National River Contaminants Program

Background

Land & Water Australia (LWA) and the Murray Darling Basin Commission (MDBC) had jointly funded the National Eutrophication Management Program (NEMP) over the five year period from 1995-96 to 1999-2000. As algal blooms were imposing a large cost on Australian water users, NEMP had primarily focused on nutrients and their sources and role in algal bloom development on waterways and water storages. The NEMP also gave attention to the role of flow in promoting algal blooms and other factors contributing to their development.

The NEMP was perceived to have made an important contribution to knowledge of the eutrophication complex and the establishment of a platform for further applied research. Some (at least indirect) impacts on management of eutrophication were made as a result of the NEMP investment (LWA, 2006).

The end of the NEMP led to a new program called the National River Contaminants Program (NRCP) that commenced in the year ending June 2001. NRCP formally concluded in June 2005, although a few of its projects were not completed until later.

This program (smaller than NEMP) focused more broadly on water contaminants with salinity, nutrients, and sediments as high priority. Contaminants were recognised as being pivotal to river management as they influenced water quality and hence had implications for irrigation and drinking water as well as the aquatic ecosystems associated with rivers and their associated floodplains, wetlands and water storages.

The National Land and Water Resource Audit (2001) reported that nearly 19,000 tonnes of total phosphorus and 141,000 tonnes of total nitrogen were predicted to be exported down rivers to the coast each year from areas of intensive agriculture. These loads were nearly 3 times higher than estimates for pre-European loads. Nitrogen was estimated to be more than double pre-European levels. The Audit also reported that gully, riverbank and sheetwash erosion delivered over 120 million tonnes of sediment to Australian streams each year. River sediment loads were some 10 to 50 times higher than pre-European settlement loads in intensively used river basins. Further, the impact of dryland salinity on streams and water quality was significant. The National Land and Water Resources Audit (2000) suggested that up to 20,000 km of streams could be affected by 2050. As a result of the increasing threat perceived from salinity, to not only water quality but also agriculture, infrastructure and native vegetation, the National Action Plan for Salinity and Water Quality was agreed by the Commonwealth and States in November 2000.

Moreover, during the late 1990s, there had been increasing awareness that many ecosystems were being influenced by more than one of these contaminants and contaminant interactions (biological, physical and chemical). The focus on developing an integrated management approach to joint contaminant processes in NRCP was expected to lead to improvements in river management and policy and hence improved ecosystem health and water quality at both a national and catchment scale.

The Project

The contaminants program was developed in conjunction with the Murray Darling Basin Commission (MDBC). Each of LWA and MDBC provided 50% of the funding for the program. A strategic plan and an implementation plan were developed, and a scientific workshop held in the two years before the program formally commenced. This planning assisted with the focus of the program and its composition.

Project Objectives

The overall aim of the NRCP was to contribute to healthy river systems by reducing the ecological impact of land-sourced river contaminants including salinity, sediments and nutrients.

The program was to provide practical technical information to directly support river management at both the national and catchment scales and to give special emphasis to the impact of contaminants on ecosystems processes.

A key outcome expected was improved and integrated management strategies and policies. The specific objectives set in the implementation plan were:

1. Gain new knowledge - to assist in developing sufficient knowledge to be able to manage the environmental impact and predict the ecological risks due to key contaminants in Australian rivers.
2. Devise new solutions and tools – to assist in better packaging new and existing knowledge in ways that could be more effectively used to minimise these risks.
3. Get new and existing knowledge used – to assist in developing innovative methods to ensure the new solutions and tools were effectively used.
4. Build capacity in research and management - to assist in improving research and management agencies capacity to better manage aquatic systems to minimise ecological risk from contaminants.

Two specific program objectives were set:

1. To develop a whole of ecosystem approach and integrated management for major contaminants
2. To apply an understanding of contaminant processes to management and policy

List of Projects

A list of 14 projects funded by the Program is presented in Table 1. A call for proposals in 2001 resulted in seven projects being funded. Four projects were either commissioned directly or were sourced from the LWA annual call. Other projects were funded later.

Table 1: List of NRCP Projects July 1999 to June 2007

Code	Project Title	Researchers /Organisations	Start Date	Finish Date
1. CLW54	Catchments, nutrients and sediment budgets: identification of knowledge gaps	Myriam Bormans, CSIRO Land and Water	January 2003	November 2004
2. CLW55	Development of a catchment contaminant cycle model for stakeholder use	Kit Rutherford, CSIRO Land and Water	October 2002	December 2005
3. DRD5	Developing a framework for making improved nutrient decisions for pastures	Ken Peverill, Jointly with Dairy Australia, MLA, Fertiliser companies (Pivot, Incitec, CSBP, HiFert)	July 2003	January 2007
4. GRU28	In-stream and riparian zone nitrogen dynamics	Christine Fellows, Griffith University	September 2002	June 2006
5. JCU18	Characterisation and dynamics of colloidal material in a turbid tropical river	John Faithful, James Cook University	November 2003	July 2007
6. RMI12	Predicting salinity induced loss of biodiversity	Ben Kefford, Royal Melbourne Institute of Technology	February 2003	April 2006
7. SKP10	Evaluation of Rivers Programs	Susanne Cooper, Sinclair Knight Merz	August 2004	October 2004
8. UMO38	National River Contaminants Program: Implementation Plan	Barry Hart, Monash University	May 2000	June 2000
9. UMO43	Development of risk based approaches for managing contaminants in catchments	Barry Hart, Monash University	March 2003	August 2006
10. UMU18	Alternative stable states: a potential paradigm for managing salinised ecosystems	Jenny Davis, Murdoch University	September 2001	March 2004
11. UMU19	Determining transition thresholds between alternative ecological states in saline waterbodies	Lien Sim, Murdoch University	March 2002	December 2004
12. UNE47	Integrated impacts of contaminants and flow on riverine ecosystem production	Darren Ryder, University of New England	January 2003	February 2006
13. UTV1	Managing Nutrients in	Paul Boon, Victoria	October	May 2002

