



RIVER AND RIPARIAN LANDS MANAGEMENT NEWSLETTER

RIVER contaminants

Australians are becoming increasingly aware of the importance of water resources and riverine environments to the future sustainability of agriculture and the environment. River restoration has become a priority for many catchment and resource agencies, with the management of river contaminants a key part of the restoration equation. This is because river contaminants determine both the quality of drinking and irrigation water, and the condition of instream habitats for river plants and animals.

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CONTents



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Land & Water Australia's mission is to provide national leadership in utilising R&D to improve the long-term productive capacity, sustainable use, management and conservation of Australia's land, water and vegetation resources. The Corporation will establish directed, integrated and focused programs where there is clear justification for additional public funding to expand or enhance the contribution of R&D to sustainable management of natural resources.

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Cover image: *Anabaena circinalis*. Photo C. Bold, CSIRO.

RIParian lands: WHERE LAND AND WATER MEET



From the Editor

Welcome to another edition of *RipRap*, this is my eleventh edition as editor and we never seem to run out of river and riparian topics to cover! This edition of *RipRap* is on River Contaminants, and Brendan Edgar and Jacky Croke deserve special mention for helping me pull these articles together. We have covered three key contaminants in this edition — salt, sediment and nutrient — and worked with scientists to present current thinking about the impact of these contaminants on rivers, the knowledge gaps that exist, and the different management approaches that can be taken to address these impacts. The 'It's a Wrap' section provides perspectives from catchment communities around Australia on how to deal with contaminants, and we also have an article on measures being taken by the cotton industry over the past ten years to reduce pesticide contamination. You will also find adverts for new CDs, the National Land & Water Resources Audit Atlas and information about Land & Water Australia's upcoming Rivers Forum. The Rivers Forum will be held next year on 20–21 of March 2002 in Canberra and Yass, it promises to be a terrific event and we are making every effort to ensure that speakers and activities are challenging, thought provoking and a little out of the ordinary. The next edition of *RipRap* will have registration forms and full Rivers Forum Program details — so look out for it!

What are river contaminants and how can we effectively manage them for riverine and ecosystem protection?

River contaminants fall into two broad categories — those substances that occur naturally, but for which significant increases in the amounts present contaminate the environment (e.g. salt, nutrients and sediment); and secondly, those that do not occur naturally, and for which even small amounts contaminate the environment (e.g. agricultural chemicals and heavy metals). Our knowledge about these contaminants is patchy, with research into salt, nutrients, and sediments providing us with a reasonably good understanding of the causes of contamination, the ecological effects, and the options for improved management. In contrast, research into the second category is limited, and we have a relatively poor understanding of the ecological effects and the extent to which we need to improve management. What is common to all, are the associated environmental, social and economic costs that arise when different river contaminant management strategies are proposed.

While understanding and managing river contamination by a single substance might be relatively simple, many rivers are affected by contaminants, and very little is known about how different contaminants interact. For example, different contaminants may chemically interact during transport or once deposited, and the ecological responses to ‘cocktails’ of chemicals are likely to be wide-ranging and complex. The interactions between contaminants, the ecological responses, and the links back to catchment and river management options are, at this stage, relatively unexplored.

To improve our understanding and management of river contamination issues and, ultimately, to help reduce the associated costs, The National River Contaminants Program (NRCP), was established in 2001 by Land & Water Australia and the Murray–Darling Basin Commission. The primary objective of the NRCP is to better manage the risk of river contamination. To do this we need to understand:

~ where contaminants are coming from in the landscape;

~ how they are transported to the river system; and,
~ what transformations will occur as contaminants interact within the water column and with other potentially harmful contaminants?

At the national level, salinity has been identified as the highest priority water contamination issue (Figure 1). However, elevated nutrient and sediment loads are also common, and are significant management issues for water quality and river health. In some areas, pesticides are recognised as a significant problem, but the full extent of the risks associated with pesticide residues is difficult to assess from existing data. The first activity of the NRCP was a workshop (June 2001) to scope the *sources, pathways and transformations* of each of these contaminants within river systems and to consider the possible interactions between these contaminants. The feature articles in this edition of *RipRap* summarise the outcomes from this workshop, and outline priorities for R&D that will contribute to the NRCP’s primary objective over the next four years.

Salt as a contaminant

Research has demonstrated the seriousness of the salinity problem in Australia. Much is now known about the causes of salinity, and a number of effective strategies have been demonstrated to

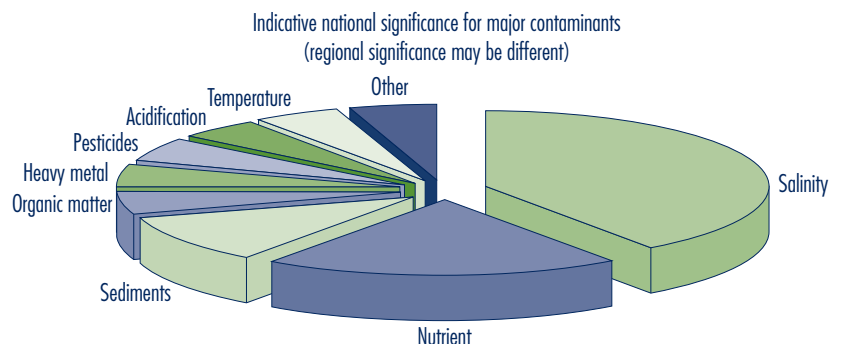


Figure 1: Indicative national significance for major contaminants. Source: ATECH Report 2000

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reduce the problem. However, little R&D has been conducted on the specific environmental impacts of salinisation. In particular, few investigations have examined the biological changes in salinised rivers or wetlands. Some research suggests that exposure to salinities of between 1000 and 2000 mg L⁻¹ for even short periods, is likely to have significant effects on lowland rivers ecology (Bailey and James 2000). In general, current knowledge concerning the effects of increasing salinity on aquatic ecosystems is inadequate to guide decision-making.

The article *Salinity Processes in Australian Rivers* by Boon, Bailey and Walker in this edition, summarises the sources, transport pathways and transformation for salt in the landscape. Ben Kefford et al's article *A Method to Predict the Effect of Rising Salinity on Freshwater Invertebrates* describes a project funded by the National Dry Land Salinity Program (NDSP) to address the salt sensitivity of aquatic macroinvertebrates in the Barwon River in Victoria. By building up a knowledge and data base of how aquatic species respond to changing levels of salt, researchers hope to inform managers of the likely risks of increased river salinity. The article by Jenny Davis on *Alternative Ecological States* outlines project aims and methods for a newly funded L&WA project to investigate different ways of managing salinised ecosystems in Western Australia.

Nutrients as contaminants

River nutrient levels do not generally constitute a serious issue for irrigation or drinking water quality. Rather, it is the ecological effects of

nutrient enrichment (eutrophication) and the associated water quality degradation that are the problem. Nutrient enrichment of rivers stimulates primary production, promoting aquatic plant growth and, more commonly excessive algal growth. Excessive algal growth — or algal blooms — are of concern to water supply authorities because both phytoplankton and attached algae can block filters and delivery equipment, and the high organic load leads to increased water treatment costs. Blooms of many cyanobacterial (blue-green algae) species are additionally problematic because of the toxins they produce.

To date, much of the Australian eutrophication research on inland aquatic systems has focused on phytoplankton blooms, and understanding the roles of phosphorus supply and flow conditions. This has proven to be well founded, as in many rivers and reservoirs, the thermal stratification (layers in the water column) that occurs during low or no flow conditions, provides the necessary environment for rapid algal population growth. The total biomass a bloom can achieve is controlled by the availability of phosphorus. This research continues to progress, with the identification of river flow options and reservoir management techniques, improvements in catchment scale approaches for identifying the phosphorus sources, improved measurements of the internal supply (from deposited sediments) of nutrients to algae, and techniques for identifying nitrogen and phosphorus limitation. Much of this work has been carried out in rivers and estuaries as part of the National Eutrophication Management Program (NEMP), and some is reported in this edition in the article *NEMP Highlights*.



Algal scum.

Photo W. Van Aken CSIRO.

Information on the way nutrients are sourced and moved in catchment-river systems and transformed by in-stream bio-geochemical processes is accumulating, and the ability to model these processes is improving. The article by Jon Olley and Bill Young on *Nutrient Sources, Transport and Cycling in Large River Systems* summarises some of these concepts and advances as they relate to sources, pathways and transformations of phosphorous and nitrogen in the environment.

Recently, it has been demonstrated that nitrogen is the nutrient that initially limits phytoplankton growth in a number of inland waters. Over the next five years, the NRCP, together with Land & Water Australia's National Riparian Lands R&D Program and National River Consortium Programs, aim to invest in key R&D on nitrogen in both riverine and riparian environments.

Sediment as a contaminant

Sediment is one of the most common river contaminants. Coarse sediments (e.g. gravel, cobbles) alter river habitats by infilling the bed and degrading benthic (river bottom) habitat. Fine sediments that are carried in suspension interfere with the respiration and feeding of many river animals, for example, favouring fish (such as carp) that are not visual feeders. By increasing turbidity and hence light penetration, suspended sediments also reduce submerged plant photosynthesis and alter the light regime for phytoplankton. The reduced light penetration favours algal species, such as some toxic cyanobacteria, that are able to regulate their cell buoyancy and move into the narrow upper light zone where they can continue to spread.

Many agrochemicals, heavy metals and nutrients chemically bind to sediments, and so are transported with sediment. This finding means that any holistic examination of river contaminants needs to consider both the direct contamination by sediment, as well as the role of sediment in transporting and transforming other contaminants.

As Ian Prosser and Richard Norris's article *Muddy Waters and Sand Slugs* outlines, recovery of a large proportion of Australian streams will not occur unless sediment is better managed. Understanding sediment transport processes is a

key part of understanding the behaviour of these contaminants in river systems. The National Land and Water Resources Audit (NLWRA) and the MDBC are both investigating large-scale patterns of sediment transport and the potential effects on river ecology. Outputs from these projects will assist catchment and resource managers to predict the hazard of sediment delivery to streams; to identify the major river reaches that are impacted by sediment; and to estimate the resulting sediment delivery to estuaries and the coast.

Pesticides and other agrochemicals

Worldwide, some 2.5 million tonnes of pesticides valued at US\$30 billion are used annually (Pimentel 1995). In Australia, the total sales of pesticides at the factory gate (Australian Commodity Statistics 1998) increased from \$92 million to \$1106 million between 1978 and 1997. Herbicides account for nearly two-thirds of total sales. While most sales are to the agricultural sector, non-agricultural use of pesticides is significant, and is probably underestimated (ATECH Report 2000). During 1978–97 the potency of pesticides has also increased, requiring smaller application rates per unit area, suggesting that data on the increases in sales alone, do not tell the full story of increases in potential impact.

Pesticides are undoubtedly of major economic benefit to Australian agriculture, estimated to be worth \$A4–5 billion each year. While pesticides undergo an assessment of their potential environmental impacts as part of the national registration process, much of the data used in this process is from overseas studies and is not always applicable to Australian conditions. There is emerging evidence of the impact these chemicals have on our rivers. In state monitoring programs, *endosulfan* was the most commonly detected pesticide, often exceeding the ANZECC (1992) guideline for the protection of aquatic ecosystems. The herbicides atrazine, diuron, metalochlor, and prometryn have also been detected in our rivers, although less is known about their ecological effects. Contamination of agricultural produce by bio-accumulation of pesticide residues through food chains has highlighted the risks that pesticides pose to all aquatic biota.

Major research and extension efforts have been directed in recent years towards the

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development of best management practices (BMPs) to minimise the impact of pesticides on the environment. Several rural industries in Australia, in particular the cotton industry, have developed BMPs to minimise non-target impacts of pesticides. Monika Muschal's article provides a ten-year retrospective of pesticide contamination in NSW rivers, and discusses the efforts that have been made to reduce the organochlorine *endosulfan* in the cotton industry. These efforts have resulted in a drop in levels of contamination by *endosulfan*, however, there is still lack of data on their distribution and limited understanding of the ecological risks associated with pesticide residues. This makes it difficult to define what best management practice should be. In particular, most research on environmental impacts of pesticides is limited to studying organism responses to individual substances under laboratory conditions. It is known that certain combinations of pesticides have synergistic effects, although the mechanisms are poorly understood and, as a result, the impact of environment conditions on these synergies is still largely unknown. This is an area that requires continued funding so that BMPs can be further developed to account for the different interactive effects of chemicals and pesticides.

Interactions between contaminants

The largest gaps in our process understanding are those related to the interactions between contaminants, both in terms of how they interact physically and chemically in transport or in storage, and in terms of the complex responses of aquatic biota to mixtures of contaminants. While relatively simple experiments can tell us about the tolerances and responses of individual organisms to particular contaminants, or even combinations of contaminants, scaling these results up to predict ecosystem level response is extremely difficult. The combination of detailed experimental work with medium scale field test and large-scale system modelling is likely to be the best way to advance our understanding.

The largest gaps in our process understanding are those related to the interactions between contaminants.

TRAINING AND EDUCATION CONTRACT awarded to Western Australian consortium

There is an increasing demand for training in river management and restoration at the catchment and regional level. People working on-the-ground, be they from government or non-government organisations, are seeking education and training about what drives changes in river condition and how river restoration and protection can be incorporated into their day-to-day catchment planning and management activities.

At the same time, community expectations and aspirations in river management are high and increasing, but there is a need to increase capacity at this level for active ownership and participation in planning, setting priorities, or on-ground works.

