary or permanent.

Permanent fencing may be required if blooms are likely to be regular events. Electric fencing may be appropriate for dairy animals which have been trained to such fences (see local fencing suppliers for prices).

Alternative water supplies available

There is a considerable range of sources from which stock obtain drinking water, such as, large and small streams, lagoons, irrigation channels, farm dams and town supplies. The stock may have direct access to these sources or the water may be pumped or channelled to troughs or other drinking facilities. It is difficult to generalise about the implications of a bloom in these various water sources as it depends to a considerable degree on the size and number of the water sources and the number and type of livestock involved. For example, a bloom in a farm dam on a property running wethers has different implications and costs compared to a bloom in a lagoon which is the only water source for several dairy farms, and different implications to a bloom on a large river from which vast numbers of stock drink directly. In the last case, total exclusion may not be feasible.

In some circumstances, an alternative source of uncontaminated supply, including bore water, may exist. Where this is the case, it is recommended for the RAM that the assessment of impacts be based on the option of temporary connection to an alternative source which is unlikely to be contaminated (say, as indicated by flow rates) if that connection is technically feasible.

Alternative water supplies not available

Where relocation of supply is not an option, alternative arrangements must be made. For the purposes of the RAM, the fall-back position is assumed to be carting water by tanker into temporary storage and distributed, probably to a restricted number of watering points on grazing properties.

Under these circumstances it is important to make an assessment of the amount of water required for the estimated number of stock involved, where the latter may be determined from the Department of Agriculture, ABS statistics or telephone survey (see local government for maps indicating property owners). In making this assessment it is important to remember that adequate provision of drinkable water is essential for production and survival of farm animals. An animal can lose almost all of its fat and about one-half of its protein during starvation and remain alive, but loss of about one-tenth of its body water can be fatal (Standing Committee on Agriculture 1990).

The amount of water required by farm animals depends on many variables including: species; dryness of feed; feed intake; composition of the feed; air temperature and physiological functions, such as gestation, lactation, growth, fattening and amount of exercise. For the purposes of the RAM, a simple daily requirement will suffice but, because of the complexity of the issues determining an animal’s water needs, statements by scientists will tend to be generous so as to encompass most contingencies. The requirements shown in Table A7-1 are proposed as guides for estimating costs of replacement supplies of drinking water during an algal bloom.

Table A7-1 Water requirement guidelines for estimating water replacement costs

	Water requirements (per litres per head per day)
Sheep	4
Dry (non-lactating) cattle, beef or dairy	30
Lactating dairy cows	50
Pigs	8
Poultry	0.2

These are indicative figures for estimating possible costs of contending with algal blooms. They are not to be interpreted as prescriptions for the provision of water supplies to animals on farms or any other establishment on which these classes of livestock are kept.

An additional requirement on dairy farms would be water for washing down the dairy shed and yards so as to prevent any chance of contaminating the dairy environment with algal cells. An allowance for this purpose for a milking herd of 200 cows would be about 6 kL/day. Special care would be needed to use uncontaminated water for the hot and cold flushes of the milk lines and equipment. An estimate for this purpose for a milking herd of 200 cows would be about 1 kL/day.

In round figures, a dairy farm milking 200 cows could require a total of about 20 kL/day for stock drinking and washing (about 100 litres per head per day), composed of:

- 10 kL of drinking water for milking cows;
- kL of drinking water for replacement stock (say, 120 calves and heifers at 30 litres per head per day); and
- 7 kL of water for cleaning.

For poultry farms and piggeries the water requirement for cleaning and cooling is assumed to add 50 per cent to the estimated requirement for drinking water. Thus, the total requirements for drinking, cleaning and cooling would be about 12 litres per head per day for pigs and about 0.3 litres per head per day for poultry.

Costs of water cartage per unit volume are likely to depend on the scale on which the cartage is performed. For example, private carters have provided estimates of about $100 per 10 kL for distances up to about 50 km. On this basis, therefore, the above estimate for a 200-cow herd would cost $200/day. If a water authority undertook the task on a large scale, the price might be lower. An estimate of the average delivery distance multiplied by the number of receiving farms would suffice for an estimate of the distance travelled per delivery cycle rather than detailed estimation of the distance travelled to each farm. Total delivery costs would be determined over the number of delivery cycles in the expected duration of bloom.