(funded in conjunction with UMO39)	Floodplain Wetlands and Shallow Lakes Salt Sensitivity Database	University of Technology and Paul Bailey, Monash University	2001	
14. UTV2 (funded in conjunction with UMO41)	Innovative techniques for managing multiple threats to high value aquatic systems	Paul Boon, Victoria University of Technology and Paul Bailey, Monash University	September 2002	December 2005

Investment Costs

Table 2 presents a summary of the annual financial contributions to the National Contaminant Program by its two principal partners:

- Land & Water Australia (LWA)
- Murray Darling Basin Commission (MDBC)

Land & Water Australia contributed 50% of the program funds in nominal terms.

Table 2: Resources Contributed by Year and By Partner for the National River Contaminant Program (nominal $)

Year	**LWA**	**MDBC**	**Total**
2000-01	100,000	30,000	130,000
2001-02	350,000	100,000	450,000
2002-03	350,000	470,000	820,000
2003-04	350,000	500,000	850,000
2004-05	350,000	400,000	750,000
Total	1,500,000	1,500,000	3,000,000

Source: LWA

The investment was made through a range of projects and research providers. Total program expenditures for the program have been assembled and are shown in Table 3. Table 3 also presents estimates of funding by other contributors to the projects (predominantly third party funding and in-kind support from the research organisations). The NRCP made up 32.9% of the total resources (in nominal terms), therefore the LWA contribution was 16.4% of the total resources.

Table 3: Summary of Actual Investment Costs for NRCP by Year (nominal $ terms)

Year	NRCP Costs	Other Contributions (a)	Total
1999-00	31,347	0	31,347
2000-01	54,273	0	54,273
2001-02	162,727	0	162,727
2002-03	676,959	2,793,256	3,470,215
2003-04	919,939	1,715,273	2,635,212
2004-05	761,546	1,332,485	2,094,011
2005-06	230,973	0	230,973
2006-07	26,344	0	26,344
Total	2,864,108	5,840,994	8,705,102

(a) Third parties and researcher contributions, some of which is in kind

Principal Outputs and Outcomes

The outputs and outcomes from the investment in the National River Contaminants Program are described briefly in Table 4.

Table 4: Outputs and Outcomes for NRCP Projects: July 1999 to June 2007

Code	Project Title	Outputs	Outcomes
1. CLW54	Catchments nutrients and sediment budgets: identification of knowledge gaps	One year desk top study that developed regional N, P and sediment budgets for the Murrumbidgee, Brisbane, Latrobe and Johnstone rivers and catchments. Applied existing Sednet/ANNEX model and compared prediction of sediment and nutrient delivery with field data. Focussed on the difference between modelled and measured loadings and the adequacy of modelling processes such as denitrification. Identified critical knowledge gaps and new understanding developed	Data will allow improved formulae to estimate nutrient transformations within catchments required to assess impact on ecosystems of current and future land use and land management systems; findings are now part of the mindset of land/water resource managers. Ultimately CMAs may get a powerful decision support tool for end of valley target setting. Contributed in part to CMA efforts to target high priority changes to land management (enhanced the importance of groundwater /stream interactions and understanding of the

		for in stream and riparian zone carbon and nitrogen cycling. Recommendations made for improved monitoring programs.	potential importance of both the various nitrogen-containing species and nitrogen sources). Reinforces view that catchment models are useful for comparing scenarios but have difficulty in producing estimates with absolute accuracy.
2. CLW55	Development of a catchment contaminant cycle model for stakeholder use	Information concerning end user needs that focus on sediment, salt, phosphorus, total nitrogen, pathogens and pesticides and also on the management interventions of land use change, riparian zone management and flow management and associated contaminant loads and responses of aquatic ecosystems. Project has integrated information from other NRCP projects including GRU28, CLW54, UMO43 and UNE47. Development of catchment contaminant modules that have involved prospective users in their development.	Potentially these modules can be used to test alternative catchment plans for controlling and meeting targets for river contaminants on a catchment basis. The Riparian Particulate Model (RPM) has been added as a "plug-in" in the E2 model framework. Discussions towards making the Salinity Effects module a "plug in" to E2 or C2SALT and ongoing. The Salinity Effects module has been used independently by Ben Kefford (RMIT) for his research purposes. Known implementation of the RPM model include extensive use in projects across Australia by WBM Oceanics. For example, it has been used in the North Pine Dam catchment for assessing pollutants entering storage and how they might be managed; also for quantifying pollutant loads and how treatments may work across a whole of catchment basis.