River manuals and guidelines have been developed to support groups wishing to undertake river restoration and protection. While they have been developed with the user in mind, there is a need for them to be supported by people with formal training skills. This is essential to build community confidence to act.

The National Rivers Consortium has recently contracted the development of a framework for two national training and education programs. These include a graduate diploma in river management targeted towards people with tertiary qualifications wishing to move into a career in river management, as well as for those wanting to strengthen their existing skills and knowledge. The second course will be practical training in on-ground river management and restoration, and will be available to community members actively involved in river restoration and catchment protection.

The Western Australian, Albany-based Centre of Excellence in Natural Resource Management has been awarded the national contract by Land & Water Australia to provide advice to the National Rivers Consortium on how to best provide the proposed education and training in river management across Australia. The tender for the provision of the advice on a national framework received a number of high quality submissions from institutions across Australia. The submission from the Natural Resource Management Centre involved collaboration with The University of Western Australia, the Department of Agriculture and the Water and Rivers Commission. The results of this study will be available in early 2002.

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LAND & WATER AUSTRALIA'S RIVER FORUM

20–21 March 2002, Canberra

We are all getting a bit tired of going to conferences and workshops where the same people give the same talk on the same topic... Land & Water Australia Rivers Forum is doing something different!!!

We are providing a Rivers Forum that gives participants a mix of formal thought-provoking presentations and field-based experience. The first day of the forum is designed to promote debate, stimulate ideas and provide perspectives and insights about river management from people outside our 'rivers industry'. It will be held at Old Parliament House, Canberra and will focus on four themes: *Protecting our rivers*; *Planning for river protection and restoration*; *Rivers and rural industries*; and *Promoting and communicating our message*. These themes have been identified by Land & Water Australia's Rivers Arena as the key areas we need to focus on over the next five years to bring about further change in river management. We will have insightful and entertaining speakers cover these topics and we hope to attract policy makers, land owners, rural industries, catchment management and community based groups (Landcare, Rivercare etc.) as well as researchers!

The second day of the Forum is called 'Researchers on a Riverbank' and will be held in the Yass region, just outside of Canberra. We will have researchers funded through Land & Water Australia's Rivers Arena talking about different aspects of river and land management (e.g. sediment control, stock management, instream health, revegetation, monitoring and evaluation techniques, using demonstration sites, knowledge exchange strategies). Participants will be broken up into groups and circulated around the researcher groups who will be stationed along the riverbank (rather like a round robin). We have used this technique before with our Riparian Land Management Workshops and it really does give people time to talk directly to researchers about the issues they are facing in river management.

This is an event not to be missed — make a date in your diary now for Land & Water Australia's River Forum. Registration forms will be available on the www.rivers.gov.au website in December, and the December/January edition of RipRap will have full details of the Rivers Forum program and registration forms — it will be an affordable Forum with no high fees, so mark it in your diary today!

20–21 MARCH 2002, CANBERRA



SALINITY PROCESSES

in Australian rivers

Adapted from a paper by
Glen Walker, Paul Bailey,
Paul Boon and Kay Morris

Australian rivers are expected to suffer major effects from the increase of salinity in the landscape. Rivers receive the majority of surface runoff waters within catchments, and as they occupy the lowest points in the landscape, they are also the first to intercept rising groundwater systems. The largest ecological impacts of salinity on rivers are likely to be found in floodplains, wetlands, backwaters and lakes, rather than the main channel itself. For these ephemeral water bodies, the whole waterbody and/or the soil zone can be saline over long periods of time, having a major impact on the biota that live there.

The ecological effects on biota occur at many scales, from individual plants and animals up to entire ecosystems. Salinity affects individual plants via osmotic effects (changing the plant's water balance), ion toxicity (e.g. chlorine toxicity) and ion antagonism (competition between ions affecting a plant's metabolism). In contrast, the effect on animals of increasing salinity is mainly via changes in salt and water balance (e.g. loss of water and taking in of salt). These phenomena can have lethal or sub-lethal effects depending on the organism and the concentrations of salts. The responses that occur to individual plants or animals are then reflected as changes at the population level; for example, plants and animals grow more slowly and have lower reproductive ability. The

subsequent response at the species community level is generally a decrease in diversity as salinity increases.

There is also a broad suite of salinity impacts at the ecosystem level. Primary and secondary productivity is likely to decrease following salinisation. Salinisation has ecosystem implications for phytotoxicity, pH shifts, availability of elements, nutrient cycling, and nutrient transformation rates. In the longer term however (i.e. decades to centuries), salinised environments can also be highly productive (e.g. water birds on salt lakes).

Current information on ecological responses to salinity is very limited. Data that is available is mainly for commercial species (e.g. fish and agricultural plants), usually restricted to adults, and normally only in the form of the effects on presence/absence, rather than abundance of species. The information that is available linking salinity and ecological responses is largely correlated rather than experimental, and limited to species rather than processes. In addition, salinity is usually measured at a small number of sampling times (not reflecting temporal variability), and generally only in surface waters (not reflecting spatial variability and sediment stored salinity). This type of approach means that salinity has been treated as a static phenomenon in isolation from other landscape changes, especially changes to the overall water regime.

Within the main channels of rivers, high salinity is mostly due to groundwater inflows. This generally occurs through the processes of *surface wash-off*, *direct baseflow*, or *perched groundwater inflows*.

- *Surface wash-off* results from evaporation of shallow groundwater, and will generally enter rivers as flows are increasing following rain. While this can result in transient moving slugs of high salt concentration, this process will generally not cause overall high salt concentrations in the stream. However, this process can cause salt scalds, flocculation of clays and sediment movement.
- *Direct baseflow* occurs when the groundwater levels are higher than the surface water. This is generally at drier times of the year, but can



Cover photo from Mary E. White's
"Listen... Our Land is Crying".



Weirs and dams have altered flows and changed salinity ranges. River Murray, South Australia.

The two key knowledge gaps are the availability of salt sensitivity data at the species level, and information on the effects of salinity on ecological processes.

also occur as river flows fall after rainfall or flooding. Direct baseflow can cause dense, stable, anoxic pools of water at the bottom levels of the river. This water will mix at times of higher flows and be dispersed. Direct baseflow may also result in slumping or erosion of banks and a reduction of turbidity in-stream.

- *Perched groundwater inflow* consists of different but related processes. A store of salt builds up adjacent to the stream, which can be caused by a wide floodplain in which groundwater flow to the stream is intercepted by evaporation processes. This is only released during and after high flows. A second process is leakage of saline water from a deeper groundwater system to a perched system, which is then pushed into the stream.

The type of groundwater system (geology, scale, recharge, stream incision) will affect the type of processes along different portions of the river. Along the river, there will be *losing* and *gaining* stretches, and saline pools will come and go. Thus, salinity in the river can be highly variable in time and location.

One of the largest human impacts on salinity processes in rivers is river regulation. The installation and operation of storages and weirs has caused huge changes in flow regimes and the natural range of salinities both in the main channel and associated floodplains and wetlands. The release of irrigation drainage water has also

increased saline inflows, often directly to wetlands. Rising water tables are widespread across southern Australia and have caused losing streams to become gaining streams, fresh lakes to become saline and vice versa, the salt balance in some streams to be increased by as much as 200 times, increased waterlogged areas and higher base flows. In unregulated streams, groundwater pumping has reduced baseflows of fresh water. Management responses to these problems include:

- ~ implementing salinity and wetland management plans incorporating salinity and ecological goals;
- ~ undertaking salinity remediation with large scale land use change, dilution flows and environmental flows;
- ~ introducing wetting and drying cycles in wetlands;
- ~ flushing salt from wetlands and using groundwater pumping and changes in surface water drainage; and
- ~ releasing salt from storages/disposal basins at high flows and reducing drainage water at low flows.

While in some cases it is feasible to predict the salinity improvements of these measures, the information required to protect or rehabilitate freshwater systems from increasing salinities is currently insufficient. The two key knowledge gaps are the availability of salt sensitivity data at the species level, and information on the effects of salinity on ecological processes.

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"Ecoman and Dr Earth Getting a Grip"
by Morgan Kurrajong and Ed Radcliffe.

TRIALING METHODS to predict the effect of rising salinity on freshwater invertebrates

By Ben J. Kefford, Tricia A. Paradise, Phil J. Papas, Diane Crowther and Dayanthi Nuggeoda

Although salinisation is considered to be one of the most serious environmental problems in Australia, there is little knowledge of its likely effect on freshwater biodiversity. It would be a major boost for the management of freshwater ecosystems if reliable predictions could be made about the effect of rises in salinity concentration, as these predictions could be used to assess the impacts on aquatic biodiversity of predicted rises in salinity in particular rivers and wetlands. This information would enable managers to predict the impact of different salinity management strategies on freshwater ecosystems, for example, saline water disposal strategies and other intervention approaches designed to reduce salinity in wetlands and rivers.

In response to this need, a predictive system to estimate such responses has recently been proposed. The system will be trailed in the Barwon River in south-west Victoria, with salinity tolerance of aquatic macroinvertebrates from this river being used as the case study. The system uses a mathematical model to predict the proportion of species that will have their salinity tolerance exceeded at particular salinity levels. If the system works in the Barwon, it can be expanded to other catchments, either by developing many local models with local data, or by developing a few large-scale models. These new models will need new data, but the Barwon

model may be able to be used for approximate models in other catchments following testing to see how the predictive system work.

When the system is developed it will be possible to enter the initial or current salinity, for example 500 EC, and the predicted salinity, say 5000 EC, with the system then providing details about the percentage of species for which salinity tolerance is exceeded. Conversely, this equation can be used to calculate the maximum rise in salinity that can occur before a pre-determined proportion of species are lost from a system. If, for example, a 2% loss of species from a water body is considered unacceptable and the current salinity is 500 EC, the model will be able to predict the increase above 500 EC before 2% of species are lost. This represents the maximum rise in salinity that can occur before an unacceptable impact will occur.

This project started in 2001 and is due for completion in 2002. It is funded through the National Dryland Salinity Program.

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National DRYLAND SALINITY Program



Using science to understand the impact of salt on aquatic communities. Photo Nick Schofield.

ALTERNATIVE ecological states: a potential paradigm for managing salinised ecosystems

By Jenny Davis

Secondary salinisation of rivers, streams and wetlands, often accompanied by altered hydrology and nutrient enrichment, is a major national environmental issue. For some systems in south-western Australia, the history of secondary salinisation spans 30–50 years. Preliminary information suggests that such systems exist in states that differ from the original conditions but, nevertheless, represent viable, functional ecosystems. For these systems, the goal of river and wetland rehabilitation programs may be to prevent transitions from one state, to another less desirable one, rather than to reduce salinity per se. ‘Desirability’ of ecological condition is a critical feature of restoration planning and needs to be established according to criteria such as water quality, introduced pests and/or reduced biodiversity.

The aim of this new research project funded by L&WA, is to apply the state and transition models of landscape and vegetation ecology, and the alternative stable states model for shallow lakes, to inland rivers and wetlands. We will determine whether recognition of these states can be used to guide the development of restoration principles and practices for salinised aquatic ecosystems.

We hypothesise that in addition to clear/macrophyte-dominated and turbid/phytoplankton-dominated states that are characteristic of shallow Northern Hemisphere systems, there are at least four further states in Australian inland waters. These include: coloured/macrophyte-dominated, turbid/sediment-dominated, brackish/macrophyte-dominated and saline/benthic microbial mat-dominated. Confirmation and quantification of these states, and potential transitions, will be undertaken using data obtained in previous studies, new data collected from strategic fieldwork and ecological modelling.

Conceptual modelling and fieldwork will provide a basis for using the ecological model CAEDYM. The conceptual model will be used to adapt wetland and river transitional processes

in CAEDYM, and provide qualitative predictive outcomes against which to compare numerical results. The most important outcome from CAEDYM will be the ability to test scenarios that may lead to a ‘catastrophic’ change from one state to another, and to examine whether restoration to a previous state is an achievable or realistic goal.

The unique feature of this project is in the possibility of alternatives for waterbodies currently facing secondary salinisation. This form of salinisation is an intractable problem where amelioration of its effects on ecosystem condition may be difficult, if not impossible. If there are states that meet desirability criteria, then our restoration efforts should try and manage waterbodies towards those states, or prevent them from developing undesirable features. The development of this approach in southwestern Australia will have relevance to systems in eastern Australia where there is a shorter history of salinisation, but a similar sense of urgency to deal with the problem. The three main outcomes of the project will be:

- ~ development of a new understanding of the ecological function of aquatic systems that have undergone secondary salinisation;
- ~ a new conceptual framework for the management and restoration of saline systems; and,
- ~ guidelines for aquatic restoration that involve predicting the ecological consequences of specific management actions so that these are known and evaluated before implementation.

The project is a collaborative one bringing together researchers from three universities and a state conservation agency.

