NRA

THE MANAGEMENT OF BLUE-GREEN ALGAL BLOOMS IN SOUTH-EAST AUSTRALIA

A REPORT ON THE VISIT

TO AUSTRALIA BY

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IN JANUARY/FEBRUARY 1993

National Rivers Authority
Anglian Region

NRA Regional Box 1

FIGURE 1 - BLUE-GREEN ALGAE ON THE MURRAY-DARLING RIVER

CONTENTS

1. INTRODUCTION

Background

In late Summer 1989, the deaths of sheep and dogs at Rutland Water in Leicestershire and the hospitalisation of two soldiers at Rudyard Lake in Staffordshire were both associated with toxic blooms of blue-green algae. Further investigation showed that blue-green algal blooms were widespread throughout England and Wales and many water-based recreational activities were closed. There was little information available, the public were concerned and the media was giving the incidents wide coverage. This situation presented the NRA with a major management problem within days of the organisation's formation.

In order to manage the immediate incident and provide short and long-term strategies for dealing with the problem, the NRA's Chief Scientist set up a Toxic Algae Task Group which was composed of a team of national experts and NRA personnel. The work of this Group is documented in the NRA's Water Quality Series Report, No. 2, "Toxic Blue-Green Algae" which was published in 1990. The Group has continued to meet on a regular basis to assist with the implementation of the report's long-term recommendations for resolving the problems.

In the late 1980s and early 1990s a drought persisted in the Murray-Darling basin in South-East Australia. This led to extensive blooms of toxic blue-green algae in the Barwon-Darling River which extended along a 1,000 km stretch of the river (see Figure 1). The blooms of Anabaena reached 600,000 cells/ml and were found to contain both hepatotoxins and neurotoxins. This outbreak was the most serious event ever experienced in Australia and probably the biggest outbreak in the world. As a result, approximately 1,600 sheep and 40 cattle were killed. The New South Wales Government declared a state of National Emergency and the army was called in to help supply many isolated farmsteads, who depended on the river for cattle watering and for their own drinking water, with alternative supplies.

The NRA was aware of the problems which had occurred in Australia in 1991/92 and that many parallels existed between these events and those in the UK in 1989. The NRA also had details of the actions taken by the regulatory Authorities in Australia to manage the problem in the short and long-term. These included the setting up of State Algal Task Forces, the production of publicity material, the preparation of reports on algal toxins and the setting up of major research and development programmes. The NRA was also aware that there were some fundamental differences in the management actions. This report summarises the information gained during the visit to Australia in January 1993 by Mick Pearson (Regional Water Quality Manager - Anglian) and Alastair Ferguson (Regional Biologist - Anglian), the Chairman and Secretary respectively, of the NRA's Toxic Algae Task Group. The report also examines the similarities and differences between the management actions taken by the NRA and Australian authorities.

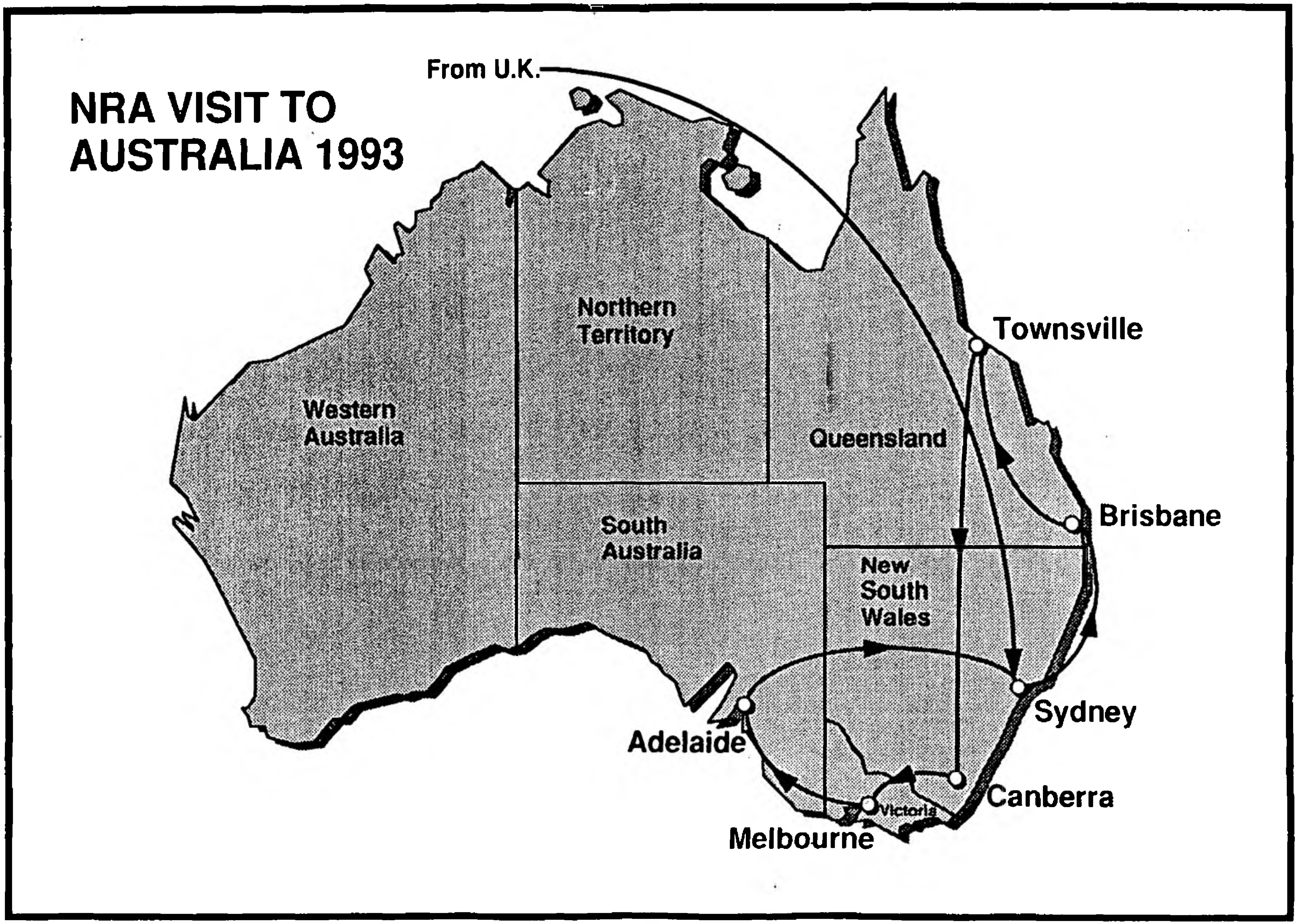
NRA VISIT TO AUSTRALIA 1993
From U.K.
Northern Territory
Western Australia
Queensland
South Australia
New South Wales
Victoria
Townsville
Brisbane
Sydney
Adelaide
Canberra
Melbourne

FIGURE 2

Objectives

The principal objective of the visit was to exchange information on the management of the events and discuss our current and future strategies to resolve the problems. The overall framework for our discussions with the regulatory authorities and research organisations was to investigate:-

a The management of the problem in the short-term, both locally and across State boundaries.

b The monitoring, surveillance and analytical programmes established.

c The longer term eutrophication control options under consideration.

d Campaigns and information carried out to raise public awareness.

e Water quality standards for toxins and nutrients.

f Health implications of the toxins.

g The nature and extent of toxic blooms in Australia.

h The effects on recreational activities.

i Research and development programmes.

The objectives were achieved by a combination of meetings with 14 regulatory and research organisations and site visits, in 5 States in Australia.

Organisation of the Tour

The Chairman of the New South Wales Toxic Algal Task Force, John Verhoeven, arranged a series of visits for us to New South Wales, Queensland, Canberra, Victoria and South Australia. Meetings and seminars had been arranged with the relevant groups currently involved with managing the problems in these States or carrying out research and development programmes. The flights taken during the tour are shown in Figure 2. Each State has a separate regulatory framework for water management: the organisations visited in each State were therefore necessarily different. In addition to the meetings, a number of visits to important blue-green algal problem sites had been arranged. The organisation of the tour by Mr Verhoeven was impeccable and included bookings for all flights and the accommodation.

2. NEW SOUTH WALES

Management Framework for Water

The Department of Water Resources plays a key role in both the operational and policy aspects of water quality and water resource management in New South Wales. The Department reports to the Minister of Natural Resources and it was the Minister who had requested a Report from the Department on blue-green algae. The Department has a similar role to the NRA but, although it is responsible for licensing abstractions, it does not set consents for discharges from sewage treatment works. The Department has four Divisions under the Director General. These Divisions are Policy, Technical, Support and Rural Water Supply. Discharges are consented by the newly formed New South Wales Environmental Protection Agency.

Water supply and sewage disposal are the responsibility of two large Water Boards which are wholly owned by the government and by 157 smaller local councils. The two main Water boards are the Sydney Water Board and the Hunter Water Board.

The Conservation and Land Management Department and the Agriculture Department are also involved with this issue, and report separately to the NSW Government.

Meetings and Visits

The main contacts in New South Wales were with John Verhoeven, Manager of the Environment Branch of the Technical Services Division in the Department of Water Resources and Ian Smalls who was the Chief Scientist for the Environment Branch.

Urban Problems in Sydney

Following our first meeting, to discuss and agree an agenda for our meetings, we visited one of the urban trouble spots for blue-green algae. This was a series of lakes associated with the main Sydney golf course which, following weed clearance, regularly develops toxic blooms of Anabaena circinalis. The golf course is in the middle of Sydney and has open access to the public as well as the golfers. The short-term solution to the problem has been to post notices warning the public of the potential dangers of contact with the algae. A longer-term strategy has been to build a silt trap at the top of the lake system. However, this is thought to be only part of the possible solution because the lake is also fed by groundwater which has a high phosphate concentration. A local management committee has been set up to make recommendations for resolving the problem, but has not yet reported on its findings. This site was one of a number of high profile trouble spots in Sydney which create a large amount of media attention and public interest.

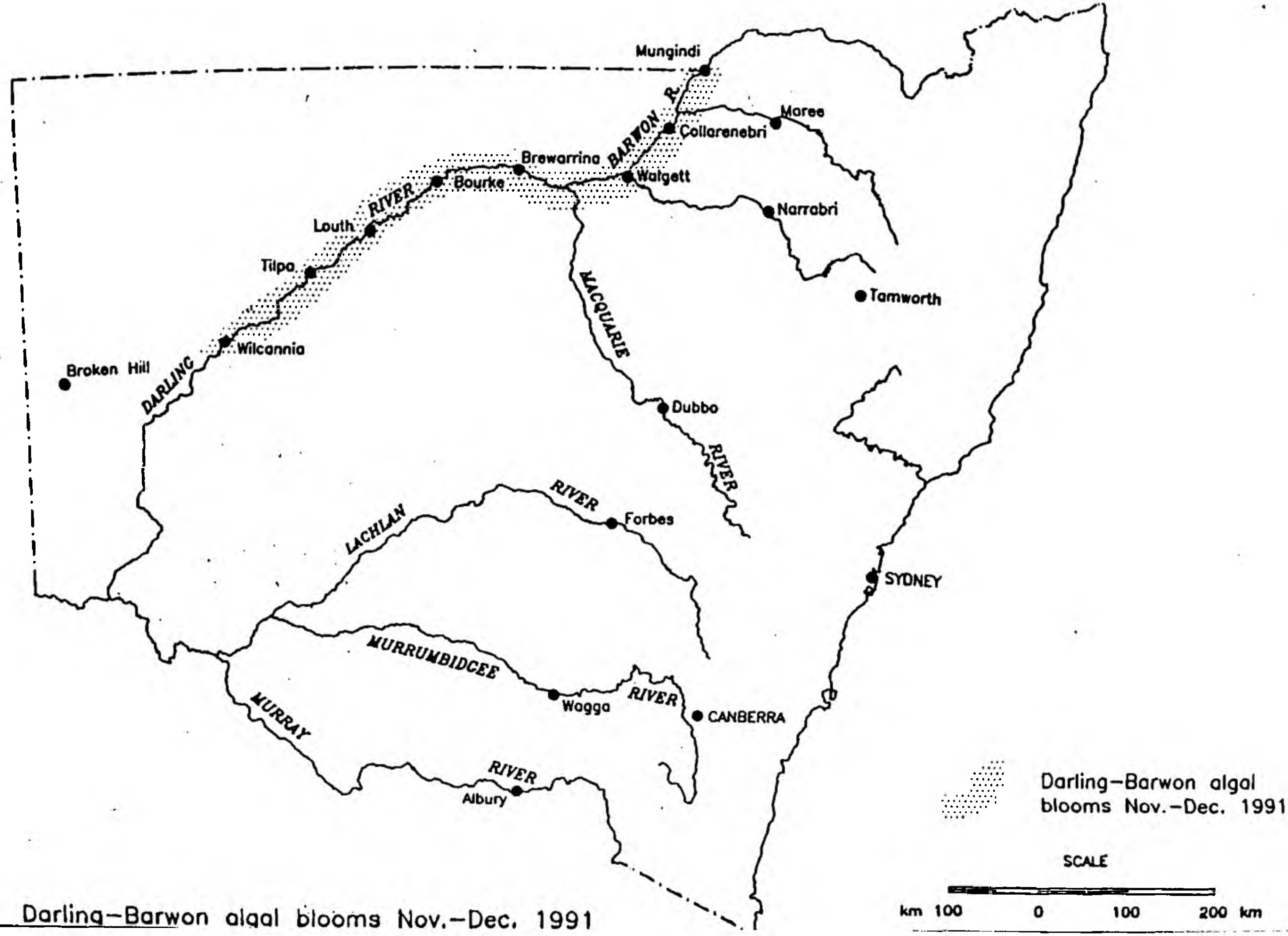

Figure 3 Darling–Barwon algal blooms Nov.–Dec. 1991

Seminar on New South Wales Experiences

Management Framework - John Verhoeven

John Verhoeven described the events of 1991 which led to increased pressure to deal with the problems of eutrophication in the Murray-Darling basin and elsewhere in Australia.

In November 1991, following a three year drought over 70% of New South Wales, severe problems with blue-green algae were experienced in the Barwon-Darling River. In the past, the large weir pools had been affected, but on this occasion low flows led to an almost continuous bloom in 1,000 km of the river. The drought was not exceptional (1:15 to 1:20 year event) and was therefore recognised as a serious event which is likely to reoccur. The extent of the blooms is shown in Figure 3 and illustrated in Figure 4.

The region affected is only 200 m above sea level, has a population of 15,000 people living in the river corridor and has intensive irrigation for agriculture. The agriculture includes a vast cotton growing area, wheat production and over 1 million stock. The stock watering requirements are equivalent to approximately 10 million people. Many isolated farms use the river for drinking water and the lower Murray-Darling is used as the principal water supply source for Adelaide.

During the event, the Minister declared a State of Emergency and a State Disaster Plan was drawn up by the Public Works Department. The Disaster Plan concentrated on the provision of drinking water for those living in the affected area. The Water Resources Department worked with the Public Works Department by providing technical information and the army were called in to assist.

A number of short-term measures to deal with the blooms were considered, which included proposals to flush the system with water held in reservoirs in the upper basin. This was not considered to be feasible due to practical problems, including water loss by evaporation and a four week travel time. Contingency plans for monitoring the extent of the blooms in the river and reservoirs throughout New South Wales were also implemented and it soon became clear that this was a statewide problem with blooms occurring through the winter at many of the sites (Figure 5). As in the UK, publicity played a major role in dealing with the problem. There was very considerable media attention and public alarm.

Early in 1992, the Minister of Natural Resources requested a report on the problem and recommendations for action to be taken to resolve it. This led to the formation of the New South Wales Toxic Algae Task Force, which was chaired by John Verhoeven, and included representatives from counterpart organisations in the other affected States. Their Report has now been published and the Task Force has been replaced by the New South Wales State Algal Co-ordinating Committee. The executive summary, including recommendations, is given in Appendix 1.

FIGURE 4 - BLOOMS ON THE BARWON-DARLING RIVER

FIGURE 4 (CONTD) - BLOOMS ON THE BARWON-DARLING RIVER

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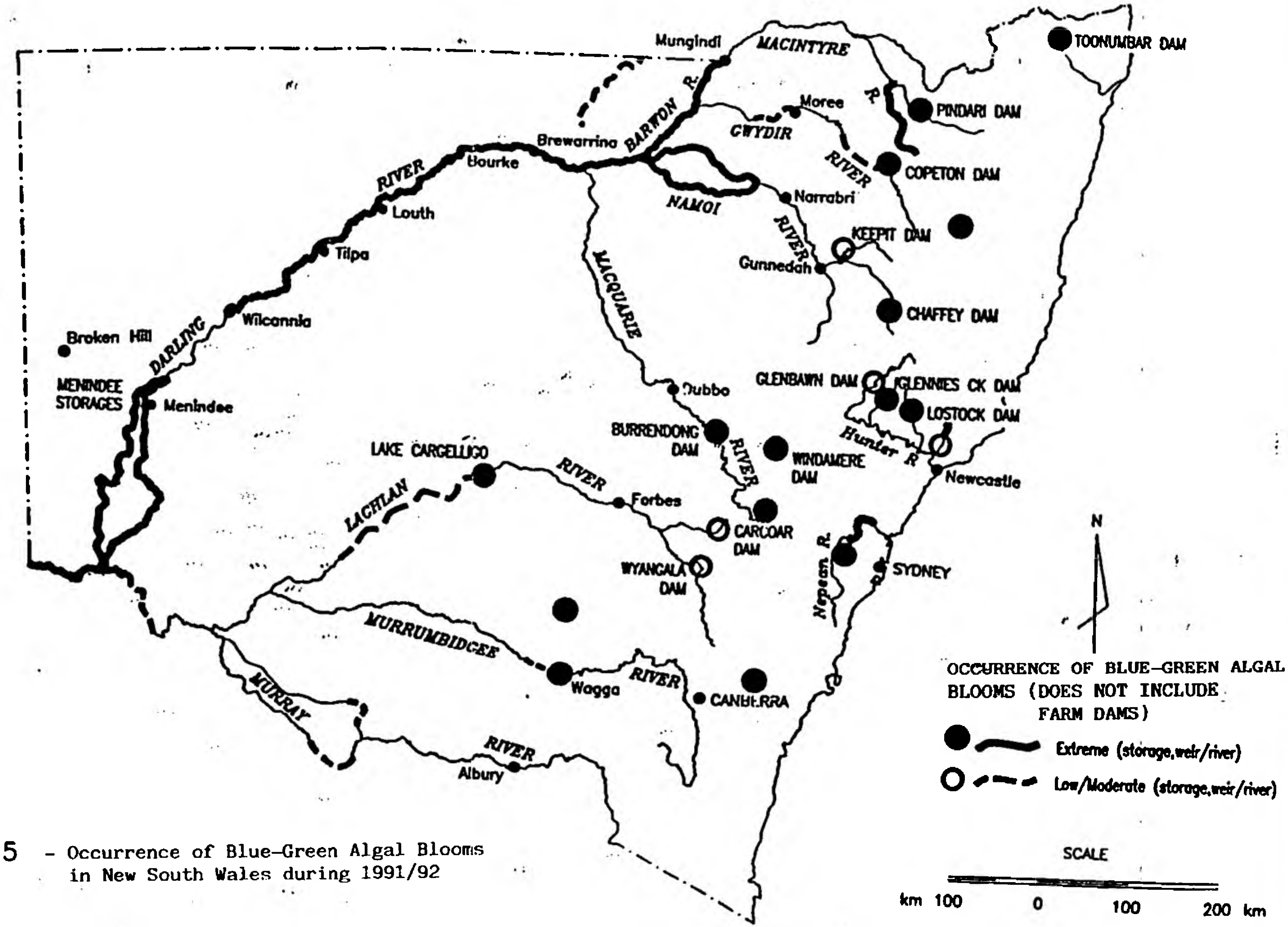


Figure 5 - Occurrence of Blue-Green Algal Blooms in New South Wales during 1991/92

Blooms in Australia - Ian Smalls

Ian Smalls described some of the other problems experienced with blue-green algae in New South Wales. These included problems at Carcoar Reservoir, where blooms had occurred over the past 15 years which were associated with livestock deaths, and with Prospect Reservoir, a storage facility for Sydney's water supply. Prospect Reservoir had been treated with hydroflourosalicilic acid to increase fluoride concentrations in the supply to 1 mg/l. This effectively added 6-8 ug/l total phosphate and increased phosphate concentrations from 6 to 69 ug/l. As a result, a major bloom of Anabaena circinalis occurred in the reservoir in 1969 which led to massive complaints of taste and odour problems with the water supply in Sydney. Mouse toxicity tests at the time showed the bloom to be non-toxic. The only treatment at this reservoir is chlorination.

A considerable amount of work has been carried out on phosphorus budgeting in New South Wales which indicates some major water quality differences compared with the UK situation. These include:-

a Lower point source input of phosphorus
b Higher turbidity
c Greater influence of salinity
d Differences in phosphorus/chlorophyll relationships
e Greater geological diffuse source inputs of phosphorus

Analytical Programmes - Dr. Azim Awad

Dr. Azim manages the Water Resources Department laboratory service and described how they have dealt with a three-fold increase in algal nutrient analyses resulting directly from the problems with blue-green algae.

The Department has one main laboratory in Paramatta, which deals with the majority of the workload. In addition, they have access to other State laboratories for chemical analyses and biological expertise for algal analyses at their Regional sites. Chemical analyses are carried out on a client/contractor service agreement and the laboratory has a LIMS system for data management. The laboratory is also NATA Registered (equivalent to our NAMAS accreditation).

Dr. Azim stressed the importance of interlaboratory quality control.

Biology Services and Sampling Programmes - Lee Bowling

The Department has five biology laboratories and employs 18 staff on work associated with algal sampling and analysis. These staff have an extensive routine monitoring programme on 80 river sites and 19 reservoirs on the western side of the Great Divide. The position of the Great Dividing Range is shown in Figure 6. These mountains are on the east and south east of the Murray-Darling Basin. Rivers on the east side flow to the east coast while those on the west side flow towards Lake Alexandrina, just south of Adelaide.

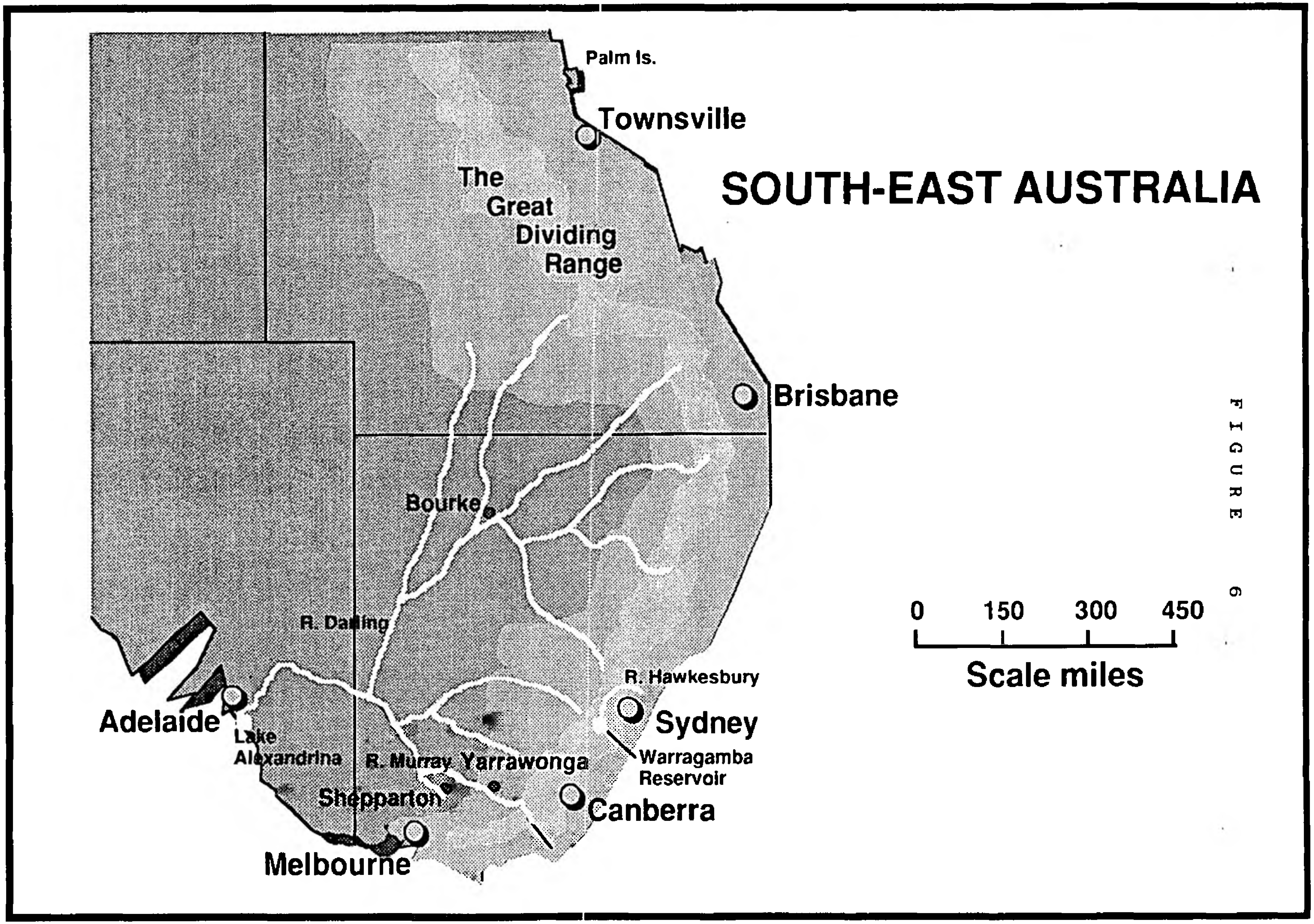

SOUTH-EAST AUSTRALIA
Palm Is.
Townsville
The Great Dividing Range
Brisbane
Bourke
R. Darling
R. Hawkesbury
Sydney
Warragamba Reservoir
Adelaide
Lake Alexandrina
R. Murray
Yarrawonga
Shepparton
Canberra
Melbourne
0 150 300 450
Scale miles

FIGURE 6

Semi-quantitative enumeration of algae, similar to the NRA's, is used to provide alert levels of blue-green algae and full quantitative analysis of algal samples is carried out for trend analysis. Further details of the "Alert Levels" used to manage the problems are given later. In addition to the algal samples, water temperature profiles are measured and water samples are taken for nutrients, pH and conductivity. The sites are visited monthly in winter and weekly or twice-weekly during the summer.

Samples of blue-green algal scums are also regularly taken for mouse toxicity tests. These tests have shown that the toxicity is more variable than in the UK and that most of the blooms are neurotoxic rather than hepatotoxic. The neurotoxins are not all anatoxins and their chemical structure is not known. This has led to differences in the management of their sampling programme and frequency of toxicity testing compared with the NRA.

The Department produces a weekly algal report which includes their own data plus information from a network of other sources of information. These sources include the Water Boards who have their own sampling programmes.

Visit to Hawkesbury River and Warragamba Reservoir

The Sydney Water Board arranged for a helicopter flight over the Prospect Reservoir to the Hawksbury River, and up the river to the Warragamba Reservoir. The location of these sites is shown in Figure 6. The flight terminated at the Warragamba Conference Centre where a seminar was held on blue-green algal problems.

Helicopter Flight

We travelled with three representatives of the Sydney Water Board:-

Derek Cannon	-	Biologist (formerly from the Freshwater Biological Association, Windermere).
Colin Heath	-	Principal Environmental Scientist.
Jay Sticker	-	Natural Resources Manager.

During the flight we initially passed over the Prospect Reservoir which is the main short-term storage reservoir for Sydney. This had been subject to blue-green algal problems which were described earlier by Ian Smalls. The reservoir now has a blanket of benthic Oscillatoria. Water from the main Reservoirs surrounding Sydney, including that from the Warangamba Reservoir, is fed to the Prospect Reservoir. From here water is chlorinated before entering the water supply. A new and more sophisticated treatment plant is planned for Prospect Reservoir.

We also learned that the Board aimed to ensure that no deterioration in the quality of the Hawkesbury River occurred, particularly in relation to nutrients, despite a rapidly increasing population. A number of actions had been taken to achieve this, including nutrient removal from sewage treatment works discharges and proposals to include a dual water supply in new township developments, including one of 30,000 people. The proposals for a dual system for each household include a primary supply for drinking water and kitchen use etc., and a secondary supply of recycled and treated primary supply for toilet flushing.

During our flight up the Hawkesbury River, we passed over a number of small reservoirs affected by blue-green algal blooms and made a closer inspection of two billabongs, near to the river. These had blue-green algal blooms and scums. The billabongs were fed by run-off from an intensive cattle rearing unit.

A number of points relating to algal problems on the Hawkesbury River and the water supply reservoirs were discussed in detail at the Seminar in the afternoon.

Seminar on Blue-Green Algae - Warragamba

The Seminar was chaired by Colin Heath and attended by about 20 Sydney Water Board staff. Presentations were given by Mick Pearson (NRA) and a number of staff from the Sydney Water Board.

<u>The UK Experience - Mick Pearson</u>

Mick Pearson opened the seminar with a talk on the UK experience with blue-green algal blooms. This was followed by a lively discussion on the management of the problem in the UK. Many parallels in the difficulties encountered in both countries were discussed. The main differences related to the Board's concern with toxins and their importance to water supply. These are discussed in more detail later.

<u>Operations and Monitoring - Craig Baragry and Ian Fisher</u>

Craig Baragray gave a description of the Water Board's operations and monitoring related to algal problem. Craig is the Operations Manager responsible for most of Sydney's water supply (3.7 million people).

The Board are increasingly concerned with blue-green algal problems, particularly in relation to toxins in water supply and the threat to water-based recreation. Although they do not generally permit recreation on the main reservoirs, they do own some urban lakes which have public access. In the previous month blue-green algal blooms had developed in Sydney on Botany Marshlands and in Sentinel Park, both of which now have warning notices. There was also a dinoflagellate (red-tide) bloom on the coast. These incidents serve to highlight public concern through newspaper headlines and keep the whole issue in the political arena.

The Board has therefore made every effort to safeguard water supply by developing an integrated strategy. Of primary concern is "the production of toxins".

Ian Fisher described the Board's strategy which was based on a combination of nutrient reduction from STW discharges, monitoring and water resource development planning.

The Board has an extensive routine monitoring programme for all their water supply reservoirs and the Hawkesbury and Georges rivers. The programme is generally monthly or fortnightly, but includes weekly samples at key sites. The determinands routinely measured include:-

pH, DO, DOC, TP (filtered and unfiltered), NO_2, NO_3, NH_4, Silicate, Chl-a, and algal counts.

They also have a "reactive" monitoring programme which is flexible, depending on events at the site: Under these circumstances monitoring may be twice weekly. They normally carry out algal counts and carry out mouse bioassay toxicity tests. Experience has shown that concentrations of algae are worst on their rivers and that about 25% of the blooms are toxic.

In the short-term they have produced a report for the Board and have set up an information phone-line for the Hawkesbury River. The Hawkesbury River is used extensively for recreation, is slow flowing and has a shrimp fishery in the lower section.

The Board has some influence on long-term planning, particularly where new townships are being developed around Sydney.

The overall strategy is to reduce nutrient input from STWs, both in reservoir catchments and to the rivers, and to ensure that no increase in nutrient status of the river occurs, even where populations are increasing. This is to be achieved by reducing the nutrient load to the STW and removing nutrients from the discharges. This was discussed on the helicopter flight (see above).

Research and Development programme - Kieran Horkan, Liza Ashton and Peter Hawkins

The Board has an extensive research programme which was briefly described.