			The RPM model has also been used in SA by EPA and it is likely that other E2 model users have applied the RPM for their purposes.
3. DRD5	Developing a framework for making improved nutrient decisions for pastures	Regionally specific response curves from grazed pastures for N, P, K and S applications, for various pasture types and soil conditions. Compiled from previous nutrient response trials. A stand-alone Nutrient Loss Index (NLI) tool was also developed that allows consultants to assess nutrient loss from paddocks on a farm Program $186,000 total but total investment about $1m	Initial exposure has been in Gippsland with local extension groups (advisory services) using the management tools. However, there is potential for Australia-wide impact as the information and the NLI tool have been incorporated into training by Fertiliser Industry Federation of Australia via FertCare. FertCare is a national training and accreditation initiative for all fertiliser and soil ameliorant industry businesses and staff. Investment will have significant impact on improved fertiliser management with less nutrient runoff to waterways.
4. GRU28	In-stream and riparian zone nitrogen dynamics	Trials on small streams were located in Southern Victoria, Southwest WA and Southeast Queensland and focused on groundwater hydrology and chemistry, effect of shade on primary production and nutrient uptake, rate measurement for nitrogen cycling processes and stable isotopes as an integrated signal of nitrogen cycling. New scientific knowledge and understanding re role of nitrogen and carbon cycling processes	Outputs provided an improved understanding of the pathways for nitrogen entering streams and how it might be intercepted by vegetation. Specific carbon types and anaerobic processes favour improved nitrogen stripping by vegetation This has implications for increases in shading of streams to reduce algal growth and therefore stream vegetation policies and practices.

		(transport, uptake and transformation) in streams and their adjacent riparian zones. Enhanced guidelines for riparian and stream restoration in terms of nitrogen management of streams in a range of farming systems and catchments.	The findings regarding denitrification potential and the distribution of organic carbon in stream sediments and riparian zone soils have also contributed to improved modelling of catchment water quality.
5. JCU18	Characterisation and dynamics of colloidal material in a turbid tropical river	PhD student project Involved fieldwork and analysis of sediments in the Burdekin River in order to determine their shape, size, composition, surface textures and behaviour. The sediment being transported by the Burdekin and Suttor Rivers into and through the dam is very fine, takes a long time to settle and is easily re-suspended.	Resulted in an improved understanding of the dominant colloidal contaminant in northern Australian rivers
6. RMI12	Predicting salinity induced loss of biodiversity	Assessment of the relative salinity tolerance (levels and variability) of macro-invertebrates from the Barwon River in SW Victoria, southern and northern Murray Darling Basin and tropical Queensland. Micro-invertebrates found to be more sensitive to salinity than macro-invertebrates (important as food chains start with micro-invertebrates). Impact prediction model (salinity changes on freshwater fauna) developed and validated. Results are complementary	The knowledge of salinity tolerances generated in this project has been used by EPA in Victoria (Wimmera region) and by the Queensland Department of Natural Resources and Water (QDNRW) (South East Queensland and northern Murray Darling). Principal uses are for setting salinity targets and guidelines for disposal of saline water (e.g. power stations, mines, groundwater pumping). Using the same methodology QDNRW have repeated the project to produce more data.

		to Project CLW55.	QDNRW have then applied the pooled data in the southeast of Queensland with NRM regional bodies as the target audience (NAP project). This is aimed at assisting them with setting targets for water quality.
7. SKP10	Evaluation of Rivers Programs	Review report including findings of a well balanced research portfolio, good linking of projects and some projects have potential to influence river management practices or policy.	Considered to be an effective program
8. UMO38	National River Contaminants Program: Implementation Plan	Produced data for more detailed planning.	Assisted with the final composition and direction of the program including its role and objectives.
9. UMO43	Development of risk based approaches for managing contaminants in catchments	Ecological risk assessment models (with emphasis on Bayesian network models) developed that can link catchment contaminant reduction targets to ecological outcomes Two case studies with inputs from CMAs demonstrating how the ERA framework can work in real catchment /regional situations. Gudleines produced for quantifying the ecological risks from contaminants in catchments (update of ERA guidelines previously prepared for the Australian irrigation industry). Strong linkages with NPSI project UMO45 via regional awareness workshops. An extension to this project (small study on the	It is understood that the ERA models have been increasingly used. Victorian EPA has been running a number of workshops with the CMAs. Wimmera CMA in Victoria is now developing their own ERA environmental flow model and may have used the fish modelling work that was associated with UMO43 (Ph D thesis). This will enable the CMA to test different options for environmental flows under different water availabilities with regard to water quality, habitat and macro invertebrates. A number of agencies have benefited from the WorriYallock case study within UMO43 (in Western Port CMA region).