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NEW CD S

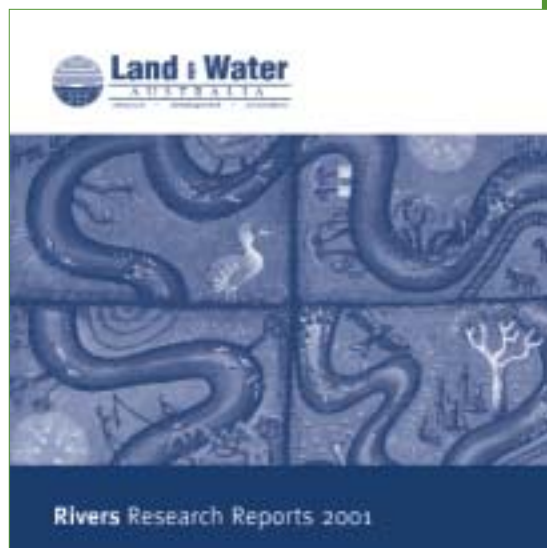
Rivers Research Reports CD ROM

This easy-to-use CD ROM contains 20 of the most popular publications from the Riparian Lands Program and the National Rivers Consortium. It features Rehabilitation Manuals and Riparian Land Management Technical Guidelines, RipRap and six Research Reports, all with easy navigation through the contents pages. The CD ROM is a compact way to store your reports and it allows you to explore electronically or download your favourite sections to print.

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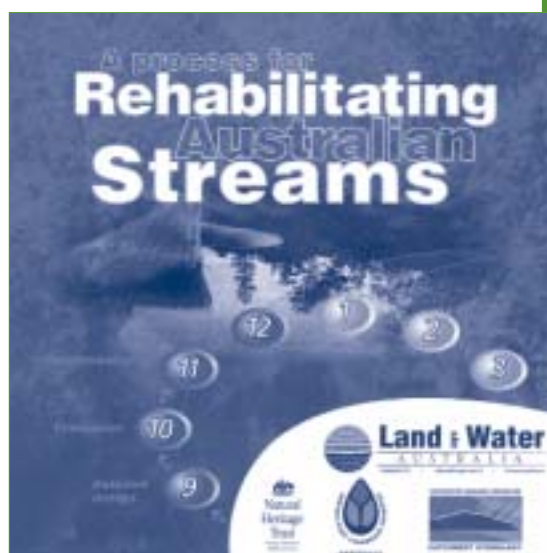


A process for rehabilitating Australian streams CD ROM

Land & Water Australia and Agriculture Fisheries Forestry Australia have teamed up to produce an exciting new CD ROM to assist groups and individuals undertake 'A process for Rehabilitating Australian Streams'.

This CD is an interactive version of *A Rehabilitation Manual for Australian Streams* by Ian Rutherford, Katheryn Jerie and Nick Marsh. It brings to life this important manual through the use of videos, audio, animation, virtual reality and real life case studies. It has been developed to assist anyone involved in stream rehabilitation and provides a dynamic and innovative way of working through the planning, implementation and evaluation processes that are important to follow when undertaking stream rehabilitation activities.

The CD is easy to use, enjoyable and fun. You can work through it on your own or with a group, so why not get a copy!



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INLAND RIVERS WORKSHOP: new report

Limited hard copies are also available through Canprint and the report is also on the new River Reports CD ROM!! See top of page for details.

"The paths to the future are made not found". With these inspiring words, 70 participants gathered at a workshop in Alice Springs, Northern Territory, in March 2001 to create a future for Australia's inland rivers. The workshop achieved a number of outcomes including:

- ~ increasing national attention on inland rivers;
- ~ converging ideas from the numerous people involved in inland river management; and
- ~ guiding the emergence of principles, issues and actions on which to base policy development, research and future river management.

Sponsored by the National Rivers Consortium, the two-day Inland Rivers Workshop report is now available on the web at www.rivers.gov.au.

Muddy Waters and sand slugs: Sediment transport in Australian rivers

By Ian Prosser and
Richard Norris

Rivers naturally carry sediment as part of the normal processes of erosion. Cobbles and gravels (coarse sediment) deposited on river beds are vital for providing habitat for macroinvertebrates and for fish spawning. The finer sediment, the clays and silts, have nutrients attached to the sediment surfaces. These nutrients may ultimately dissolve into the water and feed the growth of algae and other organisms at the bottom of the aquatic food chain. The role of sediment in nutrient transport is described in the associated article by Jon Olley and Bill Young (page 19). A problem that many of our rivers face today is a surplus of sediment, fed by accelerated erosion in degraded catchments.

Bedload sediment

Streams have only a limited capacity to transport coarse sediment of sand, gravels and cobbles. Coarse sediment is transported by rolling and bouncing along the bed and is referred to as *bedload*. If the bedload supplied to a river reach exceeds the rivers' capacity to transport it, the excess accumulates on the riverbed. In lowland rivers this leads to the natural deposits of sandbars on the inside of meander bends. Upland and coastal streams have higher energy flows and naturally have beds of coarse gravels, cobbles, and boulders. They have shallow riffles and deeper scour pools that provide a wide range of habitats of varying depth and flow velocity. A diverse set of plants and animals live in these habitats by adapting to particular niche environments (e.g. under cobbles or in scour pools). The diversity of habitats also provides refuges for protection from floods and predators.

Many Australian rivers have experienced massive increases in the supply of sand from erosion upstream. This is particularly true for catchments with extensive areas of sandstone and granite rocks because these produce sandy soils. Increased catchment erosion has swamped many rivers in sand to the extent that pools have been filled and woody debris, cobbles and gravels have been covered removing much

habitat and shelter. The sand deposits themselves are relatively poor habitat. They are unstable surfaces for algae and poor habitat for invertebrates and fish. Algae have received much publicity through the impact of eutrophication on algal blooms, but algae that are attached to sediment do not form blooms and can be a primary food source supporting the complex food chains of rivers, especially in the midslope reaches. Large, continuous deposits of sand and fine gravel are referred to as sand slugs. They migrate slowly downstream by transport during floods and they are thought to be barriers for fish passage because they have very shallow flow over them or can dry out altogether (Figure 1).

The main sources of sediment for sand slugs is gully erosion and streambank erosion. Broader-scale erosion of paddocks and hillslopes delivers little sand to rivers. Riverbank erosion and sand slugs are often a symptom of cleared riparian vegetation. The roots of the vegetation add strength to the banks, which stops them from slumping into the river. Macrophyte and other low vegetation also protects banks from scouring flows. Without the protection of riparian vegetation the banks erode, with some rivers widening by over 100 metres. In addition, much of the sediment is deposited on the bed of the river and there is a major transformation of stream habitat. Relatively narrow rivers with deep pools, woody debris, cobble bars and fringing riparian vegetation that provides shade, shelter and food are transformed to broad shallow streams with sand beds, bare banks and little shade, shelter or food. The fundamental living conditions in the stream are altered by the supply of coarse sediment and this could have as big an influence on the health of many streams as the more traditionally thought of natural pollutants of fine sediment and nutrients.

The National Land and Water Resources Audit (NLWRA) has recently assessed sediment transport in river basins across the more densely populated third of the continent. The assessment included coastal catchments from Cape York around to the Eyre Peninsula and the south-west of Western Australia and the Murray-Darling

Figure 1: Summary diagram of some of the main changes related to sediment following disturbance of rivers. The river on the left has a complex bed, relatively clear water, and a riparian forest. The river on the right is wider, has a shallower bed of sand and is cleared of riparian forest.

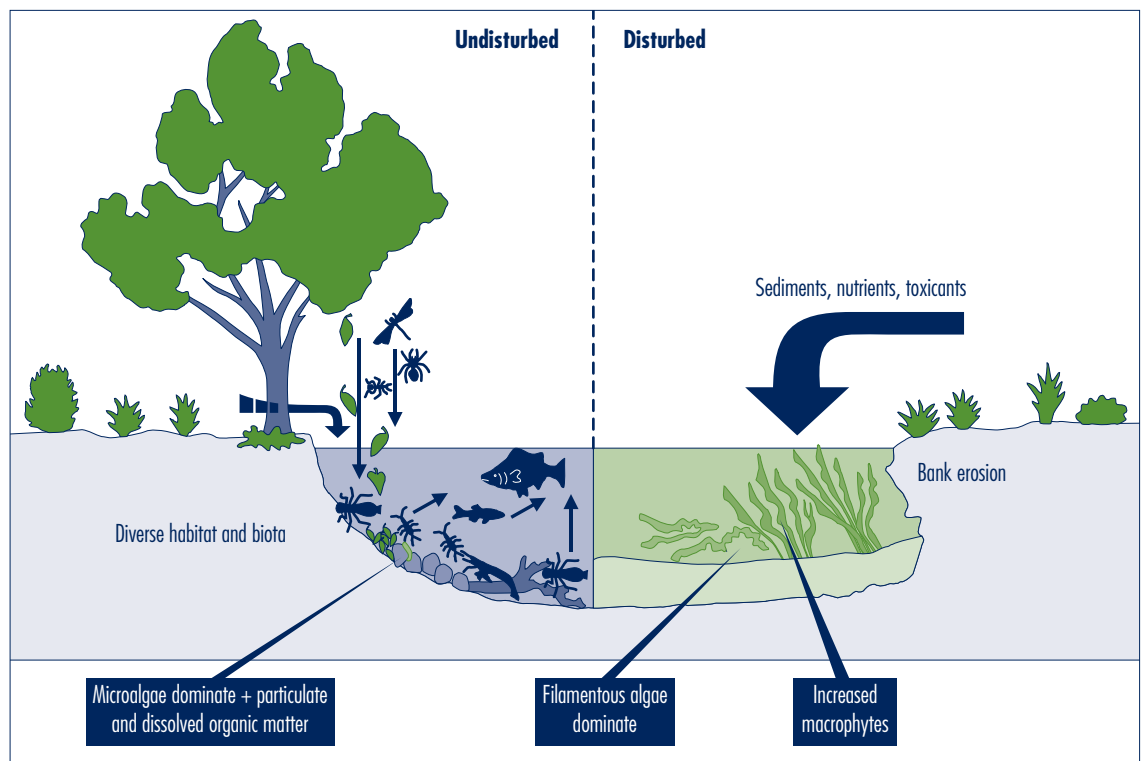
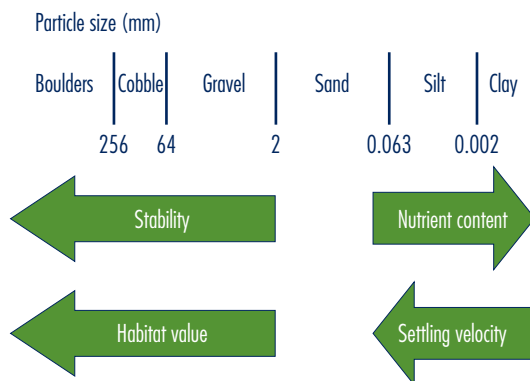


Figure 2: Classification of sediment particle sizes in rivers and some aspects of their behaviour. Particle size classes are defined by their diameter, measured in millimetres. Clays have the greatest ability to hold nutrients, because of their high surface area, and settle slowly through water (about 20 cm in 8 hours). Boulders and cobbles are good habitat and are very stable, requiring high velocity flows to move them.



Basin. A total of 180,000 kilometres of stream was assessed and it was predicted that 30,000 kilometres has experienced accelerated deposition of sand to the extent that sand slugs and related phenomena could be expected. The Murray-Darling Basin had 20% of its stream length affected, largely because of low energy reaches downstream of an extensive arc of gully, and streambank erosion that passes across the midslope and headwater uplands. The Avoca and Wimmera Rivers are examples of impacted rivers. The south-west of Western Australia was another highly impacted region because of its low energy streams that cannot cope with any significant increase to the supply of sand. Coastal rivers of Tasmania and Queensland with high energy

flows were found to be relatively unaffected by sand deposition, except downstream of areas of high gully erosion or alluvial mining.

Much of the increased load of sand and gravel was delivered to streams many decades ago, and in some areas the supply has largely recovered to more natural levels. The consequences of the increased load will, however, continue to work their way through rivers for hundreds of years. Thus, restoration needs to focus on promoting the recovery of bed forms and habitat rather than erosion control after the sand slugs have formed. An example of restoration of bed forms for habitat was given for the Murrumbidgee River in the ACT in *RipRap*, vol. 19, 2001, pp. 31–32.

Suspended sediment

Rivers have a much greater capacity to transport suspended sediment: the particles of clay, silt and even sand that are suspended within the turbulent flow of rivers. If the supply of suspended sediment is increased it is matched by increasing sediment concentrations, not by depositing the increased load onto the stream bed. Suspended sediment concentrations higher than 200 g/l (grams/litre) have been observed in China, much



Figure 3: A tributary of the Murrumbidgee River showing eroded banks, a lack of riparian vegetation and a sand slug which has produced a uniform shallow stream bed.

Figure 4: Babinda Creek, Far North Queensland showing clear water, a cobble and boulder bed, a wide variety of habitats and riparian vegetation providing shade and shelter.

higher than values of 1–10 g/l or lower in Australia. This is not to say that all of the suspended sediment supplied is exported by the rivers to the coast, the NLWRA assessment of river sediment budgets indicated that only 20% of the sediment carried by rivers was exported from river basins. The rest is deposited along the way. The main areas of net accumulation of suspended sediment are floodplains, lakes and reservoirs and sediment is stored in these areas for hundreds to thousands of years.

Suspended sediment has a direct effect on aquatic organisms in addition to that from the nutrients it carries. The effects will depend on the nature of the stream. Upland streams that

naturally have low levels of suspended sediment are likely to be more affected by sediment than lowland streams, this is because lowland streams normally have higher levels and the ecology has adapted to these conditions. Suspended sediment contributes to the cloudiness of the water (its turbidity), which limits light penetration. Low light levels reduce photosynthesis, restricting it to the water's edge or the top few centimetres. Such conditions may also favour undesirable blue-green algal blooms. Unnaturally high-suspended sediment concentrations may make feeding difficult for fish and invertebrates that rely on sight to catch their prey. It may accumulate on the leaves of macrophytes, inhibiting growth; and when deposited, clog the spaces where invertebrates live on the stream bottom causing loss of habitat. Suspended sediment also clogs the gills of fish and invertebrates and a common reaction to abnormal turbidity is for fish and other organisms that swim, to leave the river reach until conditions improve.