Livestock deaths or sales

Where the size of the affected area does not permit total exclusion, alternative supplies or consistent water deliveries to meet the requirements of all stock, an allowance must be made for stock deaths because some proportion of the stock will drink contaminated water. Or, farmers may sell stock and repurchase after the bloom.

It is almost impossible to supply any clear guideline figure to allow for deaths. Observation on the Darling River in 1991 suggest that the death rates amongst the stock which were potentially exposed to contaminated water were low. Of the estimated 230,000 sheep on a surveyed reach of the river, the number of reported deaths attributable to algae may not have exceeded 2000, say, 8 per cent. Amongst the 4600 cattle dependent on the same reach, the reported number of deaths was 40 head, say, about 8 per cent also (Scott Orr undated). The cost of restocking at the conclusion of the bloom would also be included.

If farmers sell stock in order to prevent deaths, they would need to replace those stock when the bloom is over. Any differences in expected buying and selling prices and the costs of making the two transactions would need to be evaluated. Stock and station agents or the rural press should be consulted for values of the various types of livestock.

(ii) Impacts of contaminated domestic water on farms

The issues involved here will be similar in many respects to those set out for livestock. It is a reasonable assumption that farms will have sufficient storage of rainwater to cope with their requirements for drinking water and other kitchen uses during a bloom.

If relocation of the source of supply or connection to the town supply are not options, water would have to be carted to the farm for livestock. Average indoor water consumption is typically about 7.25 kL per month, costing about $70.

For the purposes of forming a conservative estimate of the cost of delivered water, garden watering is assumed to cease for the period of the bloom.

(iii) Impacts of contaminated irrigation water on farms

Irrigation of pastures

In some cases, it may be possible to relocate the source of irrigation supplies if the main source is contaminated by a bloom. Mostly, however, the strategy will be to manage the irrigation and grazing of pastures so as to maximise the interval between irrigating with contaminated water and grazing. This allows sunlight and bacteria to decompose, and rainfall to wash off, algal cells and toxins which may be on the edible parts of the plants or on the soil which grazing animals inevitably take in. A period of 14 days is deemed appropriate for this purpose[7].

At the time of the year at which blooms are most likely, temperatures are high and there are long hours of sunlight so that the rapidly-growing irrigated pastures will wilt and die if deprived of water for too long. Indeed, dairy farmers in northern Victoria are likely to irrigate their pastures more frequently than once in 14 days – every five to seven days would be common intervals. Therefore, farmers need a management regime which attempts to balance the risks of loosing pastures against the risk of poisoning livestock.

Graziers and dairy farmers have a number of options in attempting to strike this balance. They may, for example:

- adopt a grazing regime which keeps pastures taller so that less toxin gets on to edible parts;
- irrigate to maintain pastures and totally handfeed stock;
- shift some or all stock to a dry land block with uncontaminated water supplies, if available, possibly with some amount of handfeeding;
- seek agistment for some or all stock in areas with uncontaminated water supplies, possibly with some amount of handfeeding;
- irrigate and graze as normal, that is, take the risk of liver damage or death of livestock[8];
- attempt to extend the exclusion period for as long as possible with hand feeding with some loss of pasture and some risk to cattle; or
- some combinations of these plans.

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[7] This period may need to be longer for high infestations of *Microcystis*.

[8] It is noted that there are many other potential causes of liver damage in livestock on the irrigated pastures of northern Victoria, such as fluke and fungi. Therefore, it has proved difficult categorically to attribute known cases of liver damage to algal toxins.

In any event, there is likely to be some damage to pastures, whether from becoming rank or dying, and some loss of production from livestock, particularly dairy cows, arising from hand feeding and the possibility of liver damage. The degree of damage would be difficult to predict over large areas, and in the case of losses of milk production or liveweight due to liver damage, available knowledge is insufficient to form reliable estimates. Until available knowledge indicates otherwise, these affects can probably be ignored for a rapid appraisal.

For the purposes of a rapid appraisal, one could not attempt to pick the strategies to be employed by each and every farmer or grazier as this depends on the costs involved and their degree of risk aversion. In some areas, however, the strategies may be clear cut, for example, where private diverters have only small areas of irrigated pasture or grazed crops for finishing stock, where many farmers have dry land blocks or agistment is available.