Kieran Horkan is working with Judith Windsor of the University of Technology in Sydney on mathematical models to predict the growth of Anabaena circinalis. Most of this work is based on determining the optimum growth conditions in laboratory based experiments. Initial findings included the determination of an optimum temperature for growth of 25°C, and of death at 38°C.

Liza Ashton has been working on the role of sediments in the control of algae in reservoirs, and the efficacy of destratification for control of nutrient release.

Peter Hawkins described their work on modelling the control of algal biomass in the Hawkesbury River, and on the role of recycling of nutrients from the sediments. He also described their work on analysis of historical records, which included a thirty year data set from Lake Burrongorang.

The Board also have an extensive programme of work to improve their monitoring which includes:-

a Remote sensing,
b The development of fluorescence monitoring,
c Culturing thirty isolates of blue-green algae,
e Toxin detection methods (with CSIRO),
  including - a phosphates enzyme bioassay
  - DNA sequencing (field test kit)
  - fish biomonitors.

Peter Hawkins also outlined their research on control techniques, which includes work on the efficacy of granular activated carbon for removal of toxins at N. Richmond Water Treatment Works and experiments on the use of zooplankton for controlling algae in the Hawkesbury River.

<u>Management and Policy - Colin Heath and Jay Stricker</u>

Colin Heath gave an overview of the Board's management policy which included acting on the recommendations of the New South Wales' Toxic Algae Report, carrying out the necessary monitoring, and planning for nutrient and algal control. He stressed the Board's overall responsibilities for water resource planning which, in this context, included algal control in both water supply reservoirs and in rivers affected by their discharges. He also stressed the need to co-ordinate their efforts with those of others and the need to incorporate nutrient control measures from other sources (mainly agriculture and natural sources) in the Total Catchment Management (TCM) schemes.

Jay Stricker (Natural Resources Manager) looked at the wider aspects of reduction of nutrient input through the control of land management practices. The legislative and regulatory framework is complex and, despite having 43 legislative measures relating to land-use practice, they have not yet been able to control current land-use.

The framework for catchment management is a complex system of committees with regulatory and public membership, ultimately reporting to the New South Wales Cabinet. Rehabilitation of rivers is managed on a Regional basis through a system of TCM Committees. The status of these committees is boosted by the support of the

Prime Minister. The TCM scheme ensures that the people living in the catchment are able to understand the needs and actions necessary for river restoration, and that the plans produced to achieve improvements are implemented. This provides a system for community ownership of the problems and goes much further than the NRA's catchment management planning system, particularly in relation to public consultation.

New South Wales' Algal Co-ordinating Committee

We attended a routine meeting of the New South Wales' Algal Co-ordinating Committee which replaced the New South Wales' Toxic Algae Task Group. There are 15 members of the Committee with representatives from:-

New South Wales' Water Resources Department,
Water Boards,
Chairmen of TCM Committees,
Other State Algal Task Groups,
New South Wales' Health Department,
New South Wales' EPA,
The National Algal R&D Co-ordinator (Phillip Johnstone)

The role of the Committee is one of co-ordinating the actions arising from the recommendations of the Toxic Algae Report and of developing policy for dealing with the short and long-term problems. Regional Committees had also been set up to deal with local problems and were able to make their own policy decisions, if necessary, but the Co-ordinating Committee was seen as the overall source of policy recommendations for the implementation of the State Algal Contingency Plans.

The Committee dealt with a long agenda but the following items were of particular interest.

<u>State Algal Contingency Plans</u>

The legal position regarding liability arising from posting notices about algal blooms was discussed. It was noted that legal precedents had been set and that the notices should be posted. Providing that the wording stated that the water <u>is</u> contaminated rather than <u>maybe</u>, and that the notice was signed by the Regional Algal Co-ordinating Committee, the Council posting the notice would not be liable to legal action. There does not seem to be a parallel to this in UK law.

<u>Current Status of Blooms</u>

Weekly "Bloom" reports are produced by the Committees and compiled by the Water Resources Department. These had shown a decrease in the frequency of blooms in December during rain and an increase in January. It was also noted that there was a major bloom in the Gippsland Lakes in the State of Victoria. This bloom currently covered 40 km^2 of the 400 km^2 lake and was a mixture of <u>Anabaena</u> and <u>Microcystis</u>.

Monitoring and Testing

A discussion of the needs for toxicity testing noted a difference in policy between the UK and Australia. In New South Wales (and other States) there was a policy of testing blooms on a regular basis because:-

i The toxicity of the blooms is less predictable than the UK. There was sufficient evidence from monitoring of blooms in the UK to show that there is a 70% chance of any bloom being toxic. In Australia there was insufficent data to establish patterns in toxicity. For example, all results of toxicity tests on the east side of the Great Dividing Range have been found to be non-toxic.

ii In many cases there are no alternative sources for water supply and activated carbon treatment may not be available.

iii A precautionary approach is taken in relation to the significance of the toxins to drinking water, particularly because some of the toxins are of unknown chemical composition.

Current policy is therefore to test the blooms for toxicity, using mouse bioassay, until the tests are found to be toxic. The frequency of testing is then reduced or stopped altogether.

In view of the different strategy adopted by the NRA, the Committee decided to have a further look at the data. However, it was generally agreed that the difference in strategy between the two countries was related to the differing situations regarding bloom toxicity.

Water Quality Guidelines

Water quality guidelines were currently under investigation but did not yet have any formal status. Other, national initiatives were also noted such as those being formulated by ANZAC (a joint Australia and New Zealand Committee).

Medical guidelines were also being formulated, using risk assessments based on Professor Falconer's experiments with pigs in South Australia (further details of these are given later).

Media Relations

A fact sheet about algal problems had been produced (see Appendix II) and 10,000 copies had been distributed. It was generally felt that media relations were good and that the Regional Committees were coping well.

One of the TCM Chairmen (Alan Sinclair) pointed out the need to increase publicity and to provide a high standard of information. It was agreed to produce a further 10,000 copies of the fact sheet.

Algal Bloom Management

A Catchment Management Model (CMSS) had been produced in collaboration with CSIRO to aid the TCM Committees with decisions about nutrient control options. This has similarities to the NRA's Action plan strategy model (PacGap). The model is very user friendly and operates on a portable PC so that the Water Resources Department can take the model to TCM meetings as an aid to their discussions. Generally, it was felt that this was a very helpful model and a useful part of their strategy. The model is still being updated to deal with new situations and to incorporate new scientific knowledge (eg. to deal with internal nutrient recycling in rivers).

The availability of funds for the State's nutrient control programme was discussed and it was clear that substantial sums of money could be available from National Government by 1993/94 to deal with major problem catchments. Project teams were being set up to target these resources.

It was also noted that the Minister of Natural Resources was keen to progress the Task Group's recommendations relating to the reduction of phosphates in detergents. The Minister had suggested that a list of "preferred" detergent products, identified by the Sydney Water Board, should be made public. The list was based on the Board's own analysis of phosphates in detergents.

Septic Tank Project

A presentation of a project looking at discharges from septic tanks was made by Rod Weiss and Greg Rhodes from the Sydney University of Technology.

The project was looking at discharges in Lake Timolabyne where they estimated that the septic tanks in the catchment were contributing to approximately 200 times the recommended phosphorus load for the lake. They had found that about 50% of the tanks were overflowing and that there was a lack of advice to owners and Councils on how to repair the tanks. There are over 250,000 septic tanks in New South Wales. The project was due to be completed in 1993 and was likely to show that the tanks are a significant source of pollution problems and eutrophication.

Barley Straw

It was noted that, based on the advice given by Pip Barrett of the Aquatic Weeds Research Unit in England and the work of Michael Hindmarsh in Australia, barley straw was being used as a control method for blue-green algae at a number of farm reservoir sites in Australia. It was also noted that barley straw was being specifically grown and pelleted in Victoria for this purpose.

The Committee discussed the evidence for the efficacy of using barley straw as a control option and concluded that more evidence was needed before they could endorse this method: exactly the same conclusion was reached by the NRA Task Group in 1992.

Seminar on UK Experience - Mick Pearson

In the afternoon, Mick Pearson gave a presentation on the UK experience with toxic blooms of blue-green algae. During the following discussion there was particular interest in the development of the field test-kit for Microsystin-LR and our experience of control methods including the use of barley straw.

Meeting with John Millington, Director Water Resources Department

A meeting was held with the Director of the Water Resources Department, Mr Millington, before leaving for Queensland. During this meeting it was agreed that it would be very important to maintain our contacts in the future and to exchange information on developments relating to toxic algae and other water quality problems. It was also thought that the exchange of personnel between the NRA and their Department would continue to be very useful. Peter Whalley from Severn-Trent NRA Region was on a one-year exchange visit at the time of our visit to the Department.

Comments on New South Wales' Visit

Management in the Short-Term

Monitoring

More extensive monitoring programmes than in the UK may reflect the greater extent of the problem and more critical nature of water resources in New South Wales than in the UK.

Differences in the toxicity testing strategy reflect scientific differences in the toxicity of the blooms, nature of the toxins and a precautionary approach to protection of drinking water supplies.

Actions

When blooms are reported a number of actions are taken based on an alert level system outlined in the "State Algal Contingency Plan". The actions are carried out through nine Regional Algal Co-ordinating Committees which report to the State Algal Co-ordinating Committee. The Regional Co-ordinatiing Committees are responsible for ensuring that the monitoring and reporting is carried out in-line with the Contingency Plan's recommendations.

The reporting system recommended that the Contingency Plan is based on a two-tier system:-

a The first level is set at 2,000 cells/ml of known "taste and odour forming" blue-green algal species. At this level, water suppliers may need to consider the use of alternative water supply sources and the use of appropriate processes in water treatment. Repeat sampling and toxicity testing of algal concentrates are also required.

b The second level is set at 15,000 cells/ml of potentially toxic blue-green species. At this level, warnings are given to water users to avoid direct consumption, either by humans or livestock, and to avoid bodily contact. Water users are advised to use alternative sources and to treat contaminated water to remove toxic compounds.

Weekly news sheets are compiled by the Water Resources Department from various sources. Information is supplied freely and openly. There is a network of informed people in the Regions to answer questions from the public and press and a "hotline" is set-up during incidents. As in the UK, notices are posted to warn people to stay away from the blooms and press releases are regularly issued.

Management in the Longer-Term

Management Framework

The Regional Algal Co-ordinating Committees are also responsible for local aspects of managing the problem in the long-term. The legal framework for control of point and diffuse sources of eutrophication is complex.

Point sources are controlled by the Water Boards, Councils, Water Resources Department and the State Environmental Protection Agency.

Diffuse sources are controlled by a complex land management legislative framework and, more recently, by Total Catchment Management (TCM) Committees. The TCM scheme involves a higher degree of public involvement than in the UK and is backed by the Prime Minister. Ownership of catchment problems is taken on by the TCM Committees while the Water Resources Department provides technical and administrative help in the development of catchment management plans.

Apart from the TCM scheme the strategy for long-term resolution of the problems is very similar to that adopted by the NRA. Differences are noticeable in the more rigorous perusal of the Task Force Report recommendations and greater availability of funds. This probably relates to the direct contact between the Minister of Natural Resources and the Water Resources Department and on the greater stress on water resources in Australia.

Scientific Differences

a Phosphate concentrations in lakes and rivers are lower than in lowland Britain. Problems with algal blooms are more frequently found in rivers than in water supply reservoirs, but many small farm reservoirs are also affected.

b Retention times in New South Wales reservoirs are more variable and less predictable than in the UK. Sydney has seven years storage capacity for water supplies. High rainfall events are extreme and unpredictable in their timing.

c Most of the major problems are in rivers which have a relatively high proportion of diffuse (run-off) problems which are associated with agriculture and high proportion of ancient soils of sandstone origin. STW discharges are a less significant source of nutrients, but may be locally important.

d Although Microcystis is a source of toxins Anabaena circinalis is more common and produces neurotoxins, some of which have an unknown chemical structure. The dominance by Anabaena probably relates to the higher N:P ratios found in Australia, particularly in rivers.

e Water temperatures are higher, but water clarity is much lower. The difference in water clarity is related to a high component colloidal material in the run-off from poor (ancient) soils.

3. QUEENSLAND

On arrival in Queensland we were accompanied by :-

Dr. Desmond Connell	- Chairman of the Queensland State Toxic Algae Task Force.
Mr. Colin Hazel	- Co-ordinator of the Queensland State Toxic Algae Task Force.
Dr. Peter Johnstone	- Queensland Water Resources Department.

Introduction

Periodic blue-green algal problems have occurred in Queensland, particularly in reservoirs in the south-east, but have never really posed a serious problem until the summer of 1991/92, when simultaneous blooms in a number of reservoirs resulted in their closure for many months. The closure of the reservoirs denied the community access for recreational uses and in some cases, notably Warwick and Palm island, restricted the availability of domestic water supply.

In response to the public concern, and to address the problem, the Minister for Primary Industries established the Queensland Water Quality Task Force. This Task Force has produced a report on the situation which contains information on toxic algae and recommends a strategy for dealing with the problems in the short and long-term. This has many parallels with both the New South Wales report and the NRA report.

Meeting at James Cook University

A meeting was held at James Cook University in Townsville with Professor Griffiths and Dr Richard Pearson to discuss monitoring for toxic algae. This meeting was also attended by our hosts. Professor Griffiths is a member of the Task Force and has been involved with the problems on Palm Island for some years.

At the meeting we heard about the development of problems with blue-green algae in Queensland with particular reference to the analytical services which the University provides for the Region and their involvement with helping to resolve the problems on Palm Island.

We also heard about a Microcystis bloom which recently had been found to produce neurotoxins.

(COLIN HAZEL WITH MICK PEARSON)

FIGURE 7 - PALM ISLAND - SOLOMAN RESERVOIR BLOOMS AND SCUMS

Visit to Palm Island

Palm Island was originally established as an Aboriginal Reserve in about 1910 and has a current population of about 2,500 people. In the late 1970s the Soloman Reservoir was constructed to create a 490 mega-litre water supply reservoir. The reservoir is the only water source on the Island and originally only had chlorination treatment before supply.

In October 1979 an algal bloom of unknown species was observed in the reservoir which resulted in severe taste and odour problems. Subsequently, the reservoir was treated with copper sulphate to kill the algae. Five days after the treatment the first case of what was subsequently known as "Palm Island Mystery Disease" was reported. By the end of the outbreak 149 people had contracted hepatoenteritis (liver and intestinal problems). Seventy of the people affected, most of whom were children, were evacuated to Townsville General Hospital. A copy of a report on the problems on Palm Island is given in Appendix III.

It is now generally accepted that the "disease" was caused either by direct copper toxicity or by toxins released when the algae were killed.

Since 1979 a number of actions have been taken which include a search for alternative groundwater sources, installation of destratification equipment in the reservoir and construction of a full water treatment plant. The water treatment plant includes slow sand filtration and dosing facilities for powdered activated carbon.

We visited Palm Island with our hosts from the Task Group, John McLeer (Health Inspector from Townsville) and Alan Murdoch (Client Advisory Services Officer for the Water Resources Commission, Ayre.)

Solomon Reservoir is at the bottom of a small entirely forested catchment and contained an extensive bloom of blue-green algae with classic surface scums (Figure 7).

The treatment works was small. One of the sand filters had no water passing through and deposits of blue-green algae and activated carbon were clearly visible on the surface of the sand (Figure 8). The activated carbon was continuously dosed at 2.5 mg/l to reduce taste and odour problems and was increased to 15 mg/l at times of heavy blooms.

After visiting the reservoir, we were invited to take tea with members of the Aboriginal Council who discussed the problems with us.

FIGURE 8 - POWDERED ACTIVATED CARBON AND
MICROCYSTIS ON SAND IN THE PALM ISLAND WATER TREATMENT WORKS

Symposium on Blue-Green Algae, Hotel Cleveland, Townsville

An overview of Blooms in Australia and Queensland - Desmond Connell

Desmond Connell gave an overview of the problems recently experienced in Australia with blue-green algae and estimated that the incidents were currently costing 150 billion dollars.

He also described the situation in Queensland which had led to the formation of the State Water Quality Task Force which had recently produced a report. The contents of this report paralleled those of other State Task Forces, but includes a more detailed series of actions to be taken in relation to the severity of the blooms. The "Alert Levels" are based on algal cell concentrations and require increasingly complex actions dependent on the waterbody. Full details are given in the report (see Appendix VI) but can be summarised as follows:-

Alert Level 1, (500-2,000 cells/ml) early stages of bloom formation; requires full monitoring programme and inspections for scums.

Alert Level 2, (2,000-15,000 cells/ml) established bloom; requires the operators to carry out toxicity tests and to advise Queensland Health Department, so that a risk assessment can be carried out and media releases made.

Alert Level 3, (>15,000 cells/ml) persistent toxic blooms; requires that Level 2 actions are taken, but needs further investigations including alternative supplies to be sought and more detailed press releases including ".. The water is unsuitable for normal household purposes such as drinking, washing and cooking."

The scheme is based on a model developed by the Engineering and Water Supply Department of South Australia, adapted for Queensland conditions.

The Task Force had made it clear that, even if long-term control measures were introduced immediately, it would be a minimum of 5 years before any real benefits were seen. The problem had developed over a very long time and they are only now beginning to realise the full implications of the effects of eutrophication.

The Work of the Queensland Task Force - Colin Hazel.

Historically, Queensland had not experienced algal blooms to the same extent as some of the other States, but recent events had highlighted the need to quantify the nature and extent of the problem in the State and to produce a strategy for short- and long-term measures to deal with the problem.

In much of Queensland, groundwater is used as a primary source of water supply, but survey work carried out in 1990/91 had shown that at least 14 of the 230 reservoirs in the State were affected by blooms. Unlike New South Wales, the rivers did not seem to have been affected. However, this may be due to the fast flowing nature of the coastal rivers in tropical Queensland.

Routine monitoring has not been carried out on most Queensland reservoirs, but the implementation of the report's recommendations should resolve this situation. The Minister has requested a weekly status report which will include a report on the extent of the blooms, the status of water supplies and details of what action is being taken to resolve the problems.

Colin Hazel also described the intention of the State to carry out catchment management studies and to support the needs for research currently being evaluated on a national basis by Phillip Johnstone (on behalf of the National Water Resources Council). The local need for research was mainly into the factors affect blooms in the tropical area of Queensland.

The UK Experiences - Mick Pearson

Mick Pearson gave a presentation on the factors leading to the formation of the NRA Toxic Algae Group and progress being made with the implementation of the Report's recommendations. There was particular interest in the research on modelling blooms and the field test kit for Microsystin-LR

During the discussion at the end of the Seminar there was considerable interest on the efficacy of barley straw as a control method for blue-green algae and on the UK strategy on toxicity. It was concluded that barley straw may be effective, but that the evidence was not conclusive, due to a lack of controlled experiments.

Comment on Queensland Visit

It was clear from our visit that the problems experienced in Queensland were locally important, such as those on Palm Island, but not widespread. It was recognised by the Queensland Government that a strategy for dealing with the problems was needed. A State Water Quality Task Force was established to develop the strategy.

It was also noticeable that the Queensland Task Force had made full reference to the experience gained in the UK, and the other Australian States in the formulation of their strategy and that they had adapted this experience to meet their local needs. The work of the NRA was acknowledged. This highlights the value of good communications on the issue.

Differences found in Queensland included:-

a Most of the problems are in reservoirs, rather than rivers.

b The observation that Microcystis may be producing neurotoxins.

c Problems have been confined to the more temperate areas of Queensland and are infrequent further north in the tropical areas.

4. CANBERRA

Meeting with Professor Cullen

Professor Cullen is based at the University of Canberra Biology Department and has been involved in water quality research for many years. Professor Cullen is also involved with phytoplankton research on a national basis through his membership of the Blue-Green Algal Board of The Australian Water Research Committee. The latter is a Federal State Committee.

Professor Cullen is currently involved with setting up a major research initiative on water quality, particularly related to eutrophication. The programme has four main aspects which are:-

a Water quality monitoring
b Flood plain influences
c Urban runoff (nutrients)
d Eutrophication in rivers.

The programme was due to start in July '93 and is part funded from industry (eg Sydney Water Board).

The University Department has also been heavily involved in the design of stormwater lakes and associated drainage in Canberra. There are parallels with Milton Keynes balancing Lakes in their function. These lakes are eutrophic, but the drainage has been specifically designed to reduce the input of gross solids through a system of wet wells and screens, and to reduce the input of nutrients by extensive use of grass in and around the urban drainage channels. This reduces phosphorus loading to these lakes by 70-80%.

We also met Dr.Richard Morris from Professor Cullen's Department who has been investigating the relationships between phosphorus loads and phytoplankton in Australian lakes. His results indicate that the turbidity in many of the lakes, caused by clay particles, frequently limits phytoplankton growth. Vollanvinder models work well for clear Australian lakes, but underestimate phytoplankton abundance in the turbid lakes.

Meeting at CSIRO

CSIRO is Australia's equivalent organisation to our NERC, has 6000 staff and an annual budget in the order of A$750 million. The organisation has no Statutory responsibilities, but like NERC has been heavily involved with water quality research, particularly on applied problems of national importance.

Seminar on the UK Experiences with Blue-Green Algae - Mick Pearson.

Mick Pearson gave a talk on the UK experiences with emphasis on the research sponsored by the NRA. During the discussion there was considerable interest in the development of the toxin field test-kit, modelling of algal blooms and the fate and behaviour of the toxins. There was also interest in our experience with the development of action plans for controlling blooms and our opinions on the efficacy of barley straw as a control method.

Meeting with the CSIRO Blue-Green Algae Group

Richard Davies, who is project co-ordinator for work on blue-green algae, introduced the members of the group and described the overall responsibilities for research in this area. The group members then gave a summary of their research.

a Ian Webster - based at the Centre of Environmental Mechanics is primarily interested in mixing processes, the coastal zones programme and exchange processes between sediments and water. His current project is on algal blooms in rivers, particularly the River Murrumbidgee where he is working on control options for blue-green algae in weir pools. The pools are used for drinking water supply and, with a 90% water loss, flushing the pools during blooms is not an option. The project is currently looking at the effects of stratification and mixing and of light adsorption as controlling influences on the phytoplankton. The aim is to model the influence of these factors with a view to using artificial mixing as a control mechanism in the weir pools. They are also looking at the influence of wind on sheer stresses in the surface layers using wind tunnel experiments.

b Graham Skying - a Microbiologist whose principle interests are in the role of microbial processes in sediments and the development of automatic monitoring systems, particularly in relation to algal monitoring. CSIRO have six contracts for the development of automatic monitoring systems, including one on the use of an electrochemical system for soluble reactive phosphorus monitoring on unfiltered samples. Remote systems for monitoring in Australia are extremely important due to the scale of the river systems. Communication between the monitoring stations and base is by satellite.

c Graham Harris - Algologist currently working for the National Space organisation on remote sensing.

d Robert Gerritise - is working on the effects of nutrients on algal growth in the Swan River in the Perth area in Western Australia.

e Garry Jones - is working on the fate and behaviour of algal toxins with interests in biodegredation, food chain bio-accummulation and the genetic control of toxin production. Dr. Jones gave a brief presentation of his work on biodegredation of the toxins, using HPLC and phoshatase inhibition methods of analysis of lake samples. He also reported on his tank experiments on biomanipulation of blue-green algae using Daphnia carinata (6mm) and Gambusia affins (mosquito fish). He has also been working on the identification and characterisation of some Anabaena neurotoxins which are not anatoxin-a.

f Andrew Murray - specialises in work on sediment origin and transport and is involved with the use of radio tracers to determine the origin of phosphorus inputs to the Murrumbidgee River.

g Terry Donnelly - is a Goechemist who is currently carrying out a three year study of sediment phosphorus release in the Darling River.

h Richard Davies - also described their involvement in the production of an expert system for identifying control options. This computer based system is currently being used to aid the TCM Committees in the choice of their options for catchment management described earlier.

i Discussion - The presentations were followed by a general discussion on research needs into the significance and control of blue-green algae: many of which are common to our own. It was concluded that the apparent overlap in some aspects, such as on the modelling, was necessary to account for differences in climate and scale, but that there was an obvious need to continue to exchange information and experiences. One area of work discussed was the significance of the recent UK findings of neurotoxins in matts of benthic Oscillatoria.

Meeting at the Murray-Darling Basin Commission

A meeting was held at the Commission Offices in the centre of Canberra. Present at the meeting were:-

Dr. A. Landrig	- Head of the Commission
Martin Shafron	- Murray-Darling Basin Commission
David Lambert	- Dept. Primary Industries
Craig Bradley	- Dept. Primary Industries

Dr. Landrig described the history of the Commission and their involvement with blue-green algal problems. The catchment is vast and has major uses, not least of which is Adelaide's water supply which is drawn from the lower end of the river. Cross boarder needs were recognised as early as the Federal split in 1902. In 1917, the Murray Commission was set up to agree minimum water allocation and no problems were experienced for 70 years.

Increases in the use of the water for irrigation, and subsequent problems associated with rising water tables and salinity, led to the establishment of the Murray-Darling Ministerial Council in 1985. This made a complete study of the natural resources in the basin and recommended that the Murray-Darling Basin Commission should be set up to control the management of the river basin.

The Commission was set up in 1987 and has a Board of senior public servants and representatives from each State. The Board is Chaired by the President and reports to the Council of Ministers. As such, the Commission is an executive arm of the Council.

The Commission has a number of roles relating to the management of natural resources and has a controlling influence on improvement works in the catchment through it's management of development budgets (ca. A$50 million). The Commonwealth is an equal partner in the Commission with the Federal States (Victoria, New South Wales, South Australia and Queensland) and relationships between these partners are generally good. Any legislative measures resulting from the work of the Commission are lodged in all the State Parliaments (eg. relating to the reduction in salt load to the river resulting from irrigation).

Dr. Landrig then described the Commissions involvement in co-ordinating work on the reduction of problems associated with blue-green algae. This has largely been administrative and operates through the Australian Water Resources Council's Algal Management Strategy Group, which is preparing strategies for dealing with the problem on a national basis and co-ordinating the work of the individual State Algal Co-ordinating Committees and Task Groups. The Commission is particularly keen to influence land-use practices in their overall strategy for eutrophication control and would like to see wider use of the TCM system to provide for "community ownership" of the problems.

Martin Shafron then went on to describe the development of the Algal Management Strategy which is primarily aimed at managing the blooms through a combination of control of nutrient inputs and flow management. They have identified the point sources, which took two years to complete and publish (Nutrient Pollution document 1992). They are currently working on the identification of diffuse sources. Altogether, the Strategy Group has set up 14 Advisory groups to report to the Commission on various aspects of the overall problem with blue-green algae and eutrophication.

Craig Bradley - from the Department of Primary Industries briefly described their role in providing independent overview of water quality problems. They have specifically been involved with the development of water quality standards on a national basis.

Comment on the Visit to Canberra

The visit to Canberra University and the CSIRO was particularly important because it provided a complete overview of the recent research programmes which have been carried out in Australia relating to eutrophication and blue-green algae. Australia is currently spending large sums of money on understanding the nature and extent of problems associated with blue-green algae, eutrophication control and on monitoring. Although the results may not be directly applicable to the UK situation, there is a clear need for us to keep in touch with the findings of this research.

The role of the Murray-Darling Basin Commission is seen to be very important in influencing the implementation of national strategies for dealing with the blue-green algal problems. This is not simply a question of monitory control, but also political influence.

5. VICTORIA

Our host in Victoria was Dr. Phillip Johnstone who is currently seconded from the Victoria State Department of Conservation and Natural Resources to the Australian Water Resources Council as National Project Manager for Algal Bloom Research. Dr Johnstone's first task has been to produce a report on current research activities on blue-green algae in Australia and to identify the key issues. Dr Johnstone took us on an extensive tour of Victoria to visit a number of interesting sites.

Site Visits in Victoria

Melbourne's Water Supply Reservoirs

On the south side of the Great Dividing Range in Victoria the reservoirs are primarily used for water supply. Most of the catchments of these reservoirs are well protected with little or no farming or recreational activities. They are mostly forested and Crown owned, but managed by the Melbourne Water Supply and Sewerage Corporation. These reservoirs have generally not experienced major algal problems and use destratification to protect the quality of the resource. Melbourne has a high standard of drinking water quality, but many of the other water supply catchments in Victoria do not have the same protection.

We were taken to the Sugarloaf Reservoir as an example of one of the water supply reservoirs. This is one of a series of reservoirs which form the Lower Yarra Development. There are no recreational activities on the reservoir and public access is restricted to the reservoir dam and an information centre. The reservoir contains destratification equipment and the treatment works is relatively sophisticated with alum pre-treatment, slow sand filters and chlorination.

Irrigation Reservoirs

On the North side of the Great Dividing Range, the water flows north and west towards the Murray River (see Figure 6.) On the plains below the mountains there is a vast area of land used for cattle rearing and horticulture which is supported by irrigation. This irrigation is controlled by a complex series of reservoirs and irrigation channels. Most of the reservoirs are situated on the edge of the mountain range, but there are additional reservoirs on the plains. Water from the reservoirs and drainage channels is slowly fed by gravity across fields and through the groves of fruit trees.

The persistent use of irrigation has raised the water table over much of the plain. This results in the salts, which have been accummulated at lower levels, rising to the surface soils. The clearest evidence for this is the damage to fruit trees. There are many examples of this in other parts of Australia and in other countries (eg California in the USA).

The first of the major irrigation reservoirs visited was Lake Eildin which is in the foothills of the mountains and has an irregular shape approximately 20km wide. This reservoir has a secondary role in water supply, is used for recreation and suffers from occasional blooms.

The next part of our tour of Victoria was devoted to a flight in a light aircraft over lake Mokoan and the plains to the Murray River and Yarrawanga weir pool. We were joined by Julie Harrison and Andrew Schalken from the Rural Water Commission of Victoria for this part of our tour. Julie Harrison has been studying the water quality of Lake Mokoan since 1989.

Lake Mokoan is a large shallow irrigation reservoir 8,000 ha. in area and was built by constructing a 7.5m earth dam around a swamp area in 1973. This swamp contained a large stand of Redgum trees prior to construction, so that there is now an extensive area of drowned trees in the lake. Initially, the lake remained clear and supported a diverse range of macrophytes but, following an earlier drought and drying of the lake, the reservoir is now turbid and suffers from extensive blooms of Microcystis aeruginosa. During the blooms the lake has been closed to recreation for extensive periods and sheep, grazing on the reservoir margins, have been killed due to ingestion of blue-green algae. In 1991 "about 50 sheep died". Further details of a study of water quality in this reservoir are given in Appendix IV.

After flying over Lake Mokoan we travelled down the Broken River to the town of Shepparton. On arrival at Shepparton and the neighbouring town of Mooroopna, we flew over extensive tertiary sewage treatment lagoons (Figure 9). Most of these lagoons contained dense blooms of blue-green algae. Trials for controlling the blooms with barley straw were being carried out in three of the lagoons, but the degree of success of these trials was not known by our hosts.

During the flight from Shepparton to the Murray River we could clearly see the complex series of large drainage channels and field ditches used to irrigate fields as described above (Figure 10). In this area there was grazing pasture with approximately 600 cows per ha. and vast acreages of fruit trees as far as the eye could see from the aircraft. The damage to the fruit trees, caused by the rising water table and salt, was visible from the air.

On arrival at the Murray river we travelled approximately 5km up river to the Yarrawanga weir pool. The river was turbid but, owing to heavy rains in December 1992 and increased flow, did not contain blooms of algae. The Yarrawanga weir pool was approximately 3 km long and a maximum of 800 m wide. This pool is used for irrigation, water supply and recreation and, like many of the other weir pools, suffers periodically from intense blooms of blue-green algae.