		Tully River in North Queensland) is almost completed and a report will be available in June 2007.	
10. UMU18	Alternative stable states: a potential paradigm for managing salinised ecosystems	A major finding was that although many water bodies in SW WA have increased in salinity, not all ecological values have been completely or irretrievably lost. It is suggested that it may be easier to prevent a system from moving from a saline to a hyper saline state than it is to return a saline system to a freshwater system. Wetlands dry and fill at different times and salinities varied according to evapo-concentration and dilution. Development of management guidelines that integrate interactions between water regime, salinity and primary and secondary productivity will be more effective in protecting biodiversity in aquatic ecosystems than by managing salinity as a discrete factor.	Potential outcome is improved aquatic biodiversity through improved salinity management. The principles for managing increasing salinity that have emerged from the project have been used by some consulting firms in Western Australia. The Wheat Belt Drainage Council is likely to use the information in the future. The Wetlands Coordinating Committee in Western Australia has set up a working group to establish a framework for drainage to wetlands There will be limited transfer of the principles to eastern State in the short term but they may be relevant in the future if salinity increases in waterways in the east.
11. UMU19	Determining transition thresholds between alternative ecological states in saline waterbodies	Ph D student project. Produced quantitative data and actual threshold values to complement UMU18 At high salinities, the salt-tolerant macrophyte-dominated ecological regime may be replaced by a regime dominated by benthic microbial communities, further reducing the structural and	UMU18 and 19 should be considered together as they are complementary. The outcomes listed above for UMU18 also apply to UMU19.

		functional diversity of salinised wetland ecosystems. Identified some of the potential mechanisms for the transition between the salt tolerant submerged macrophyte-dominated regime and the benthic microbial community-dominated regime. Existing conceptual models of ecological regime transitions, such as the alternative regimes model, did not account for the effect of water regime on the dynamics of seasonally-drying systems. Therefore, a new conceptual model incorporating the interaction between hydrology and salinity in seasonally-drying wetlands was proposed.	
12. UNE47	Integrated impacts of contaminants and flow on riverine ecosystem production	Experimentation based on highly regulated Murrumbidgee and Macquarie Rivers in NSW. Improved understanding and modelling of the interaction between flows, contaminants and energy cycles and other ecological processes in regulated floodplain rivers. Knowledge produced on how relationships vary along the length of the river and with the seasons.	Contribution to improved integrated ecosystem management of floodplain rivers to sustain ecological processes and improve river health Information can be used in models of the interaction between flows, contaminants and ecosystem processes. Contributed to improved monitoring processes for ecosystem productivity.
13. UTV1 (funded in conjunction with UMO39)	Managing Nutrients in Floodplain Wetlands and Shallow Lakes Fact Sheets and Salt	The first part of this project built on earlier work funded by LWA. Two fact sheets produced on nutrient enrichment of	Fact sheets have had wide exposure, for example, among CMAs and appearing in River and Riparian Land Management Technical

	Sensitivity Database	shallow lakes and wetlands. The second part of the project developed a comprehensive database identifying sensitivity and tolerance of different taxonomic groups of biota. Salt sensitive data base now available on line. There are 1500 entries on over 1200 different taxa, statistically analysed in order to identify sensitive and tolerant taxonomic groupings, and with interpretive notes.	Guidelines. Use of data base expected by water resource managers to minimise the impact of salinity on aquatic ecosystems and maximise the potential for rehabilitation of salt affected sites. Data base has been used principally by consultants and some CMAs. However, the database is not easy to find on the LWA website. Potentially has resulted in amelioration of biodiversity loss due to salinisation of streams and rivers.
14. UTV2 (funded in conjunction with UMO41)	Innovative techniques for managing multiple threats to high value aquatic systems	Development of general indicator tools that can be used in wetlands to establish benchmarks, establish how threatening processes are interacting and affecting the wetland and providing assistance with setting realistic objectives. Condition indicators identified including the cover, health and regeneration of species in the understorey Identification of optimal salt and water regimes for ecologically significant water plants to recruit. Information workshops held with a range of agencies. Definition of impacts at	Project associated with high levels of leverage from CMAs and State Departments. Knowledge applied by West Gippsland CMA, Gippsland Catchment Board, and Parks Victoria.

		species, community and ecosystem levels from multiple ecological threats. Three single page fact sheets produced. 1500 case study handbooks prepared on community involvement, adaptive management and vegetation dynamics of seasonally inundated wetlands; only 180 handbooks left.	

Summary of Principal Outcomes

Overall, a majority of projects were aimed at better understanding the relationship between the existence and introduction of contaminants (singularly and jointly) and aquatic ecosystem health. Others added understanding of the wider impact of interventions and management options on both contaminant levels and ecosystem health (Table 5).