Where such strategies are not readily or generally available, it is proposed for the purposes of assessing impacts in the RAM that:

> **graziers and dairy farmers are assumed to follow the strategy of irrigating as normal to maintain pastures and totally hand feeding livestock for the expected duration of the bloom.**

Irrigation of crops

It is most unlikely that irrigation of grain crops with water contaminated with algal toxins will cause any problems. Most grain crops are flood irrigated and the grain does not normally come in contact with the water.

Due care would need to be exercised with irrigated grain crops and any other crops, such as turnips, which are grazed by livestock. In most circumstances, it could be assumed that the period of 14 days between irrigation and grazing could be fulfilled without difficulty. Graziers are not so dependent on the grazing of irrigated crops as they are on pasture and the survival of crops which go unirrigated for this period of time is less of a problem.

The irrigation of crops intended for hay production should not cause a problem since there would be sufficient time, and exposure to sunlight, between the last irrigation and consumption by livestock.

The main area of possible concern for human health is vegetable and fruit crops where the irrigation water may come in contact with the edible parts of the plant. For example, lettuce irrigated with water containing the cells of blue-green algae may retain the cells in a favourable micro-climate between the leaves where they could persist and produce toxins for long periods.

This is a circumstance where the economic analysis cannot consider every possible contingency. Most vegetables and fruit for human consumption will be washed before sale and certainly before processing (and often peeled). An exception may be potatoes from areas of heavy soils. These are usually brushed before sale on the fresh market. However, it must be assumed that consumers of fresh fruit and vegetables wash all those fruit and vegetables in clean fresh water before eating them. Therefore, given careful treatment of the edible products, for the purposes of a rapid appraisal of controlling algal blooms, it is reasonable to assume that:

> **irrigating crops for human consumption with water containing algal cells and toxins is unlikely to impose significant risks or costs on the community.**

Blooms affecting entire irrigation areas

It is difficult to predict the consequences of a large scale bloom affecting one or more entire irrigation regions since many farms would be affected and each farmer would be faced with a range of options about how to adjust the management of farm resources in response to the bloom. Ideally existing economic models, specified for the particular region, would be used to identify the ‘optimal’ response by farmers. Unfortunately the consultants know only of such models for the Goulburn Murray irrigation system. For regions where no such models are available, the analysts will need to seek advice from agronomists and other scientists and farm advisers about the likely responses of farmers to a large-scale bloom. Farm budgets should then be formulated to describe the effects. For example, effects of water restrictions on pasture production, and hence on animal production, would need to be specified.

APPENDIX 8 ESTIMATING IMPACTS OF ALGAL BLOOMS ON AMENITY FOR FORESHORE RESIDENTS

Amenity is reduced for residents of houses with frontages to waterbodies and waterways during algal blooms. Blooms would reduce visual amenity as well as cause unpleasant odours and fears associated with the presence of toxins from blue-green algae. These factors have been shown to reduce the desirability of properties with frontages to waterbodies and waterways that are subject to blooms. The evidence for this statement arises from four sources:

1. a benefit–cost analysis of proposals to reduce algal blooms, in the Peel-Harvey Estuary at Mandurah in Western Australia, used a contingent valuation which suggested that the average impact on land values would be valued at $600 per block (Mattinson and Morrison 1985);

2. an economic study in the U.S. found that water quality was a significant determinant of the prices paid for properties with water frontages on 53 lakes in Minnesota (Steinnes 1992);

3. property values for frontages around Lake Boga have dropped since the major blooms in the summers of 1993/94 and 1994/95. Properties were re-valued in late 1995 and the municipal valuer concluded that on average, lakeside properties were down-valued by 20 to 25 per cent; and

4. real estate agents in Colac reported that foreshore properties around Lake Colac were ‘close to impossible to sell’ following the algal blooms in the summer of 1993/94. The market for foreshore properties recovered after the following summer when blooms did not re-occur. The agents have not observed any sustained reduction in prices, but postulate that properties would become difficult to sell in the period following any major blooms.