In areas of low flow velocity, such as deep pools, backwaters, or in the tiny spaces between rocks on the bed, suspended sediment can settle out of the flow and coat the river bed, macrophyte vegetation or woody debris. Sediment can also attach to these surfaces by adhesion. Rivers with high-suspended sediment concentration will result in thicker coatings and greater impacts of deposition. These coatings can have several deleterious effects. They are fatal for fish eggs and for epiphyton (organisms attached to surfaces on the river bed). Smothering of the beds of estuaries and in the sea is one the main contributors to loss of the sea grass beds that support much life. When fine sediment fills the spaces between rocks in a stream it prevents water from flowing through those spaces. This potentially prevents food and oxygen from reaching the bacteria and invertebrates that live in that area. Those bacteria and other micro-organisms are significant processors of organic material. Preventing the flow of water through the stream bed may thus contribute to problems of eutrophication.

Deposits of sediment can be resuspended into the flow contributing to ongoing turbidity in our rivers even well after flood events that transport most of the suspended load. Under natural conditions, floods flush sediment out of the spaces between rocks, turn over the cobbles and

renew life in those areas, but flow regulation in many streams has reduced the frequency of flushing flows which, together with increased sediment supply, contribute to greater stores of sediment than is natural.

The precise impact of suspended sediment loads in our rivers is uncertain, as are the loads and conditions of our rivers before European settlement. However, an assessment of suspended sediment loads conducted for the NLWRA provides some warnings. The work predicted natural sediment loads by assuming that all bare gullies we see today were absent 200 years ago; that river banks were naturally vegetated and thus contributed negligible suspended sediment; and, that the land surface contributed suspended sediment at the rate observed today in forests and other areas of remnant natural vegetation. Sediment budgets constructed using this reasoning show that current sediment loads in many rivers are 5–20 times higher than the natural rate and, in the most degraded areas, are up to 100 times higher than the natural rates. Such increases sound high but are supported by the limited comparisons of disturbed with undisturbed catchments. We cannot dismiss the likelihood that these increases have had a major ecological impact.

The NLWRA suspended sediment budgets also show where there is significant sediment delivery to the coast. This is largely an issue along the Queensland coast where there are open estuaries and large rivers that export several million tons of sediment per year. Some NSW rivers such as the Clarence, Hunter and other north coast streams are significant contributors as well. Along southern Australia, the delivery of sediment to estuaries is much lower and flushing of estuaries is much less effective. The delivery of sediment from rivers that drain to the Great Barrier Reef is of particular concern for the near shore reefs and sea grass beds. An encouraging result of the assessment of the Great Barrier Reef catchments is that 90% of the sediment exported is predicted to come from 20% of the catchment area draining to the coast. Many areas have either low erosion rates or are so remote from the coast that most of the sediment is deposited well before reaching the sea. The source of sediment can be further focussed upon the main contributing processes, whether they be stream-bank erosion, gully erosion or hillslope erosion.



Sand accumulation and bank erosion has led to willow infestation. Photo by Ian Rutherford.

The NLWRA work suggests that each process dominates sediment supply in particular parts of Australia.

The NLWRA results rely in many places on scant data and upon several testable assumptions that are worthy of further investigation. If true, they offer hope that restoration focussed strategically in limited areas can go a long way to meeting ambitious targets for reduced sediment loads and improved water quality. The same principles apply for the catchment area to any down valley target, not just the Great Barrier Reef.

Further reading

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We cannot dismiss the likelihood that these sediment load increases have had a major ecological impact.

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Prosser, I. and Karssies, L. 2001

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Lovett, S. and Price, P. (eds) 1999

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Code EC010091

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Principles and Tools for Protecting Australian Rivers

Phillips, N., Bennett, J. and Moulton, D. 2001

This report identifies the principles associated with the protection of riverine ecological values, and methods for assessing those values. It is aimed at planners and policy makers, river managers, community groups and individuals. The report addresses conceptual frameworks for river protection and is not intended as a prescriptive document.

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Volume Two: Rehabilitation Tools

Rutherford, I., Jerie, K. and Marsh, N. 2000

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Roberts, J., Young, B. and Marston, F. 2000

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On the website www.rivers.gov.au and also available from Canprint \$11.00 plus P&H costs. Code PR000212

River Restoration Framework

Koehn, J.D., Brierley, G.J., Cant, B.L., and Lucas, A.M. 2001

The River Restoration Framework provides a simple step-by-step process through which the complex task of river restoration can be undertaken across Australia.

On the website www.rivers.gov.au and also available from Canprint \$11.00 plus P&H costs. Code PR010187

Australian River Management — A Legislative Framework for the 21st Century

Maher, M., Cooper, S. and Nichols, P. 2000

This report defines a best practice legislative framework for Australian rivers. This includes protecting rivers as a vital part of our natural capital; managing conflicts between users; enabling management and improving performance in response to change; and protecting the public interest.

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Dunn, H. 2000

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NUTRIENT SOURCES,

NUTRIENTS

transport and cycling in large river systems

By Jon Olley and
Bill Young

The biogeochemistry of carbon, nitrogen and phosphorus in river systems are intimately linked. They often originate from common sources, follow similar transport pathways, and are all important for riverine productivity. In this article we discuss the sources, transport pathways, transformations, and ecological consequences of nutrients in large river systems, as well as our ability to model these processes in these large river systems.

Nutrient sources

Nutrient inputs to rivers are classified as either point or diffuse sources. Point sources discharge into rivers at defined points, usually through drains or pipes. Point sources include sewage treatment plants, cattle feedlots, piggeries, and various industrial discharges. Diffuse sources enter rivers by numerous surface and sub-surface flow pathways. Diffuse nutrient sources include soil erosion, drainage of soil pore water containing dissolved nutrients, wash-off of plant litter, and wash-off of livestock manure. For many catchments, significant nutrient loads associated with atmospheric deposition also make their way into rivers. In heavily populated, industrialised, or intensively farmed areas, point sources can dominate nutrient supply, however, diffuse sources dominate nutrient supply to most Australian rivers.

Figure 1: In turbid rivers and streams a large nutrient load, especially phosphorus is chemically bound to suspended sediments. Dawson River photo by Anthony Scott.



Prior to European settlement many of the headwater river valleys in Australia were vegetated shallow depressions rich in organic matter. Due to the high trap efficiency of these areas the mineral sediment yield from headwater catchments would have been quite low, and any mineral sediment is likely to have been derived from the surface soils. The organic/inorganic ratio of river sediments derived from these areas is likely to have been high, and the nutrient supply is likely to have been dominated by organic matter. Early records indicate that many of the major channels in the upland areas were cobble bedded and the waters clear. European land use practices resulted in these vegetated valleys being incised by massive gully networks. Subsoils were exposed to erosion and there was a massive flux of inorganic sediment and associated phosphorus into the rivers. These gully networks continue to supply fine sediment to the rivers and most of the phosphorus in these now turbid systems (Figure 1), is derived from subsoil sources. It is only in the clear water systems, typically draining sandy catchments, that most of the phosphorus is transported in dissolved form (e.g. Peel-Harvey River systems in Western Australia). These systems can be seen as the extremes of phosphorus transport.

In regions which experience extensive gullying, the massive influx of fine sediment and its associated phosphorus must have significantly changed the Carbon (C) : Nitrogen (N) : Phosphorous (P) ratios. Carbon and nitrogen supply will also have been decreased by extensive clearing of riparian vegetation. What the ecological effects of these changes are at this stage is unknown, but these systems are now dominated by algal and bacterial production. Primary production in freshwater systems is usually considered to be phosphorus limited, but recent work has shown that in the turbid inland systems nitrogen limits production as often as phosphorus. Primary production in many floodplain systems depends on the delivery of nutrients during floods. Changes in the C:N:P ratio and the relative amount of organic to inorganic sediments may well have altered floodplain production.

Nutrient transport and transformations

Nutrients travel either in solution, or associated with sediment. Nutrients in solution reach rivers in overland and subsurface flow. The levels of nutrients in subsurface flow is partly a result of the movement of nutrient ions to and from soil particles. Nutrients associated with sediments reach rivers from channel bank, gully and hillslope erosion. All of the material generated by channel bank and gully erosion enters the river network. The pathway from hillslopes is less direct with most of the nutrients mobilised from the hillslopes being trapped at the toes of the hillslopes or in the riparian zone, and as a result do not reach the river channel.

In the aquatic environment, nutrients can be found in one of four pools (1) dissolved in the water column, (2) associated with suspended sediments (3) bed sediments/porewater or (4) incorporated into the biota [sediment includes both mineral and organic particles]. These 'pools' are shown diagrammatically in Figure 2. The arrows in the diagram indicate the exchanges between each of these 'pools'. Upstream inputs (arrow A) into a river reach can add nutrients into any of the four defined pools. Water and sediment chemistries and biological activity then control the exchange between each of the pools in the water body. Chemical exchanges of nutrients occur between the dissolved pool and the sediment pools (arrows B and C). Nutrients are also released from the sediment pools to the dissolved pool by the conversion of organic matter present (both in the bed and in suspended sediments) to inorganic nutrient ions. Nutrients are incorporated into the biological pool from the dissolved pool through the growth of algae, bacteria and aquatic plants (arrow E). For simplicity, organisms further along the food chain have been omitted from the diagram. The release of nutrients from the biological pool back to the dissolved pool occurs either through direct excretion (arrow E) or during decomposition following the death of the organism (arrows F through C and G through B). Exchanges between the bed sediment and the suspended sediment pools occurs when suspended sediment settle out and are deposited on bed, and conversely when bed sediments are disturbed by flow or aquatic animals and are thus re-suspended (arrow D). For carbon and nitrogen, both loss to, and uptake

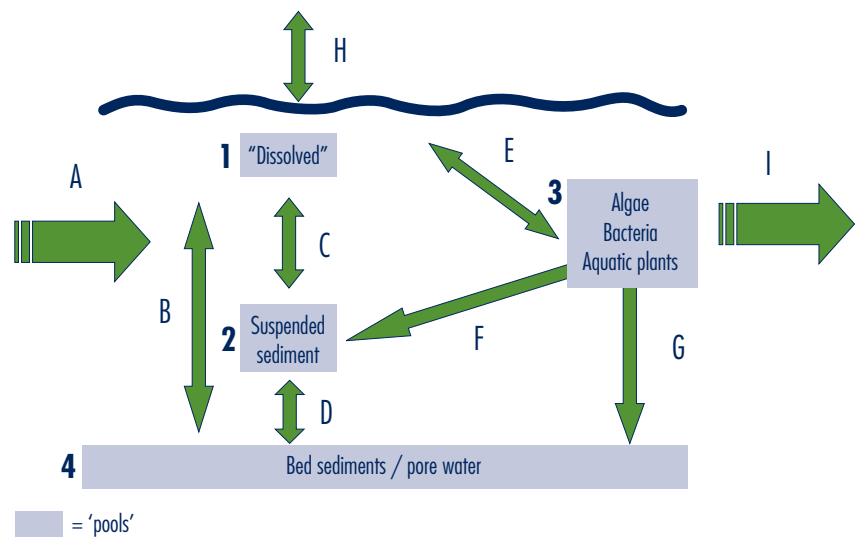


Figure 2: The stores and fluxes of nutrients within a river reach.

from the atmosphere to the dissolved pool can also occur (arrow H). Downstream transport to the next reach of river from each of the pools removes nutrients from the reach (arrow I).

Ecological consequences

Nutrients are essential for all life. However, it is the widespread occurrence of blue-green algal blooms that has raised people's awareness about river nutrient levels. Nitrogen and phosphorus are the nutrients which limit phytoplankton growth so elevated nutrient levels can lead to excessive algal growth under suitable environmental conditions. Many algal species produce toxins that can cause serious water quality problems, not only because these substances directly affect humans and stock by ingestion, but also because some toxins have the potential to bio-accumulate and be passed through food chains. Little is known about the properties of algal toxins, but the potential for environmental and economic costs is significant.

All life also requires carbon. Plant growth termed *primary production* provides the carbon for all higher forms of life — *secondary production*. If a food web depends on local primary production it is termed autotrophic. If it depends on plant material grown elsewhere is termed heterotrophic. Whether a system is autotrophic or heterotrophic depends on the supply of primary nutrient such as nitrogen and phosphorus. Altering the primary nutrient supply can change the base of the food

web affecting the whole food chain. Current understanding, however, does not allow us to predict how changes in the source or amount of nutrients will change the structure of the aquatic food web. In particular, predicting the changes to the highest levels of the food web is difficult, not only because of the complex biotic-interaction of the food web, but also because of the confounding effects of environmental conditions at a range of scales and at all levels of the food web.