FIGURE 9 - SEWAGE TREATMENT LAGOONS
AT SHEPPARTON WITH BLUE-GREEN ALGAL BLOOMS

FIGURE 10 - LAKE MOKOAN -
IRRIGATION CHANNELS AND IRRIGATED LAND IN NORTH VICTORIA

FIGURE 11 - SMALL LAKE BESIDE LAKE MOKOAN ILLUSTRATING THE FORMER CONDITION OF THE LAKE (ABOVE)

LAKE MOKOAN SHORELINE TODAY

FIGURE 12 - SHORELINE SCUM ON LAKE MOKOAN

Following our return to the airport we were driven down the side of lake Mokoan to a small lake on the north-east side of the dam. This lake was about half an acre, was clear and contained a diverse community of macrophytes (Figure 11). Julie Harrison explained that this illustrated the original condition of Lake Mokoan and acted as a reference and target for the restoration programme for the main lake. The restoration programme is currently being developed by setting up a management committee on similar lines to the Total Catchment Management schemes in New South Wales.

After visiting the small lake we travelled to the shore of the main lake. The water was very turbid and contained a bloom of Microcystis which was accumulating in a classic shore-line scum (Figure 12). A combination of the turbidity of the lake water and buoyancy of the algae leads to a competitive advantage for blue-green algae, so a reduction in the turbidity of the lake is a key issue in the restoration programme.

Meetings at the Rural Water Corporation, Armadale, Melbourne.

In the morning, a meeting was held with members of the Rural Water Corporation. The meeting had been organised by David Heeps, who is the Chairman of the Blue-green Algal Project Team, and our host was Warren Wealands who was from the Water Resources Division of the Department of Water Resources of Victoria.

<u>Warren Wealands</u>

Warren Wealands described the structure of water resource management in the State of Victoria and the membership and terms of reference of the Victoria Blue-green Algae Project Team. The team structure and means of determining the nature and extent of the blooms was similar to that found in New South Wales and Queensland, and details of the their arrangements for managing the problem in the short and long-term paralleled those of the other States. Victoria had experienced blooms which were equally serious to those of the other States, such as on the Murray River in Lake Mokoan. The Gippsland lakes were highlighted (see Figure 13). During our visit to the State, details of a massive 40 km^2 bloom on the Gippsland Lakes were coming through and, although we were unable to visit this site a sample of the bloom had been brought to the meeting.

As a result of the blooms experienced over the past few years and the worsening situation in 1991/92 when over 40 major blooms were reported in Victoria, the Minister of Water Resources reviewed contigency planning arrangements. Following this review, he asked for a system for co-ordinating the actions of the relevant organisations to be set up, emergency plans to be fully defined and that all sewage disposal authorities take action to improve discharge quality to minimise blue-green algal problems, wherever practicable.

Gippsland Lakes Catchment.

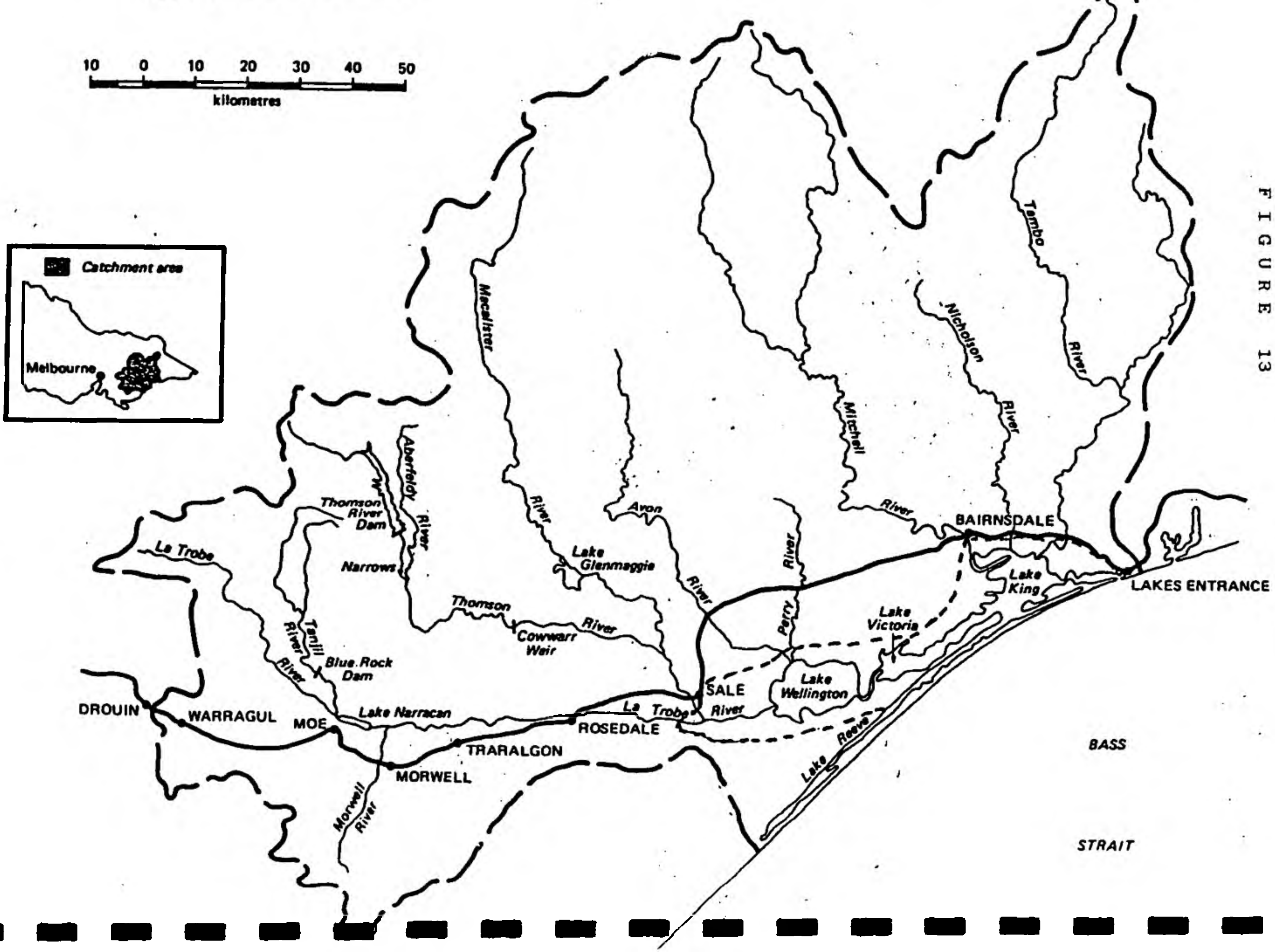


FIGURE 13

Ken Fung - State Water Laboratory

The State Water Laboratory is producing a monitoring protocol for blue-green blooms which includes biological, chemical and physical parameters in lakes, rivers and estuaries. They have also set up workshops and training seminars to introduce the protocol which will be reviewed after one year's operation. In addition to this they are also co-ordinating the introduction of a national proficiency testing scheme. This includes interlaboratory calibration of 20 participating laboratories in the State and the introduction of Analytical Quality Control schemes.

Kevin O'Halloran

Lance Creek reservoir is a eutrophic pumped storage reservoir which is used for public water supply. In 1990, the reservoir developed a dense bloom of toxic Anabaena which was sufficiently serious to shut down the water supply and use alternative sources. There was a great deal of media and public interest in the problem which paralleled experiences in the UK and other parts of Australia.

The blooms have occurred each year since 1990 and are controlled by using copper sulphate. Monitoring is carried out weekly until the blooms develop and then daily during the blooms. Copper sulphate is used when the bloom reaches 5,000-10,000 cells/ml. In December 1992, the bloom was a mixture of Anabaena, Microcystis and Oscillatoria and was treated with 4 Tonnes of copper sulphate which reduced the numbers of blue-green algal cells at the outlet from 20,000 cells/ml to zero within one day. The scum found on the reservoir margin prior to dosing was shown to be toxic by mouse bioassay.

Monash University has been carrying out a study of the nutrient balance in the catchment which is being used to develop a plan to reduce the algal blooms. This was described by the next speaker.

Barry Hart

Research is currently being carried out in collaboration with Monash University on algal control in the Lance Creek /Candowie system. This includes a study of internal nutrient loading by phosphorus exchange between sediments and water under anoxic conditions in the laboratory, and on external loads from the catchment. The external loading has been extensively studied and control measures are being discussed with farmers in the catchment. These include reducing the input from intensive beef rearing operations and dairy sheds by treating the effluent, and through more efficient fertiliser applications. Additional control measures include the construction of wetlands and a study of the efficacy of destratification.

David Robinson

A working group has been set up by the Blue-green Algal Project Team to produce a number of technical reports to assist with the short and long-term management of the problem. In the long-term they are looking at Regional plans which are catchment based and include local groups in the planning process. Like other States, the community participation in the planning process is a high priority.

The Technical reports include an algal status report, resource description reports and a strategy document. The proposed working method of long-term management of the blooms will be project based and similar to the NRA "action plan" approach. When the documentation is complete there will be a two month consultation process prior to submission to Government.

Garry Bennison

An investigation into the history of problems experienced with blue-green algal blooms in Victoria showed that they were widespread throughout the State, but the information was scattered. Problems were experienced by recreational users, but until recently they had not been properly assessed. Copper sulphate has been widely used as a control method, but long-term measures using nutrient control were now being considered on a catchment management basis.

Phil Jeffrey

Under the 1958 Health Act, Regulations for water quality standards for drinking water had been made.These are based on the WHO guidelines in rural areas and on the 1987 Australian Guidelines for Melbourne. The double standards were necessary because of the difficulties of meeting the more stringent Australian Guidelines in isolated areas where full water treatment was not practical.

The water supply guidelines do not include standards for algal toxins currently, but they have started to use the Australian Water Resources Commission "Alert Levels" system for use at the take-off point to water supply reservoirs. These guidelines have been developed in South Australia by Mike Burch and Professor Falconer and are fully described in Appendix VI. At Level 3 of this system (blooms greater than 15,000 cells/ml) activated carbon treatment of the water supply is recommended and weekly toxicity testing is carried out.

Dr Jeffrey also described their work to find quantitative analytical techniques for the toxins to replace the mouse bioassay, and work being carried out on the biodegredation and stability of the toxins, all of which would be used to refine the measures taken to ensure the safety of water supplies and recreational facilities.

Kevin Love

The Agriculture Department was principally interested in animal health problems associated with blue-green algae. These were most acute in areas where relatively small reservoirs were used for livestock watering and irrigation. They had received a number of reports of photosensitisation of cattle associated with liver damage which may have been caused by drinking water containing algal toxins. The photosensitisation results in severe skin problems in the cattle. In order to combat the problem at farm level the Department has produced an algal test-kit which includes a free algal identification service and advice on the control of blooms. This advice includes the use of barley straw as a control option, but does not recommend the use of copper sulphate. Many farms have a very restricted water supply for their livestock so the use of copper sulphate could potentially cause toxicity problems to livestock from the resultant dissolved copper residue, particularly if it is used on a regular basis.

Agricultural research and development into the management of the problems associated with blue-green algae ranges from molecular biology to farm management. Research at the molecular biology level is currently being carried out on analytical methods for toxins, the development of ELISA immunoassay tests for toxins and on the effects of the toxins on wildlife.

Research at the farm level is based on improving sustainable land management and includes project work on dairy shed management, improvements in catchment management (soil erosion and fertiliser use). This work is being used to improve the guidance on landcare provided for farmers. The Landcare Programme is a major State initiative and is based on the development of Regional Land Care Action Plans. The water quality aspects include measures to reduce eutrophication problems and guidance on this aspect will be given in a publication called "Best Management Practice for the Control of Nutrient run-off". This is a voluntary Code and is currently in draft form.

Ian Smith

The Gippsland Lakes are the largest inland waterway in Australia and are 400 km^2 in area with a 20,000 km^2 catchment. The catchment is partly alpine and contains intensive industry (Figure. 13). The lakes are used extensively for recreation and have a top class fishery in the estuary which has an annual catch of about 700 tons.

In 1988 a bloom of Anabaena and Nodulaira covered the whole lake. This resulted in a number businesses associated with recreation on the lakes, going bankrupt. The value of the fishery has also been reduced by about 50% as a result of the blooms.

Since the major problems experienced in 1988, a management plan has been drawn up by the relevant Government Agencies to reduce the nutrient input to the lakes. About 35% of this plan has so far been implemented but, as stated earlier, blooms still occur.

Lance Lloyd

Lake Mokoan has had severe blooms of blue-green algae since 1987. We had visited the lake on the previous day and details of the problems are described above. Lance Lloyd concentrated on a description of the production of a strategy for the restoration of the lake, particularly in relation to setting up a Community Working Group to help with developing and implementing the strategy. The Working Group has 20 members and meets on a monthly basis.

Seminar on UK Experience - Mick Pearson

The seminar was held in the main lecture theatre at the Rural Water Corporation's offices in Armadale. The seminar was introduced by Mike Anderson who was the acting General Manager of the Water Resources Division of the Department of Conservation and Natural Resources of Victoria. Mr Anderson described the importance the State attaches to the problem of blue-green algae and the need to develop contingency plans for dealing with the problem in the short and long-term. He then welcomed the participants to the seminar.

Warren Wealands then introduced Mick Pearson who gave a talk on the experiences with blue-green algal problems in the UK. In the discussion which followed the talk, most of the questions were centred on the development of control strategies, including the use of algicides, destratification and barley straw, cost benefit analysis of eutrophication control, water quality standards and quality assurance for analysis of blue-green algal samples.

Barley straw is being used in farm irrigation and livestock watering reservoirs for controlling blue-green algal blooms with varying degrees of success. It was pointed out that in many cases these reservoirs were the only water source for livestock watering and that it was considered to be a significant problem. In some instances light induced skin sensitivity had developed in cattle drinking from bloom affected waters, which was associated with liver damage in the cattle.

Comment on the Visit to Victoria

Blue-green algal problems in Victorian lakes and reservoirs are as widespread and severe as those in other States and following major out breaks in 1991/2 major initiatives to resolve the problems were taken by the Government. This included a complete review of contingency planning and the development of long-term strategies for reducing the frequency of the blooms.

The management framework for dealing with the blooms was similar to that found in the other States. This included :-

- setting up an Algal Project Team
- the development of co-ordinated monitoring programmes for bloom identification
- routine use of toxicity testing
- production of publicity material
- the use of copper sulphate, de-stratification and barley straw for controlling blooms in the short term
- extensive research programmes
- production of technical reports on the problem
- catchment management planning involving the community in the decision making processes.

6. SOUTH AUSTRALIA

Our main hosts in South Australia were Dr Dennis Steffensen and Mike Burch from the Engineering and Water Supply Department.

Meeting at the Engineering and Water Supply Department's Water Supply Contingency Planning Committee

The Water Supply Contingency Planning Committee has 20 Members. The membership includes scientists, water supply engineers and a representative from the Murray-Darling Basin Commission.The Committee deals with all emergency arrangements including those associated with blue-green algae. A copy of the Agenda for the meeting is given in Appendix V. which includes a list of members.

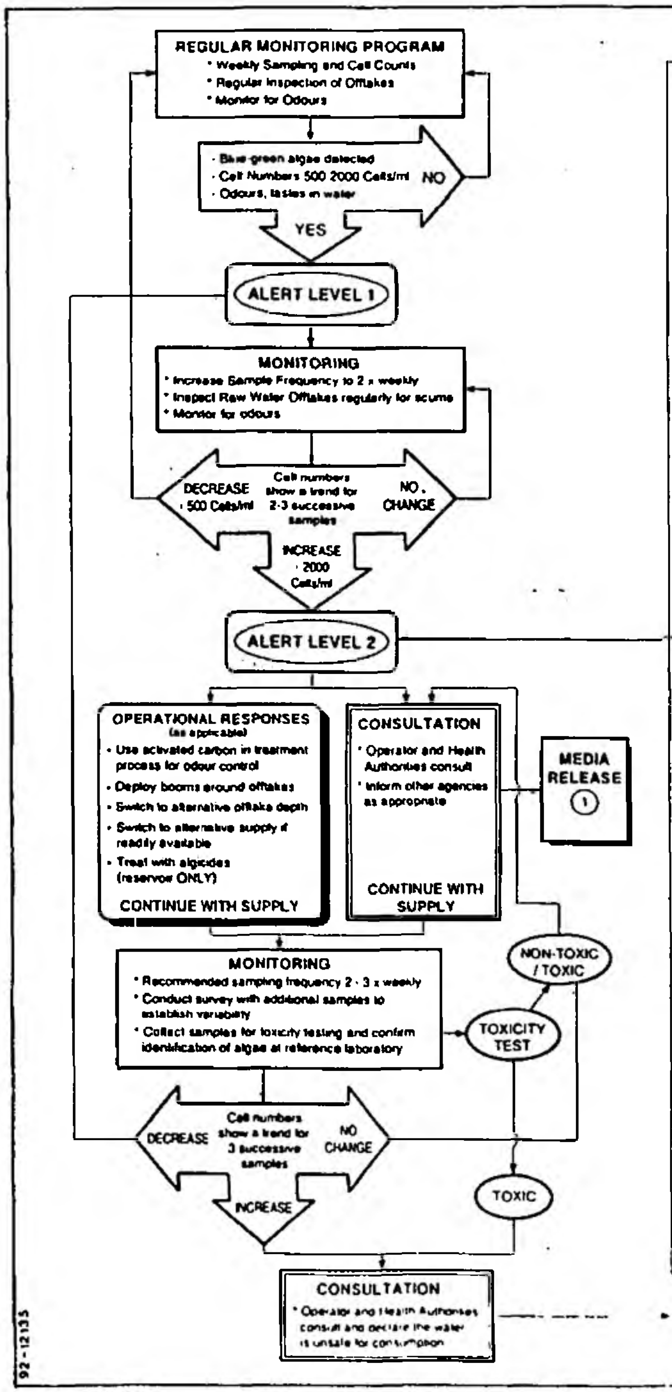
An update on problems with blue-green algae in South Australia was given by Dr Steffensen. Following heavy rain in some parts of the Murray-Darling catchment in December 1992, there were only sporadic reports of blooms in the Murray river. Blooms were occurring at a number of lakes and problems at Jane Elisa Marina were highlighted. In most cases Anabaena circinalis had been the dominant species in the blooms and, despite being toxic for the past two years, were not toxic this year.

Dr. Steffensen also gave an update on progress with research projects which include increasing interaction with scientists working for CSIRO and Health Department and on water treatment with Lyonase d'Eau. Recent work includes efforts to identify the neurotoxins produced by Anabaena and on the effects of chlorine dosing on microcystin and nodularin.

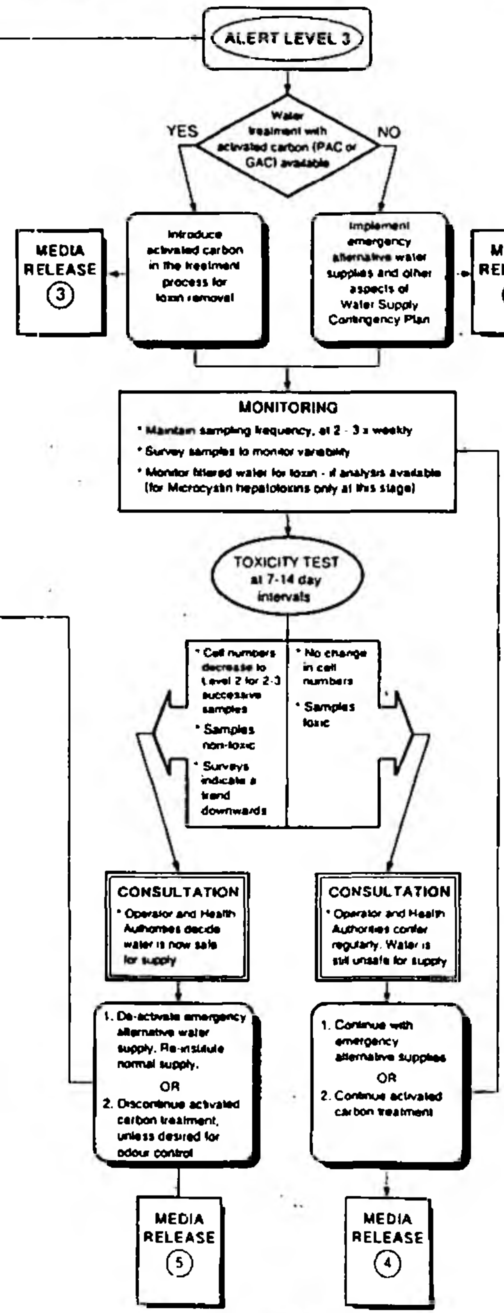
Professor Codd, who was visiting South Australia at the same time as us, gave an update on the situation in Scotland which included a description of the recent problems at Loch Leven.

Mike Burch from the Engineering and Water Supply Department had produced a discussion paper on contingency planning which is based on a three level "Alert Levels" System. This is summarised in Figure 14. We had seen the details of the Alert levels in Queensland and Victoria both of which had adopted the scheme.

Mr Burch gave details of the scheme, which includes provisional drinking water standards for microsystin toxins and blue-green algae cell counts. In the development of these standards, they had adopted the American EPA risk analysis for determining the standard for Microcystin-LR, using data on mammalian toxicity. The toxicity data included work carried out by Professor Falconer of Adelaide University using pigs.



REGULAR MONITORING PROGRAM
* Weekly Sampling and Cell Counts
* Regular Inspection of Offtakes
* Monitor for Odours
- Blue-green algae detected
- Cell Numbers 500 2000 Cells/ml
- Odours, tastes in water
NO
YES
ALERT LEVEL 1
MONITORING
* Increase Sample Frequency to 2 x weekly
* Inspect Raw Water Offtakes regularly for scums
* Monitor for odours
DECREASE
500 Cells/ml
Cell numbers show a trend for 2-3 successive samples
NO CHANGE
INCREASE
2000 Cells/ml
ALERT LEVEL 2
OPERATIONAL RESPONSES
(as applicable)
- Use activated carbon in treatment process for odour control
- Deploy booms around offtakes
- Switch to alternative offtake depth
- Switch to alternative supply if readily available
- Treat with algicides (reservoir ONLY)
CONTINUE WITH SUPPLY
CONSULTATION
* Operator and Health Authorities consult
* Inform other agencies as appropriate
CONTINUE WITH SUPPLY
MEDIA RELEASE
1
MONITORING
* Recommended sampling frequency 2 - 3 x weekly
* Conduct survey with additional samples to establish variability
* Collect samples for toxicity testing and confirm identification of algae at reference laboratory
TOXICITY TEST
NON-TOXIC / TOXIC
TOXIC
DECREASE
Cell numbers show a trend for 3 successive samples
NO CHANGE
INCREASE
CONSULTATION
* Operator and Health Authorities consult and declare the water is unsafe for consumption
92-12135



BLUE - GREEN ALGAL BLOOMS - AN ALERT LEVELS FRAMEWORK FOR WATER SUPPLY CONTINGENCY PLANS

NOTE:

The threshold definitions include a general description followed by specific criteria. These criteria are meant to be indicative at Levels 1 and 2, ie. they don't all have to be met. The criteria at Level 3 are prescriptive - and will all be met with a severe toxic bloom.

ALERT LEVELS - THRESHOLD DEFINITIONS

ALERT LEVEL 1

Initial detection or early warning of an impending bloom.

EITHER • Cell numbers 500 - 2000 Cells/mL (if routine monitoring is in place)

OR • Offensive odours / tastes in supply

ALERT LEVEL 2

Confirmation of an established bloom which is causing water quality problems. Bloom has potential to escalate. Operational intervention is recommended.

- Cell numbers 2000 - 15000 Cells/mL (potentially toxic species) for 2 - 3 successive samples
- Bloom is confirmed as one of the potentially toxic species, ie. *Microcystis aeruginosa*, *Anabaena circinalis*, *Nodularia spumigena*, *Cylindrospermopsis raciborskii*
- Persistent odours / tastes
- Surface scums / localised high concentrations becoming apparent

ALERT LEVEL 3

Well established toxic bloom. Assessment by the Health Authorities indicates the water may be unsafe and is unacceptable for supply without treatment to remove toxins.

- Persistently high numbers widespread throughout source water for three successive samples
- Toxic
- Cell numbers > minimum acceptable for safe supply (assessment required)
  Provisional cell numbers > 15000 Cells/mL for most toxic *Microcystis aeruginosa*
  Slightly higher for *A. circinalis*, *N. spumigena*
- Persistent surface scums
- Control measures partially or not successful in preventing the bloom from contaminating water supply offtake point

FIGURE 14

As a result of this work, they are recommending a provisional drinking water standard of 1 ug/l. of Microcystin. The drinking water cell count provisional standard of 15,000 cells/ml of Microcystis, is also based on the EPA methodology using an intraperitoneal dose of 5mg algae/kg mouse. Although the data are based on microcystin toxins the absence of toxicological data for other species of algae or toxins has led to the use of these standards for all blue-green algae in the "Alert Levels" system. Decisions on the safety of water supplies are subsequently based on toxicity tests on a case by case basis.

Klaus Schonfeldt then gave a description of the work of the National Blue-Green Algae Task Force which had been set up by the National Water Resources Council (We were aware of much of the information given from our visit to Canberra). The main aim of the Task Force has been to set a framework for dealing with both technical and strategic aspects of bloom management. In order to achieve this they had set up Technical Advisory Groups, reviewed monitoring programmes and increased public awareness. One of the main problems which they have to tackle is the over allocation of water in the Murray River. In order to resolve this they are looking at target flows with catchment communities and are providing A$1.5m for an investigation into flow management in the river. Mr Shonfeldt also described research programmes sponsored by the Task Group which include work on biodegredation of the toxins, skin irritation by the toxins and on identification of phosphorus sources.

Meeting at University of Adelaide

A meeting with Dr Goerge Ganf of the Botany Department of the University of Adelaide and Mr Robert Oliver, from the Murray Darling Freshwater Research Centre at Albany in South Australia, was held at the University. The discussion centred around the factors affecting bloom population dynamics in Australian waters and contrasts with the UK situation.

Dr Ganf has been working mainly on the effects of algal control techniques, including Barley Straw and copper, on macrophyte communities and the longer term consequences of these to lake ecology. Robert Oliver is currently working with Dr Ganf on the use of flow cytometry for algal population estimates. The technique is particularly useful in turbid water, which is a common feature of Australian waters, because the flow cytometer is used to separate out the algal cells into species groups from other particles in the water. They are also working on the use of fluorescence to examine cell pigment suites in Oscillatoria species. This is being used to distinguish species populations.

Meeting with South Australian Health Commission

Later in the afternoon we met with four members of the Health Commission. Present at the meeting were:-

Dr. Ossama-El-Saadi	- Epidemiology Registrar
Dr. Les Trosemicts	- Biochemist
Dr. Scott Cameron	- Communicable Diseases Specialist
Dr. Robert Ressom	- Toxicologist

The Health Commission had been heavily involved in the bloom emergency incidents on the Murray River. During the incident most of the problems encountered were with the drinking water. Many of the towns abstract water for public supply and in many cases the water is only chlorinated before going into the supply system. A survey carried out during the bloom events has shown that patients suffered from gastrointestinal problems, rashes and mouth blisters and concluded that a much broader survey of water use along the Murray River was necessary.

In addition to the problems associated with direct abstraction to towns on the river, the Commission were also investigating the significance of the problems to Adelaide's water supply. During the summer, 1.1m of the total population of 1.4m in Adelade receive water from the Murray River via long pipelines and a series of reservoirs (Yarra complex). During the events in 1992 the Commission and Water Board had received a number of unsolicited complaints from people in Adelade which could have been associated with the algae, and from water skiers who had suffered from rashes.

The Commission were concerned about the lack of proper epidemiological studies and felt that there was insufficient information on the medical significance of the toxins. They were waiting with interest to receive the results of Professor Falconer's tissue analysis from the pig experiments which were being carried out at the time of our visit. These pigs had been given Microcystis laden water (from Lake Mokoan) to drink for three months.

They had concluded that a precautionary approach should be taken and were advising the public not to drink water affected by the blooms. The Commission have powers to close waters on health related grounds, but had not apparently used these powers because they relied on close co-operation with the Engineering and Water Supply Department with whom they had developed the contigency plans associated with the "Alert Levels" system.

Information on the advice given by the SA Health Commission is shown in copies of the publicity leaflets in Appendices VII and VIII.

Seminar on the UK Experience - Mick Pearson

Mick Pearson gave a talk on the UK experiences with blue-green algal blooms at the Engineering and Water Supply Department's State Water Laboratory. The talk was attended by approximately 70 people from many of South Australian's Government Departments, research organisations and the university. During the discussion which followed, the main topics were barley straw, the use of copper sulphate and the development of immunoassay test kits.

Analysis and Water Treatment

The State Water Laboratory staff are carrying out research on analytical techniques and on the treatability of water affected by blue-green algae. A meeting was held with the following laboratory staff:-

Andrew Humpage	Piere Pieronne
Sale Newcombe	Johanna Rositano
Brendon Nickalson	Mr. Costdoati

At the beginning of the meeting it was stressed that much of the work they would be discussing was unpublished and still being evaluated. However, it was felt that a discussion of these results would be of value to our understanding of the management actions being taken to safeguard the quality of drinking water in Australia in relation to toxin production by blooms in water supply reservoirs.

Chlorine Treatment

Experiments with microcystin have shown that a residual of 0.5 mg/l chlorine and a contact time of half an hour is sufficient to remove hepatotoxins. In one experiment using 100ug/l of microcystin in distilled water 2mg/l chlorine was sufficient to reduce the toxin to below detection limits (using HPLC analysis).
Similar experiments with nodularin also showed toxin removal but no results have been obtained for anatoxin-a. Mouse bioassay has shown no toxic effects associated with the breakdown products from the treatment.

Ozonation

Experiments using an ozone residual of 0.1mg/l have shown that a contact time of 15 seconds is sufficient to cause breakdown of microcystin, anatoxin and nodularin.

Coagulants

None of the coagulants so far studied had shown complete removal or breakdown of the toxins. There was evidence that toxin levels were reduced by about 80% from an initial concentration of 40 ug/l of microcystis with PACL, ferric sulphate, Alum and cationic polymers. Some of the results were from french data.

Potassium Permanganate

There was some evidence that potassium permanganate oxidises toxins but the results of these studies had not been fully evaluated.

Granular and Powdered Activated Carbon

Extensive work was being carried out on the efficacy of GAC and PAC in toxin removal. This was partly because this method is recommended for water treatment during bloom development both here and in other parts of Australia. The first publications on removal of the toxins in laboratory experiments using PAC were produced by Professor Falconer when he was working in New South Wales.

The State laboratory's work with GAC has shown that $1m^3$ of GAC can effectively treat 10,000 m^3 of water containing an initial concentration of 20ug/l of microcystin. Experiments with anatoxin-a indicate lower removal efficiency which is thought to be related to the smaller molecule size and the hydrophilic nature of anatoxin-a. GAC did not effectively remove anatoxin-a from water containing toxin at an initial concentration of 10ug/l. Results with nodularin were similar to those found for microcystin.

Powdered activated carbon was found to have variable performance depending on the quality of the product. There was good correlation with mesopore size. They are currently looking at the relationships between the contact time needed to remove the toxins and the product quality.

Site Visits

Dr. Dennis Steffensen and Peter Baker from the State Water laboratory took us on a tour of the South Para reservoirs which form the main water supply system for Adelaide. These reservoirs are situated on east of Adelaide in the Mount Lofty range on the south end of the Barrosa Valley. Although the reservoirs fill from their natural catchments during the winter much of the supply relies on water from the Murray river during the summer months or during droughts. One of the driving forces which resulted in setting up the Murray-Darling Basin Commission, to oversee the management of river, was the position of the abstraction point for the pipeline at Mannum at the bottom end of the Murray River.