Table 5: Project Impact on Knowledge Types

Project	Ecosystem health as a function of contaminant level and type	Includes interventions
CLW54	No	No, but has implications for management options
CLW55	Yes	Yes
DRD5	Yes	Yes
GRU28	No	No, but has implications for management options
JCU18	No	No
RMI12	Yes	No, but has implications for management options
UMO43	Yes	No, but has implications for management options
UMU18	Yes	No, but has implications for management options
UMU19	Yes	No, but has implications for management options
UNE47	Yes	No, but has implications for management options
UTV1 (UMO39)	Yes	Yes

UTV2 (UMO41)	Yes	Yes

The projects funded were particularly focused on understanding of the relationships between contaminants and ecosystem functioning and biodiversity. Several of the projects were highly scientific in nature and in that respect contributed predominantly to the pool of scientific knowledge available. Overall, the emphasis on management interventions was not explicit in that only limited attention was given to comparing specific management interventions. For example, there was little attention paid to the feasibility and costs of specific interventions and most were referred to on a generalised basis. The link from the research to the interventions was also quite general. There were three broad interventions mentioned throughout the projects:

- Streamflow management
- On farm soil and fertiliser management practices to reduce nutrient, sediment and salt export via surface and groundwater flows
- Management of riparian lands to intercept and reduce export to streams

Much of the research has general implications for catchment and regional management as opposed to direct use by land owners and managers. However, apart from direct action by CMAs and river managers regarding flow management, other knowledge produced will need to be applied by land managers in order to reduce contaminant levels and their impacts. This may be encouraged by incentive mechanisms under development in many catchments.

One of the significant contributions of the program came from the emphasis on integration of the interactions between and the combined effects on ecosystems and the associated potential for the management of interventions on a whole of contaminant basis.

A key final outcome of the application of the knowledge produced is the improvement in water quality that benefits the natural ecosystem (aquatic system health) and the associated biodiversity. Apart for improved aquatic health, the potential improvement in water quality will have implications for a range of human uses associated with waterways as described within the next section on benefits.

Benefits Associated with the Investment

The major immediate benefit from the National River Contaminant Program is a heightened awareness of integrated contaminant management principles by catchment and land managers. This awareness is being translated into improved management of contaminants leading to enhanced aquatic biodiversity and a higher level of water quality.

Several projects included the impact of salinity on species or organism classes. This information has been used by CMAs and regional groups in assisting with the setting of targets and determining priorities for investment in salinity reduction management within a catchment from a biodiversity protection point of view.

A number of projects addressed the impact of nutrients and in that regard continued the approach used by NEMP which was completed in June 2000. The benefits from the investment in NEMP are described in another investment analysed by LWA (LWA, 2006). While continuing an interest in nitrogen, the NRCP gave a stronger emphasis to the impact of sediment in its own right in contrast to NEMP where most emphasis was given to sediment as a carrier and releaser of phosphorus. Overall, the major impact of the information on nutrients generated in NRCP was therefore similar to NEMP where a principal benefit was defined as a reduction in the incidence and severity of algal blooms. The main benefit from algal bloom reduction is an improvement in water quality, reducing the cost of water treatment in some cases and impacting positively on public health, aquatic biodiversity and recreational uses of waterways.

Aquatic biodiversity and water quality are closely linked. Salinity directly affects water quality and its impact on the balance of aquatic organisms. Depending on the degree of salinity involved, saline water can also impact on a range of human uses for water including irrigation and livestock consumption, town consumption, and some recreational pursuits (e.g. fishing).

In the longer term the program has produced information that has the potential to develop improved policies and management systems for contaminant management, particularly at catchment level.

The Australian State of the Environment Committee (2006) stated that there was some evidence that the management interventions over the past decade may have stabilised the decline in river health in some regions. The Committee quotes the Victorian Government's assessment of trends in river health in that State with no broad change in rivers during 1999-2004 and that the previous deterioration in stream conditions had been arrested.

Categories of benefits presented in a triple bottom line format are shown in Table 6.

Table 6: Categories of Benefits

Economic	**Environmental**	**Social**
Reduced water treatment costs for industry and domestic use due to reduced turbidity, salinity and algae	Improved aquatic biodiversity due to reduction in impacts from salinity, sediment and nutrients	Greater recreational use of waterways (boating, swimming)
Improved water quality for irrigation and stock watering		Reduction in human health impacts of algal blooms
		Improved quality of drinking water due to less treatment required

Public versus Private Benefits
The benefits identified from the investment in NRCP are predominantly public benefits derived from improved water quality and enhanced biodiversity. Some smaller private benefits may be delivered to irrigators and others extracting water privately from waterways.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 7.

Table 7: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

The NRCP research predominantly addressed National Research Priority 1 (an environmentally sustainable Australia) with some minor implications for National Research Priority 2. In terms of the Rural Research Priorities, the NRCP addressed Priorities 1 and 3.

Quantification of Benefits

A large part of the program investment has been aimed at understanding the relationship between type and amounts of contaminants and ecosystem health with general implications for management interventions. The program investment should contribute to improved management of nutrients, algal blooms, sediment, and salt entering waterways so that such contaminants inflict less damage on ecosystems. This in turn will lead to an improvement in water quality through less turbidity, lowered frequency of algal blooms, and reduced water treatment costs.

Much of the investment was strategic and is not likely to result in specific management strategies that can be applied quickly and generically across the management systems of most Australian rivers. However, the impact of the program is most likely via changes to regional and catchment management and the treatment of contaminants in an integrated fashion by regional and catchment management bodies.

Value of Waterway Health Improvement

The value of waterway health improvement is assumed to capture both improvements in aquatic ecological health and the improvement in water quality. Two studies for valuing improvement in waterway health are considered here.