Modelling nutrient transport

The three best known catchment-scale models for nutrient supply to large rivers are the river continuum concept (Vannote et al. 1980), the flood pulse concept (Junk et al. 1989) and the river productivity model (Thorp and Delong 1994). These conceptual models all focus on carbon sources and transport. The river continuum concept emphasises the downstream transport of organic matter from the headwaters to the lowland river. Upper catchment sources are considered to dominate the supply of organic matter to the lowland reaches, lateral supply from the floodplain or riparian zone is considered to be unimportant. In contrast the flood pulse concept, developed on systems with regular floods, emphasises the lateral links. Most of the carbon in aquatic animals is thought to derive directly or indirectly from production within the floodplains, and not from downstream transport of organic matter produced elsewhere in the basin. The river productivity model proposes that the major source of organic matter in large rivers is derived from either local primary production or by direct input from the riparian zone. It is argued that headwater and floodplain derived carbon is in forms that are difficult to break down, and so is less easily assimilated into the food webs. None of these conceptual models describes Australian rivers well. Many Australian rivers have highly variable and irregular floods, and have extended periods of little or no flow. A composite model of nutrient sources and transport for the large rivers of the Murray-Darling Basin has been proposed by Young et al. (2001), that combines elements of each of the three models described above, and that emphasises the different sources and transport pathways that dominate under different flow conditions.



A typical algal bloom.

These conceptual models of nutrient sources and transport help in communicating qualitative understanding of nutrient processes, and are a means for proposing hypotheses of how large river systems function. For the large rivers of Australia, current understanding and existing data do not allow us to quantitatively model the full range of processes that we believe to be important in determining daily nutrient concentrations throughout the river network. It is these predictions of daily nutrient concentrations that we require if we are to predict phytoplankton (algae) response. Our current understanding of algal ecology allows us to reliably make these predictions if we know what the chemical conditions are. Complex models have been calibrated for reasonably large Australian catchments to give reasonable predictions of daily instream nutrient conditions. These models capture the variability in daily nutrient levels under current catchment conditions, however, they cannot at

present be used to predict the affect of catchment changes on instream nutrient concentrations because they can only be reliably calibrated for current conditions.

For predicting the affects of catchment changes on nutrient dynamics in large river systems, we are currently limited to models of longer-term, or average, nutrient loads. Models such as ANNEX (Young et al. 2001) smooth out the daily variability in nutrient conditions, but describe the average patterns of nutrient supply, transport and transformations across catchments. For lakes, reservoirs, and estuaries, total nutrient loads do help predict the likely long-term ecological responses. The two main gaps in understanding that prevent more daily modelling of large river nutrient dynamics are understanding at the large-scale the processes that: (i) control delivery of nutrients from the catchment into the river network, and (ii) control the downstream transport and transformations of nutrients. At the small scale, these processes are reasonably well understood, however, it is difficult to scale these processes up to reliably describe large scale system behaviour.

Knowledge gaps and research priorities

The conceptual models highlight the key question for understanding the nutrient dynamics of large river systems: *to what extent do upstream sources and processes control the productivity of a river reach and to what extent is productivity controlled by local reach scale processes?* It is clear that most of the nutrient load is delivered downstream during flood events. However, under low-flow conditions in lowland rivers, water can take months to travel a couple of hundred kilometres. Long residence times increase the probability that in channel local reach scale processes are likely to dominate. Our understanding of how nutrient sources and the size of the nutrient pools vary with distance down a large river system is poor.

What is needed to provide this understanding are:

- ~ Catchment-scale nutrient budgets that assess the variation in the sources and pool sizes along the river network. Because the biogeochemistry of phosphorus, carbon and



nitrogen are intimately linked they all need to be assessed simultaneously.

- ~ An understanding of how changes in the nutrient ratios and sources affect food web structures along the river.

This will require a combined physical, chemical and ecological approach to understanding riverine systems. Experts need to work closely together to understand the interactions between the physical and chemical environments and the riverine ecology. Only then will we reach the *Holy Grail*: an ability to predict the ecological consequence of varying the supply of nutrients to river systems.

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We need to understand river process interactions under different slow conditions. Above: The Wyong River, photo by Anthony Scott. Below: The upper Lachlan River, photo by Nicki Taws.

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National Eutrophication Management Program: Highlights 1995–2001

NUTRIENTS

The National Eutrophication Management Program (NEMP) began in 1995 following community concern about outbreaks of algal blooms in rivers and lakes across Australia. The Program invested in research and development to reduce the frequency and intensity of harmful algal blooms in Australian fresh and estuarine waters, as well as raising awareness and understanding about the processes that cause these blooms to develop. Over five years, the Program identified and funded key research and development gaps that covered over-arching eutrophication issues. This research was 'grounded' in four focus catchments: Wilson Inlet (WA), Fitzroy (Qld), Namoi (NSW) and Goulburn-Broken (Vic).

The program concluded in 2001, with a review finding that it had increased understanding about the causes of algal blooms, and provided a wide range of management techniques that could be practically applied. Some of the management techniques developed through the Program include:

- ~ Managing flows to reduce the stratification in the water column that promotes blue-green algal blooms.
- ~ Managing light penetration within waterbodies to control blue-green algal growth.
- ~ Using bio-manipulation to directly control concentrations and growth of blue-green algae.
- ~ Managing sediments in rivers, storages and estuaries so that the anoxic conditions favouring blue-green algae growth are avoided.
- ~ Managing nutrients so that they are not entering river systems in 'pulses' and promoting algal growth.
- ~ Controlling nitrogen to better manage algal blooms.
- ~ Using tests to determine whether a particular waterbody is nitrogen or phosphorus limited and developing management strategies accordingly.



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Photo DNRE.

These techniques have been developed into tools and information designed to assist natural resources managers. Key Program outputs are outlined below, with more details provided about these outputs available on the www.rivers.gov.au website.

Cost of algal blooms to Australia

Although there have been one-off estimates of the costs of individual algal bloom events — e.g. Darling bloom, closure of North Pine dam — until NEMP there had not been a national assessment of the cost of algal blooms to Australia. A NEMP report conservatively estimated the cost of freshwater algal blooms to be between \$180 and \$240 million, based on the

Stratification — separation of water into layers of different temperature within the water column

Cyanobacteria — blue-green algae

Anoxic — oxygen depleted

Bio-available — nutrients available as food to animals and plants

Bio-manipulation — manipulating plant and animal growth to achieve a management outcome

community's willingness to pay for preventing blooms. This cost covered rivers only, and did not include coastal and estuarine blooms such as outbreaks in the Gippsland Lakes and the Swan River, WA. The cost of algal blooms is divided equally by urban water users, irrigated agriculture and dryland farmers, illustrating the need for community action to tackle the problem.

Managing storages to minimise risk of algal outbreaks

Burrinjuck Storage in NSW near Canberra has a unique record of water quality data stretching over 18 years, including a period of nitrogen and phosphorus removal from in-flowing waters due to upgrades of the Canberra Sewerage Treatment Plant. A detailed study of this data has shown that the nutrients that fuel the blooms are most likely to come from bottom sediments, rather than directly from in-flowing waters. Research found that it is the availability of nutrients that limit the biomass of the algae and not other factors such as light. Organic carbon coming from the upstream catchment appears to be driving the release of bottom sediment nutrients. Measurements showed that overall algal biomass reduced after phosphorus was removed from Canberra effluent, in addition, there was a switch from harmful blue-green algae to more acceptable green algae. Based on this work, scientists and storage managers have developed a flow chart and guide outlining different management options — this is a first for reservoir managers and was enthusiastically received.

Bio-manipulation

Bio-manipulation is one technique for managing algal blooms in storages that has had success overseas but has been untested in Australia. The technique involves the introduction of predatory fish that manipulate the foodchain

in such a way that nuisance algae are suppressed by zooplankton. NEMP supported a trial of this technique in a storage in Queensland with promising results.

Influence of nitrogen, phosphorous and light on blooms

Although it has been accepted for some time that algal blooms require access to a range of nutrients and light in order to develop to nuisance proportions, the accepted wisdom has been that phosphorus has been the critical factor in controlling their development in freshwaters. As a result, many algal management policies are directed towards reducing phosphorus concentrations. NEMP research has, however, shown that both phosphorus and nitrogen are equally important nutrients and that access to light is even more important in controlling growth in turbid Australian rivers.



Cartoon Simon Kneebone

Influence of flow on algal blooms

Many of the rivers in south-east Australia are impounded behind weirs that control flow for irrigation purposes. Research has shown that the algal blooms that form in these weirpools arise primarily because of the stratification of the water. Cyanobacteria, unlike other forms of algae, can regulate their buoyancy and so move up and down in the water column. This provides them with a competitive advantage in these weirpools where they can move between the nutrient enriched, oxygen deficient bottom waters and the light zone in the top waters. NEMP researchers have developed a number of flow management techniques that will break the stratification and so remove this advantage for cyanobacteria.

Sources of phosphorous in the landscape

When algal management plans were drawn up in the early 1990s, there was considerable emphasis on reducing the phosphorus entering rivers from fertilisers. NEMP funded research into radio-isotopic tracers that act as sensitive markers for fertilisers. The results showed that for a typical catchment in northern NSW with dryland agriculture, fertilisers were a negligible contributor to the phosphorus attached to sediment particles. Most of the phosphorus comes from natural stores in soils and is liberated by sub-surface and surface soil erosion. In contrast, however, in irrigated pasture areas such as in the Shepparton district of northern Victoria, or on the sandy soils of Western Australia, researchers discovered a significant contribution to the phosphorus load from applied fertilisers. This work highlighted the need for management strategies to take account of local conditions when developing approaches to phosphorous management.

Role of bottom sediments and their need for management

Most of the phosphorus and nitrogen in rivers, storages and estuaries comes from bottom sediments that have been eroded over decades

since the catchments were cleared for agriculture. These nutrients are released into the water column, particularly when the bottom waters turn anoxic. A project in Wilson Inlet, Western Australia measured the flux of nutrients from the sediments of that estuary and showed that about seven times as much nitrogen comes from these sediments as from fresh river inflows. The project has also shown that the sediments act as a trap for the phosphorus entering the estuary from the rivers i.e. there is a steady build-up of phosphorus in the sediments each year. This research shows that if there is an extended period of anoxia in the estuary, there could be a large release of nutrients from the bottom sediments that would fuel a major algal bloom.

Bio-availability of different forms of phosphorous

For many years there has been a belief that phosphorus from sewage is more readily taken up by algae than phosphorus attached to soil particles originating from erosion in catchments. If true, then this would support arguments for upgrading sewage treatment plants since, as pound for pound, this source of phosphorus is more potent. However, a project in the Namoi area of NSW showed that there was very little trace of phosphorus from the Narrabri Sewerage Treatment Plant within 20 kilometres downstream of the outfall. This meant that the discharged phosphorus may have had a local effect but it was a very small contributor to the downstream phosphorus load in the river.

New and standardised techniques for algal and nutrient monitoring

Laboratories have long used the total phosphorus and total nitrogen concentrations in rivers as the standard measure for nutrient levels. However, research has now shown that most of the phosphorus is bound to sediment particles and, depending on the sediment characteristics, the phosphorus can be more or less available to fuel algal growth. Total phosphorus (and total nitrogen) are, therefore, poor measures of the potential for algal blooms; with bio-available phosphorus and nitrogen much better measures.

NEMP has supported the dissemination of a technique — the iron strip method — for simply and cheaply measuring the bio-available fraction of phosphorus. In addition to this work, NEMP funded the development of a technique to determine whether nitrogen or phosphorus is controlling the growth of blue-green algae in a particular waterway. This is important because it indicates whether managers should be trying to reduce phosphorus or nitrogen levels.

NEMP has also produced a manual for sampling algal blooms in both standing waters and flowing waters. Up until recently it had been very difficult to get a comprehensive picture of the extent of algal blooms because agency staff had sampled the water at different depths, at different distances from the shore, etc and had used different laboratory procedures to count the algal cells in these samples. The manual has been assessed by laboratory managers and is now in widespread use throughout Australia.

For more information about NEMP go to www.rivers.gov.au and look under 'activities' where you will find a link to the NEMP website. This website has lots of information about all the projects and products discussed in this article, so check it out!



Photo CSIRO Water Resources.

NEW

National River Contaminants Program

The recently launched National River Contaminants Program builds upon the highly successful National Eutrophication Management Program that addressed issues concerning the cause and management of algal blooms. The program continues the partnership between Land & Water Australia and the Murray-Darling Basin Commission, and addresses issues of declining water quality in Australia's river systems, with salinity, nutrients and sediments being identified as the highest priority river contaminants for consideration.

The program has responded to a major review that concluded that contaminants affect not only the health and ecological value or riverine systems (including wetlands and floodplains) but also threaten consumptive and commercial uses of water resources. River contaminants are also a major threat to receiving waters (estuarine, coastal, wetland and reservoirs) and some ecosystems under serious threat are of enormous national value, e.g. the Great Barrier Reef, Gippsland Lakes, Macquarie Marshes, and Swan-Canning estuary. Salinity, nutrients and sediments were identified as the highest priority river contaminants for consideration under the program.

Projects will be contracted to initiate the program in the 2001/2002 financial year, including calls for proposals under specific research topics.

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CLICK AND LEARN

ABOUT WATER AND RIVERS IN YOUR AREA



Want to know more about the rivers or waterways in your area but don't know where to start? Try the informative, innovative and interactive Australian Natural Resources Atlas (www.nlwra.gov.au/atlas).