The experience at Lake Boga suggests a once-off and permanent loss associated with the onset of blooms at the particular site equivalent to 20 to 25 per cent of property values. This would be equivalent to an annual loss of about 2 per cent of property values (that is, the cost per year in each year subsequent to a major bloom, calculated as an annuity at a discount rate of 8 per cent over a period of 30 years).

The experience at Lake Colac suggests a once-off but temporary loss and it has been calculated to be equivalent to 1 per cent of property value. This is based on the interest foregone by delaying sale of a house by one year and assuming that, without a bloom, houses would be sold on average every 10 years.

It is suggested that, for a RAM, an appropriate measure of the impact for a toxic bloom would be calculated as:

- low estimate – 1 per cent of property values; and
- high estimate – 2 per cent of property values.

This is not the cost of every bloom at a particular site as the impact would occur only with the first occurrence of a major bloom at that site.

APPENDIX 9 CALCULATING INCREMENTAL COSTS FOR NUTRIENT MANAGEMENT ACTIVITIES

In estimating the incremental costs for each nutrient management activity, it is necessary to derive four important pieces of information:

1. location of point sources, or type of land use, in which to implement the activity;

2. percentage reduction of nutrient export that would be achieved by implementing the activity at those locations;

3. existing nutrient loads generated at those locations; and

4. costs of implementing that activity.

Even approximate estimates of incremental costs can provide some information with which to identify which potential actions should be studied in further detail. For example, in considering programs with respect to wastewater treatment plants for the nutrient management plan for the Glenelg Hopkins region, the relevant water authorities supplied estimates of the:

- existing nutrient loads generated at each plant;
- likely reduction in nutrient loads after upgrading of the plants; and the
- costs required for the upgrades.

This enabled the calculation of incremental costs as presented in Table A9-1. In a similar fashion, incremental costs can be estimated rapidly for a range of nutrient management activities. In the case of the Glenelg region, the consultants (Read Sturgess and Associates 1999) were able to conclude that the most cost-effective actions would represent, in order of cost effectiveness (see Table A9-2):

1. community education program for urban stormwater BMP;

2. changing techniques in forests;

3. upgrading of waste water treatment at Casterton and Hamilton;

4. changing techniques on farms;

5. treatment of gully erosion in the high priority management units (Casterton Tableland and Undulating Alluvial Plains);

6. stream bank fencing and revegetation in high priority management units (Casterton Tableland and Undulating Alluvial Plains); then

7. treatment of gully erosion in the moderate priority management units (Dundas Tableland, South West Sands, South West Wimmera Plains and Wimmera Plains).

Table A9-1 Incremental costs of proposed works at wastewater treatment plants in the Glenelg Hopkins Region (Read Sturgess and Associates 1999)

Wastewater treatment plants	**Reduction in export of nutrients to surface waters (kg/yr)**		**Costs of achieving upgrade**			**Incremental costs ($/kg/yr)**	
	TP	**TN**	**Capital**	**Recurrent ($/yr)[1]**	**Annual equivalent ($/yr)[2]**	**TP**	**TN**
Glenelg Catchment							
Coleraine	390	780	$400,000	$0	$35,531	**$91**	**$46**
Casterton	723	10,000	$100,000	$0	$8,883	**$12**	**$1**
Hamilton	4,140	24,000	$1,230,000	$0	$109,258	**$26**	**$5**
Dunkeld*	1,206	429	$3,500,000	$145,000	$455,896	**$378**	**$1,063**
Hopkins Catchment							
Warrnambool	Discharges to sea						
Ararat	3,794	9,932	$3,156,500	$78,287	$358,671	**$95**	**$36**
Ballarat North	1,125	0	$8,000,000	$0	$710,619	**$632**	**n.a.**
Terang	878	1,207	$2,000,000	$25,000	$202,655	**$231**	**$168**
Beaufort	699	0	$60,000	$7,000	$12,330	**$18**	**n.a.**
Mortlake	963	342	$6,700,000	$200,000	$795,144	**$826**	**$2,322**
Allansford	725	258	$1,900,000	$75,000	$243,772	**$336**	**$946**
Willaura	269	355	$606,000	$13,000	$66,829	**$248**	**$188**
Lake Bolac*	1,035	368	$1,423,700	$41,700	$168,164	**$162**	**$457**
Portland Coast Catchment							
Heywood	840	634	$1,750,000	$0	$155,448	**$185**	**$245**
Portland	Discharges to sea						
Port Fairy	Discharges to sea						
Port Campbell	No additional costs						
Koroit*	450	160	$4,900,000	$145,000	$580,254	**$1,289**	**$3,627**

1. This refers to additional recurrent costs because an upgraded plant is more costly to operate, i.e. $0 implies the recurrent costs of the upgraded plant are about the same as the existing plant.
2. calculated over 30 years using 8% discount rate.