During the tour we visited the Warren, South Para and Barrosa Reservoirs. The Warren reservoir was originally built to supply the Barrosa valley and was constructed on the South Para river in 1914. The reservoir contained a Microcystis bloom and had a small scum on the margin. Copper sulphate has been used to control the algae on a regular basis for some years and Dr Steffensen indicated that an increasing amount was required for effective control, thus indicating the development of resistance to copper. In addition to the use of copper sulphate as an algicide, destratification is also used as a control method.

FIGURE 15

POISONOUS SCUM ON LAKE ALEXANDRINA. — The Chief Inspector of Sheep has received a report from Inspector Wells, stating that he had received information from Mr. Hughes, of Wellington East, that green scum had again appeared on Lake Alexandrina, and that a few of his sheep had died after drinking, and also that Daenke, a farmer had lost some calves and pigs at Mulgundawah from the same cause. He (the Inspector) had been round the lake, and was glad to report that nothing serious had happened yet, and that stockowners who water their flocks on the lake are on a watch for it. That it had appeared at Mulgundawah is certain from the report of a respectable man named Coonamble, who had been many years in Mr. Hughes's employment. He told the Inspector that about the end of January, when mustering sheep, he noticed a margin of something like green paint, about eight yards wide, floating on the water round the edge of the lake. Knowing from past experience the poisonous nature of the scum , he rounded his flock up and drove them off, but so potent was the poison that four of the animals died on the spot. He at once gave notice to the neighbours, but in a few days the scum disappeared with a change in the wind ; and although a careful watch had been kept since, it had not again been noticed, but a considerable quantity was driven inshore and dried in the sun into hard cakes of a dark-green colour, some of which was collected and forwarded to Mr. Valentine. Mr. Wells adds that the scum had only appeared in this one place, but if the weather continued hot he had no doubt it would appear again. Mr. Francis, in his report on the subject some two years since, attributed this substance to the high temperature of the water more than to the lowness of the lake at that time, and from what Mr. Wells observed he believes this opinion was perfectly correct. The germs of this microscopic vegetable, it seems, are always in the water, but it requires a certain temperature to develop the plant.

The South Australian Register
February 14th, 1880

FIGURE 16 - LAKE ALEXANDRINA

As in other States the South Australian Engineering and Water Supply Department has extensive monitoring programmes on their water supply reservoirs and on the Murray river. These include algal samples taken routinely at fortnightly intervals and at weekly intervals during blooms. Toxicity tests using mouse bioassay are also carried out as part of the contingency plans at "Alert Levels" 2 and 3.

Visit to Lake Alexandrina

Lake Alexandrina is situated at the mouth of the Murray River about 20km south of Adelaide. The lake is noteworthy as being the first site where toxic algae were reported to be causing the deaths of livestock. This report appeared in the South Australia Register in 1880 and is shown in Figure 15. No blue-green algal scums were present during our visit (Figure 16). The size of the discharge at the end of the lake gave us a clear idea of the volume of water discharged by the Murray River.

Comment on our Visit to South Australia.

The main focus of attention on blue-green algal problems in South Australia has been on the problems experienced with water supplies from the Murray river in November 1991. Although problems have been experienced in the Adelaide water supply reservoirs and Lake Alexandrina for many years there does not seem to have been the same Statewide problems as in New South Wales and Victoria. The problems have, however, been tackled in similar fashion to those in the other States involving short-term contigency planning, including the publication of leaflets, longer-term strategic planning and research. Drinking water safety is a major issue and probably related to Adelaide's dependence on the lower Murray river as drinking water source in dry conditions, which is coincident with bloom development in the river.

7. MANAGEMENT OF BLUE-GREEN ALGAE PROBLEMS IN AUSTRALIA

Water Quality Regulation

The Australian legislative framework for water management is complex. This complexity arises from the relationships between the Federal and State Governments and interstate differences in management structure.

On the national level the Australian Water Resources Council (AWRC) plays a key role in dealing with problems relating to algal blooms. The Council is chaired by the President and any legislative measures to deal with national issues are lodged in all the Federal State Parliaments.

The Murray-Darling Basin Commission also has a significant role to play in co-ordinating the work related to resolving the major problems in the Murray Darling basin, particularly in relation to nutrient control and flow regulation.

Each of the Federal States has differing regulatory structures with responsibility for algal problems resting in Ministerial Departments. In many cases the Ministers have a direct role in determining the actions required to deal with blue-green algal problems. Despite the different reporting structures, each of the States has managed the problems, from an administrative point of view, by setting up Algal Co-ordinating Committees.

It was also noted that, although the individual States are responsible for making recommendations relating to conditions in their own State, they do act within a national framework and communicate frequently, even to the extent of having representatives from outside States on the Task Groups.

Responsibilities for water resource and water quality management within each State are also variable and in some cases unclear. In New South Wales for example their Water Resources Department, Water Boards (owned by the Government) , Local Government, the Environmental Protection Agency and the Department of Conservation and Land Management, all have a role to play in water quality management.

FIGURE 17 - BARWON-DARLING RIVER WITH BLUE-GREEN ALGAE

Algal Bloom Management Strategies

Short-Term Management Strategies

The major blooms in the Barwon-Darling River in November 1991 were mainly confined to New South Wales (see Figure). Details of the sequence of events are given in Appendix I, but once it had been established that the blooms extended for 1000 km the Water Resources Department, together with other relevant regulatory bodies, set up an administrative framework to deal with the problem. This included a Blue-green Algae Regional Emergency Committee and a Blue-green Algae Task Force. Among the first actions taken were to:-

a provide publicity material for the media and public.

b carry out monitoring programmes to determine the nature and extent of the problem.

c formulate contingency plans.

Early on in the investigation it became clear that the problem was extremely serious and, within two weeks, the Government of New South Wales declared a "State of Emergency". The short-term measures taken during the emergency included drafting in the army to assist with the provision of emergency water supplies and communications with the many isolated farmsteads along the river.

Although the major incident was confined to New South Wales, early investigations elsewhere revealed widespread problems with blue-green algae throughout South East Australia which required urgent action to minimise the problem. This resulted in the AWRC setting up the national Algal Management Strategy Group which is responsible for developing a Draft National Algal Strategy for action to be taken by all the Federal States. The national group has set up 14 Advisory Groups to investigate various aspects of the problem and to produce reports with recommendations for developing the Strategy. These reports include a review of research and development needs.

Other States followed New South Wales in setting up their own Algal Task Forces or Co-ordinating Committees to review local problems and carry out similar short-term actions. Although these Committees have responded to local problems there is a good deal of commonalty in the way that short-term management of the blue-green algae problems is approached. This includes:-

a extensive monitoring of blooms, particularly in water supply reservoirs, with weekly or daily sampling during bloom events. Analysis of samples includes a high standard of taxonomic description and quantitative enumeration. Samples are also routinely tested for toxicity by mouse bioassay.

b a system of "Alert Levels" for blue-green algal blooms which was set up for domestic drinking water supply at 2000 cells/ml of blue-green algae species known to cause taste and odour problems, and for other domestic water supply use, recreation and stock watering when potentially toxic blue-greens exceed 15,000 cells/ml.

c extensive publicity and reporting procedures of blooms. Although this varied between States, in some cases it includes the requirement for production of bloom status reports for Ministers on a monthly or weekly basis and the provision of a "hotline" service for the public during bloom events.

d recognition of risks to recreational users of waters affected by blooms. Warning notices and publicity material has been produced to guide water-sports enthusiasts and recommend that contact with blooms and scums should be avoided.

e risks to livestock are also recognised and in one State, advice is given to farmers about the risks of livestock watering in bloom affected waters and a free algal identification service is provided.

f Short-term algal control measures which regularly use copper sulphate as an algicide in water supply reservoirs (not recommended for livestock watering because of the risks associated with copper toxicity), and the use of destratification equipment.

Long-Term Management Strategies

Following the events in 1990/1 and the establishment of National, State and Regional management structures, monitoring programmes and short-term measures to deal with the problems, all the States have produced longer term strategies for dealing with blue-green algal blooms. These include refinements in monitoring programmes and alert levels, the development control strategies and an expansion of national and regional research programmes.

Monitoring programmes

Although monitoring programmes varied in detail between States, most had an extensive programme of routine monitoring at water supply reservoirs and at important sites on the rivers. In most cases these included quantitative counts. Training for staff involved in algal sample analysis was also increasingly sophisticated with two States introducing quality control on algal counts and seminars for the staff. Victoria provided a free algal identification service for farmers and New South Wales was developing an Algal Watch Kit at an estimated cost of A$33,000.

"Alert Levels"

Initial "Alert Levels" described above were based on identifying the presence of a bloom which was sufficiently serious to take emergency action. Later a more complex system of "Alert Levels", based on the best estimates of algal toxicity to mice and pigs was developed. This system includes a complex series of management actions relating to drinking water supply. These can be summarised as follows:-

Alert Level 1 (500-2000 cells/ml) early stages of bloom formation; requires full monitoring programme and inspections for scums.

Alert Level 2 (2000-15,000 cells/ml) established bloom; requires the operators to carry out toxicity tests, advise Health Authorities so that a risk assessment can be carried out and that media releases be made.

Alert Level 3 (>15,000 cells/ml) persistent toxic blooms; requires that Level 2 actions are taken but needs further investigations and action, including the use of activated carbon for treating the water, provision of alternative supplies if possible and more detailed press releases including ".. The water is unsuitable for normal household purposes such as drinking, washing and cooking."

In addition to this a proposed drinking water standard of 1 ug/l microcystin-LR has been suggested. However, this is only used as a guide value.

Control Measures

Long-term management of the blooms has been directed at setting minimum flows in rivers and the control of nutrient inputs. In the case of nutrient control, the initial phase has been to define nutrient loads and identify the sources. Much of the investigative work on nutrient load calculation has been carried out by the Regulatory Authorities and Water Boards.

Nutrient control strategies are currently being developed on two main fronts. Point source inputs from STWs are being reduced by phosphorus removal and inputs from agricultural sources and the land are being controlled through catchment management. The Australian system of "Total Catchment Management" (TCM) has a high degree of public involvement.

In New South Wales, the TCM Committees are set up by the Department of Water Resources, with membership consisting principally of residents from the catchment. These Committees make recommendations for improving the catchment with the assistance of the Department. This assistance includes the use of a PC based nutrient control model developed by CSIRO which will help evaluate the efficacy of the measures for nutrient reduction recommended. The measures considered include reduction of discharges from septic tanks and intensive cattle rearing units, construction of wetlands and changes in land use. As many of the measures require the co-operation of the farmers and other people living in the catchment, the high degree of ownership of the decision making process by the committee members provides peer pressure to implement the recommendations.

Other long-term measures taken to reduce problems with the blooms include recommendations to reduce the use of phosphorus based detergents, increased education on land management targeted at reducing soil erosion and better use of fertilisers, investigations into the use of tradeable property rights in nutrients and the use of market forces to optimise the reduction in nutrients.

Research

There has been a high level of commitment to research on eutrophication and algal bloom management in Australia for some time but, following the events in 1990/91, the level of funding for this research from Government and industry has increased dramatically. The report of the New South Wales Toxic Algae Task Force makes 42 recommendations relating to research required to resolve the problems and the Australian Water Resources Council has sponsored a major review on "Algal Bloom Research in Australia". This document identifies current research activities, including 76 projects on nutrient control alone, and reports on 69 key issues for research. The key issues include research into the causes and effects of the blooms and on their control and treatment. The issues are given in full in Appendix I and a number of the initiatives are of particular interest are shown below:-

- factors controlling nutrient dynamics in rivers and lakes,
- bioremediation and biomanipulation,
- detection identification and analysis of toxins,
- the fate and significance of the toxins in the environment,
- identification of factors affecting toxin production,
- epidemiology of the effects of toxins,
- treatment processes for water supply
- economic analyses of the causes, control and consequences of cyanobacterial blooms.

Although research is initiated and carried out separately in different States, co-ordination of the work is carried out through the AWRC Algal Project Manager who carried out this review.

8. COMPARISON OF AUSTRALIAN AND UK BLOOM MANAGEMENT

There are very clear parallels between the events in the UK in 1989 and those in Australia in 1990/91. In both countries toxic blooms were previously documented, the first in Australia being reported from Lake Alexandrina in 1878. The only apparent difference in the UK 1989 event and the Australian 1990/91 event was the scale of the problem.

In the first instance, the regulatory authorities responsible for water management in both countries reacted in very similar ways, particularly in the short-term management actions. This included setting up Toxic or Blue-Green Algal Task Groups, developing monitoring programmes, setting action levels, arranging publicity and producing reports which incorporated short- and long-term strategies for dealing with the problem. The Australian authorities built on the UK experience and had followed similar themes for the development of their strategies.

In some aspects there were differences in the actions taken in Australia when compared with those of the NRA, but many of these could be explained by differences in the regulatory framework or to scientific differences in the nature and extent of the blooms. The latter are thought to be mainly due to differences in climate and geology and the varriablity in toxin production.

In Australia the major problem was caused by a long drought which resulted in sufficiently low flows in the Barwon-Darling river for the extensive blooms of Anabaena to develop. The river provides an essential water resource for all the community needs, including livestock watering. As in the UK, the first fatalities involved animals drinking directly from the water but, without the sophistcated water treatment available in the UK, the authorities took a precautionary approach to the safety of drinking water for livestock and people.

Many of the subsequent actions were similar in relation to recreation and livestock watering, including posting warning notices, the production of leaflets (Figure 18) and a general warning to keep away from the blooms and scums. The actions relating to drinking water were different and included the provision of emergency water supplies, an attempt to find suitable groundwater supplies and on site treatment with activated carbon.

In 1989 and 1990 the NRA carried out an extensive monitoring programme which was aimed at describing the nature and extent of the problem. This effort involved the collection and analysis of over 5500 samples from 1372 waters throughout England and Wales. In 1991, and subsequent years, the NRA only carried out reactive

WARNING:
BLUE-GREEN ALGAL BLOOMS

The South Australian Health Commission has stated :

'Overseas and interstate reports indicate that illnesses including skin rashes, eye irritation, vomiting, diarrhoea, fever, muscle weakness or cramps and pains in muscles and joints have occurred in some recreational users of water who swallowed or swam through algal scum. There have been no reports of long-term effects or deaths in humans, but in some cases the illnesses were severe.

ALTHOUGH ALGAL SCUM IS NOT ALWAYS HARMFUL, IT IS A SENSIBLE PRECAUTION TO AVOID CONTACT WITH THE SCUM AND THE WATER CLOSE TO IT.'

The following warning has been issued by the Chief Veterinary Officer, South Australian Department of Agriculture:

'Algal scum or visibly discoloured water may be toxic to livestock.

FARMERS SHOULD REMOVE THEIR STOCK FROM AFFECTED AREAS AND PROVIDE ALTERNATIVE SUPPLIES OF WATER. DOGS ARE PARTICULARLY VULNERABLE TO TOXIC ALGAE.'

Further information may be obtained from :

S.A. Health Commission	Tel (08) 226 6315 Fax (08) 226 6316
S.A. Dept. of Agriculture	Tel (08) 226 0570 Fax (08) 226 0200
Engineering and Water Supply Department	Tel (08) 259 0211 Fax (08) 259 0228

Based on a pamphlet issued by the Anglian Region, National Rivers Authority, U.K.

BLUE-GREEN ALGAL BLOOMS

S.A. Health Commission

S.A. Department of Agriculture

Engineering and Water Supply Department

FIGURE 18 - SOUTH AUSTRALIA BLUE-GREEN ALGAE LEAFLET

monitoring with a much reduced routine programme at key sites. The decision to change to the reactive monitoring programme was made on the grounds that, in the UK lakes, the blooms and scums were likely to recur annually to varying degrees depending on climatic change. It was felt that letters to the owners of previously affected waters would be sufficient to remind them to be vigilant and take appropriate action if the scums reappeared. This would then release resources to help resolve the problems by the development of "action plans" for priority waters.

Reporting systems in both countries have been concentrated on rapid provision of information to managers and the public. In these aspects reporting procedures are similar but the provision of "hotlines" for the public during incidents and of weekly status reports for Ministers have not been necessary in the UK.

In Australia, the authorities responsible for water quality management in each State carried out similar investigations into the extent of the problems in 1990 and 1991. However, unlike the NRA, they have continued to carry out extensive routine monitoring, particularly of raw water supply sources in rivers and reservoirs, in order to provide data for the management of these resources. In some instances this monitoring is used to target the use of copper sulphate as an algicide. Here again, there is a divergence of action because the NRA's Toxic Algae Task Group had specifically recommnded that algicides should be avoided because of the potential release of toxins during the breakdown of the cells. During our visit, experiments were being conducted by CSIRO research scientists to investigate this aspect and a number of States are reviewing their policy on this method of control. Despite these differences in approach, the monitoring programmes used in each country were appropriate to the circumstances.

Strategies for toxicity testing also differed. The NRA found that the toxicity of the blooms varied in time within individual waters and that there was a 70% chance of any particular scum being toxic. On the basis of these findings the NRA's Task Group recommnded that routine toxicity testing should be discontinued. The toxicity tests also indicated that the toxins were all hepatotoxic and probably all microcystins.

In Australia however, the blooms were neurotoxic or hepatotoxic and some of the neurotoxic blooms contained unidentified toxins. Also, although bloom toxicity is variable, no predictable patterns in the results of the toxicity tests have been found to enable managers to make the decision to stop testing. Although there is a policy of moving away from toxicity testing by developing robust chemical analytical techniques, routine toxicity testing continues as part of the actions required in the system of "Alert Levels". In these respects the difference in poilicy between the NRA and Australian authorities relates to differences in the nature of the toxins, greater varriablity in toxin production and insufficient data.

Long-term strategies for dealing with the problem in Australia were similar to those in the UK. The control measures under consideration were also similar and included nutrient control and the use of destratification in reservoirs. Setting minimum flows is a major issue in relation to reducing blue-green blooms in the Murray-Darling system, not only because of the effects of the communities living near the river, but also because of the abstraction of Adelaide's water supply from the lower end. Although setting minimum flows is a major issue in the UK, this is not generally related to blue-green algal problems.

In both countries, the production of long-term action plans to reduce the problem by the use of catchment management planning is similar. There was one significant difference in the approach. In Australia, there is a much greater degree of community ownership of the problems and actions taken which is provided by a Total Catchment Management Committee system. These Committees are set up by the regulatory authorities, but have a membership consisting almost entirely of residents from within the catchment. Technical assistance, including easily used PC nutrient models, is provided by the regulators. In the UK, catchment management plans are produced by the NRA and then undergo public consultation. These methods of early community involvement, or later consultation have evolved separately and opinions on the relative merits of these two systems could only be speculative without a thourough investigation.

In both countries it was recognised that research prgrammes would be required to resolve the problems in the long-term and that there were many gaps in our knowledge of the nature and significance of the toxins. Many of the questions being asked by those responsible for managing the problem, and by those affected by the blooms could not be answered. This has led to an expansion of research on algal toxins and algal control both in the UK and in Australia. There is considerable overlap between the NRA and Australian research effort in these fields and continued communication on progress with this research is of paramount importance.

9. RECOMMENDATIONS

1. The success with which the Australians have adopted and built on the short and long-term management stategies, developed by the NRA's Toxic Algae Task Group after the 1989 events, streghtens the NRA's strategy. Therefore, it is recommended that the current policy and procedures for short and long-term management should remain unchanged.

2. Exchange of information on the efficacy of control measures currently being introduced should continue.

3. Exchange of information on progress with research into the nature and significance of the toxins and on control measures should be increased.

4. The NRA should consider the use of increased publicity, including the use of education packs, as a means of improving public understanding of blue-green algal problems.

5. The relevant authorities should be encouraged to review the Australian's policy and procedures relating to toxins and drinking water.

6. The NRA should examine the Australian Total Catchment Management system, particularly in relation to public involvement in the catchment management planning process.

APPENDICES

APPENDIX I

[JVE587R]

BLUE-GREEN ALGAE

Final Report of the New South Wales Blue-Green Algae Task Force

August 1992

EXECUTIVE SUMMARY

1. Introduction

Eutrophication, the enrichment of water by nutrients, is an increasing problem in NSW. Over the last 20 years, toxic and non-toxic algal blooms, resulting from eutrophication and increasing water abstraction from the state's waterways, have been reported with increasing regularity on water storages, weir pools and rivers. The problem was highlighted with the occurrence in the Darling-Barwon River System in November and December 1991 of the world's largest recorded riverine algal bloom. The bloom extended for 1,000km, some cell counts were in excess of 600,000 cells/mL, and most samples contained algal toxins. The problem was brought dramatically close to Sydney with algal blooms in the Hawkesbury River in December 1991 and January 1992.

Faced with the serious situation in the Darling-Barwon, and with conditions favouring development of the problem statewide, the Minister for Natural Resources announced on 28 November 1991 the establishment of a Blue-Green Algae Task Force to minimise the impacts of the immediate problem as well as developing longer term solutions. A strong commitment to the Total Catchment Management (TCM) approach was foreseen, particularly in the long term.

Membership of the Task Force is drawn from TCM, a broad range of NSW Government agencies (natural resources, primary industries, environment protection, health, water supply), two universities and the Murray-Darling Basin Commission (MDBC). Queensland, Victoria, South Australia, CSIRO and the Australian Water Resources Council (AWRC) have observer status, thereby speeding information transfer. This membership reflects an important principle; that management measures must be implemented as part of an integrated resource management approach.

This report describes the 1991/92 blue-green algal blooms in NSW, and places them in perspective with the occurrence and causes of blooms elsewhere. It contains a lengthy description of the physical, chemical and biological factors which cause blue-green algal blooms and their many impacts. It illustrates the complexity of the system which needs to be understood if the algal problem is to be successfully minimised. Sources of nutrients in NSW are examined as a part of this study.

The report stresses that future management of the blue-green algal problem in NSW must be cost effective, and that it should integrate cause and effect relationships in the short and long term. It proposes a range of management strategies from the State Algal Contingency Plan to minimise the effects of algal blooms in the short term, to medium term measures to control the factors affecting blooms, to longer term land and water management measures to control the cause of blooms, particularly nutrients. It also contains proposals for research to improve our understanding and management of the problem.

2. Objectives

The Blue-Green Algae Task Force has worked to its four objectives:

(i) Oversee the establishment of Regional Algal Coordinating Committees, monitor their operation, and facilitate resourcing and coordination of these committees where necessary.

(ii) Review the problems associated with blue-green algae in NSW.

(iii) Produce reports for the Minister for Natural Resources and the Natural Resources Subcommittee of Cabinet; regular reports on algal blooms and responses during the 91/92 summer, an interim report by end March on progress, and a final report by end August 1992.

(iv) Make recommendations to minimise the problem in the future (both short and longer term).

While the focus of the Task Force was the investigation of blue-green algae in NSW inland waterways, most of the findings apply to more general algal and water quality management. Similarly, land and water management measures apply to estuarine as well as freshwater bodies.

3. Task Force Operation

The Task Force met its objectives by completing a range of activities including research and investigations; literature reviews; technical workshops; monitoring; contingency planning; information exchange, negotiation and dissemination to secure the participation of the broader state community.

The Task Force has not operated in isolation. Its work programs linked with and complemented the work of a large number of other bodies at national (AWRC), basin-wide (MDBC), state and regional levels.

The Interim Report of the Task Force was completed on 31 March, 1992. That report, its executive summary and a broadsheet have been widely distributed, receiving interest nationally as well as within NSW.

An essential part of Task Force operation was the participation of the broader community in providing statewide input to help shape this final report.

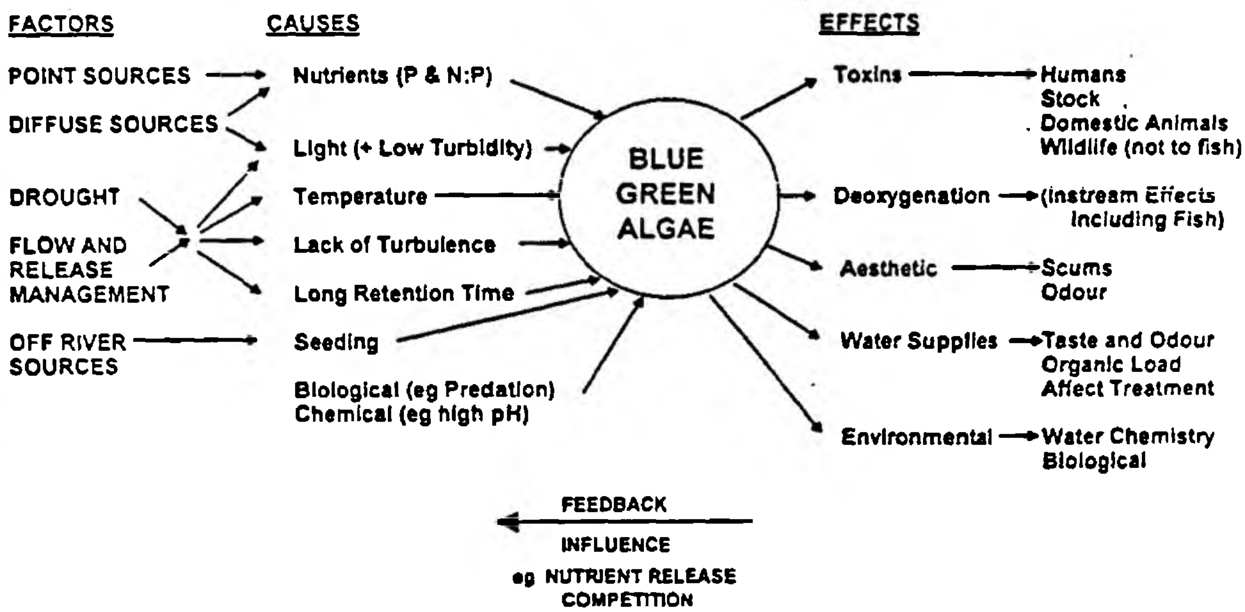
4. Overview of Blue-Green Algae

Blue-green algae are primitive photosynthetic organisms which are found in many environments, notably inland waterways, estuaries and the sea. They are now known to be bacteria, the Cyanobacteria, but in common with other contemporary documents this report will refer to them by their popular term, the blue-green algae. Their bacterial properties have major implications in their behaviour and management.

Blue-green algae in low numbers are important contributors to the aquatic biology of Australian waterways. However, their numbers can often rise to a level where their noxious properties can cause problems for a range of water users. They are unsightly and create an extremely unpleasant odour. Importantly, their toxins have been known to cause sickness in humans and death in stock and pets.

Troublesome blue-green blooms have been recorded worldwide for centuries and the first toxic bloom was noted in South Australia in 1878. In recent years there has been an increase in reporting of noxious blooms, despite the lack of an effective algae monitoring system.

The multiple causes and effects of blue-green blooms create a complex interactive system which is summarised in the diagram below. An understanding of the relationships is vital if successful management is to be implemented. In resource management, decisions may need to focus on one or more target areas, such as the causative factors, the algae itself, or the effects of their growth.



Blue–Green Algal Blooms –Major Causes and Effects

For 1991/92 the NSW Task Force has reported 48 waterways throughout the state with blue-green algal blooms, of which 30 were regarded as serious events, having the potential to cause problems with water resource use.

5. 1991/92 Algal Blooms in NSW

The first objective of the Task Force was to minimise the problems associated with algal blooms during 1991/92. To meet this objective, an interim State Algal Contingency Plan was put into operation in late November 1991. A two-tier organisation structure comprising the Task Force and nine Regional Algal Coordinating Committees (RACCs) was established to develop and implement the plan.

The role of the Task Force in this objective was to oversee the establishment of the RACCs, to monitor their operation and to facilitate their resourcing and coordination where necessary. The roles of the RACCs included rapid identification and monitoring of algal blooms, provision of timely and accurate advice to the community, development and implementation of bloom management measures, provision of safe drinking water supplies, and support of the Task Force.

It is concluded that effective response to algal bloom problems requires a combination of regionally based technical and professional staff supported by a centrally based core of specialists (engineers, scientists, etc). This is reflected in the State Algae Contingency Plan for the minimisation of algal bloom problems (outlined in section 10) which was developed from NSW experience augmented by models in use interstate.

The Darling-Barwon algal blooms generated intense media interest (within NSW, nationally and internationally). The Task Force responded with factual information to make the public more aware of algal and nutrient issues, and of more general water quality issues; an important first step if solutions are to be implemented in the long term. This communication and information related experience gained in 1991/92 has been used to develop relevant sections of the State Algae Contingency Plan.

Algal monitoring by the Department of Water Resources, other government agencies and individual shires was of considerable value and included the provision of weekly reports and maps of algal occurrence and severity. However the 1991/92 experience has revealed shortcomings in the NSW monitoring program and these have been addressed by the Task Force (Section 10).

Blue-green algal blooms have a range of economic, social and environmental costs and impacts. They include impacts on water supplies, human health, recreation and tourism, agriculture, fish and wildlife. Not all costs associated with the 1991/92 algal blooms could be obtained. In many cases impacts weren't identified, or costs were not separated from other related issues such as the impact of drought, or the recession, which have also imposed costs on the community.

Costs which were assembled include:

(i) The direct cost to the NSW and Commonwealth Governments to provide water supplies during the State of Emergency for the Darling-Barwon blooms is estimated to be $1260,000. The direct cost of operating the interim State Algae Contingency Plan for 1991/92 and of the Task Force is $730,000. These costs have a very narrow definition; they do not include the operational costs of state government agencies working on algal and related water problems not tagged with the Task Force label, nor do they include the costs incurred by individuals, communities, local government or research organisations.

(ii) Lost income from tourism and recreation in local regions was $9.4 million, ascribed both to the occurrence of blooms, and to negative media coverage.

(iii) Up to 1600 sheep and 40 cattle deaths were suspected of being caused by the Darling-Barwon algal blooms.

Human health impacts were not rigorously assessed. There were no apparent adverse effects on fish collected from bloom infested waters, but information obtained is not conclusive.

6. Factors Causing Blue-Green Algal Dominance

It is important to understand the factors controlling algal blooms in order to develop effective management programs to minimise blue-green algal problems.

The characteristics of blue-green algae which give them a competitive advantage include their possession of gas vacuoles providing buoyancy regulation which enable them to overcome the spatial separation between light and nutrients in the water column. Their nitrogen fixing capability enables them to dominate in low nitrogen waters. Blue-green algae produce spores or "akinetes" which can last for several years and provide a means of seeding water bodies, and they produce toxins which kill or inhibit their predators and which may inhibit their competitors.

The growth of blue-green algae is determined by many environmental factors (physical, chemical and biological), as discussed in the report. Since these factors are continually interacting with one another in a very complex way, it is not possible to attribute algal occurrence to any specific set of factors.

Physical factors affecting the growth of blue-greens include temperature, evaporation, light, turbidity, colour, flow, turbulence, flooding, thermal stratification, depth and morphology of water bodies, and sediment.

The main chemical factor is nutrients from catchment point and diffuse sources, and from internal recycling from sediments within waterways. Nitrogen and phosphorus are the most important nutrients with phosphorus being the limiting nutrient for blue-green algae. In catchment areas disturbed by human activity phosphorus is rarely in short supply. It is present in a variety of forms from the mineral hydroxyapatite through to phosphorus based detergents. Phosphate phosphorus appears to be the form preferentially assimilated by blue-greens. Other chemical factors influencing blue-green algae include carbon dioxide, pH, micronutrients and dissolved oxygen.

Biological systems are very complex. Biological interactions between blue-green algae and other members of the food web can affect algal biomass; the roles of zooplankton grazers, macrophytes, carp and other microorganisms (viruses and bacteria) are significant.