The Atlas is the web-based interface to all the information being prepared by the National Land and Water Resources Audit (a program of the Natural Heritage Trust). For example, you can read the Audit's *Australian Water Resources Assessment 2000* — the most recent assessment of surface water and groundwater use, availability and quality. Water is just one of the seven topics the Atlas reports on. The others are agriculture, coasts, land, people, rangelands, vegetation and biodiversity. It's Australia-wide information detailed at national and regional scales. You can get the national perspective, or type in the name of your town and obtain a list of available information including links to key statistics, maps, text and tables and to relevant state and territory sites.

The Atlas is much more than simply good reading, it provides access to an unprecedented amount of information — courtesy of a unique agreement between the Audit and representatives of the State and Territory governments. You can even download data from the Australian Natural

Resources Data Library (adl.brs.gov.au). But the best thing about the Atlas is it's interactive. The dynamic mapping facility allows you to construct a map for a region of interest incorporating a wide range of natural resource, social and economic information. For example, create a map of salinity risk or water quality and show the towns, local roads and rivers.

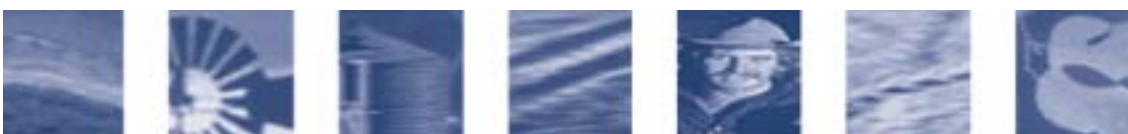
By the end of 2001, many more Audit products will become available including:

- ~ An Australia-wide compilation of native vegetation, type and extent
- ~ Information on Australia's rangelands, including grazing pressure, feral animals, weeds, tenure etc
- ~ Soil acidity, where it is and its affect on production
- ~ Soil properties — combining all the various soil sampling over the years across Australia
- ~ Soil erosion and nutrient budgets — predicting sediment and nutrient loads of land to rivers, and through rivers to estuaries and marine environments
- ~ River condition
- ~ Estuaries — assessing their condition and management needs of about 100 Australian estuaries.

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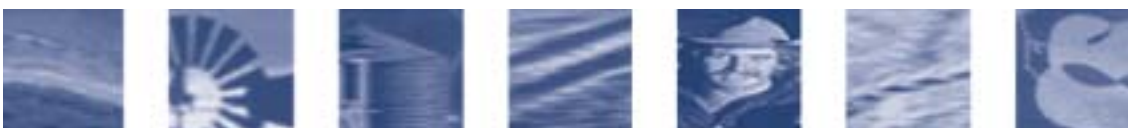
Visit the Audit's Atlas website www.nlwra.gov.au/atlas



Want to know about the Audit?

The National Land and Water Resources Audit is one of the key programs of the Natural Heritage Trust. The Audit's main objective is to assist natural resources managers make informed decisions about natural resources. To achieve this, the Audit is:

- ~ Assessing the status of land, water and vegetation resources
- ~ Identifying the costs, and benefits of resource change and remedial action
- ~ Developing compatible Australia-wide information systems and data
- ~ Developing a monitoring framework for natural resources.



Congratulations

TO BLACKWOOD AND GOULBURN-BROKEN CATCHMENTS

BLACKWOOD



BASIN GROUP

Blackwood wins gold in International RiverPrize



GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY

Goulburn-Broken wins gold in National RiverPrize

A prizefest for Australian river management

Australian river management was recognised as being of 'world class' standard at the recent *Riversfestival* in Brisbane. Much to the delight of the audience, the Blackwood Basin Group won the 2001 Thiess Services International Riverprize (A\$100,000) becoming the first Australian organisation to win one of the world's most prestigious environmental awards. The night turned out to be double celebration when the Goulburn-Broken Catchment Management Authority won the inaugural 2001 Thiess Services National Riverprize (\$25,000). These awards were made in recognition of the innovative, world-class scientific, planning and management approaches used by these two groups, combined with their demonstrated commitment to involving local communities in making decisions about their rivers.

Both these groups have received Natural Heritage Trust funding, as well as being part of Land & Water Australia's National Riparian Lands R&D Program. We are thrilled that the groups have done so well, as they will provide inspiration and experience that we can all draw on as we continue to work to protect and restore Australia's river systems.

Congratulations again!

Siwan Lovett (Land & Water Australia) and Kirsten Willcox (Rivercare AFFA)



Water quality management in Queensland

Currently, water quality management in Queensland is being addressed on a number of fronts. These 'fronts' are making significant progress in raising community awareness and understanding of water quality issues, building on the earlier valuable work of Waterwatch groups across the state. Going beyond the traditional condition and trend information, community groups are now better appreciating the range of land and water use practices that potentially have significant impacts on ground and surface water quality.

Responsibility for water quality management in Queensland is shared between the Department of Natural Resources and Mines (DNR&M) and the Environmental Protection Agency (EPA). DNR&M addresses ambient freshwater quality, whereas EPA focuses on marine water quality and point source contamination.

DNR&M's ambient program collects basic physio-chemical water quality data (salinity, acidity, temperature, turbidity and dissolved oxygen) at 175 sites across the state three times a year, plus nutrients at some sites. In addition, sediment bed load is measured at a number of key sites. Macro-invertebrates are measured using standard AusRivAS protocols. Under previous Federal programs, macro-invertebrate data have been collected at some 500 stream sites in the state. The current ambient biological monitoring program samples 30 new sites per year along with 50 fixed 'reference' sites.

The state's ambient freshwater networks to measure flows, water quality and ecosystem health are being continually reviewed to ensure that they are cost-effective in delivering appropriate data for water resource planning and management. Specific programs such as the National Action Plan for Salinity and Water Quality, South East Queensland Regional Water Quality Strategy, Murray Darling Sustainable Rivers Audit and the Reef Protection Plan are also providing a focus for improved water monitoring methodologies, including the need for integrated networks, ecosystem process-based indicators and community involvement in monitoring.

The ongoing identification of indicators that are scientifically robust and cost-effective to measure is a major challenge, particularly for

measuring ecosystem health impacts. This is a major issue for the monitoring, evaluation, and review of water resource plans. Relationships between water management activities and ecosystem outcomes need to be clearly defined and will be the subject of targeted scientific research effort over the next few years.

The National Action Plan for Salinity and Water Quality is providing an innovative approach to community engagement in addressing water quality issues through better condition assessment, target setting and action planning. While the main focus in the state has been on salinity potential, there are expected to be traditional water quality spin-offs, such as nutrients and sediments. Part of this process is the setting by local communities of environmental values in accordance with the National Water Quality Management Strategy Guidelines.

The South East Queensland Regional Water Quality Strategy has been a major study of water quality issues affecting Moreton Bay, including the discharge of nutrients from industrial and sewage treatment plants, as well as the release of sediments and nutrients from rural areas in the catchments draining to the Bay. The study has excelled in terms of science, community participation and communication. Water quality monitoring is being undertaken in the Bay and estuaries, and a freshwater component, called DIBM3, will be implemented in mid 2002. DIBM3 has developed a set of innovative indicators to measure stream health as influenced by catchment and reach scale effects. These indicator groups include physico-chemical, ecosystem processes, macro-invertebrates, fish and algal bioassay.

The Reef Protection Plan is placing the spotlight on the range of nutrients, sediments and contaminants being delivered from catchments into the reef lagoon and their impacts on the health of the reef. A Queensland Reef Taskforce has been established to address the issue and is expected to develop plans and strategies to reduce these inputs to acceptable levels.



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River pollution and real estate: What does water quality mean to us?

When we think of pollution we often think of dramatic ecological effects, with images of soap-sud filled rivers covered by a carpet of dead fish floating belly-up easily coming to mind. However, the effects of pollution may be more subtle, and affect our psyches as much as the organisms that live in rivers. This is because rivers have an important cultural value for us all, and in indigenous cultures these water bodies, and even the water itself, may have a deep spiritual significance that can be affected by a pollution event.

These values can create great gulfs in understanding between regulators and affected communities about the severity of pollution, and about the extent to which the pollution needs to be cleaned up. Regulators often view the pollution in purely scientific terms, and judge the extent of contamination by how much it exceeds relevant water, sediment or soil criteria. Affected communities on the other hand, include a large number of social factors in their judgement of the pollution and, in many cases, the mere presence of a “toxic” chemical is enough to indicate that there is a problem and that something needs to be done. The size of the gulf in understanding between regulators and the affected communities depends on a large number of intangible factors, including the degree of trust in the regulatory process and the degree to which people feel they have any influence on the process. These differences in understanding can only be bridged by a commitment to ongoing dialogue between regulators and communities, and involving both groups in the clean-up process as much as possible.

Many of these cultural issues become apparent when old, contaminated industrial land next to a river is being redeveloped for housing, and developers and government agencies often have to try and balance a range of community values and expectations about how contaminated land and water will be managed. The Minim Cove residential development next to the Swan River in Perth is a good example of how cultural values of Aboriginal custodians and local residents, affected how contaminated land and pollution in the adjacent river was perceived and, secondly, how these perceptions impacted on management of the area.

Pollution at Minim Cove

Minim Cove is located on the Swan River foreshore about 14 kilometres to the west of the centre of Perth. Land in the area was formerly occupied by a fertiliser manufacturing plant that operated from 1909 to 1961. The plant imported pyrite which was roasted on-site to make sulfuric acid, and some gold was also extracted from the pyrite using cyanide and mercury. Large amounts of roasted pyrite cinders were left on-site, with widespread soil contamination by heavy metals, and localised groundwater contamination by cyanide. Pyritic wastes were also disposed of along embankments adjacent to the river, and contaminated material has fallen into the river and onto a fringing beach (Figure 1). The discharge of contaminated stormwater and groundwater from the site over a long period also contributed to pollution in the river.

Land in the area was badly contaminated by the long history of industrial activity at the site and, to a large extent, the high real-estate value of land near the ocean and the river funded the clean-up of the area by the development of an exclusive housing development. However, extensive sediment, water and aquatic fauna sampling indicated that although contamination on the beach posed a marginal health risk to users of the beach, levels of contamination in the water column and aquatic sediments in the river did not pose a significant threat to aquatic organisms in the river.

The original development proposal did not include any remedial work on the river foreshore or in the river.



Pyritic waste

Figure 1: Photo taken of the site from the air. Pyritic waste (shown here) which is being removed from the surface and being disposed of in a containment cell. Minim Cove is on the left, and the ocean is on the right.



Social issues

The foreshore area near Minim Cove is significant for the local Nyungar people because of its association with the great serpent, the *Wagył*, which in the Dreamtime created the Swan River and the limestone cliffs along the foreshore in this area (considered to be the hardened excrement of the *Wagył*). Minim Cove is of particular significance because the *Wagył* is believed to have slept underground here after it caused the great flood that submerged the land between *Wadjimup* (Rottnest Island) and the coast. Ethnographic and archaeological evidence suggests that the Minim Cove area has been extremely important to Aboriginal people for at least the last 10,000 years.

From an Aboriginal perspective, land around Minim Cove has been desecrated and severely degraded since Europeans were first seen in the area in January 1697 and permanent settlement commenced in 1829. Apart from being a fertiliser factory, since 1829 land in the area has been used as:

- ~ a limestone quarry with the complete removal of seven sacred hills (known as the “Seven Sisters” by early colonists) which were also closely associated with the *Wagył*;
- ~ a dairy farm;
- ~ a motocross track; and
- ~ a landfill site that has contaminated some groundwater seeps with leachate.

The construction of an exclusive residential development at the site is not generally seen as an improvement in land use by the Nyungar community.

From the perspective of other residents in the area, the river is an important social amenity that provides their properties with unique views across the river and the ocean, contributing greatly to high real estate values in the area. The river foreshore and land between the Swan River and the ocean in the area also has great historical significance, as this was where the Dutch explorer Willem de Vlamingh walked to become the first European to view the Swan River in January 1697.

Foreshore clean-up

Extensive consultation with nearby residents and the Aboriginal custodians in the area indicated that a clean-up of the river foreshore and possibly

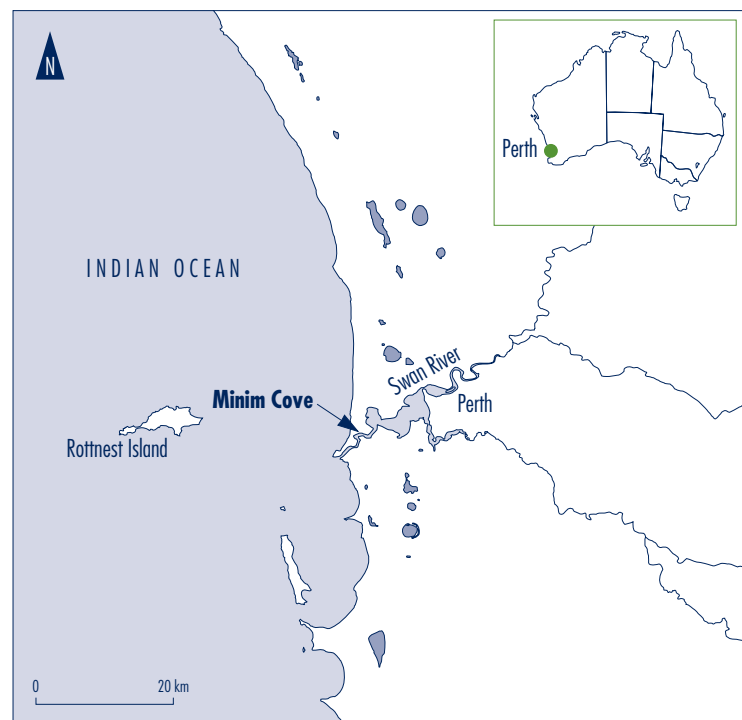
the river-bed should be included in the remediation program for Minim Cove. Nearby residents were concerned about the health impacts of contaminated material on the beaches and in river sediments, and felt that the original development proposal would greatly restrict public access to the river for swimming or fishing. For the Nyungar custodians, the river foreshore and the river are the most sacred parts of the development site, and it was totally unacceptable to them to leave contaminated sediment in this area.