Van Beuren and Bennett

A willingness to pay estimate (WTP) by households in the community for improved river condition was derived from Van Bueren and Bennett (2000). This was the WTP estimate of 8 cents per 10 km of river restored to fishable and swimmable as defined by the EPA in NSW. The proportion of Australian households where the above WTP is assumed representative is 45%. The value of improvement in water quality is therefore estimated as 45% of 7 million households each willing to pay 8 cents per 10 km of waterways where water quality is improved. This is equivalent to $25,200 per km of waterway improved.

It should be noted, however, that there may be significant thresholds (e.g. proportion of a waterway improved) before a significant ecosystem change or water quality improvement is evident. For example, if all the kilometres of "protection" only represented 5% of each waterway in Australia, any impact may be substantially reduced as it may be so small as not to influence treatment costs or recreational opportunities for any specific waterway. This is accounted for in an assumption that recognises that only 5% of the advance towards swimmable and fishable is likely to be achieved from the outputs of the National Contaminants Program.

Windle and Rolfe

Windle and Rolfe (2007) used choice modelling to build a reference data base of community values for protecting soil, water and vegetation stocks in Queensland. Healthy waterways were specifically addressed in this valuation study.

The statewide model estimated WTP of $6.62 per household per annum for 15 years for a 1% improvement in healthy waterways. A 1% improvement was defined as a 1% increase in the length of rivers in good condition in 15 years time. To translate this estimate to a $ value per km restored to good condition will depend on the proportion of total river length currently in "good" condition. For example, if there were 10,000 km of waterways in Queensland and 50% (5,000 km) were in good condition, then a 1% improvement would represent 50 km being rehabilitated. Given a Queensland population of about 4 million, and given an average household size of 3, the total annual WTP for Queensland Rivers per km would be $(4,000,000/3) * $6.62/50 = $267,000 per km per annum. If 80% were in good condition currently, then 1% would represent 80 km so the WTP would be lower at $4,000,000/3 *6.62/80 or $110,000 per km per annum. It would therefore be impossible for the WTP for healthy waterways in Queensland to be as low as what was estimated by Van Beuren in the earlier study ($25,200 per km of waterway improved).

Investment in Addressing Contaminant Issues in Waterways

The NHT and NAP programs are investing in resource assessment, planning, capacity building and on-ground activities. In 2004-05 the total invested from the two programs was $216 m. Approximately $7.7 m had a major focus on nutrients in aquatic ecosystems, $11.6 m on surface water salinity and $2.5 m on turbidity in aquatic environments. The major focus of the nutrient investment was in SE Queensland, the Hawkesbury Nepean region of NSW, the Corangamite, Glenelg-Hopkins and North Central regions of Victoria, the Murray Darling Basin region in SA, and the south coast of WA. Achievement ratings in terms of targets that had been set for 2004-05 were assessed as low for South East Queensland, the Central West of NSW and the NE of South Australia. In all these regions 0-49% of management action targets had been achieved, with regard to nutrients. It was still too early for reports for other regions.

For salinity, achievement ratings of low (0-49% of management action targets achieved) were given to Fitzroy and a number of regions in Southern Queensland, regions in the north and northwest of NSW and the Murray Region in southern NSW, and the Wimmera region of Victoria . For turbidity in aquatic environments, achievement ratings were provided only for south-east Queensland and the Central West region of NSW.

Overall, there is substantial evidence that contaminant issues were being addressed and that some progress had been made in meeting targets even by the year 2004-05. However, it is unlikely that meeting management action targets will rapidly result in improvements in river health.

The knowledge, models and guidelines produced by the LWA-managed National Contaminants Program are assumed to contribute to the degree of success of these investments. If a value is to be placed on the benefits from the River Contaminants Program, assumptions are required on the following:

(a) Time frame. This is the frame until rivers are rehabilitated and water quality and ecosystem health improve. It is assumed that adoption of knowledge from the program would have commenced in the year ending 2006-07 with full adoption being realised five years later in 2010-11

(b) Waterway length affected. This is the length of waterways that will be improved to the extent assumed. The length of major rivers that have multiple contaminant issues (more than two) is estimated at about 12,000 km from the 18 river basins that have more than two contaminants (salinity, sediment, total phosphorus and total nitrogen) rated as major issues in their catchment by the NLWRA (NLWRA, 2001). The 18 basins include those of the Burdekin, Fitzroy, Mary, Gwydir, Namoi, Macquarie, Border Rivers, Lachlan, Murrumbidgee, Wimmera-Avon, Avoca, Murray, Loddon, Broken, Ovens, Campaspe, Glenelg and Mallee. It could be expected that these river basins would constitute where most of the knowledge and tools produced from the contaminants program would be most applicable. However, the 12,000 km of main river system for these 18 rivers would be an underestimate of the length of the total target waterways as their tributaries and feeder streams could increase this estimate many fold. For example, the Burdekin (732 km) has main tributaries of 1,499km and the Fitzroy (60 km) is associated with streams of 15,500 km. A conservative estimate of 10% of 12,000 km (1,200 km) of waterways is assumed to have been affected by the knowledge from the program.