A scientific advisory team working for the Task Force inspected and sampled the Darling-Barwon bloom in December 1991. Their findings support the literature review conducted by the Task Force.

It is concluded that the environmental conditions which favour the development of blue-green algal blooms are:

* High nutrient levels, particularly phosphorus;
* Low N:P ratios (less than 29:1);
* High water temperature (above 20 degrees Celsius);
* High pH (pH 8-10) and low carbon dioxide concentration;
* Abundant zooplankton (blue-greens are relatively inedible);
* Low flows, leading to long retention times and calm water conditions; and,
* Reduction in turbidity to moderate levels, leading to increased light intensity.

The Australian environment is characterised by many of these environmental conditions, which make Australia's waterways particularly vulnerable to blue-green algae blooms.

To determine the triggering mechanisms of blue-green algal blooms, the effect of each of the above environmental conditions must be quantified since all conditions are rarely, if ever, optimum for algal growth at any one time. Strategies to manipulate environmental parameters may then be developed to prevent blue-green algal dominance.

7. Nutrients in NSW

Phosphorus is essential to sustain life, and part of the foundation of the economic, social and environmental structure of NSW. Phosphorus is also a limiting factor in blue-green algal growth. The challenge facing NSW is to minimise the input of phosphorus to the State's waterways.

The nutrient levels (particularly phosphorus) in NSW rivers are already predicted by various trophic classification models to cause significant water quality problems. The median levels of phosphorus exceed a nominated desirable level of 50ug/L at 60% of sites sampled throughout the state; with exceedance in all western river basins and some coastal basins. Over the past 18 years total phosphorus levels have risen by an average rate of 5% per year statewide. There have been significant increases in the Namoi and Hunter valleys. North-western basins generally have the highest phosphorus values (Darling, Intersecting Streams and Border Rivers, Gwydir) or the greatest upward trend (Namoi).

These nutrient levels show an existing and increasing potential for algal problems throughout most of western NSW and in many coastal rivers.

Research is still needed to quantify the relative contribution of nutrient sources to the State's waterways. The report "An Investigation of Nutrient Pollution in the Murray-Darling River System" recently released by the MDBC estimates the annual input of phosphorus throughout the Murray-Darling River System contributed by point sources (sewage treatment plants, irrigation drains, industrial inputs and intensive animal industries) and diffuse sources (forest, pasture, crops and urban stormwater). The study was based on limited data which was most complete for point sources and only derived for diffuse sources. It did not take into account in-stream assimilation or recycling from sediments.

More specific nutrient studies of the Upper Darling (rural catchment) and the Lower Molonglo Water Quality Control Centre (Canberra's sewage treatment plant) and their conclusions are described.

8. Impacts of Algal Blooms

Blue-green algal blooms have a wide range of social, economic and environmental impacts. There are impacts on water supplies, human health, agriculture (livestock), fish, native fauna and flora, recreation and tourism. There are also potentially broader economic impacts; the widespread coverage of the Darling-Barwon algal bloom by the media overseas has created an image of an environment of polluted waterways, with potential commercial consequences.

Statewide there are major cost implications for water treatment works should upgrading be required to handle increasing taste and odour problems, toxins and organic loads arising from algal blooms.

Cases of human poisoning by blue-green algal blooms are rare. Examples include people who have been exposed to algae accidentally when participating in water sports or through contamination of drinking water supplies.

One of the most obvious direct impacts is on local tourism and recreation. The 1991/92 losses to local NSW communities are in the order $10 million (although this figure may be influenced by factors such as drought and recession). A significant amount of these losses can be attributed to intense media coverage surrounding the presence of blue-greens in waterways (for example, deserted caravan parks along the Hawkesbury River).

Blue-green algal toxins have resulted in the deaths of livestock and pets. Livestock are further weakened by their avoidance of algae infested water, if no alternative water supplies are available. Livestock deaths are likely to occur in future algal blooms, as the majority of primary producers claim that it is not practicable for them prevent livestock having direct access to river banks, nor is it practicable for them to treat water to remove toxins.

The impacts on fish and shellfish are examined in terms of the impact on their populations, the accumulation of toxins in their tissues and the safety of these organisms as natural foods. The best understood impacts are those associated with the death and decay of algal blooms and consequent uptake by the organic loading of available oxygen within the water body, which commonly accounts for fish kills.

The toxicity of individual algal species to fish is not known, but needs to be researched.

Research into the toxicity of edible mussels has clearly shown a consumer hazard; the mussels ingest the toxic blue-green algae and accumulate toxins in their digestive system. The toxins are retained, even after freezing and boiling the mussels. Fish sampled and analysed to date have not shown toxins in their tissues. However it is advised that the liver and gastro-intestinal tract of fish taken from toxic algae infested waters are likely to be poisonous to human consumers.

Three major classes of toxins have been isolated from blue-green algal blooms; neurotoxins, hepatotoxins and lipopolysaccharides.

Methods for testing the toxin content of algal blooms and related water supplies include bioassay, immunoassay, enzyme assay and chemical measurement. The Task Force concluded that the only secure and comprehensive method for the monitoring of toxin concentration and presence is by mouse bioassay; subsequent monitoring can use other more specific tests as an important augmentation of bioassay. This work can be done by only a small number of laboratories in Australia.

Research is underway into 'dipstick' rapid assay techniques. Until such a simple test is available for water treatment plant operators, a useful guide is the absence of taste or odour from treated water.

9. Measures to Minimise Blooms and their Impacts: An Overview

As described in the preceding Sections 4 to 8, blue-green algal blooms have a considerable complexity in their cause and effect. This is not a single issue problem with a simple quick-fix solution. Minimising algal problems in NSW is to be cost effective, and to integrate the cause and effect relationships.

This includes integrating:

- Immediate, short and longer term measures.
- Land and water resource management.
- Measures catchment-wide and basin-wide.
- Ideas to fast track 'best bet' solutions.
- The efforts of the community and government.

The table below summarises this integrated approach, placing in context the detailed management strategies recommended in Sections 10, 11 and 12.

Integrated management approach to minimise algal bloom problems

Timing	Immediate	Short to medium term	Short to long term
Chapter	10	11	12
Algal issues	Bloom effects	Algal crop	Bloom causes
Management Strategies	State Algae Contingency Plan	Manage Blooms	Land and Water Management
	. contingency plans	. water allocation and water systems management	. nutrient control strategy
	. monitoring and action levels	. chemical methods	. waterway management
	. communication and information	. biological methods	

The implementation of these management options should be on the basis of identified benefits (economic, social and environmental) and costs, where the benefits of minimising blooms and their impacts outweigh or equal the costs of control works or activities.

10. State Algae Contingency Plan

Blue-green algal blooms will decrease in occurrence and impact as the range of measures are implemented and take effect. However they will not disappear, especially for those areas where it is considered appropriate to 'live with the problem'. The State Algae Contingency Plan is being finalised, to effectively manage and control algal blooms in order to minimise their impact. The Plan is to be implemented at two levels; by the State Algal Coordinating Committee (SACC) and by nine Regional Algal Coordinating Committees (RACC's). Membership, meetings, roles and responsibilities are described.

The state and regional levels of the Plan are at various stages of completion. They will contain an outline of agency responsibilities, guidelines for the development of plans, training programs, public information material and press releases, and mechanisms for information dissemination, the majority of which have been developed. The Plan will be further refined over the years, as the management of blooms is progressed.

The Task Force has established provisional guidelines for water quality. The most sensitive issue for domestic water supplies is that of taste and odour. Domestic water suppliers should be alerted when known taste and odour forming blue-greens exceed 2000 cells/mL, or when taste and odour are detected (in the absence of cell count information). At such levels water suppliers will need to apply their judgement to local conditions; they may need to consider alternative sources of raw water or to implement water treatment to remove taste and odour for drinking use. This is also the alert level for repeat sampling and toxicity testing.

Alert levels for other domestic uses, recreation and stock watering use should be issued when potentially toxic blue-greens exceed 15000 cells/mL. Water users should avoid direct consumption or bodily contact; they should treat contaminated waters to remove toxins, or use alternative water sources.

The entire closure of water bodies contaminated by blue-green algae is often impractical and unnecessary. There is a need to provide sufficient warning against inappropriate use of such waters, but land-based recreation can continue.

The Task Force has produced a multi-layered approach to algal monitoring which fills the present gap between the laboratory analysis of routine algal counts and casual field observation. The approach ranges from observation by the public to observation by a water system operator, water system operator with field aids, specialist operator with field laboratory, to the use of central laboratories. The monitoring approach needs to be tested and further developed within NSW.

The Task Force has also recognised the need for development of Algal Watch Kits, which would be used routinely by personnel at key river and reservoir sites. The kits would form part of Regional Algal Contingency Plans, providing for routine statewide monitoring coverage and enabling algal alert conditions to be activated locally. The report describes components of these kits, estimates the costs of development and production, and contains a recommendation for their development.

Effective two-way communication between government and the community is an important part of contingency planning, as it assists in the early detection of algal blooms, facilitates in bloom management, and helps reduce their impact on the community. The Task Force has produced or obtained a range of information items for general community use, for people who may be affected by blue-green algae in the future, and to help people in dealing with an algal bloom.

11. Managing Blooms and their Effects

Blue-green algae bloom management options for the state's waterways are categorised into physical, chemical and biological controls.

Feasible physical control options for NSW waterways include flow regulation, destratification, light restriction, variable offtakes, aeration, turbidity, floating booms, dredging and mechanical harvesting.

The Task Force recognises the need for a river flow regime which will maintain the health and function of the state's waterways and related environments, while integrating the needs of communities and other water users. An effective and efficient approach is to provide this additional water at times of maximum environmental benefit, with one of the aims being to minimise the physical factors which favour the development of blue-greens. To succeed, the approach must reintroduce important features of natural variability in river flow and address other particular bloom development factors. Components of the approach include:

* Managing flow in the state's regulated waterways, including a review of abstraction licences.

* Managing unregulated flows.

* Managing releases from the state's storages, including flushing flows, minimum release rules and variable offtakes.

The Task Force notes that the Department of Water Resources has started to address each of these components as part of an Environmental Flows Policy, and stresses that the Department's timetable of staged implementation over the next five years be adhered to.

Chemical control options include the use of algicides and algistats (in off-river, water supply storages and farm dams) and various nutrient controls. Algicides should not be used in the natural environment.

The Task Force sponsored laboratory and field trials which showed that alum and gypsum dosing were effective in removing turbidity in water and preventing algal growth by the removal of phosphorus from the water column. The dosing procedure, described in detail, has been developed for farm dams and other off-river storages, to provide livestock quality water.

Biochemical/biological methods involving enzymes and bacteriophages are still experimental, with no proven field information. Biological control options include the use of macrophytes, wetlands, bank vegetation, biomanipulation and artificial substrates.

Though control measures will minimise the occurrence and impacts of algal blooms, there will be occasions when communities will be faced with "living with the problem". In such instances there is a responsibility for water supply authorities to continue to supply potable water (either treated water or alternative source)

12. Managing the Causes of Blooms: Land and Water Measures

There are a range of solutions to the nutrient problem and each will need to be tailored to the particular source(s) and its (their) nature as well as to the benefits and costs involved, on a catchment by catchment basis. Success will depend on extension and education programs based on catchment demonstration works.

Examples of activities which may be used to control diffuse sources include control of runoff; timing and quantity of application of fertilisers; holding dams, land application and reduced water use for intensive rural industries; riparian buffer strips; erosion control strategies to reduce soil loss; control of livestock access to waterways; grassed spoon drainage systems in urban environments; limitations on use of phosphate based detergents; and improved siting, design and operation of septic tanks.

Examples of works to control point sources of pollution include land application of sewage effluent, abattoir waste and feedlot waste; on-farm and in-stream phosphorus removal; and amelioration works including detention ponds, contour banks and artificial wetlands.

Examples of waterway management activities (most already outlined in Section 11) include the development of sustainable levels of water abstraction, environmental flow allocation in waterways, fine-tuning of water flows to improve water quality, instream management to utilise available nutrients, and restoration of riverine ecology to restore the food web.

One of the sources of phosphorus to the state's waterways is detergent phosphorus. The Task Force estimates that up to 55% of the phosphorus discharge from sewage treatment plants is from detergents and other cleaning agents. As one of a range of strategies targeting different sources of phosphorus, the Task Force has developed a strategy for detergent phosphorus control. Implementation of the strategy includes a study to further quantify the contribution of detergent phosphorus, truth in labelling, and the setting of a limit of 5% by weight of phosphorus in detergents and other cleaning agents.

Costs and benefits are still to be quantified and are likely to be considerable. For example, preliminary costs to minimise nutrient output from key sewage plants in the Murray Darling Basin is estimated to be in excess of $200M. Land management and waterway management costs are likely to be considerably higher.

Given the magnitude of the problem and the potential range of works required, funds made available for control works will need to be allocated particularly wisely, by choosing catchments where nutrient enrichment of waterways is highest and where control activities will reduce the likelihood and outweigh the costs of algal blooms. This is best achieved through the development and implementation of a Nutrient Control Strategy which has three phases:

1. Identify the activities requiring control on a catchment by catchment basis.

2. Using environmental, economic and social criteria determine the key catchments, nutrient sources and waterway conditions that can be targeted for nutrient control.

3. Implement the Strategy through a program of works and activities.

The Task Force concludes that the magnitude of the nutrient control problem and the need to weigh up environmental, social and economic considerations necessitates that NSW develop a Nutrient Control Strategy. This will ensure that those funds available are allocated to where they can most effectively reduce the likelihood of algal blooms; and where the benefits of bloom control outweigh or equal the costs of control works or activities.

Work has already commenced on a number of activities to manage the causes of blooms:

* Phase 1 of the Nutrient Control Strategy has commenced.

* Work has commenced on an extension/education program, with the allocation to the Department of Water Resources of $750000 for the construction of catchment water quality control demonstration works such as artificial wetlands, riparian vegetation buffer strips, etc.

* The concept of tradeable property rights in nutrients, using market forces to optimise the reduction of nutrients to waterways, is being researched.

* Nutrient control strategies are being investigated in the Hunter Valley.

* A project aimed at reducing the impact of septic tanks on nutrient levels in NSW waterways will be completed by mid 1993.

* A State Environmental Flows Policy is being developed and implemented in stages over the next five years; the first interim off-allocation flow plan is in operation.

Responsibility for overseeing the development and implementation of the Nutrient Control Strategy will be with the State Algal Coordinating Committee.

13. Research

From its investigations and deliberations, it is clear to the Task Force that there is still much to be learned about blue-green algae, their causes and effects, if the problems they cause are to be minimised. Forty-two research needs have been identified and described, including whether they are required to be researched in the short, medium or longer term and a broad indication of who should do the work.

These needs are categorised into the following major issues:

* Factors causing blue-green algal dominance.
* Impacts of algal blooms.
* Monitoring.
* Managing blooms and their effects.
* Managing the causes of blooms.

The Task Force recognises the need to establish an integrated research program in NSW which is complementary to the National Algal Research Program and gives focus to the more specific research needs of the state. The incoming State Algal Coordinating Committee is the appropriate body to oversee this state package of complementary and coordinated research and investigation projects. The Task Force recommends that State Government fund the Committee $500 000 annually for the needed research.

As a result of a collaborative effort between the Task Force and the AWRC National Algal Bloom Research Manager, a register of Australian researchers and activities in algal bloom research has been compiled and is included in the Appendices Volume.

14. Recommendations

The Blue-Green Algae Task Force has already taken many actions on the road to minimising the problems of blue-green algae and their impacts. Recommendations for further action are categorised under issue and management headings; they are not presented in any order of priority.

14.1 Measures to minimise blooms and their impacts: an overview

1. That management options only be implemented where the benefits (economic, social and environmental) of minimising blooms and their impacts outweigh or equal the costs of control works and activities.

14.2 Administration of blue-green algae management strategies

2. That the Blue-Green Algae Task Force be disbanded in mid September 1992 after public release of its final report.

3. That the Task Force be replaced with the State Algal Coordinating Committee whose core membership includes the Departments of Water Resources (chair), Public Works, Conservation and Land Management, Health; Environment Protection Authority, NSW Agriculture; three TCM representatives (for environmental interests, rural interests and a chairperson of a regional TCM committee); Sydney Water Board; Hunter Water Corporation; and State Rescue and Emergency Services Board. Other organisations such as UTS will be co-opted as required.

4. That the State Algal Coordinating Committee be responsible for developing and implementing algal policy and strategies; facilitating algal contingency response within the state; liaising with organisations intrastate, interstate and overseas; identifying and coordinating research; public information; planning and implementing phases of the Nutrient Control Strategy; monitoring strategies; coordinating procedural developments; preparing an annual report.

5. That the State Algal Coordinating Committee be structured under and report to the State Catchment Management Coordinating Committee for the development and implementation of the Nutrient Control Strategy. Government will need to adequately resource the TCM structure to implement the measures arising from recommendations of the Task Force and the State Algal Coordinating Committee.

The State Algal Coordinating Committee will also need to liaise with and report to:

(i) State Emergency Management Committee, on the occurrence of extreme algal bloom events.

(ii) NSW Water Resources Council for water management related issues.

14.3 State Algae Contingency Plan

6. That the State Algae Contingency Plan, its proposed state and regional structure, and the roles and responsibilities as described in Chapter 10 be adopted to minimise the impact of blue-green algal blooms.

7. That the State Algae Coordinating Committee direct the establishment of Regional Algae Coordinating Committees, provide guidelines for the development of Regional Algae Contingency Plans, monitor progress, and facilitate resourcing of regional committees.

8. That the nine Regional Algal Coordinating Committees be responsible for ensuring monitoring, communications, implementation of response(s), and training in their regions. These committees will liaise with and report to the State Algal Coordinating Committee, as they are only responsible for algal bloom contingency plans.

9. That mouse bio assay be used as the first test for toxicity of algal blooms (after sample concentration, if required). Subsequent monitoring using specific tests can then be used as an important augmentation of bio assay. A useful guide for water treatment plant operators is the absence of taste or odour from treated water.

10. That water quality guidelines for blue-green algae are:

* Domestic water suppliers be alerted when known taste and odour forming blue-greens exceed 2000 cells/mL or when taste and odour are detected (in the absence of cell count information), for drinking use.

* Alerts for other domestic use, recreation and stock watering be issued by RACCs when potentially toxic blue-greens exceed 15000 cells/mL.

11. That closure of water bodies contaminated by blue-green algae is not necessary. Rather, there is a need to provide sufficient warning against inappropriate use of contaminated water.

12. That the multi-layered approach to algal sampling and monitoring proposed by the Task Force be tested and further developed within NSW.

13. That State Government fund the development of an Algal Watch Kit. The kit will form part of Regional Algal Contingency Plans, enabling local sampling and monitoring, and the activation of alert conditions on a local basis. Development costs are estimated to be $33 000.

14. That effective monitoring programs be implemented to determine causative factors, bloom size and occurrence, toxicity and the effects of blooms.

15. That accurate information be prepared for water treatment plant operators on algal related issues including activated carbon dosing and the operation of treatment plants.

16. That every effort is made to inform the community of algal problems, impacts and coping measures, including the use of:

    . Fact sheets in a format accessible to non English speaking people.

    . A 008 telephone number carrying general algal information and a hotline to be used in emergencies.

17. That the public be educated not only on the problems caused by blue-green algal blooms, but also that waterways can be safely used for water supply, recreation and other uses once blooms are dispersed.

14.4 <u>Managing blooms and their effects</u>

18. That the various water allocation and water system management measures (to provide water to meet environmental needs) being developed by the Department of Water Resources in consultation with water user groups and communities be finalised as quickly as practicable, and within five years. Measures include:

    * Review of regulated flow management and licensing, resulting in an Environmental Contingency Allowance for all the state's river valleys by 1997.

    * Developing unregulated flow plans for all regulated rivers by late 1993, and then for unregulated rivers.

    * Developing minimum flow rules for all Department of Water Resources storages, and incorporating them into the water system management and Security of Supply agreements for the state's river valleys.

19. That algicides and other intrusive toxic chemicals not be used to control blue-green algae in natural waterways. If they must be used, do so in off-river storages.

20. That prevention of bloom development is the best course of action in reservoirs and off-river storages. Only low doses of algicides or algistats are then required.

14.5 Managing the causes of blooms: land and water measures

21. That the Nutrient Control Strategy be implemented for NSW, as outlined in Chapter 12. Phase 1 of the Nutrient Control Strategy is being undertaken in 1992. This involves the identification of the types of activities and the extent to which they contribute to the nutrient problem on a catchment-by-catchment basis.

22. That Phase 2 of the Strategy be funded by State Government in 1993. It is estimated that identification and prioritising of control works and activities, including options for grants, subsidies, incentives and guidelines will take a multidisciplinary team of natural resource managers about 12 months and cost $500,000 (this is in addition to annual funding for research, see recommendation 30).

23. That the following strategy for detergent phosphorus control be implemented:

* A study be carried out within the next two years, by the State Algal Coordinating Committees working with urban water authorities, to quantify the contribution of detergent phosphorus to sewage and to waterways.
* Truth in labelling of phosphorus content in detergents.
* Industry aim for a target of 5% or less by weight of phosphorus in detergents and other cleaning agents, within 18-24 months.
* Government set a 5% by weight phosphorus limit in detergent and other cleaning agents within 18-24 months.
* Government raise public awareness on the use and control of phosphorus in the broad environment.
* Integrate future detergent phosphorus controls with the findings of Phase 2 of the Nutrient Control Strategy after two years. This will identify whether there is priority for further reductions in detergent phosphorus.

24. That programs be developed for other phosphorus mitigation measures including increased phosphorus removal at sewage treatment plants as part of the Nutrient Control Strategy.

25. That current extension/education programs directed at the prevention and control of soil structural decline and erosion, and the appropriate use of fertilisers be reviewed and modified as necessary.

26. That Government continue to support the use of demonstration catchment models and field extension services provided by the natural resource agencies as a means of implementing `best bet' solutions with communities to reduce the amount of phosphorus and other nutrients entering the state's waterways.

27. That government agencies complete by mid 1993 studies already commenced into:

* The concept of tradeable property rights in nutrients, and the feasibility of using market forces to optimise the reduction of nutrients to waterways.

* Reducing the impact of septic tanks on nutrient levels in NSW waterways.

14.6 Research

28 That the State Algal Coordinating Committee oversee the development of a package of complementary and coordinated research and investigation projects for NSW to address the many unresolved questions regarding blue-green algae.

29. That the 42 research needs be brought to the attention of the National Algal Research Board, and national and state research agencies.

30. That State Government fund the State Algal Coordinating Committee $500 000 annually, to accelerate research needed to resolve key identified algal issues for NSW.

WHAT YOU NEED TO KNOW

WHAT ARE BLUE-GREEN ALGAE?

Blue-green algae is the common name for several types of algae which have similar characteristics, one being that they sometimes add a blue-green tinge to water or form blue-green scums on the surface when present in excessive numbers. They are extremely small and are only visible under a high powered microscope as single cells, or small clumps of cells.

HOW DO I KNOW IF WATER CONTAINS BLUE-GREEN ALGAE?

If you detect an unpleasant smell or taste, see surface scums or otherwise suspect the water contains blue-green algae, you should not use it until the algae have been identified.

WHY ARE BLUE-GREEN ALGAE A PROBLEM?

They spoil water quality when present in large numbers by producing toxins, odours or thick scums. The toxins they produce are poisonous to humans, and may be deadly to livestock and pets. When algae decompose they may use up oxygen in water and cause fish kills.

WHAT ARE THE EFFECTS OF BLUE-GREEN ALGAE TOXINS ON HUMAN HEALTH?

- Skin contact through showering, bathing, swimming, water skiing, and other recreational activities may result in skin irritation and rashes, swollen lips, eye and ear irritation, sore throat, hayfever symptoms and asthma.
- Drinking water with blue-green algae in it may cause nausea, vomiting, abdominal pain, diarrhoea, liver complications and muscle weakness. The more water you drink, the sicker you may become.
- Visit your local doctor or hospital if you experience medical conditions that you think may have been caused by water with blue-green algae in it.

CAN I DRINK WATER WITH BLUE-GREEN ALGAE IN IT?

No! The water needs to be filtered through activated carbon to remove any toxins. Toxins will not be removed by boiling, or by using household disinfectant.

IF MY WATER HAS BLUE-GREEN ALGAE IN IT, WHAT ELSE CAN I USE?

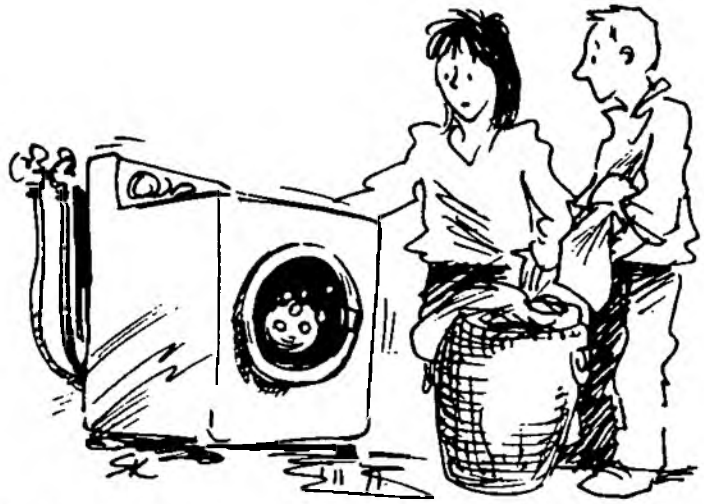
You can use good quality bore water, bottled, carted or tank water. Advice on the safety of alternative sources may be obtained from your local council or water authority.

IS WATER WITH BLUE-GREEN ALGAE IN IT SAFE FOR WASHING CLOTHES OR DISHES?

Alternative water supplies should be used if possible. If there are no alternatives, take extra care by:

- Using rubber gloves when washing clothes and dishes.
- Rinsing dishes with uncontaminated water.
- Removing surplus water with a tea towel.
- If possible, give the laundry a final rinse with non-toxic water. Sun-drying clothes and storing them for a few days can also help.

CAN I WATER FRUIT OR VEGETABLES WITH WATER WHICH HAS BLUE-GREEN ALGAE IN IT?



- Fruit and vegetables do not appear to take-up toxins. However, it is recommended that water with blue-green algae in it does not come into contact with plants being grown for food. This is especially so for salad vegetables.
- Before eating, vegetables should be thoroughly washed and rinsed with non-toxic water.

CAN I COOK WITH WATER WITH BLUE-GREEN ALGAE IN IT?

No! Remember, boiling does <u>not</u> remove toxins from water.

CAN I EAT FISH, SHELLFISH AND YABBIES CAUGHT IN WATER WITH BLUE-GREEN ALGAE IN IT?

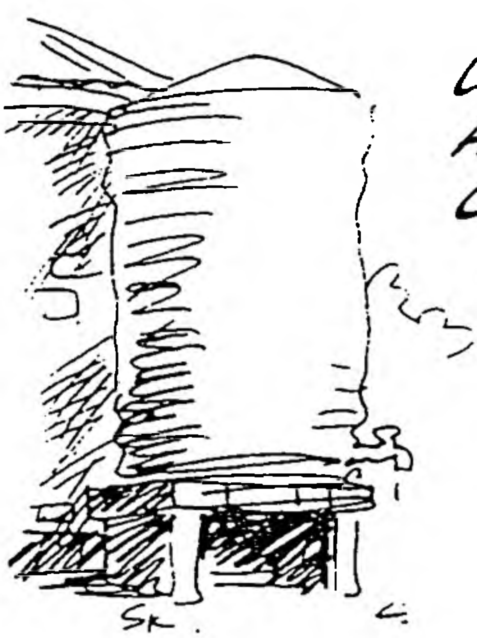
- You should not eat mussels, snails, yabbies and other shellfish, as they can concentrate toxins.
- More studies need to be done on the build-up of toxins in fish. The liver and gut of fish are likely to be poisonous. Other parts of the fish may be eaten, but they may taste muddy or earthy.

CAN LIVESTOCK, PETS, FISH OR WILDLIFE DRINK WATER WITH BLUE-GREEN ALGAE IN IT?

Livestock deaths can occur as a result of drinking water heavily contaminated with blue-green algae. Pets can also be affected, particularly dogs. The effects on fish and wildlife need more research.

CAN I USE CHEMICALS TO TREAT WATER WITH BLUE-GREEN ALGAE IN IT?

Algicides can be used to safeguard water for agricultural use in farm dams before algae blooms occur. You should never attempt to treat rivers, creeks or lakes with algicides (in this situation they may not work, are harmful to the environment and are illegal).



CAN I USE WATER WITH BLUE-GREEN ALGAE IN IT IN MY EVAPORATIVE AIR COOLER?

- Yes, but use an alternative source of water if available.
- Hose down filter pads more regularly, and properly dispose of cooler scums and routine bleed-off water.

FOR FURTHER INFORMATION CONTACT:

PREPARED BY THE NSW DEPARTMENT OF WATER RESOURCES FOR THE STATE ALGAL COORDINATING COMMITTEE. ILLUSTRATIONS BY SIMON KNEEBONE, NOVEMBER 1992. PRINTED ON RECYCLED PAPER

APPENDIX III

BLUE GREEN ALGAE AND THE PALM ISLAND WATER CRISIS

04 NOVEMBER, 1992 JOHN McALEER.

Hello, my name is John McAleer. I am presently employed as an Environmental Health Officer by the Northern Regional Health Authority in Townsville. Between February 1983 and July this year, I was employed as a Hygiene Officer on Palm Island.

BACKGROUND

Palm Island was originally established as an Aboriginal Reserve about 1910, after an earlier community at Hull River was destroyed by a cyclone.

The Palm Island Aboriginal Council is responsible for local government activities on the Island which has a population of approximately 2,500 persons.

In the late seventies, Solomon Dam was constructed with a capacity of 490 mega litres. A sewerage system was implemented at the same time and increased the water consumed by the community dramatically. Originally, water was supplied from the dam with chlorination only. Algae blooms were observed quite early on and Solomon Dam was and still is Palm Island's only source of drinking water in the dry season.

In October 1979, an algae bloom (of unknown species) occurred in Solomon Dam. Severe taste and odour problems were noticed in the reticulated water supply and subsequently the dam was treated with copper sulphate.

Five days after this treatment, the first cases of what was to become known as the "Palm Island Mystery Disease" occurred. The epidemic reached its peak eight days later and lasted 21 days. By the end of the outbreak, 149 people had contracted hepato-enteritis (that is liver and intestinal problems). 139 of these were children and only 10 were adults. About seventy of these people were evacuated to Townsville General Hospital.

Various possibilities were suggested to explain the outbreak. One being that it was from parasites deposited on mangoes by flying foxes. Another possibility suggested that since the reticulated water tasted so bad, people were using contaminated well and creek water and so falling ill.

It is now generally accepted that the "Palm Island Mystery Disease" was linked to the treatment of the algae bloom with copper sulphate, either involving actual copper poisoning or by the sudden death and subsequent release of toxins by the algae itself.

It should be noted that in 1979 there was no aeration/destratification of Solomon Dam, and that as the dose

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rate for copper sulphate was calculated for the whole dam, mixing may not have occurred and so the surface layers of water may have contained much higher concentrations that anticipated.

In December 1982, Solomon Dam was again treated with copper sulphate. This time two important precautions were taken. The dominant species of algae was checked and found not to be blue green and the Island's one million gallon concrete reservoir was filled before dosing began. This reservoir water was used for several days after the copper sulphate treatment. This time there were no reports of hepato-enteritis in people, however, there was a die off of eels and crayfish in the dam itself.