Consequently, the site remediation plan was changed to incorporate the removal of as much as possible of the contaminated sediment from steep banks next to the river and from the foreshore beach. These banks were then recontoured to prevent further sediment falling onto the beach and into the river. Some contaminated material was also removed from shallow river sediments, but care had to be taken to minimise the disturbance of the riverbed as this also has an important cultural value for the Nyungar people. The recontoured banks of the river were then revegetated with local native species at the request of the Nyungar people.

With improved access to the beach and the reinstatement of a walking and cycling trail, the Minim Cove foreshore is now an amenity that can be enjoyed by the whole community.

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Erosion and irrigation on Ballarat potato crops: Research to save water and reduce sediment runoff

The basalt soils found throughout the Ballarat potato-growing region are friable, permeable and free draining. Although these soils are inherently stable, they are subject to erosion by heavy rainfall and over-irrigation. The most common irrigation system used in the district is the travelling gun irrigator. Although used by approximately 80% of the region, they have some drawbacks. One drawback is that they are severely affected by wind, causing uneven watering. Water winches throw large droplets of water over long distances. This, combined with the possibility of wind doubling the desired rated on one side and the chance of breakdown leading to local flooding, can make irrigation a worse soil hazard than a thunderstorm.

Fixed boom travelling irrigators (Figure 1) are designed to overcome many of the problems inherent with travelling gun irrigators. The low-pressure operation of the sprinklers spaced along the boom makes them energy efficient, gives an even distribution of water over the crop particularly on windy days, and can be tailored to soil and crop requirements. As a result their use has been steadily increasing in the Ballarat region. Often however, if the grower is late returning to the irrigator, or a hose has burst, travelling irrigators can be left on for a period of time



Figure 1: Researchers sampling erosion runoff under the travelling boom irrigator.

when they reach the end of the row. Research was conducted earlier this year at the Central Highlands Integrated Production Systems (CHIPS) Ballarat Demonstration Farm looking at the fixed boom irrigator and the implications on water usage, soil erosion and water quality if an irrigator is left standing at the end of the row with the pump running.

Research results

The results of this research were released at the CHIPS Potato Growers Seminar at the Ballarat Demonstration Farm on Wednesday 22 August. The results found that if an irrigator is left stationary for 15 minutes, it would apply water equivalent to a rate of 105 millimetres per hour, well exceeding the infiltration capacity of the soil, and rapidly causing soil movement. The magnitude of soil mobilised is described in Figure 2. In this situation, a 10% slope would erode at 10 kilograms of soil per hour with 85% crop coverage, and 18 kilograms per hour with 50% crop coverage. On steeper slopes (i.e. 20%) it was found that soil would erode at 20 kilograms per minute with 85% crop coverage, and 40 kilograms per minute with 50% coverage. The results suggest that more care must be taken to quickly cease pumping earlier in the season

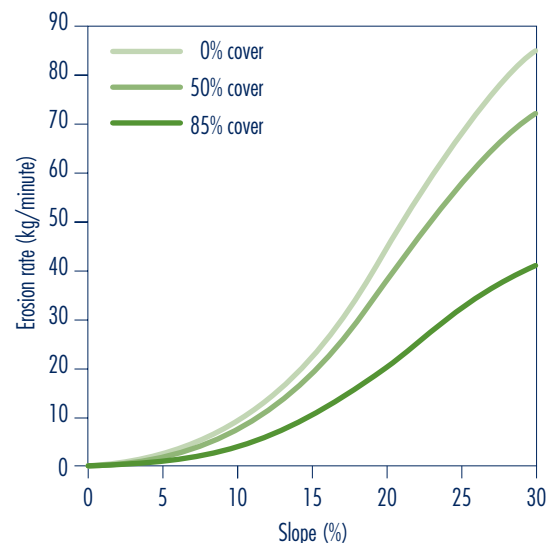


Figure 2: Effect of slope and plant cover on erosion rates under a 50 metre lateral irrigator.



and on steeper slopes where erosion rates are much higher.

Very high phosphorus and nitrogen levels were also found in the runoff (Figures 3 and 4), indicating a huge export of nutrients from the area of plantation. In addition, nitrogen and phosphorus levels were found to be 150 times higher than the natural stream levels found in earlier studies, and 400 times higher sediment loads than natural levels. If runoff washes directly to a waterbody via a drainage line or road table-drain it can potentially be a serious pollution problem.

Management implications and solutions

The environmental benefits described by this research are both clear and significant. Levels of sediment and nutrients in runoff from stationary irrigators are extremely high. In locations where runoff links with natural and constructed drainage lines, impacts on water quality may be very high.

There are options to prevent over watering and erosion at the end of the run. One such technique is the installation of a cut off switch on the irrigator. A UHF radio attached to the tractor sends a signal to switch the pump off when the irrigator hits the back of the tractor and knocks

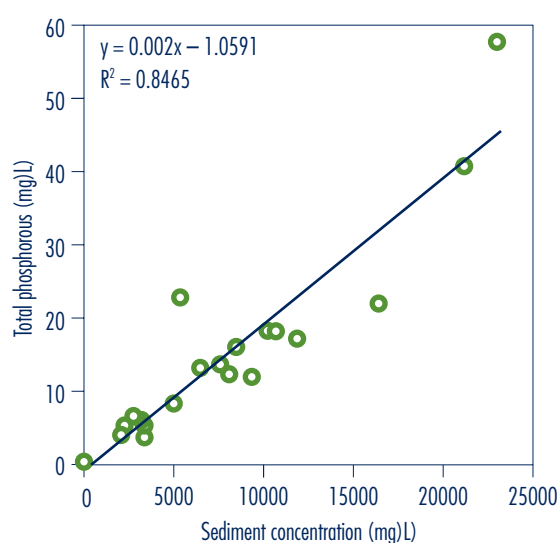
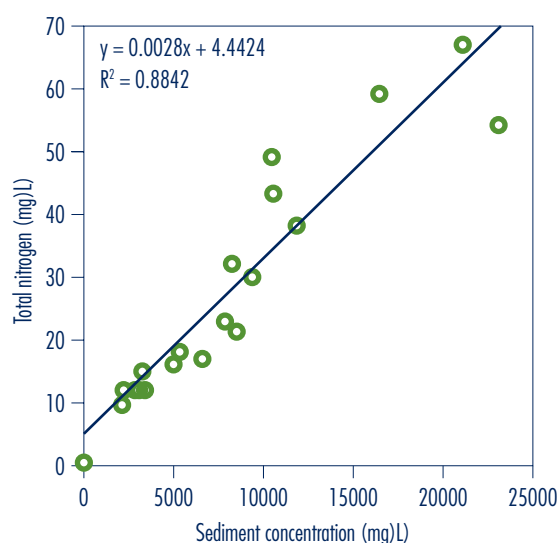
it out of gear. These switches can also detect a loss in pressure due to a burst hose triggering the pump to switch off. By not allowing the irrigator to stand stationary in the one spot they can have remarkable effects in keeping soil and nutrients on the crop where they belong. These devices are especially convenient, as the grower does not have to turn off the irrigator pump when the irrigator has reached the end of the row. They are now readily available from irrigation specialists.

In addition to cut off switches, grassy buffers, diversion banks and grassed landings are all effective measures to trap moving sediment on-site and thus keep soil and nutrients on the paddock doing what they should be doing — growing spuds.

The research was conducted by Department of Natural Resources and Environment and the Corangamite Catchment Management Association in conjunction with Central Highlands Water and the Central Highlands Integrated Production Systems (CHIPS).

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Figures 3 and 4: The relationship between suspended solids in runoff and nutrients from the lateral irrigator plots

Figure 3 (left): Total nitrogen. **Figure 4 (right):** Total phosphorus.

Managing salinity and nutrients in the Glenelg Hopkins region

The Glenelg-Hopkins region is a great place to live. It is recognised as one of Victoria's most vital agricultural and tourism districts and it is the area that dominates historic writings about the early settlement of this state. It stretches east to Ballarat, west to the South Australian border, north to the Grampians and south to the coast.

Clearing for agriculture has stripped the basin of its cover of forest and open woodland. Only a few woodland remnants remain in the far north of the region. According to the Glenelg-Hopkins Native Vegetation Plan, shallow rooted introduced grasses are now the predominant vegetation community covering 95% of the catchment. Such a significant ecological shift in the region's vegetation communities has had a serious impact on native fauna with 18 endangered, 19 vulnerable, 39 rare and 12 restricted species. Additionally, this change to introduced grasses creates significant fuel loads in summer leading to a tremendous fire hazard as well as being a contributor to a major water quality problem, particularly high levels of salt and nutrients.

Salinity

Salinity is increasingly becoming a priority issue in the Glenelg Hopkins region. Like many Australian catchments, extensive clearing for agricultural production has led to significant changes in the water balance. Currently 27,500 hectares are affected by dryland salinity in this region, which is estimated to increase five-fold over the next 50 years according to the Australian Dryland Salinity Assessment 2000. Many waterways are degraded, with deteriorating water quality from salinity resulting in a high reliance on the groundwater supply.

Monitoring of ground and surface water bodies provides the basis for evaluating changes in salt affected resources. Amelioration efforts include:

- ~ Local native tree planting — direct seeding and seedlings in recharge areas
- ~ Saline agronomy — high water use species including lucerne
- ~ Soil testing using the electromagnetic induction technology
- ~ Waterwatch activities.

Glenelg Hopkins



C M A

The Glenelg Hopkins CMA provides regional strategic direction to achieve integrated catchment management in partnership with the government and community. It has taken a proactive approach to the National Action Plan for Salinity and Water Quality, with the planning work it has undertaken now setting the benchmark for other CMA's across the state. Importantly, the Glenelg Hopkins region will benefit from the CMA's efforts through a variety of salinity and water quality projects in areas of research, on-ground works, regional capacity building and communication.

In late August, the CMA submitted to the Victorian Government a 'Foundation' application consisting of 24 sub-projects and four Priority Action applications including:

- ~ stream stabilisation works to enhance environmental flow management and stressed rivers in the catchment;
- ~ development of effective and sustainable dairy effluent management practices;
- ~ development of new generation trees and pasture systems for saline bio-regions; and
- ~ opportunistic intensive soil and hydrological data collection during pipeline construction.

State and Commonwealth Ministers are expected to sign off on final National Action Plan allocations by October. Community members have been involved at every level of decision making about where these funds will be spent and on what.

Nutrients — dairy effluent

Rivers within the dairy areas of both the Glenelg-Hopkins and Corangamite CMA's consistently show high levels of phosphorus and nitrogen (P&N) which are of sufficient magnitude to cause a major impact on water quality, aquatic

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Map: Three basins of the Glenelg Hopkins CMA region of south west Victoria.

Inset: Waterwatching at Lake Hamilton during National Water Week last year.



biodiversity and blue-green algae outbreaks (EPA 1995).

Waste from dairies is recognised as one of the major point sources of nutrient pollution of waterways (Nutrient Management Strategy for Victorian Inland Waters). Objectives in the Glenelg-Hopkins Nutrient Management Plan state that 100% of dairy farms in the region will comply with the State Environment Protection Policy within five years (Waters of Victoria 1988). The State Environment Protection Policy — Waters of Victoria, requires that waste is retained within the boundary of the property and reused in an appropriate manner.

To address dairy effluent management on a catchment basis across the south-west, a Dairy Effluent Steering Committee is working to develop a project that will achieve the above results. This Committee includes representatives from Glenelg-Hopkins and Corangamite CMA's,

WestVic Dairy, Department of Natural Resources and Environment, the Environment Protection Authority, United Dairy Farmers of Victoria and community members. The objective of the group is to achieve a holistic approach to effluent management across the two catchments, through extension, research, one to one contacts and learning groups.

Of the 2300 dairy farms in the region, it is estimated that only 50% have effluent systems and, of these, only 25% are deemed effective. With the exact number of effective effluent systems unknown, there is a need to increase the profile and importance of effective effluent management systems on farms amongst the community.

The Steering Committee has developed a South West Effluent Management Strategy and Communications Plan, that will lead the way for effective effluent management in the region. The committee is working towards a common goal of improving the health of the region's river system by minimising nutrient run-off through effective effluent management on dairy farms.

Through an integrated approach with coordination between the diversity of Glenelg Hopkins CMA partners, the issues of salinity and nutrient management are being managed in a proactive manner.

A ten-year retrospective of pesticide contamination in NSW rivers

Seldom are we given the opportunity to reflect on the outcomes of a monitoring program that has spanned ten continuous years. The Central and North West Region's Water Quality Program, run by the Department of Land and Water Conservation (DLWC) NSW, has recorded pesticide contamination in the central and north-western inland rivers of NSW since 1991. The program has also monitored the basic physico-chemical parameters of water quality (such as pH, EC, turbidity and nutrients) and included a bio-monitoring component (macro-invertebrates).