(c) Degree of improvement. For example, poor water quality may only be restored partly to some quality level such as 'fishable and swimmable'. Using rehabilitation to "fishable and swimmable" as a surrogate for 100% improvement, it is assumed that the degree of improvement due to the program knowledge increases from 10% (without the program) to 20% (with the program).

A summary of all assumptions made is presented in Table 8.

Table 8: Assumptions for the Valuation of Benefits from River Contaminants Program

Variable	Value	Source
Impact		
Length of waterways in which the contaminants program would have had some impact	1,200 km based on 10% of the 18 river basins (12,000km) where more than two contaminants are major issues	Agtrans Research
Average water quality improvement likely without program	10% of full improvement to fishable and swimmable	Agtrans Research
Average water quality improvement likely with program	20% of full improvement to fishable and swimmable	Agtrans Research
Year of first improvement	2006-07	Agtrans Research
Year in which maximum improvement to fishable /swimmable reached	2010-11	Agtrans Research
Value of Waterway Health Improvement		
Willingness to pay per household	8 cents per 10 km of waterway restored to "fishable and swimmable"	Van Bueren and Bennett (2004)
Number of households in Australia	7 million	ABS
Proportion of households where the above WTP is assumed representative	45%	Van Bueren and Bennett (2000)

Results

All past cost and benefits were expressed in 2006-07 dollar terms using the CPI. All benefits after 2006-07 were expressed in 2006-07 dollar terms. All costs and benefits were discounted to 2006-07 using a discount rate of 5%. The base run used the best estimates of each variable, not withstanding a high level of uncertainty for many of the estimates. The base analyses ran for the length of the investment period plus 25 years from the last year of investment (2006-07) to the final year of benefits assumed (2031-32).

Investment criteria were estimated for both total investment and for the LWA investment alone. As well as for the 25 year benefit period, each set of investment criteria were estimated for different periods of benefits. Benefits to the specific LWA investment are calculated based on the proportion of the total investment which LWA contributed (before discounting, in real terms), which in this case is 16.15%. The investment criteria are reported in Tables 9 and 10.

Table 9: Investment Criteria for Total Costs and Benefits
(Discount rate 5%)

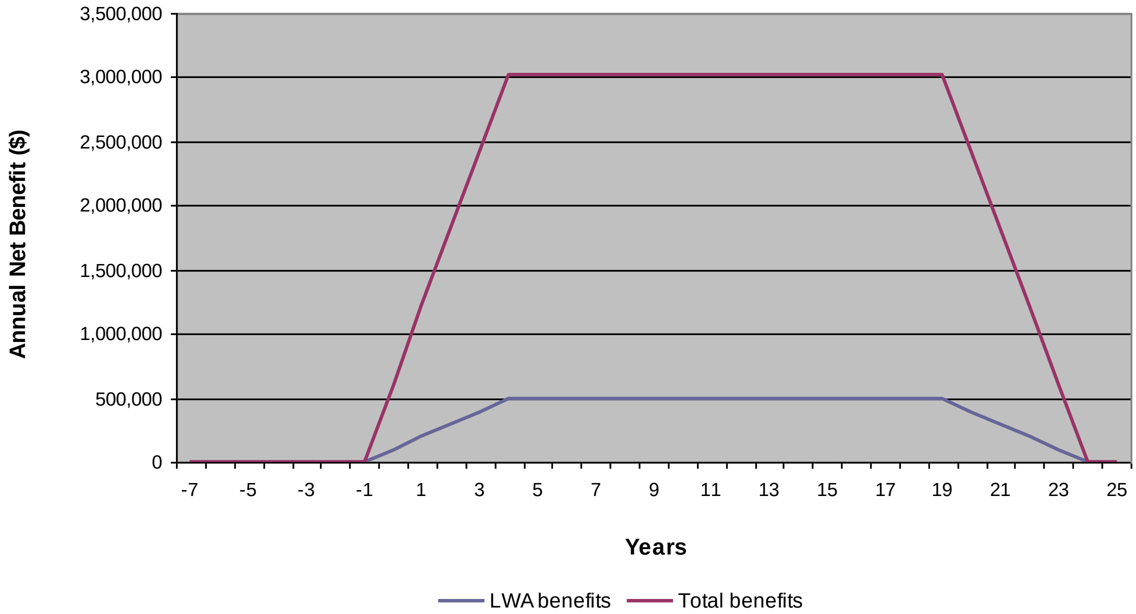
Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
Present value of benefits ($m)	0.60	10.35	20.61	28.65	34.71	35.98
Present value of costs ($m)	11.12	11.12	11.12	11.12	11.12	11.12
Net present value ($m)	-10.52	-0.77	9.49	17.52	23.59	24.85
Benefit-cost ratio	0.05	0.93	1.85	2.58	3.12	3.23
Internal rate of return (%)	negative	3.8	12.9	15.3	16.2	16.3

Table 10: Investment Criteria for LWA Costs and Benefits
(Discount rate 5%)

Criterion	**0 years**	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
Present value of benefits ($m)	0.10	1.67	3.33	4.63	5.61	5.81
Present value of costs ($m)	1.81	1.81	1.81	1.81	1.81	1.81
Net present value ($m)	-1.71	-0.14	1.52	2.82	3.80	4.00
Benefit-cost ratio	0.05	0.92	1.84	2.56	3.10	3.21
Internal rate of return (%)	negative	3.7	12.9	15.3	16.2	16.3

Figure 1 demonstrates the rate at which net benefits accrue.