I arrived on Palm Island in February 1983 and commenced duties as the Island Hygiene Officer. One of the first things I noticed was the difficulty I had maintaining chlorine residuals, particularly during algae bloom. I put this down to the fact that at this time there was no filtration and assumed that all the chlorine was used up by the high organic load coming through in this raw water.

This was not a good situation, but by the end of 1983, Palm Island had a new Water Treatment Plant. This Treatment Plant utilised the slow sand filtration technique before chlorination - giving a far superior finished water supplied to consumers.

After the 1979 incident, Peter Hawkins, of the James Cook University Botany Department was commissioned by the then department of Aboriginal and Island Affairs, with regards the control of blue green algae. An artificial destratifier was installed in the dam at about the same time as the Water Treatment Plant.

Artificial destratification simply involved the use of air pumped into a fifty meter length of PVC pipe submerged seven meters below the surface of the dam. Air passed through one millimetre holes thirty millimetres apart and formed a rising curtain of air bubbles that very effectively mixed the entire dam. Peter Hawkins' study showed that although species of blue green algae were still present in Solomon Dam, the numbers were lower than prior to the implementation of artificial destratification.

Once destratification and the slow sand filtration were functioning, the only big problem with algae was the winter blooms of diatoms. Diatoms have a skeleton of silica which doesn't break down and so can form a mat on the surface of the filters blocking them quickly and completely at times. As there was no backwash facility, the only way to clear them was to physically shovel the crust off the filters and over the sides. Diatoms were a normal problem in normal years and during some very thick and long blooms, it became difficult to maintain supply. This eventuated as no sooner had a bed cleaned, that it would block up again.

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THE PALM ISLAND WATER CRISIS OF 1992

1992 began very dry, so dry in fact that concerns were raised that the Island may run out of water completely. It was also discovered that the dominant species of algae in the dam at this time was Clindrospermoposis and Microcystis species, both know toxin forming blue green algae. In addition, the aerator could not be used because the dam land was too low. Manganese and Iron were giving taste and odour problems and to top off the situation, the Council was in financial crisis, so the Water Treatment Plant operator was retrenched. Given the bad memories of the 1979 "Palm Island Mystery Disease", the scene was now set for the "Palm Island Water Crisis of 1992".

In 1991, six bores were sunk on Palm Island. These were supposed to yield all of the water the Island could use. However, on pump testing, these bores in January this year, it became obvious that these expectations were incorrect. In fact, with water consumption in January at around 1.7 megaliteres per day, the one bore that could produce any water at all could only give 15,000 litres a day.

By March 1992, it was painfully obvious that the wet season had been all but missed, with virtually no rainfall of significance after March 1991. I calculated that with the rate of consumption at the time and the amount of water left in storage, the Island had perhaps two months supply left. Things started happening quite quickly, then with visits by Ministers and Members of Parliament. The Queensland Water Resources Commission became heavily involved and quickly drew up a report detailing what could be done to solve, or at least reduce the severity of the crisis.

The Queensland Water Resources Commission report looked at alternate sources of water that could be used, conservation of what water remained and possible treatment - management for the blue green algae problem.

Alternate sources considered included the use of bore water (which was of limited supply) desalination of sea water and construction of a pipeline from the mainland, however, both options were considered too expensive. The use of sub-surface (swamp water) was abandoned for political reasons. As a result, barging water in from Townsville was found to be the most likely short term solution, even though it to was extremely expensive with one quote being $10,000 per day and this delivering only a fraction of water needed. Barging water would have begun if relieving rain had not fallen.

The only other source of water was that obtained from Palm Valley Creek. In this instance, the Department of Family Services, Aboriginal and Island Affairs, supplied a water tanker truck and operator to deliver water from the Palm Valley Creek to the Water Treatment Plant during the crisis. In addition, they also rebuilt

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an obsolete pipeline from a weir in Palm Valley to the one million gallon concrete reservoir and provided a sodium hypochlorite chlorinator to chlorinate this water.

The other line of attack was to conserve what water was left. All outside hose cocks were removed, all leaks repaired and all sprinkling had been banned after October 1991. Water consumption fell from 1.7 megaliters per day to about one megalitre per day and I believe that with the installation of low flow shower roses, dual flush toilets and water restricting devices on al taps, the average daily usage has now dropped to about 0.7 megaleters per day.

Another suggestion put forward was the use of a product from sperm whales - an oil which was to be put on the surface of the dam to reduce evaporation. Apart from not being very "green" there was some confusion with "whale sperm", the idea was never put into practice.

As far as management of blue green algae, treatment with copper sulphate was discounted, as there was no alternate supply to use during the ten day withholding period (which is now advised) and because it was a politically unsuitable option. Other ideas were to use straw or potassium permanganate to inhibit the growth of the algae, but these are apparently still experimental.

What we did do, was to install an activated carbon dosing system whereby the carbon was to absorb the toxin produced by the algae. The only way the activated carbon could be introduced into the plant was via the inlets and onto the slow sand filters as a slurry at a rate calculated at 2ppm. This required a vat to hold the slurry, a mixer to keep it in suspension,a suitable pump to dose with (as powdered activated carbon is very abrasive) three phase power and suitable plumbing to deliver the slurry and allow flushing. All of this was housed in a three by three meter garden shed on a concrete slab.

At the beginning of this year, my knowledge of blue green algae was such that I knew little more that what not to do. There were several questions that came to mind and they included what species were in Solomon Dam, what numbers and how long would a "bloom" last?

Identification and counts were carried out by Professor Griffiths and his staff from the James Cook University and this work was done as a favour and was greatly appreciated. Another way to monitor the toxicity of a bloom is by mouse bioassay. I believe this involved injecting mice with algae and observing the effects on their nervous system and liver. One mouse bioassay was performed on a sample from Solomon Dam and gave a negative result. That is, no effects were observed. In this case, the testing was performed at the University of New England in Armadale in New South Wales.

Microcystin - the toxin produced by the blue green algae Microcystis spp can be measured at the CSIRO in Griffith, New South Wales. As such, a sample was forwarded there to look at the effectiveness of the activated carbon treatment. In this instance, we tried dosing in just one of the slow sand filters and compared the amount of microcystin remaining post filtration and post carbon treatment, with that remaining post filtration only. The activated carbon seemed to be working.

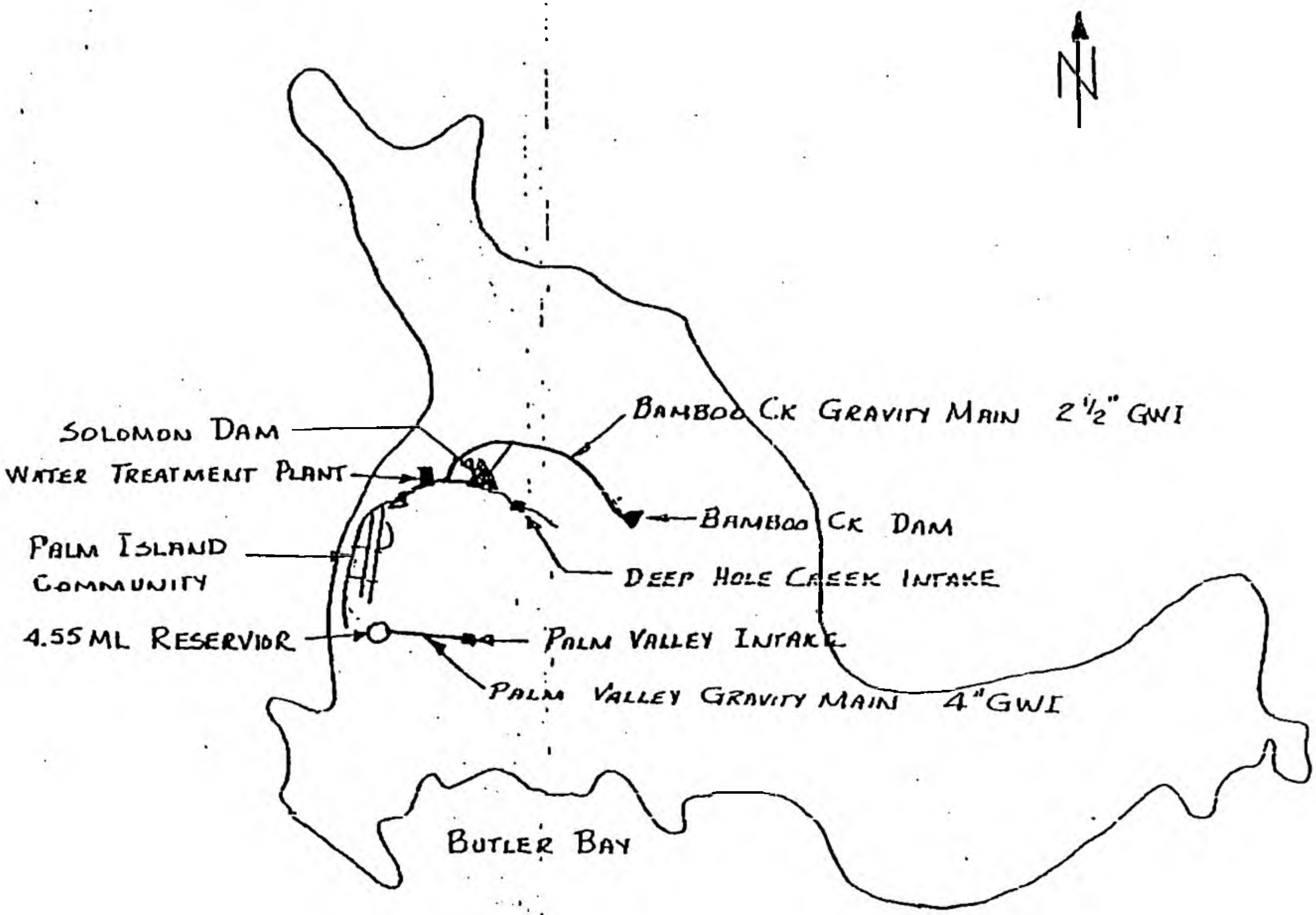
In closing, I would like to give special thanks to Professor Delwyn Griffiths and his staff, Mr. Allan Murdoch and the Queensland Water Resources Commission for their support above and beyond the call of duty during the crisis.

I understand there is quite a lot to be established about blue green algae and that management guidelines are still under review. The present situation on Palm Island is being closely monitored by the Queensland Water Resources Commission and Queensland Health.

PALM ISLAND NOW

Blue green algae is still present, activated carbon dosing continues and with tight water restrictions, there should be enough water to last, providing the next wet season arrives.

Thank you.



PALM ISLAND WATER SUPPLY

OCT 23 '92 02:13PM P.2

JAMES COOK UNIVERSITY OF NORTH QUEENSLAND

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International +61 77 251570

20 October 1992

Mr. Alan Murdoch,
Water Resources Commission,
PO Box 1158,
Ayr. Q. 4807.

Water Samples from Solomon Dam - Received 20.10.92

(1) **Sample from pump room below Dam**

Dominant alga - a green flagellate (confirmed by examination of ~~(ca. 50 cells/ml)~~ unfixed sample). (ca. 50 cells/ml).

Synedra - occasional (<10 cells/ml)
Desmids - occasional (<10 cells/ml)
Scenedesmus - occasional (ca. 20 cells/ml)
Anabaena - 4 trichomes/ml = ca. 80 cells/ml
Microcystis - only 2 colonies observed - doubtful -not characteristic

(2) **Sample from Dam**

Green flagellates more numerous - ca. 200 cells/ml
Anabaena - 36 trichomes/ml = ca. 750 cells/ml
Diatoms (mostly *Synedra*) ca. 20 cells/ml
Scenedesmus - ca. 50 cells/ml
Microcystis - some doubtful colonies, but not really typical of *Microcystis* seen in previous samples.

D.J. Griffiths

THE COLIN BLUMER REGIONAL VETERINARY LABORATORY
NEW ENGLAND, HUNTER AND METROPOLITAN REGION
PMB (UNE), ARMIDALE N.S.W. 2351.

Telephone: (067) 73 4888 Fax: (067) 71 2558

AN92/1292

BLUE GREEN ALGAE TOXICITY TESTING

RECEIVED 05 MAY 1992

SUBMITTER: J McAleer
Palm Island Aboriginal Council
PALM ISLAND QLD 4816

ph: 077 701 177 fax: 077 701 241

SAMPLE HISTORY: Sample taken from drinking water ex Solomon Dam. Water tested and claimed to have cylindrospermodsis present.

SAMPLE COLLECTED: 7 April 1992 SAMPLE RECEIVED: 8 April 1992

ALGAL IDENTIFICATION: No distinct visible signs of Cylindrospermodsis being present.

SAMPLE DISCRIPATION: Drinking water sample

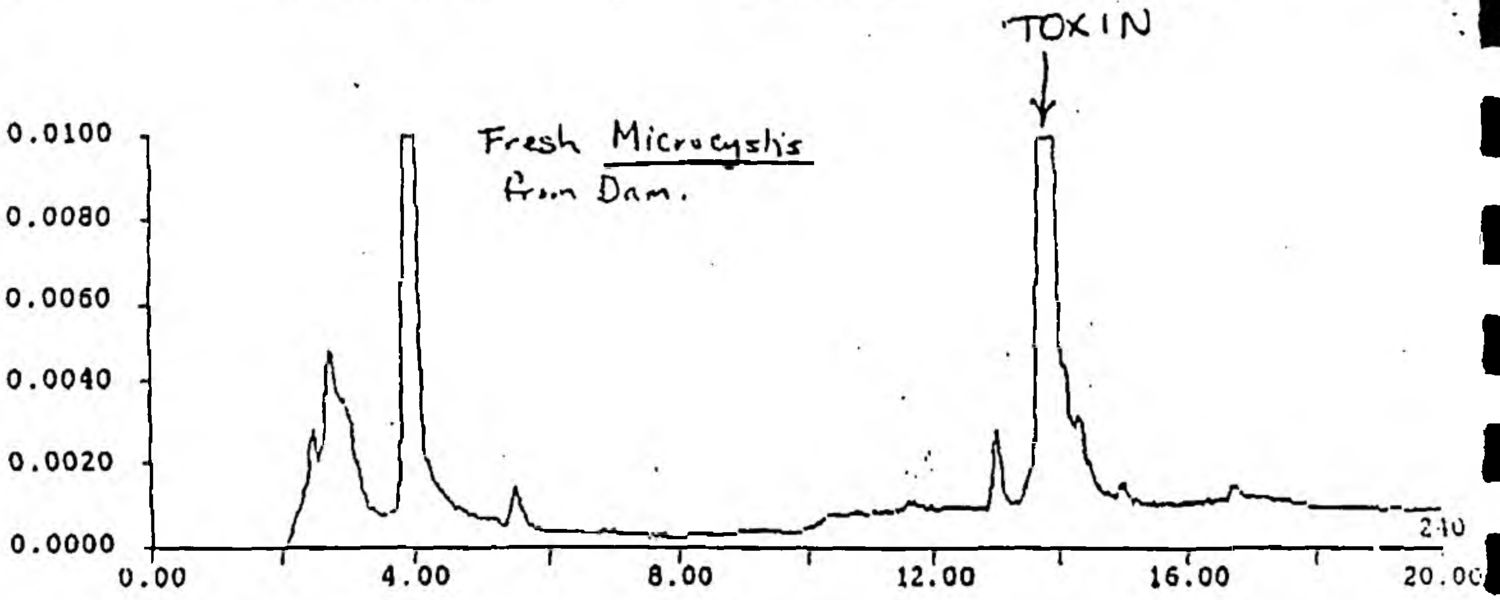
TEST RESULTS: Mouse toxin tests were all negative.
Autopsy results - no significant findings.
Histopathology - no significant findings.

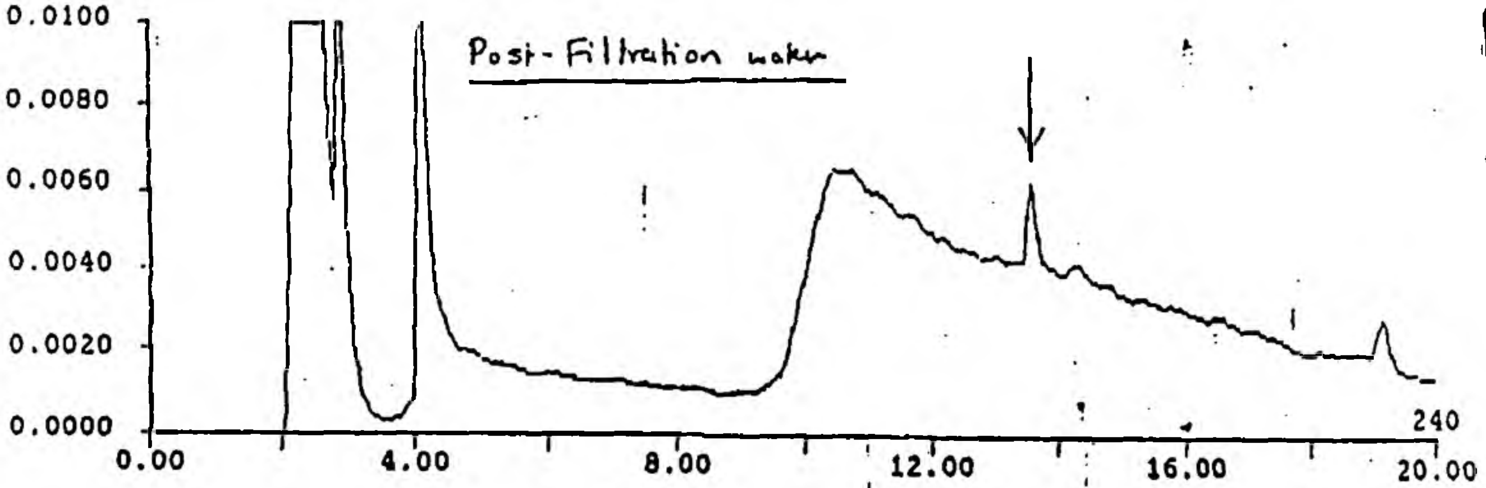
Samples not toxic.

COMMENT: For future sampling more concentrated samples of contaminated water should be submitted.

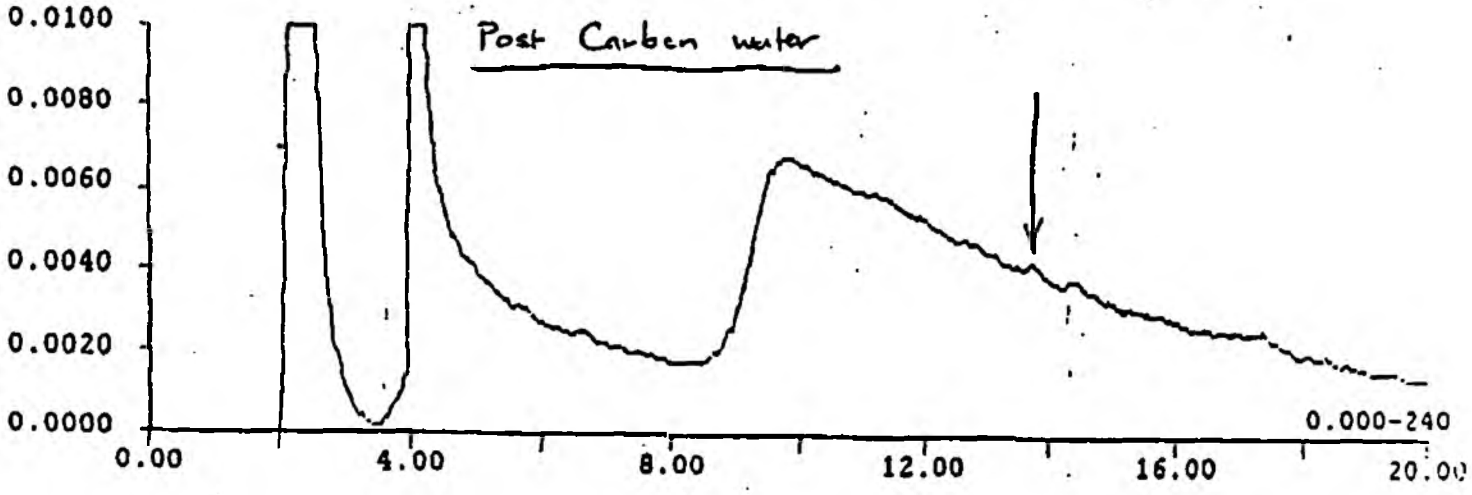
O. R. Coverdale
Officer-in-Charge

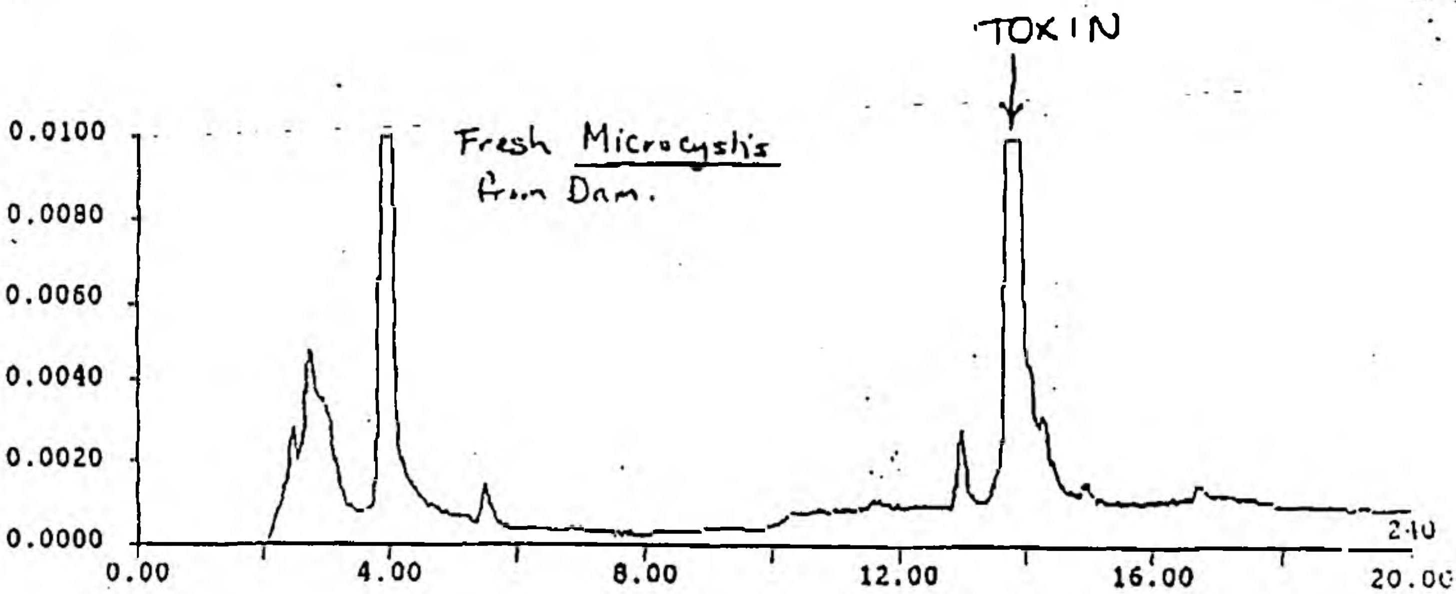
29 April 1992

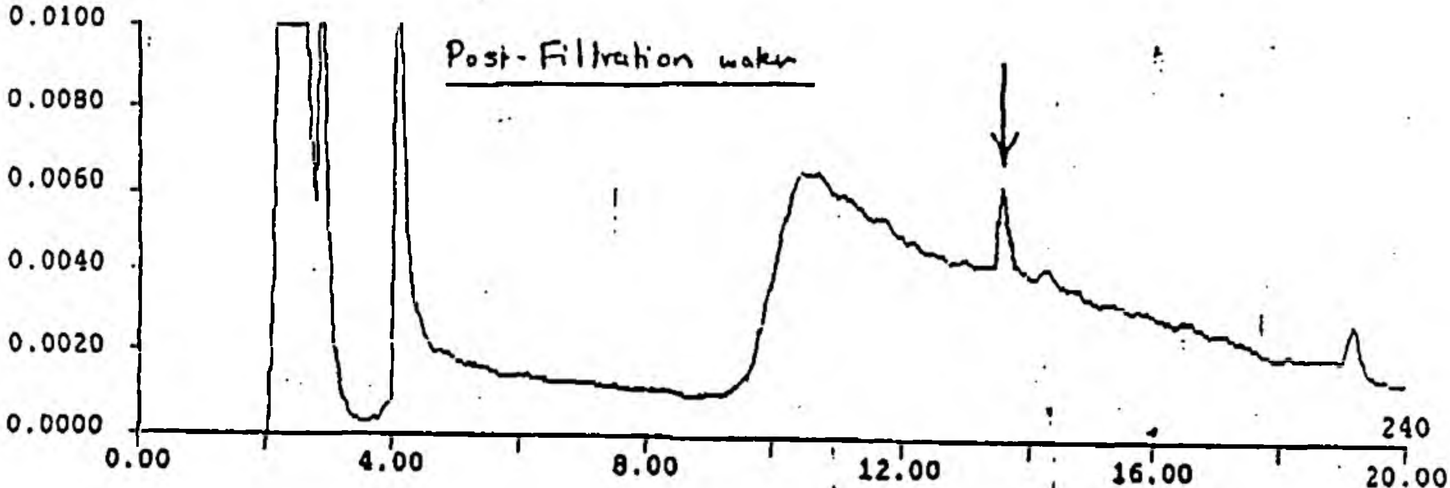




(Humps due to non-specific organic material)







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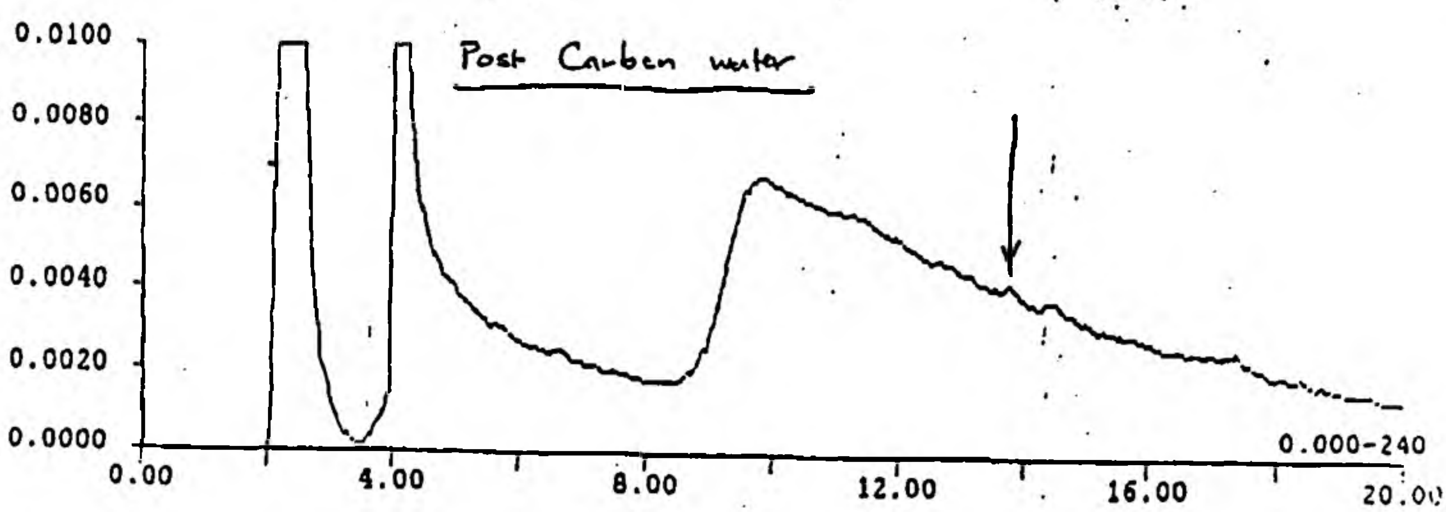


APPENDIX IV

MICROCYSTIS AERUGINOSA BLOOMS IN LAKE MOKOAN, NORTH-EASTERN VICTORIA

J HARRISON, A SCHALKEN, R CROOME
(Rural Water Commission of Victoria)

INTRODUCTION

Lake Mokoan is a large, shallow off-river storage located near Benalla in North-Eastern Victoria (Fig. 1). It has a full supply volume of 365,000 ML, covers an area of 8000 ha, and has a maximum depth of 7.3 m. It was constructed in the late 1960's (along with Lake Nillahcootie) to harness flows in the Broken River and its tributaries.

Lake Mokoan was formed by the construction of a low 7.5 km earthen wall across the natural overflow route of a series of wetlands. The largest of these wetlands, Winton Swamp (covering an area of 1850 ha) typically contained at least 3000 ML of water and dried out only occasionally during times of drought. The other swamps were predominantly ephemeral in nature and sustained mature stands of redgum (hence the extensive stands of drowned trees in the lake today).

Since first filling in 1973, Lake Mokoan has remained substantially full, acting primarily as a drought reserve for the River Murray, a function called upon during the 1982-83 drought. Works are now proposed to facilitate diversion of water from the lake, via the Broken River, into the Goulburn component of the Goulburn Murray Irrigation District. The information presented in this paper is derived from a water quality study conducted from October 1989 to May 1990 in the lake and river as part of development of the proposed diversion works (Harrison *et al*. 1990).

During the course of the study, a substantial bloom of the toxic cyanobacterium *Microcystis aeruginosa* occurred in Lake Mokoan, resulting in restrictions on water supply and closure of the lake for recreational purposes from early February 1990 until early June 1990.

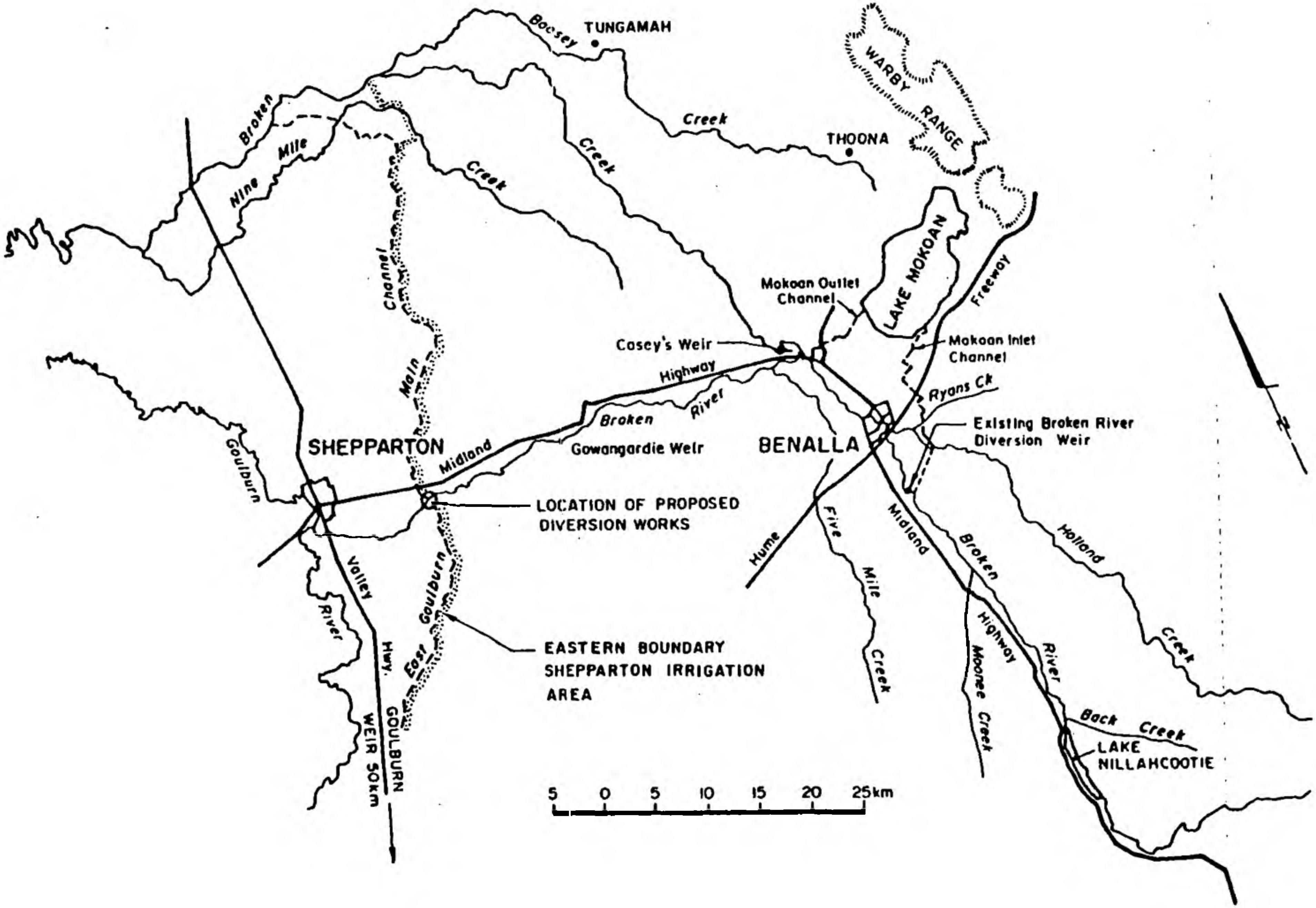


Fig.1 Lake Mokoan – Regional Map

SAMPLING AND METHODOLOGY

Detailed descriptions of sampling sites and methods are given in Harrison *et al.* (1990).