The Program was established in response to community concern about several highly visible fish kills that occurred in the northern inland rivers of NSW in the late 1980s and early 1990s. The fish kills coincided with a boom time for the cotton industry, one of the highest users of pesticides in the study area. In response to these events, the Australian cotton industry and DLWC collaborated to monitor pesticide levels and other indicators of river health in cotton growing areas of NSW. This monitoring was to determine whether agricultural chemicals were in fact contaminating rivers and whether they had the potential to cause fish kills or other deleterious environmental effects.

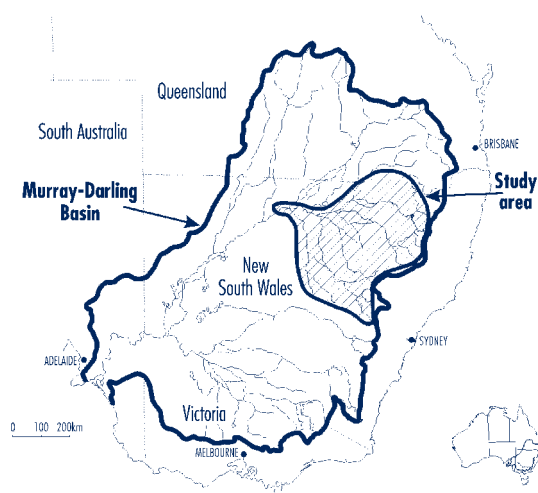
Endosulfan is an organochlorine insecticide that the cotton industry relies on heavily to protect the developing cotton boll from *heliiothis* caterpillars. In the summer of 1991/92, 52% of all samples collected exceeded the ecosystem protection guideline value of 0.01µg/L

(ANZECC 1992). This contrasted with the summer of 1999/2000 when the same measure of contamination had dropped to only 29%. Similarly, the endosulfan concentrations were decreasing. For example, the median endosulfan concentration value for the Gwydir River valley over the summer of 1991/92 was 0.08µg/L, compared with 0.02µg/L for 1999/2000 which, although still above the ANZECC guidelines, shows a marked improvement. This decreasing trend is even more significant when one considers that the area planted to cotton in this valley over the same period increased from approximately 78,000 hectares to 95,000 hectares.

In addition to endosulfan, other insecticides were detected relatively infrequently and these included the organophosphates profenofos and chlorpyrifos, parathion-methyl and dimethoate as well as amitraz (of the amide chemical type), and propargite (of the sulfite chemical type). Pesticide monitoring concluded that at times, insecticidal contaminants were present at concentrations likely to cause adverse environmental impacts. However, a decreasing trend of endosulfan levels over the ten-year period was demonstrated, with the ecosystem protection guidelines for ambient water quality (ANZECC 1992) being exceeded with far less frequency in 1999/2000 than they were in 1991/92.

The reduction in endosulfan over the 10 years of monitoring may be attributed to the cotton industry's willingness to address the issue. The industry developed self-regulation, vigorously advocating and implementing Best

µg/L = micrograms per litre



Left: *Heliothis caterpillar*.
Photo CSIRO.

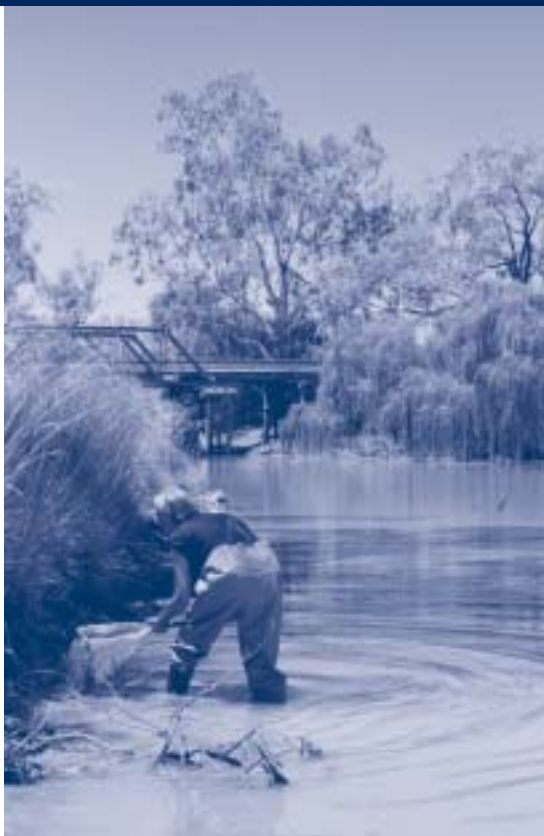


Management Practices. Over the same period, the biotechnology sector produced 'Ingard', a genetically modified cotton plant resistant to insect attack, which reduced the number of insecticide applications required on these crops. Whilst these developments were having a positive influence on attitudes towards pesticide use and application, usage rates were still in fact influenced to a large degree by whimsical seasonal and geographical variations in pest pressure.

During the 1998/99 cotton season, unacceptable levels of endosulfan were found in export beef, which led to the National Registration Authority placing restrictions on usage rates and banning some application methods allowed for endosulfan. In addition, the Parliament of NSW Legislative Council tasked the Standing Committee on State Development to prepare a report on the 'Use and Management of Pesticides in NSW'. This Committee made many recommendations, some of which involved making changes to legislation. The *Pesticides Act 1978* was reviewed and re-written to become the *Pesticides Act 1999*. The impact of these restrictions and changes to legislation were reflected in the Program's monitoring results, which recorded lower levels of endosulfan towards the end of the 10 year monitoring period.

The Central and North West Region's Water Quality Program did not just detect insecticides; eight herbicides were also recorded through the monitoring program. These herbicides were not necessarily linked to cotton production alone, but could be sourced from other broadacre cropping activities as well. There were slight fluctuations in levels of the common herbicide atrazine during the study; however there was no clear rising or falling trend. In 2000/2001, 7.6% of samples exceeded the ANZECC (1992) ecosystem protection guideline level for atrazine. Diuron, fluometuron, metolachlor and prometryn were other herbicides with relatively frequent detections. It is expected that riverine concentrations of herbicides will not change in the future, without first a change in their application methods and usage rates. Implications for the long term effect of these herbicides on algal and macrophyte communities have not been resolved.

Apart from monitoring water quality, this program participated in numerous research endeavours. It played a vital role in the research



Sampling edge of the Barwon River at Mungindi. Photo Monika Muschal.

conducted through the Land & Water Australia coordinated program entitled 'Minimising the Impact of Pesticides in the Riverine Environment, that ran from 1993 to 1997. In particular, the study contributed to the characterisation of contamination pathways and storm behaviour. Other research included mesocosm studies, which allowed field-scale investigations of the toxicity of pesticides on macroinvertebrates, the development of continuous passive samplers, allowing an alternative method to manual grab sampling and the investigation of sediment contamination levels. The program was one of the first in NSW to conduct large-scale biomonitoring of rivers through the use of macroinvertebrates.

At the ten-year milestone, the program underwent a review, which included a user survey, to assess whether the program's aims were still relevant and whether they were still being met. It was identified that the water quality monitoring needs of NSW have changed considerably over the last decade, primarily due to the NSW Water Reform process. What is required now is a better understanding of pesticide contamination at the local scale. That is why pesticide monitoring will now be conducted regionally, based on the requirements of individual catchment-scale water management plans.

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The gift of grey water

At Streaky Bay, community necessity was the mother of invention. The biggest problem in the town on the Yorke Peninsula in South Australia (SA), is the lack of water. Streaky Bay is one of the driest areas of SA — which, in turn, is the driest state in Australia with below 10 inches in rainfall. The cost of water is the biggest topic in Streaky Bay, with the local community paying double the price paid by other areas of SA to discourage water waste. SA Water has told the community to cut back its use of water by a third.

Streaky Bay Area school is one of the community's biggest users of water. It has recently received a \$70,000 Environmentally Sustainable Development Grant through the State's Partnerships local management plan to try to reduce its use by more than half. The school has identified that the key to meeting this target is management of grey water — storm water run off and recycled effluent water. Currently water run off from the streets comes down past the school but now, as part of the local management plan, the Streaky Bay council intends to develop wetlands as holding ponds on the school site. This approach will allow the grey water to be rechannelled into the wetland.

A feasibility study has indicated that water can be maintained in the proposed wetlands for 8–10 months of the year. In times of high rainfall, the school would store the excess rainfall to irrigate its oval. Streaky Bay students will monitor environmental and habitat changes, and conduct soil analyses. In addition, students will be propagating plants for the wetlands and learning how to grow fruit and vegetables via hydroponics. Students will construct business plans, participate in orchard design and planting, and trial effluent water on the diversification of horticulture eg olives, sandalwood, quandongs, mallee and herbs. They will also establish a vineyard and gain vocational education qualifications working alongside industry to install irrigation systems.

The school and the community have been jointly working on the project for four years and it has been funded from a combination of federal, state and local council contributions. The school is now waiting on the engineers' plans for



Streaky Bay students showing water re-use plan. Photo Ian Kent.

the wetlands, part one of the irrigation system has just been completed and the school is keen to get the other parts of the plan in place. An agreement will be drawn up between the Minister for Education Training and Employment and the local council over the control of the school wetlands.

The proactive behaviour of the school in participating in the broader community's environmental and water quality issue is a powerful representation of the community participation that underlies local school management. This could be a model for other communities in Australia.

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Sediment in an urban creek: Community monitoring to identify 'hot spots'

The catchment of Ginninderra Creek and its tributaries crosses the border between ACT and NSW and takes in some 32,000 hectares of land. The land uses in the catchment include urban, rural, rural residential, nature reserve and areas zoned for further development. For example, Gungahlin, the new northern urban precinct of Canberra has a projected population of 100,000 people within a twenty to thirty years timeframe. Ginninderra Creek is also of major importance in the regional context as it carries approximately one quarter of the urban runoff from Canberra directly into the Murrumbidgee River.

Historical records indicate that Ginninderra Creek and its tributaries were a 'chain of ponds' system before European settlement. At present, for most of its length the creek functions as an open stormwater channel, draining water from 28 urban and semi-rural suburbs. Gungahlin ponds and Lake Ginninderra form focal geographic, scenic and recreational sites as well as performing their primary function of sediment retention. One of the goals of the Ginninderra Catchment Group is to contribute to improving the water quality of Ginninderra Creek by reducing the amount of sediment entering the creek.

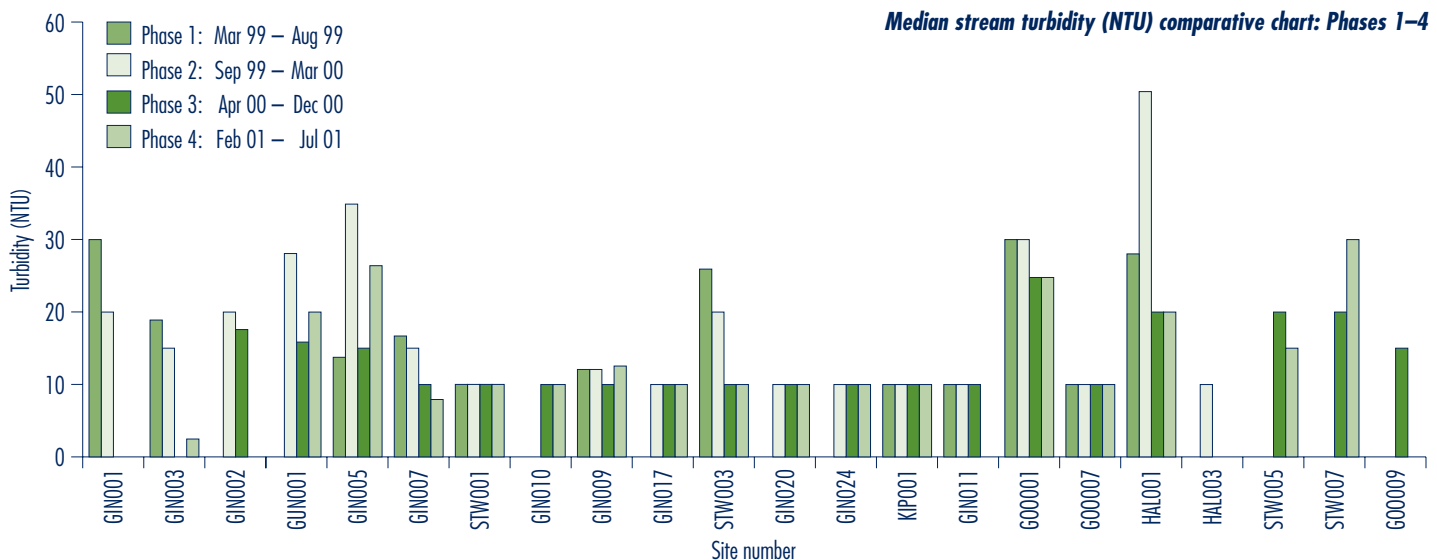
The Catchment Group has established a comprehensive water quality monitoring program that measures turbidity at 24 sites

throughout the catchment, on a three-weekly basis, in order to gather baseline data and identify turbidity 'hot spots'. The program includes quality assurance and quality control measures. The data will enable the Group to better target on-ground action aimed at reducing deposition of sediment into the creek. Data are now available over two years and some sites are emerging as needing particular attention (see Figure 1). The next step will be to identify the causes of the turbidity at these sites and to carry out remedial action.

Being in possession of reliable data has provided the Catchment Group with the confidence to approach other members, government agencies and funding bodies to seek resources and cooperation in addressing the identified problems. The monitoring program will be continued to determine the effectiveness of the Groups' actions.

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