Figure 1: Annual Net Benefit Flow



The reason for the decline in benefits after year 20 is due to the WTP estimate assumed where people indicated they were willing to pay a certain amount for a 20 year period.

Sensitivity analysis

The sensitivity of the investment criteria to two key assumptions was tested for the 25 year analysis and for the LWA benefits only. All other assumptions remained the same when the one factor was varied. The key assumptions tested were:

- Discount rate (Table 11)
- Level of improvement in water quality (Table 12)

Table 11: Sensitivity of Investment criteria to Discount Rate
(LWA benefits and costs only)

	0%	**5%**	**10%**
Present value of benefits ($m)	9.77	5.81	3.81
Present value of costs ($m)	1.56	1.81	2.09
Net present value ($m)	8.21	4.00	1.72
Benefit-cost ratio	6.27	3.21	1.82

The sensitivity of the investment criteria (LWA investment only) to the assumed average level of improvement in water quality is shown in Table 12. The results show a high sensitivity to this assumption. The break even improvement in water quality to yield a discount rate of 5% was an increase from 10% to 13.1 %.

Table 12: Sensitivity of Investment Criteria to Assumption of Improvement in Water Quality for Investment in National Rivers Contaminants Program
(Discount rate 5%)

Criterion	**Water Quality Improvement from 10% to 12.5%**	**Water Quality Improvement from 10% to 20% (Base)**	**Water Quality Improvement from 10% to 30%**
Present value of benefits ($m)	1.45	5.81	11.62
Present value of costs ($m)	1.81	1.81	1.81
Net present value ($m)	-0.35	4.00	9.81
Benefit-cost ratio	0.80	3.21	6.42
Internal rate of return (%)	3.3	16.3	25.2

The length of waterway on which the program is assumed to have impacted can be assumed to represent adoption. Table 12 presents the NPV for low, expected and high values for these two assumptions, for each of the 0, 5, 10, 15, 20 and 25 year timeframes (for all investment). The break even length of waterways where the assumed impact is evident is 371 km.

Table 12: Sensitivity of Net Present Value to Adoption (All investment)
(Discount rate 5%) ($ million)

NPV	**Project Horizon**					
	0 years	**5 years**	**10 years**	**15 years**	**20 years**	**25 years**
Low (600 km)	-10.82	--5.95	-0.82	3.20	6.24	6.87
Expected (1200 km)	-10.52	-0.77	9.49	17.52	23.59	24.85
High (1800 km)	-10.22	4.40	19.79	31.85	40.95	42.84

The principal information produced from this series of project investments has been largely of a scientific nature, and has focused on the impact of contaminants on the ecological health of waterways. Many of these projects had at least some implications for the broad choice of options for management interventions such as environmental flows, riparian land management and general on farm management. For some projects there has also been a more direct focus on the management interventions available for reducing the contaminant impacts.

Some of this information has been captured in models that can be, and have been, applied by regional and catchment groups, their consultants and state agencies in order to assist with setting catchment targets and for prioritising where in the catchment interventions may provide the greatest impact on waterway health. Application of other knowledge produced has been directly applied by State agencies, catchment groups and by individual land managers.

The degree of management changes for contaminants at both catchment and individual land manager levels that has taken place to date is hard to assess. There is some evidence that contaminant issues are being addressed by regional groups and that some progress had been made in meeting targets. However, it is unlikely that meeting management action targets will rapidly result in improvements in river health. The time lags involved in river health improvement are well recognised.

The impact of the River Contaminants Program is even more difficult to assess. Some of the knowledge products from the program are being used in decision making in land and catchment management (e.g. CLW55, DRD5, UMU18), but the degree of attribution that should be appropriately given to the program as a whole is difficult to assess as the likely magnitude of impact and timing of impact for each project will differ.

Conclusion

The NRCP has made an important and useful contribution to knowledge of the integrated management of contaminants entering Australian waterways. Some of the knowledge generated will have some practical applications and implications for decision making on contaminant management. A high proportion of the knowledge generated will contribute to an improved understanding of impacts on aquatic biodiversity from different contaminants.

Accurate valuation of the benefits from this investment has been limited by the lack of clearly defined linkages between the knowledge generated and its potential use by the wider target audiences and the end results in terms of the impact on biodiversity and water quality. This is despite most projects in the program being well engaged with end users, many of whom have trialled/applied the results to some extent.

The analysis and the investment criteria estimated have required broad assumptions regarding the capturing of the potential benefits from the program. Given the assumptions made, the investment criteria and sensitivity analyses indicate the NRCP has produced and will produce significant benefits. The analysis also indicates the investment criteria are very sensitive to assumptions on the use and impact on the knowledge produced by the investment.

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