RESULTS

The volume of Lake Mokoan since its construction in 1971 (as a percentage of full supply) is presented in Figure 2. Since filling in 1973 water levels in the lake have remained relatively high, generally above 90% capacity in the winter, and above 70% capacity in the summer. The exception to this occurred from late 1982 to late 1986 when lake levels remained below 60% capacity as a result of the 1982-83 drought and maintenance works on the embankment. During the drought, the lake was drawn down to as low as 4.5% of its full supply volume.

Water temperature data for Lake Mokoan obtained from monthly profiles are presented as isopleths in Figure 3. The lake was found to have alternate periods of complete mixing and thermal stratification. At the time of sampling in January, March and May, the water column was isothermal. During the other 5 months of the study period, varying degrees of thermal stratification were observed. Dissolved oxygen levels in the water column were generally above 80% saturation, but, did decrease to as low as 40% immediately above the sediments during stratified periods.

Turbidity levels in Lake Mokoan since 1977 are presented in Figure 4. Until 1983 (when the lake was drawn down to 4.5% of its full supply volume - Figure 1) the turbidity was relatively constant and was typically below 10 NTU. Only four data points were obtained during the following four years (when water levels remained below 60% of full supply volume) but these indicate that turbidity was between 20 and 60 NTU. From 1987 when the lake completely refilled, the turbidity values began to rise sharply to their current level of 120 NTU.

During the study period (October 1989 - May 1990) turbidity increased from 90 to 120 NTU and has since remained at 120 NTU. Secchi depth during the study period varied between 0.19 to 0.3 m.

Electrical conductivity (EC) within the lake is typically less than 300 *u*S/cm. During the study period EC increased from 170 to 210 *u*S/cm due to evaporative concentration over summer and autumn. The pH values in the lake varied between 6.9 and 7.8 pH units.

Levels of oxidized nitrogen and total Kjeldahl nitrogen for the study period are presented in Figure 5. TKN levels were typically around 1 mg/L-N, apart from high values in February and March when accumulated algal material was present in the samples. Oxidized nitrogen levels were stable at about 0.35 mg/L-N until late January when they rapidly decreased to negligible levels. The level of oxidized nitrogen began to increase again in March and continued to rise until the end of the study period in May. Further samples from July and August 1990 indicate that the oxidized nitrogen concentration has returned and stabilized at levels experienced prior to January 1990.

Phosphorus levels in Lake Mokoan are presented in Figure 6. Total phosphorus levels remained at around 0.12 mg/L-P apart from samples in February and March which were heavily contaminated with algal material. Filtered reactive phosphorus levels were generally between 0.01 and 0.03 mg/L-P apart from one sample at the end of April which appears to be an erroneous result, perhaps due to sample contamination.

Of some 20 taxa of planktonic algae identified in routine algal counts from Lake Mokoan only 4 were present at any time during the study period at concentrations in excess of 750 cells/mL (Pennate Diatoms, *Rhodomonas*, *Anabaena*, *Microcystis*). A substantial population of *Microcystis aeruginosa* was present in the lake over the period November 1989 to May 1990. The population was at its peak in January 1990, reaching cell concentrations up to 90 x 10^6 cells/mL (Figure 7) and leading to chlorophyll-*a* levels as high as 36,000 *u*g/L (Figure 8). The population declined in mid-March but sufficient colonies were still present within the lake to cause significant shoreline accumulations until May.

Microcystis appears to have formed large blooms in Lake Mokoan in the previous three summers at least (V Wingrave, pers. comm.) and has been blamed for water quality problems (taste and odour, floc blanket break-up) experienced by the Shepparton Water Board in April 1979 and March 1988 when releases were made from the lake. Blooms of cyanobacteria also occurred in

Fig.2 Lake Mokoan - Percentage Volume in Storage

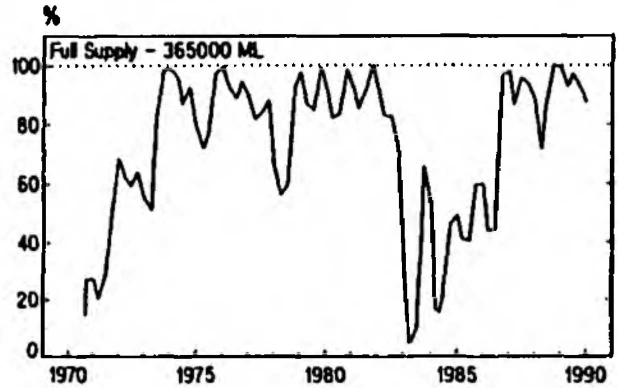


Fig.4 Lake Mokoan - Turbidity

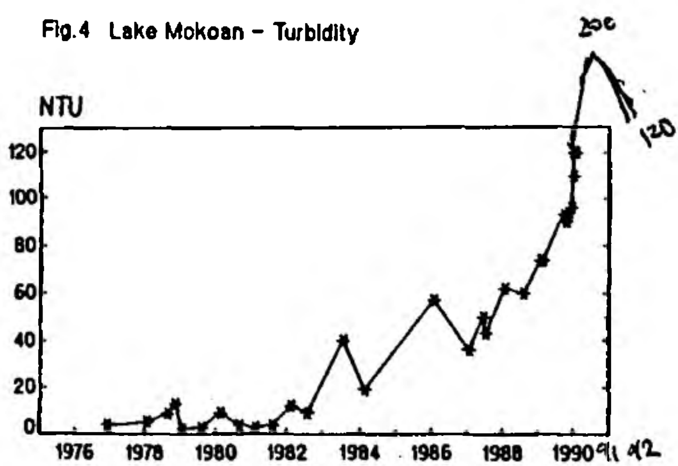


Fig.3 Lake Mokoan – Isopleths of Temperature (° Celsius)

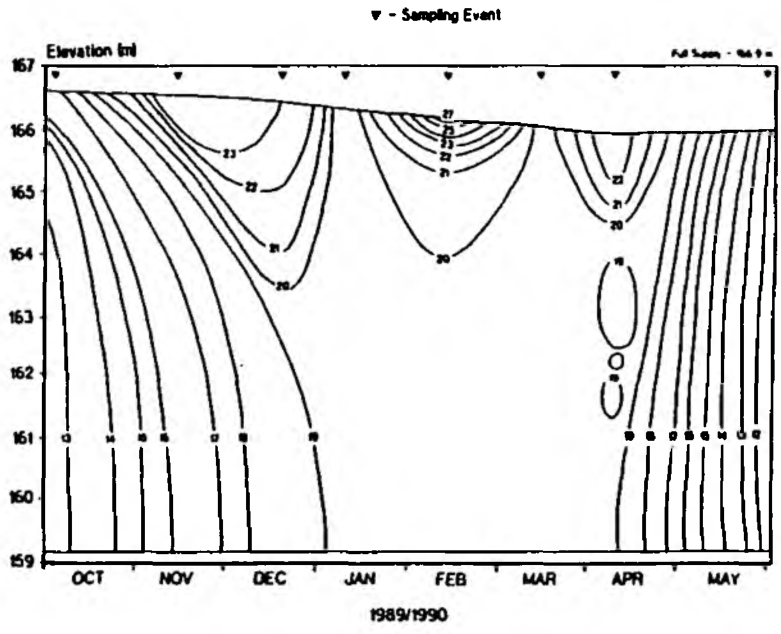


Fig.5 Lake Mokoan – Concentration of Nitrogen

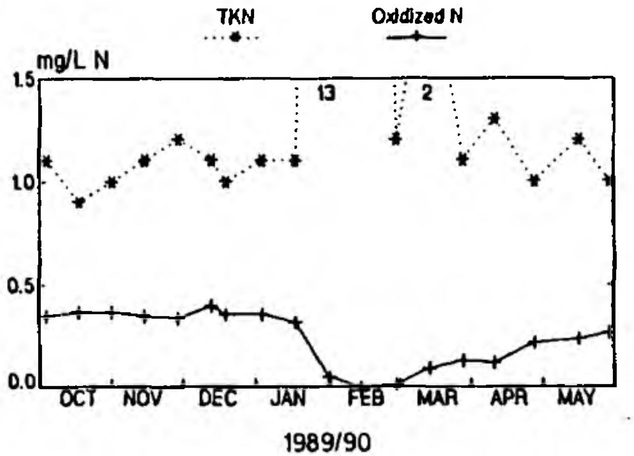


Fig.6 Lake Mokoan – Concentration of Phosphorus

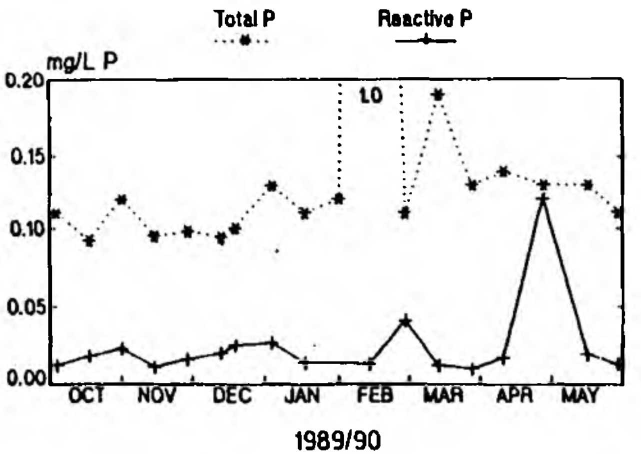


Fig.7 Lake Mokoan - Concentration of Microcystis

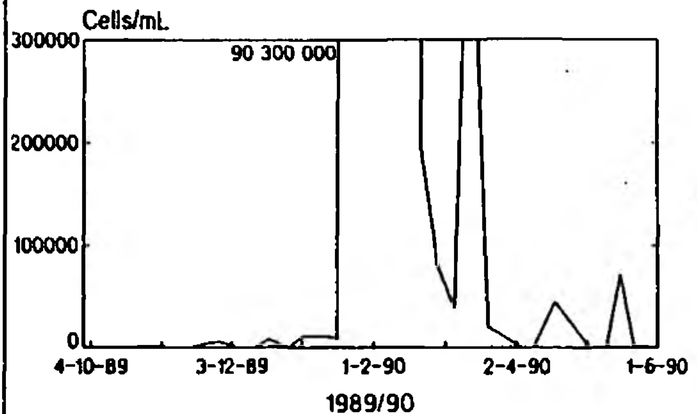
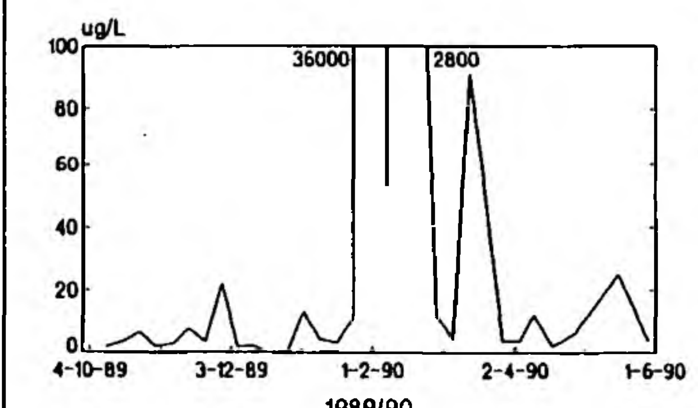


Fig.8 Lake Mokoan - Concentration of Chlorophyll-a



Lake Mokoan prior to 1979 but had not been considered a problem. *Microcystis* and *Anabaena* bloomed in the lake in 1973, and were possibly associated with wildfowl deaths at that time (Wood 1975).

When *Microcystis* first appeared in Lake Mokoan in November 1989, a sample was freeze-dried and sent to the State Water Laboratory of South Australia for chemical characterization. The sample was analysed by High Performance Liquid Chromatography (HPLC) and four potentially toxic cyanobacterial peptides were detected. The major potential toxin accounted for 67% of toxins present and corresponded with the toxin standard Microcystin - LR. The other three potential toxin components comprised 23%, 5% and 5% of the toxins detected. The sample contained approximately 0.9 mg Microcystin - LR per gram of dried algae, and was considered by comparison to assays conducted elsewhere to be highly toxic (M Burch, pers. comm.).

The sample was then forwarded to Professor I R Falconer (University of New England, Armidale) for mouse bioassay toxicity testing. Professor Falconer's preliminary findings were also that the sample was highly toxic.

Nine further samples of freeze-dried algae from Lake Mokoan were sent to the State Water Laboratory of South Australia as the bloom of *Microcystis* progressed and then diminished, to be assayed by HPLC and some forwarded to Professor Falconer for mouse bioassay. At the time of writing preliminary results only are available. Several of the samples appear to have been toxic, others non-toxic. Further replicate analyses need to be conducted by the State Water Laboratory of South Australia prior to any formal presentation of the results (D Flett, pers. comm.).

DISCUSSION

Lake Mokoan is a turbid, shallow lake which alternately stratifies and mixes throughout the year.

It is hypereutrophic with respect to levels of dissolved phosphorus, and mesotrophic with respect to levels of oxidised nitrogen.

Its underwater light climate is severely restricted, and there is little submergent aquatic vegetation. On the other hand, substantial blooms of the cyanobacterium *Microcystis* occur during summer.

The effect of the *Microcystis* bloom on nutrient levels within the lake is worthy of note. Phosphorus values were little affected (Figure 6) except where samples were obviously taken in algal accumulations. Filtered reactive phosphorus levels appeared to be unaffected by the bloom, indicating that the supply of phosphorus was unlikely to be limiting algal growth within the lake.

The situation for nitrogen was somewhat different (Figure 5). While values of Total Kjeldahl Nitrogen were little affected, except where samples were obviously taken in algal accumulations, values of oxidized nitrogen were drastically reduced by the bloom. From 17 January to 31 January the oxidized nitrogen concentration dropped from 0.32 mg/L to 0.047 mg/L and by 13 February the value was <0.003 mg/L. Subsequent to the end of February values increased steadily until the end of the study period. The data suggest that the supply of oxidized nitrogen was the factor which limited the duration and extent of the *Microcystis* bloom in Lake Mokoan during the 1989/90 summer.

Given the high levels of phosphorus still available for algal growth, it is interesting that no other species of cyanobacterium succeeded *Microcystis* since many other cyanobacterial species (including *Anabaena* which was present briefly at 11,000 cells/mL in November 1989) are capable of fixing atmospheric nitrogen. It is apparent that other factors were acting against the establishment and growth of nitrogen fixing cyanobacteria at this time (turbidity/depth of the photic zone, circulation patterns, and possibly inhibitory substances released by *Microcystis*?).

The current water quality problems experienced in Lake Mokoan appear to be a consequence of a steady deterioration in the condition of the lake since the 1982-83 drought when it was drawn down to 4.5% of full supply volume. Prior to the drought Lake Mokoan appeared to be in a stable state with relatively clear waters (10 NTU or less). Extensive stands of submergent aquatic macrophytes (predominantly *Vallisneria*) were present throughout the lake and it supported a large recreational redfin fishery and abundant birdlife (I Davidson, pers. comm.). Although the lake has had a history of cyanobacterial blooms since first filling, it seems that they were not nearly as severe as these experienced in recent years (V Wingrave, pers. comm.).

After the drought, Lake Mokoan did not completely refill until 1987, resulting in the loss of exposed aquatic vegetation and degradation of the exposed lake bed. Since refilling, the turbidity has been continuously increasing, possibly as a result of suspension of colloidal particles from the degraded clay beds in the lake floor. The resultant reduction in light penetration appears to have prevented the growth of macrophytes which may have survived the drought, and continues to prevent recolonisation of the denuded lake bed.

The loss of aquatic vegetation (and invertebrates - see Harrison *et al.* 1990) has had a negative impact on the wildlife of the lake. Fishermen claim that redfin catches have substantially decreased, abundance of birdlife is only a fraction of what it used to be, and several hundred long necked tortoises (*Chelondina longicollus*) have died as a result of starvation during 1990 (M Hindmarsh, I Davidson, V Wingrave, pers. comm.).

Although obviously not intended at Lake Mokoan, lake draw-down is an effective and accepted method of controlling excessive weed growth in lakes (Cooke 1980, Ryding and Rast 1989). Algal blooms after refilling and detrimental impact on water fowl and fish are some of the negative impacts associated with such draw-downs (Cooke 1980).

CONCLUSIONS

Lake Mokoan, a large, shallow off-river storage in North-Eastern Victoria, is highly turbid and experiences blooms of the (toxic) cyanobacterium *Microcystis aeruginosa* over summer/autumn.

Lake level draw down during the 1982-83 drought and sustained low levels until 1986 appear to have resulted in the loss of extensive stands of submergent macrophytes. Since refilling, there has been an increasing trend in turbidity, and blooms of *Microcystis* have become severe.

The extreme turbidity of the lake, and an alternation between thermally stratified and mixed conditions, appears to favour *Microcystis* over other algae. The supply of oxidized nitrogen has been identified as limiting the (albeit extensive) growth of *Microcystis* within the lake.

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Harrison, J., Schalken, A., Rankin, T., Croome, R. (1990) "Lake Mokoan and the Broken River: Factors Affecting Water Quality". Rural Water Commission of Victoria. (In preparation).

Ryding, S.O. and Rast, W. (1989). 'The Control of Eutrophication of Lakes and Reservoirs.' Man and the Biosphere Series, Volume 1. UNESCO Paris and Parthenon Publishing Group Ltd, Carnforth UK.

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MINUTES forming ENCLOSURE to EWS 4287/91

WATER SUPPLY CONTINGENCY PLANNING COMMITTEE

AGENDA for Meeting No 19

to be held 6th floor Panel Room at 10.00am, Thursday 28 January 1993

1	Opening comments. Welcome and introduce visitors.	ANK
2	Background on the role of the committee.	ANK
3	Acceptance of minutes of meeting 18.	
4	Update on algal events this spring and summer.	DAS
5	Update on research into blue green algae. Current status of risk assessment and toxicity - alert levels and acceptable levels.	MDB
6	Briefing on MDBC algal strategy.	CBS
7	Current status of contingency plans. Are they updated and ready for implementation? Raise any issues or case histories that are of news or benefit to others.	EACH REGION
8	Comments and input on matters of common interest.	VISITORS
9	Actions arising from previous minutes. Outstanding Contingency Plans. Contingency Plans to local State Disaster people. Methods for field containment of algae. Simple, cheap, small scale removal of algae/toxins.	 VSS RCT EACH REGION DBB RMJ
10	Other business. (close meeting at 12.00 noon.)	

<u>EWS INVITEES</u>: Neil Killmier, Peter Cooper, Peter Norman, Don Bursill, John Parsons, Brian Triptree, Peter Forward, Kym Wallent, Vince Sweet, Peter McGarry, Bob Jones, Robert Thomas, Paul Dellaverde, Bob Thompson, Claus Schonfeldt, Dennis Steffensen, Mike Burch, Peter Hoey, Dave Bain, Ric Ingerson.

<u>VISITORS</u>:
Mr Mick Pearson, Dr Alastair Ferguson, of the National Rivers Authority, England.
Professor Geoffrey Codd, University of Dundee, Scotland.

BLUE-GREEN ALGAL BLOOMS - AN ALERT LEVELS FRAMEWORK

FOR WATER SUPPLY CONTINGENCY PLANS

M D BURCH

INTRODUCTION

Blue-green algal (cyanobacterial) blooms have long been recognised as a water quality problem due to their production of offensive tastes and odours. More recent widespread recognition of their potential for toxicity, and the identification of many toxic blooms across south-eastern Australia, has upped the status of cyanobacteria on the problem agenda for water supply authorities.

As with many new problems there are uncertainties. For cyanobacteria the uncertainties relate primarily to the health significance of toxicity - what danger or risk do they really pose? Secondly how should water supply managers respond to a toxic bloom which threatens public water supply.

Based on the best available research and practical experience across a number of agencies, an alert levels framework for use in water supply contingency or emergency plans has been developed.

The alert levels framework is a monitoring and action sequence which operators can use to respond to the onset and progress of a particular bloom. The circumstances and operational options will obviously vary depending upon the source of supply and facilities available, but the generalised model can be adapted to individual conditions.

The proposed model is based upon following a blue-green algal or cyanobacterial bloom via a basic monitoring program through three stages, defined as alert levels. The sequence of alert levels is based upon initial detection of blue-green algae at Level 1, through to moderate numbers at Level 2 where supply is still acceptable, followed by Level 3 where the water is unsafe for supply as a result of high numbers of toxic cyanobacteria.

The progress through this sequence will vary depending upon whether the water source is a river or a storage and whether treatment options such as algicides and activated carbon are applicable or available.

The framework is developed from the perspective of the water supply operator. This can be a state or regional agency through to a local water board or local government. The actions accompanying each level cover categories such as additional sampling and testing, operational options, consultation with health authorities and media releases. An important part of the framework is consultation at various stages with other agencies, particularly health authorities, who are invariably the arbiter of the safety of water for potable supply. The consultation steps in the framework in some cases would be through already formally constituted committees, for example New South Wales has regional algal coordinating committees consisting of a number of agencies, and South Australia has a central emergency water supply contingency network group for blue-green algal blooms.

There are several areas that need qualification when using this framework. These are the status of health guidelines for cyanobacteria, importance of species composition of blooms, sampling and counting of cyanobacteria, and media and community relations. Some background comments on these issues are given, before explaining the alert levels framework in detail.

GUIDELINES FOR CYANOBACTERIA IN WATER

There are currently no guidelines issued by the National Health and Medical Research Council of Australia for cyanobacteria or their toxins in water for drinking or for recreational purposes.

As such levels contained in this document may at best be regarded as provisional health investigation levels and should be used only in this context. The final responsibility in all matters of safety of public water supply rests with the relevant Health Department in each State or Territory. The specific health risk associated with any particular cyanobacterial bloom would need to be assessed taking into account up-to-date information on toxicology and the local situation.

SPECIES COMPOSITION OF BLOOMS

Most of the bloom forming cyanobacteria in Australia can impact on water quality through taste and odour production. However a limited number of species have been positively confirmed as being toxic.

As discussed in the preceding document, not all strains of a particular species are toxic. Those which must be regarded as potentially toxic until tested are *Microcystis aeruginosa, Anabaena circinalis, Nodularia spumigena* and *Cylindrospermopsis raciborskii*.

Other *Anabaena* species including *A.flos-aquae* and *A.spiroides* are morphologically similar to *A.circinalis*, and it is prudent to treat these spirally coiled or contorted *Anabaena* spp. with caution in the absence of specialist taxonomic confirmation and/or toxicity testing.

Other bloom forming species of the genera *Aphanizomenon* and *Oscillatoria* are often found to be toxic overseas, but limited testing in Australia has not demonstrated toxicity associated with these genera. These genera can therefore be regarded with less immediate concern and high cell numbers might be treated in a less cautionary manner than those of the potentially toxic species. However, it is advisable that all cyanobacterial blooms threatening water supplies should be tested for toxicity. Likewise most cyanobacteria can produce lipopolysaccharide (LPS) toxins which are implicated in dermatotoxic contact irritations, allergic reactions and other possible health effects.

SAMPLING AND COUNTING OF CYANOBACTERIA

There are difficulties in both sampling and counting cyanobacteria to accurately estimate cell densities within a water body.

Sampling problems arise because the distribution of cyanobacteria can vary enormously both horizontally and vertically throughout the water body. Buoyancy regulation by those cyanobacteria with gas vacuoles allows them to move vertically over the water column and leads to scum formation. Scums, which often form in the early morning, are then blown across the water surface by prevailing breezes. This can have a significant and variable influence on cell density at any one particular site. This is difficult to accommodate within a sampling program and is not readily resolved.

The best advice to operators is to concentrate on the location adjacent to the water supply offtake. If the offtake point is not representative of the rest of the water body it may be necessary to incorporate one or more additional sites to better estimate a trend in population numbers in the water body overall.

Choice of the number of samples and sites has a cost-benefit as well as a statistical consideration, and both factors must be weighed by the operator.

To overcome problems of localized surface concentrations at one site, it is advisable to collect integrated water column (hosepipe) samples. These are often over an arbitrary depth of 2 or 5 m - to accommodate part of the surface mixed zone. Pooling of several closely spaced replicate hosepipe samples into one sample is another technique to reduce within-site variation.

There can also be errors in microscope counting of colonial cyanobacteria and most laboratories produce results with a precision value of 20% or greater. This is an additional consideration in assessing the sampling results.

Both issues of monitoring and counting of cyanobacteria are under review respectively by another Technical Advisory Group and by the Algal Monitoring Working Group of the MDBC. Counting methods for cyanobacteria are also currently under investigation in an inter-laboratory comparison being conducted under the auspices of NATA.

MEDIA AND COMMUNITY RELATIONS

Public information and media liaison is an important part of emergency contingency planning. Information must be prompt and concise with detail about reasons for short-term changes to supply and explanation for any differences in water quality that may result. It is important for all of the agencies involved to provide coordinated and consistent advice.

The alert levels framework contains a number of points where media releases could be issued. These are as a guide only but they represent the points, based on experience, where consumers may experience changes in water quality. The comments made in the text in relation to media releases covers the sort of information that may be appropriate.

ALERT LEVELS FRAMEWORK

The sequence of the alert levels framework and the actions at each level are shown in the accompanying flowchart. The threshold definitions for each level are also given with the flowchart. The following discussion should be considered in conjunction with the flowchart.

Alert Level 1

This level encompasses the early development stages of population growth when taste and odours become detectable in the supply. It constitutes early warning and if a routine monitoring program is not in place, it is the point to sample and despatch the samples to a laboratory for examination. The presence of these low numbers would still indicate the potential in the storage for the formation of localised surface scums, and operators should begin to regularly inspect raw water offtakes for scums or discoloured water.

Alert Level 2

This level refers to an established bloom with moderately high numbers showing a trend upwards over several successive samples. The population will have developed to the extent of forming localized surface scums.

This level warrants operational options such as treatment with algicides (in storages only) and other measures to avoid contamination of the supply. In some circumstances the use of algicides may be unacceptable due to adverse environmental impacts, and operators should obtain advice or clearance from the relevant environment authority or department. The bloom population should be sampled to establish the extent of its spread and variability. Special samples (concentrated scums) should be collected and despatched for toxicity tests.

Toxicity testing at this stage in the sequence will establish the potential for further escalation of the alert level. The toxicity test should preferably be quantitative rather than qualitative to allow for assessment of the relative toxicity of the bloom. This requires a dry-weight based estimate of [1] MLD_{100} in the case of mouse bioassay, or an estimate of microcystin content if an analytical method for peptide hepatotoxins is available.

Level 2 involves consultation with health authorities for ongoing assessment of the status of the bloom. This consultation should be done as early as possible and also after the results of toxicity testing become available.

It should be noted that it may be acceptable to continue with supply with a positive toxicity result dependent upon a risk assessment by the health authorities.

It may be appropriate to issue a press release to indicate that "water quality problems being experienced (taste and odours) are caused by the blue-green algae in storage / river. Numbers at this stage represent no immediate threat to water supply. Samples are being sent for toxicity testing and the source water is being monitored / treated". If the source water is used for recreation "people are advised to avoid swimming in discoloured water or patches of scum which may look like green paint".

Alert Level 3

The threshold definition of Level 3 encompasses an established toxic bloom with high and variable numbers due to localized scums. The sampling program will have indicated that the bloom is widespread with no indication of a population decline in the short term.

Alert level 3 is the point at which the water contaminated with toxins has become unacceptable for supply based on an assessment by the relevant health authorities. There are considerable difficulties and uncertainty in defining safe or acceptable levels for toxic blue-green algae in drinking water as discussed in the preceding document.

If activated carbon treatment (powdered or granular) is available, it should be used in the treatment process. The treated water can be monitored for microcystin hepatotoxin to confirm their removal, however, this analysis is not yet widely available. Analysis of water for the neurotoxins produced by *Anabaena circinalis* is not yet possible as the toxins in this species have not been identified. If water quality has changed under these circumstances it may be warranted to issue a media release and to reinforce warnings about recreational use of the source water if that is appropriate.

If water treatment with activated carbon is not available, Level 3 will result in the activation of a contingency emergency water supply plan which is appropriate for the operator. This may involve switching to an alternative supply and even delivery of water to consumers by tanker in some circumstances.