* to be sewered

In themselves, the incremental costs are a useful filter, for use at an early stage in development of nutrient management strategies, to develop a 'short-list' of activities for further consideration. However, estimates of incremental costs in themselves are insufficient to provide a guide as to the extent of implementation of each activity. The latter can be judged only after consideration has been given to the benefits from implementation of each activity at each location.

For example, in evaluating actions within the proposed nutrient management plan for the Loddon catchment, it was found that some actions with relatively high incremental costs can have a high benefit–cost ratio because those actions lead to a substantial reduction in nutrient loads upstream of a high priority waterbody (see Table A9-3).

On average, each kg of phosphorus eliminated from the runoff from dryland agriculture produces a net benefit of $25 (calculated as 73 less 48), but each kg of phosphorus eliminated from the runoff from irrigated agriculture produces a net benefit of $10 (calculated as 26 less 16).

Table A9-2 Summary of incremental costs for the Glenelg Catchment (Read Sturgess and Associates 1999)

	Incremental costs ($/kg/yr)	
Nutrient management actions	**TP**	**TN**
Urban stormwater education program	$5	$2
BMP for forests	$6	$1
Casterton wastewater treatment plant	$12	$1
Farm nutrient management - changing techniques on farms	$22	$0
Hamilton wastewater treatment plant	$26	$5
Gully control - high priority RMUs	$26	$3
Stream bank fence/revegetation - high priority RMUs	$47	$8
Gully control - moderate priority RMUs	$53	$6
Coleraine wastewater treatment plant	$91	$46
Urban wetlands for stormwater	$137	$149
Dairy sheds	$152	$20
Stream bank fence/revegetation - moderate priority RMUs	$156	$25
Gully control - low priority RMUs	$265	$29
Sewer small towns	$378	$1063
Stream bank fence/revegetation - low priority RMUs	$467	$76
Septic tank BMPs	$500	$23
Farm nutrient management - additional works on farms	$644	$14

Table A9-3 Comparison of incremental costs and benefits for nutrient management activities in the Loddon Catchment

Phosphorus source	Incremental costs $/kg TP	Incremental benefits (high estimate) $/kg TP
Intensive animal industry	11	23
Urban	13	21
Irrigation land	16	26
Dryland agriculture and forested land	48	73

APPENDIX 10 APPROACHES ADOPTED IN DEFINING A RELATIONSHIP BETWEEN REDUCTION IN NUTRIENT LOADS AND THE INCIDENCE OF ALGAL BLOOMS

In studies for the Upper North East, Goulburn Broken and Ovens catchments (Read Sturgess and Associates 1998 a & b and Read Sturgess and Associates and Rendell McGuckian1998), NRE and CMA officers provided estimates of the reduction in frequency of blooms and Read Sturgess and Associates adopted those estimates for the purpose of quantifying the likely reduction in frequency of algal blooms. Those estimates implied constant (i.e. linear) ratios of reduction in TP to bloom-reduction of 1:1.8 to 1:1. It was clear that the relationship was extremely complicated (see for example, Appendix 1) and unlikely to be linear, but this approach was adopted as there was no better information available.

For the Corangamite catchment (Read Sturgess and Associates 1998c), it was assumed that there would be a linear relationship between nutrient reduction and reduction in frequency of blooms, but that a lower percentage reduction in nutrients would be required to completely eliminate blooms in a stream with relatively good water quality than for a stream with extremely poor water quality. For example, it was assumed that a 30 per cent reduction in nutrient loads would lead to the cessation of blooms at a site with relatively good water quality (Rating 1 in the risk assessment [see Appendix 3.1]), but that a 70 per cent reduction in nutrient loads would be required to lead to the cessation of blooms at a site with extremely poor water quality (Rating 5 in the risk assessment).

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