1. MLD_{100} - Minimum Lethal Dose, mg freeze-dried cells/kg mice.

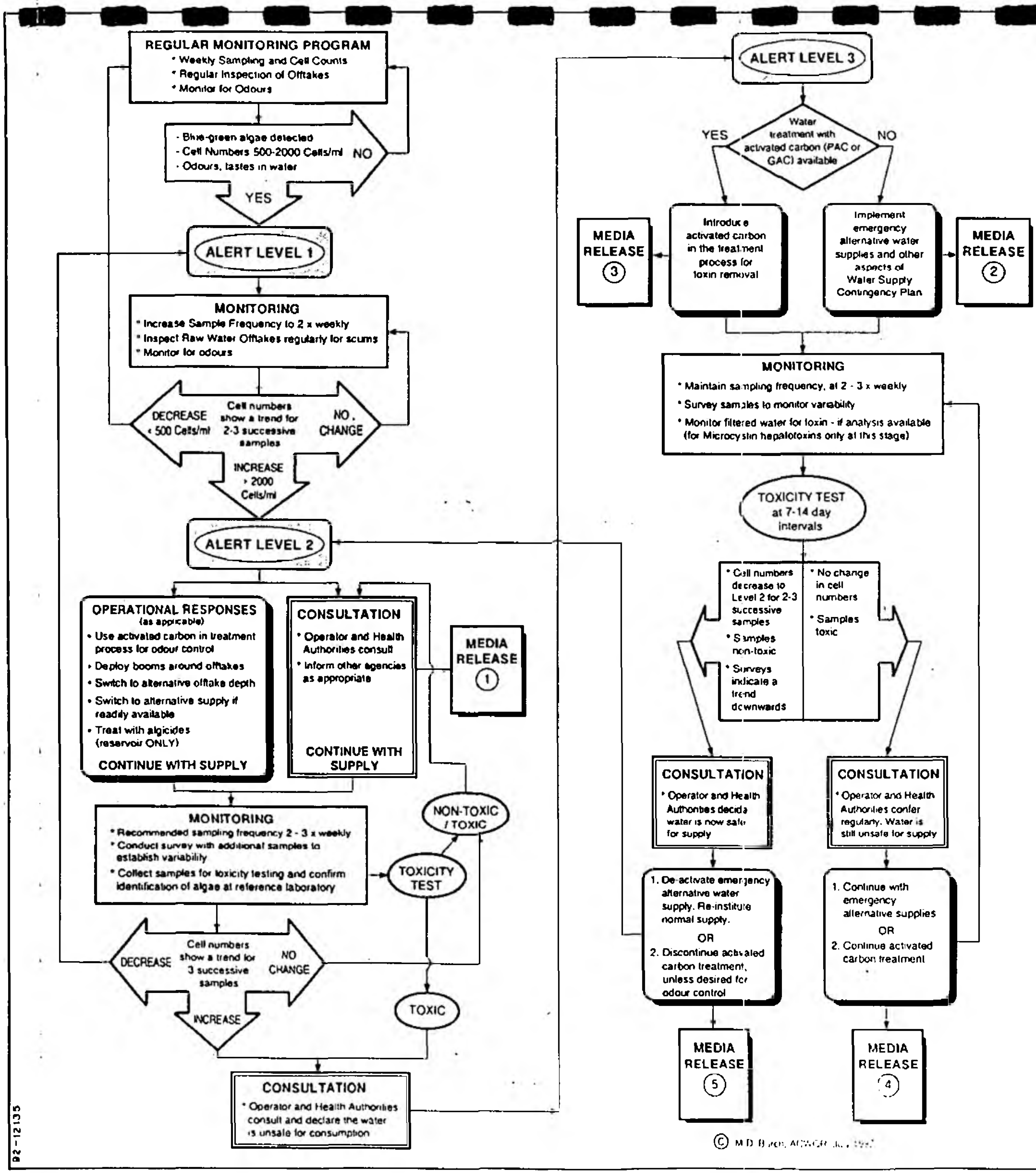
More extensive media releases and even letterbox drops of leaflets with appropriate advice to householders may be necessary.

The bloom must continue to be monitored to determine when it is in decline so that normal supply can be resumed as soon as possible. Toxicity testing is probably only warranted at 1-2 week intervals. Experience suggests that the degree of toxicity can change but it is unlikely to become completely non-toxic or decline in a short space of time (ie. days).

The sequence at Level 3 follows through to deactivation of an emergency with media releases to confirm this. It is possible that the collapse of a bloom could mean a rapid decline from Level 3 back to Level 1 or beyond. Likewise the sequence might escalate rapidly, by-passing Level 1 and 2 straight to emergency mode if early warning information is not available.

ACKNOWLEDGEMENTS

This Alert Levels plan is based on an original model developed by the Engineering and Water Supply Department, and has benefitted from useful discussions with many individuals. In particular, thanks must go to Mr Gavin Wood, Dr Dennis Steffensen, Mr Peter Baker of EWS; members of the EWS Contingency Planning Group; Dr F S Soong, South Australian Health Commission; Mr Warren Wealands, Department of Water Resources, Victoria; Mr Ian Smalls, Department of Water Resources, NSW; Dr Gary Jones, CSIRO; Dr Phillip Johnstone, AWRC - Algal Bloom Research Management.



BLUE - GREEN ALGAL BLOOMS - AN ALERT LEVELS FRAMEWORK FOR WATER SUPPLY CONTINGENCY PLANS

NOTE:
The threshold definitions include a general description followed by specific criteria. These criteria are meant to be indicative at Levels 1 and 2, ie. they don't all have to be met. The criteria at Level 3 are prescriptive - and will all be met with a severe toxic bloom.

ALERT LEVELS - THRESHOLD DEFINITIONS

ALERT LEVEL 1

Initial detection or early warning of an impending bloom.

EITHER * Cell numbers 500 - 2000 Cells/mL (if routine monitoring is in place)

OR * Offensive odours / tastes in supply

ALERT LEVEL 2

Confirmation of an established bloom which is causing water quality problems. Bloom has potential to escalate. Operational intervention is recommended.

* Cell numbers 2000 - 15000 Cells/mL (potentially toxic species) for 2 - 3 successive samples
* Bloom is confirmed as one of the potentially toxic species, ie. *Microcystis aeruginosa, Anabaena circinalis, Nodularia spumigena, Cylindrospermopsis raciborskii*
* Persistent odours / tastes
* Surface scums / localised high concentrations becoming apparent

ALERT LEVEL 3

Well established toxic bloom. Assessment by the Health Authorities indicates the water may be unsafe and is unacceptable for supply without treatment to remove toxins.

* Persistently high numbers widespread throughout source water for three succesive samples
* Toxic
* Cell numbers > minimum acceptable for safe supply (assessment required)
  Provisional cell numbers - 15000 Cells/mL for most toxic *Microcystis aeruginosa*
  Slightly higher for *A. circinalis, N. spumigena*
* Persistent surface scums
* Control measures partially or not successful in preventing the bloom from contaminating water supply offtake point

Engineering and Water Supply Department
South Australian Health Commission

January 1992

BLUE-GREEN ALGAE – INFORMATION FOR RESIDENTS IN AREAS WHERE THE WATER SUPPLY IS AFFECTED

This leaflet has been produced to help householders whose water supply has been affected by dangerous levels of toxic algae.

It is aimed at:

- People who have a private supply from a river, lake or dam known or suspected to be affected.
- People with an EWS Department reticulated supply which has been declared unsafe for human consumption or personal hygiene. PLEASE NOTE: While the department has contingency plans to avoid this happening as far as humanly possible, it will supply contaminated water rather than turn the pumps off; closing down supplies would result in unacceptable risks in relation to firefighting and personal sanitation (flushing of toilets). Any such situation will be heavily publicised.

The Department of Agriculture has a fact sheet for farmers whose stock water supply is affected.

ALTERNATIVE WATER SOURCES

Rainwater tanks. Please note - rainwater tanks should always be sealed to exclude light, or algal growths can occur in them! They should also be properly maintained to avoid bacteriological contamination; a leaflet is available from the EWS Department or the SA Health Commission.

Bores or wells where groundwater is suitable for drinking - not too saline, or contaminated with septic tank effluent, etc. The Department of Mines and Energy can advise on groundwater conditions in your area.

Swimming pool water, provided normal maintenance is kept up, can be used for personal hygiene but should ***not*** be used for drinking.

Commercially available bottled or 'spring' water may of course be used for drinking.

Water supplied by tanker. This should always be disinfected before drinking it - see next section.

DISINFECTION FOR DRINKING OF WATER FROM ALTERNATIVE SOURCES

The following advice is for people using water from a source not normally used, eg by tanker, but where algal infestation is not a factor.

This advice is ***not*** intended for use with sources which are known or suspected to be affected by toxic algae. These methods will kill the algae but will ***not*** destroy the toxin - in fact they may make the toxicity worse!

Methods available are:

Boiling for at least one minute. Useful for limited quantities, for drinking.

Chlorination. Useful for larger quantities, and can be achieved by using a 5 parts per million (5 milligrams per litre) concentration of free chlorine, using household bleach or pool chlorine (liquid or granular).

IMPORTANT NOTE: 'Stabilised' pool chlorine ***must not*** be used as it contains cyanuric acid, which is not suitable for drinking water.

TYPE OF CHLORINE	USE THIS AMOUNT TO DISINFECT: 10 LITRES OF WATER	1 000 LITRES OF WATER
Household Bleach 4% Free Available Chlorine *	1.25 mL	125 mL
Sodium Hypochlorite (Liquid) 12.5% Free Available Chlorine *	0.4 mL	40 mL
Calcium Hypochlorite (Dry Powder) 65.70% Free Available Chlorine*	0.07 grams **	7 grams

*Different brands may have different percentages of free available chlorine. Check the label and adjust quantities if necessary. Also, some brands contain detergent, sodium borate or other substances; do not use them to disinfect water for drinking.

**0.07 grams of calcium hypochlorite is equivalent in volume to a grain of rice.

Where possible, the chlorine should be allowed to do its job for a minimum of thirty minutes. Before using the water, it is necessary to allow the chlorine to dissipate to avoid ingesting a larger concentration than is normally found in town water supplies. The water will be safe to use provided the chlorine smell is not too strong. If required, the chlorine may be allowed to dissipate for half to one day in a wide open top container, protected from dust.

The use of chlorine may be corrosive to metal tanks, so it may be more desirable to disinfect smaller quantities for drinking using plastic or glass containers.

CAUTION:
There are hazards associated with handling chlorine as it is potentially dangerous to eyes, skin etc. and corrosive to metals. Check labels for handling requirements. Always add chemical to water, not water to chemical, and mix thoroughly.

HEALTH RISKS OF WATER CONTAMINATED BY ALGAE

Humans can be affected in two ways:

- Skin contact with the algae through showering, bathing, swimming and other recreational activites. Symptoms can include skin irritation and rashes, swollen lips, eye irritation and redness, earache and itchiness, sore throat, hayfever symptoms and asthma.
- Drinking water contaminated with toxic forms of blue-green algae, or toxins they have released. Symptoms can include nausea, vomiting, abdominal pain, diarrhoea, liver complications, muscle weakness and paralysis. Please note: the occurrence and severity of symptoms is strongly related to the amount of water drunk.

If it is necessary to use algae-contaminated water for some purposes the following advice should be heeded.

WASHING CLOTHES, DISHES AND PEOPLE

It is recommended that contaminated water not be used for washing clothes or dishes where a safe source of water is available.

If water has an unpleasant odour or discolouration or if the source is known to be contaminated, bathing and showering should be avoided. If water is apparently clear and free of odour there is less risk and individual discretion is required. Brief showers would be preferable to baths. Infants, toddlers and those with significant skin problems should use only treated water.

Using the water is at your own risk. Where there is no other alternative to using water that could contain algae or algal toxins the following suggestions are made to minimise the risk:

- Use rubber gloves to avoid contact with the water when washing dishes and clothes.
- Rinse dishes if possible with uncontaminated water.
- Remove surplus water with a tea towel to enhance removal of contaminated water.
- If possible, give laundry a final rinse with non-toxic water.

Should any medical conditions occur that are suspected to be caused through the use of untreated water, you should consult your local doctor or hospital.

WATERING VEGETABLES AND FRUIT

It is believed that there is no uptake of toxins by fruit and vegetables from algae-contaminated water, but with the present state of knowledge it is recommended that affected water not be used for watering edible plants if there is an alternative.

If there is no alternative, they should be watered so there is no direct spray on the edible parts of the plants.

This is particularly important with plants such as cabbages, lettuces, tomatoes and other salad vegetables.

Prior to use, the vegetables should be thoroughly washed and rinsed with non-toxic water. This is more applicable to salad vegetables than root vegetables, which are normally peeled.

Should any medical conditions occur that are suspected of being caused through the use of toxin contaminated water you should consult your local doctor or hospital.

EATING FISH FROM ALGAE-AFFECTED WATERS

On the available information concerning the effects of blue-green algae and their toxins on molluscs (eg shellfish) and crustaceans (eg yabbies) for human consumption it is recommended that you do not eat them if caught in algae affected waters.

Fish concentrate toxins in the liver, with lesser concentrations in the flesh. Therefore it is recommended that fish from contaminated waters not be eaten.

USE OF WATER IN EVAPORATIVE COOLERS

There is no evidence to suggest that the use in evaporative coolers of water affected by algal toxins can cause health problems. However, commonsense dictates that an alternative be used, and if there is no alternative that maintenance be stepped up.

In particular, the filter pads should be hosed down more regularly to remove algae and other particles and it is suggested that this be done weekly. (Note - some growth of slimes in evaporative coolers is normal).

The contents of the cooler sump and routine bleed-off should be disposed of properly, particularly as any toxins present could be more concentrated; avoid exposure to children and animals.

For further information contact:

The State Water Laboratory
Toll Free 008 801 650 Fax (08) 259 0228
Soutn Australian Health Commission
(08) 226 6315 - Fax (08) 226 6316

Produced by the Community Relations Branch, Engineering and Water Supply Department.

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Engineering and Water Supply Department
January 1992

THE FACTS ABOUT BLUE-GREEN ALGAE AND THE SECURITY OF SOUTH AUSTRALIA'S WATER SUPPLIES

INTRODUCTION

Algae are among the oldest life forms on earth. They occur in all bodies of water, whether natural or man made. They can also occur in soil, on the leaves of plants, and in a variety of other places.

They have always caused problems for the managers of water resources throughout the world, and always will. Normally their numbers are such that the public are not aware of their presence, or of the routine measures taken to prevent their numbers increasing to the point where they could cause obvious problems such as bad tastes and odours.

However, in the past two summers there have been very visible and widely publicised problems with algae in the lower lakes of the Murray (Lakes Alexandrina and Albert). Recently, there have been serious problems in other States, notably in the Darling River.

There have been no algal problems in South Australia's water resources so far this spring and summer, beyond normal ones controlled by routine measures. The fact that there have been problems interstate does not mean that we will have problems here; algal outbreaks do not behave like a disease which can spread throughout a country.

Nevertheless the EWS Department is very conscious that there is a reasonable possibility of a repeat of the problem in the lower lakes of the Murray, and a much smaller possibility of problems in the main stream of the Murray itself.

In close consultation with the South Australian Health Commission and the Department of Agriculture, the department is well prepared to deal with the problems algae can present to our water resources. Contingency plans to ensure the security of public water supplies are in place. Research is going on into the causes, effects and prevention of algal blooms. Joint initiatives are under way with the governments of the Murray-Darling Basin to implement long term measures to reduce the incidence of algal blooms.

Recognising the strong public interest in the subject, the department has produced this leaflet to give people the facts about algae and the measures being taken to deal with the problem.

WHAT ARE ALGAE?

Algae are simple aquatic plants which occur naturally in healthy water bodies. They are an essential, integral part of freshwater and marine ecosystems.

There are dozens of varieties, most being microscopic single cells or small colonies of cells suspended and drifting in water. Some form long visible strands or clumps which are commonly referred to as green slime.

Algal growth depends on adequate sunlight, dissolved nutrients (including phosphorus and nitrogen) and other factors such as warm temperatures and still water.

Healthy waters usually have a large variety of algae although the number of individuals in any particular variety is usually small. However, in waters containing excessive nutrients numbers can increase dramatically.

WHAT ARE BLUE-GREEN ALGAE?

Blue-green algae (also called cyanobacteria) is a commonly used term applied to several type of algae which have similar characteristics, one being that they sometimes impart a blue-green tinge to water or form green or blue scums on the surface when present in excessive numbers.

They are extremely small organisms visible under a high powered microscope as single cells, or small clumps or filaments of cells. They need sunlight to grow.

Three common types of blue-green algae are *Anabaena*, *Microcystis* and *Nodularia*.

Given the recent publicity about them, it needs to be stressed that there are many other kinds of algae besides the blue-greens.

WHAT IS A BLUE-GREEN ALGAL 'BLOOM'?

'Bloom' is the commonly used word to describe a rapid increase in algal numbers to a point where they discolour water, form scums, produce odours or otherwise create a nuisance and seriously reduce water quality.

Blue-green algal blooms often occur because the necessary conditions for their rapid growth are created by human activities in the catchment or water body.

These conditions include:

- High levels of nutrients (particularly phosphorus, and also nitrogen)
- Calm water
- Low or no flow
- Strong sunlight
- Relatively clear water (which allows sunlight to penetrate)
- High air and water temperatures
- Shallow water (which heats up quickly).

In the Murray system in South Australia such conditions occur mostly in lagoons and backwaters, and in the lower lakes, rather than in the main stream.

Certain types of blue-green algae have tiny air sacs in their cells, allowing them to float to the surface for sunlight or sink to the bottom to absorb nutrients. This explains why a bloom of blue-green algae can appear, disappear and reappear quickly even during a single day.

Blue-green algal blooms often persist for several weeks, sometimes months, depending mainly on the weather or flow. Cooler, windy, cloudy weather or increased flows usually reduce or stop a bloom fairly quickly.

WHY ARE BLUE-GREEN ALGAE A PROBLEM?

Many types of algae reduce water quality when present in excessive numbers by producing taints, odours or thick scum. Blue-green algae are the worst offenders. They give water an unsightly appearance with intense green or blue colouring and sometimes form thick surface scums and crusts. They produce strong offensive or earthy odours and unpalatable taints. Their worst feature, however, is their ability to produce toxins.

Humans can be affected in two ways:

- Skin contact with the algae through showering, bathing, swimming and other recreational activites. Symptoms can include skin irritation and rashes, swollen lips, eye irritation or redness, earache and itchiness, sore throat, hayfever symptoms and asthma.
- Drinking water contaminated with toxic forms of blue-green algae, or toxins they have released. Symptoms can include nausea, vomiting, abdominal pain, diarrhoea, liver complications, muscle weakness and paralysis. Please note: the occurrence and severity of symptoms is stongly related to the amount of water drunk.

There are no recorded cases of human deaths due to blue-green algae.

In human water supply systems, by far the greatest effect of algae is on the taste and odour of drinking water. The tastes and odours normally associated with water affected by algal blooms mean that people will not drink it if they have any choice at all - and they almost invariably do have a choice.

Animals often do not have a choice, and stock deaths can and do occur due to the toxic effects of blue-green algae, mainly in farm dams. Pets can also be affected; dogs are particularly susceptible.

Given the recent publicity about toxic blue-green algae, it is worth stressing that:

- Not all algae are blue-green - most aren't, and are harmless.
- Not all types of blue-green algae can produce toxins.

Some types which can produce toxins do not necessarily do so in particular blooms, or at a particular time, or in all parts of a bloom; nor can scientists predict their behaviour.

It is impossible to predict when or if a bloom will occur in a particular body of water, and if it does which will be the dominant species.

IS THE PROBLEM INCREASING?

The problem is certainly not new. Algae are one of the very oldest life forms; toxic blooms that have killed stock were recorded over a hundred years ago, for example at Lake Alexandrina in 1878, and from many parts of the world.

There is no scientific evidence of any long term trends in the frequency and severity of algal blooms. However, it appears likely that they are increasing due to a combination of factors associated with increased development along rivers and elsewhere within their catchments.

Factors include:

- Reduction in river flows caused by increased offtakes for agricultural, domestic or industrial use.
- An increase in nutrient levels, from:
  - excessive use of artificial fertilisers
  - grazing of livestock along watercourses
  - discharge of effluent from sewage treatment works
  - urban stormwater runoff.

So in recent years the EWS Department has stepped up its monitoring of and research into algae, and has a program to reduce the amount of nutrients entering the State's waterways.

BLOOMS IN PERSPECTIVE

While blooms certainly can be very serious for domestic and agricultural users, talk of the bloom in the Darling as an "ecological disaster", or of a possible bloom in the Murray as meaning "the death of the River", are unscientific and alarmist.

There is no evidence of significant adverse effects on native wildlife. Fish do not appear to be directly affected by algal toxins, although when blooms die and decay they use up oxygen in the water and this can cause some fish deaths.

After a toxic bloom dies the toxic compounds are soon degraded to harmless ones and the water body returns to normal.

However, the long term environmental effects are unknown, and in view of this together with the very serious short term effects, there is no doubt that action must be taken to dramatically reduce the quantity of nutrients entering Australia's waterways.

MONITORING AND DETECTION

Samples are taken regularly of all source waters for the department's water supply systems - all reservoirs and 20 locations on the River Murray near offtake points. Samples are regularly taken also at five points in the lower lakes, and from many more points when blooms are likely or are occurring.

Samples are taken weekly, increasing to twice weekly at key locations during critical periods. Given the rate of growth of blue-green algae, this provides ample warning of potential problems.

Cell counts and identification of species are done at the department's State Water Laboratory. With potentially toxic species, tests for toxic compounds are done there and at the Institute of Medical and Veterinary Science and the University of New England.

The State Water Laboratory is a recognised world leader in the field of toxic algae research, and maintains a close working relationship with other leading researchers in universities and scientific institutions both in Australia and overseas.

CONTINGENCY PLANNING

Algae in the department's reservoirs do not result in any health risk to consumers. When monitoring reveals levels far below any level of health concern, the reservoir is treated with an algicide which prevents blooms forming.

While this treatment is completely effective in enclosed, relatively small bodies of water such as reservoirs, it can not be used in watercourses such as the Murray or in lakes such as Alexandrina and Albert. However contingency plans have been developed to ensure that all customers have a safe and continuous supply of drinking water.

The public can inspect these plans at Regional offices. They are very much site-specific, but include measures such as:

- use of activated carbon in water filtration plants to reduce toxins
- change of source of supply where possible
- management of flows in the River Murray to move blooms away from pump intakes
- installation of floating booms around pump intakes to prevent the entry of floating algal sums
- tankering water for drinking and personal hygiene where it is impossible to prevent contaminated water entering the water supply system.

In relation to this last point, it is stressed that water supplies ***will not be shut down*** in the event of a toxic bloom, as this action would merely create other risks such as reduced firefighting capacity and reduced sanitation. Naturally, if contaminated water has to be supplied it will be heavily publicised.

INFORMATION FOR PEOPLE IN AREAS NOT SERVED BY A DEPARTMENTAL WATER SUPPLY

If you detect unpleasant odours or taints, observe surface scums or otherwise suspect that blue-green algae have infested the water you use for drinking, cooking, kitchen uses, bathroom and shower uses, swimming or stock watering you should not use it until the algae have been identified.

Where the presence of blue-green algae is suspected, alternative water sources should be used. These might include bore water or bottled, carted or tank water, or good quality groundwater. ***Boiling will not inactivate algal toxins.***

Filtration through activated carbon (a processed form of charcoal which adsorbs many chemicals and toxic substances) may remove some or all of the toxins, but results in particular applications cannot be guaranteed. Carbon filtration systems can be obtained from manufacturers of water treatment equipment. The Department of Agriculture provides advice on building simple carbon filters to treat water for farm animals.

Country dwellers should ***never*** attempt to treat watercourses with algicides. It is ineffective, ecologically unsound, very dangerous and illegal!

A leaflet is available from the EWS Department which contains advice for people whose water supply may be contaminated with algae.

LONG TERM ACTION

Strategies for prevention of blue-green algal blooms are being developed. Such strategies involve improving catchment management to reduce phosphorus entering the system, and reassessing water allocation so that, if possible, flushing flows can be maintained during critical times of high potential for algal growth.

Phosphorus sources that are being or will be addressed include sewage treatment works, industrial effluents, fertilised crop and pasture land and stock access to waterways.

Within the Murray-Darling Basin, a nutrient management strategy is being developed, which will include long term action plans, short term contingency plans and a program for further research. A paper on sources of nutrients which encourage algal growth will shortly be released by the Murray-Darling Basin Commission.

CONCLUSION

Algae do present a genuine problem which needs to be taken seriously; the department does.

At the same time, it ought to be kept in perspective. It is not a new problem, and while it may well be increasing it is certainly not doing so explosively. There is no present "crisis" in South Australia, nor has there ever been.

The department and other agencies such as the South Australian Health Commission and the Department of Agriculture are well aware of the potential problem, and in full cooperation, are well prepared to deal with it.

South Australia is also cooperating with other States on long term measures to reduce the potential problem.

It is also, through the State Water Laboratory, a world leader in research to find out more about algae and the toxicity of certain blue-green species.

For further information contact:

The State Water Laboratory
Toll Free 008 259 0352 - Fax (08) 259 0228

Prepared by the Community Relations Branch, Engineering and Water Supply Department.

The assistance of the South Australian Health Commission, the SA Department of Agriculture and the NSW Department of Water Resources is gratefully acknowledged.

LIST OF AUSTRALIAN BLUE-GREEN ALGAE PUBLICATIONS

NEW SOUTH WALES

N1 The Cyanobacterial (Blue-Green Algal) Bloom In The Darling/Barwon River System, November - December, 1991 - by Department of Water Resources Technical Services Division.

N2 State Of The Rivers - Water Quality Report To The Regions, 1991/1992 by Department of Water Resources Technical Services Division.

N3 Streamwatch, December 1992, leaflet by Department of Water Resources.

N4 Interim Unregulated Flow Management Plan For The North-West, June 1992 - by the Department of Water Resources.

N5 State Of The Storages, 1991-92 - Water Quality of the New South Wales Department of Water Resources Storages - by Lee Bowling and Vicki Martin of the Department of Water Resources.

N6 Carcoar Wetland - A Wetland System For River Nutrient Removal by G.C. White, I.C. Smalls and P.A. Bek of the New South Wales Department of Water Resources.

N7 Water Quality in New South Wales by the Department of Water Resources.

N8 Draft State Total Catchment Management Marketing Strategy - July 1991.

N9 Water - The Resource And Its Management - Guidelines and Support Material to the Study of Water Resources in Years 11 and 12 Geography - by the Department of Water Resources.

N10 Interim Unregulated Flow Management Plan For The North-West - by the Department of Water Resources.

N11 Blue-Green Algae leaflet on the Task Force - by the Department of Water Resources.

N12 Warning - Blue Green Algae - What You Need To Know - A leaflet by the NSW Department of Water Resources.

N13 Sweet Water or Bitter Legacy - State of the Rivers - Water Quality New South Wales by the Department of Water Resources.

N14 Various leaflets produced by the Department of Water Resources.

N15 The Future of our Rivers - A Community Forum about Blue-Green Algae.

QUEENSLAND

Q1 Blue Green Algae And The Palm Island Water Crisis by John McAleer.

CANBERRA

C1 An Investigation Of Nutrient Pollution In The Murray-Darling River System - by Gutteridge Haskins & Davey (January 1992).

C2 Murray-Darling Basin Commission - various leaflets.

C3 Murray-Darling Basin Commission - 1991 Annual Report.

C4 River Murray Floodplain Planning Guidelines - A Draft Discussion Paper by the Murray-Darling Basin Commission.

C5 Chowilla Resource Management Plan - Progress Report - Prepared by the Murray-Darling Basin Commission's Chowilla Working Group.

C6 Riparian Vegetation Of The River Murray - by The Murray-Darling Basin Commission.

C7 Hume And Dartmouth Reservoirs - An Economic Study Of Changed Operating Strategies - by The Murray-Darling Basin Commission.

C8 Fish Management Plan (November 1991) by the Murray-Darling Basin Commission.

C9 Watering the Barmah-Millewa - Red Gum Forest - Issues Paper by the Murray-Darling Commission.

C10 Algal Bloom Research In Australia - A progress report of current status and key issues by Phillip Johnstone of Algal Bloom Research.

C11 Catchment Wise Information For Teachers And Student Activities - by Kiam Kelly

C12 Algal Management Strategy - Minimising The Occurrence Of Algal Blooms (leaflet).

C13 Guidelines For Drinking Water Quality In Australia, 1987 - National Health and Medical Research Council & Australian Water Resources Council.

C14 National Water Quality Management Strategy - Draft Guidelines For Groundwater Protection (August 1992) by the Australian Water Resources Council.

C15 National Water Quality Management Strategy - Water Quality Management In The Rural Environment - A Reference Document - by the Australian Water Resources Council.

C16 National Water Quality Management Strategy - Water Quality Management In The Rural Environment - A Discussion Paper - by the Australian Water Resources Council.

C17 National Water Quality Management Strategy - Groundwater Protection - A Discussion Paper, by the Australian Water Resources Council.

C18 National Water Quality Management Strategy - Draft Guidelines For Sewerage Systems - Acceptance Of Trade Wastes (Industrial Wastes) - by the Australian Water Resources Council.

C19 National Water Quality Management Strategy - Water Quality Towards A National Policy - A Discussion Paper - by the Australian Water Resources Council.

C20 National Water Quality Management Strategy - Draft Guidelines For Sewerage Systems - Effluent Management - by the Australian Water Resources Council.

C21 National Water Quality Management Strategy - Policies and Principles - A Draft Reference Document - by the Australian Water Resources Council.

C22 National Water Quality Management Strategy - Water Quality - A National Approach - by the Australian Water Resources Council.

C23 Waterlink - No. 12 August-November 1992 by CSIRO.

C24 Waterlink - No. 13 December-March 1993 by CSIRO.

C25 Division of Water Resources - Seeking Solutions - Biennial Report 1990-1992 - by CSIRO.

C26 Blue-Green Algal Blooms - An Alert Levels Framework For Water Supply Contingency Plans by M.D. Burch.

VICTORIA

V1 Health (Quality of Drinking Water) Regulations 1991 - Statutory Rule No. 33/1991.

V2 Victoria Government Gazette Special - 26th February, 1988.

V3 Gippsland Lakes Algal Bloom Seminar - Discussion Papers

V4 Gippsland Lakes Management Plan - by the Department of Conservation and Environment.

V5 Microcystis Aeruginosa Blooms In Lake Mokoan, North-Eastern Victoria by Messrs. J. Harrison, A. Schalken, & R. Croome.

V6 The Control of Blue-Green Algae by Dr. Michael Hindmarsh.

V7 Algal Problems In Victoria by Wendy van Dok, Barry T. Hart & Richard Royle.

V8 Caring For Cultivated Soil issued by the Department of Agriculture.

V9 A Newsletter about the work of the Gippsland Lakes Implementation Council.

V10 A Whole Farm Plan For Your Property - A step-by-step guide to rural property planning - by Frank Hirst and Penny Morton.

V11 A Framework For The Lake Mokoan Restoration Project - October 1992 - edited by Lance Lloyd & Joanne Harrison.

V12 Blue-Green Algae Alert/Action Levels For Drinking Water Supplies, November 1992 by the Department of Conservation and Natural Resources.

V13 Blue-Green Algae In Drinking Water Supplies, December 1990 - by the Working Party on Blue-Green Algae in Water Supplies.

V14 Farmcare in the Strzelecki Catchments - leaflet.

V15 Integrated Catchment & Reservoir Management: Candowie and Lance Creek Reservoirs by Messrs. B.T. Hart, R. Royle, S. Poulson, & S. Morris.

V16 Draft Gippsland Water Strategy - Managing a Valued Resource by the Department of Water Resources.

V17 Water Victoria - Annual Report 91/92 - Department of Water Resources.

V18 Water Victoria - An Environmental Handbook by the Department of Water Resources.

V19 Water Victoria - The Next 100 Years - by the Department of Conservation & Environment.

V20 Water Victoria - A Scarce Resource by the Department of Water Resources.

V21 Water Victoria - A Resource Handbook by the Department of Water Resources.

V22 Wetland Management Program Of The Department Of Water Resources, 1992, prepared by Paul Wettin.

V23 The Environmental Condition of Victorian Streams.

V24 1992 Publications Catalogue by the Department of Conservation and Natural Resources.

V25 State Water Laboratory of Victoria - Specialists in Water Science.

SOUTH AUSTRALIA

S1 Removal of Algal Toxins In Water Treatment Processes - by the Australian Centre For Water Quality Research.

S2 Destruction Of Cyanobacterial Peptide Hepatotoxins By Chlorine And Chloramine - by the Australian Centre For Water Quality Research.

S3 Absorption Of Microcystin-LR By Powdered Activated Carbon by the Australian Centre For Water Quality Research.

S4 Welcome To Watermark - leaflet produced by Australian Centre For Water Quality Research.

S5 Watermark - second edition - leaflet produced by Australian Centre For Water Quality Research.

S6 Current Research Projects At The Australian Centre For Water Quality Research And Associated Agencies In The Area Of Algal Blooms And Cyanobacterial Toxicity.

S7 The Chemistry Of Freshwater Algal Toxins by B.C. Nicholson and J. Rositano.

S8 The Facts About Blue-Green Algae And The Security Of South Australia's Water Supplies by the Engineering and Water Supply Department.

S9 Agriculture Fact Sheet - Blue green algae toxicity - By Jack Van Wijk, District Veterinary Office.

S10 Tag 3 - Cyanobacterial Toxicity.