National Riparian Lands Research and Development Program

Background

A knowledge gap for riparian lands was identified by Land & Water Australia (LWA) in the early 1990s. This led to the development of the National Riparian Lands R&D Program that commenced in 1993–94. The program concluded in June 2005.

The program has been a highly successful LWA integrated investment in which scientific research results produced in the early stage of the program have been extended successfully to users, principally through close involvement with industries and communities and including a wide range of communication processes and products.

The Program

Program Objectives

The program had two phases. Phase One (1993–2000) sought to understand the key processes and functions associated with riparian lands. The aims of Phase One of the program were to develop guidelines and principles for sound and economic management of riparian lands to contribute to the condition and value of waterways in terms of channel stability, water quality, biodiversity and in-stream ecological systems.

Phase Two (July 2000–June 2005) focused more on the evaluation of management options and worked closely with a range of communities and industries. The goal of this phase was to facilitate communities to implement, monitor and evaluate practices for ecologically sound, effective and economic management of riparian lands.

Phase Two had seven objectives:

1. to develop and test further understandings about what motivates and drives riparian land managers, and identify opportunities and means to influence their decisions
2. to quantify the socio-economic impacts of changes in riparian land management based on practical examples
3. to develop proactive linkages that are effective in influencing legislation and strategic policies to improve riparian land management
4. to research identified knowledge gaps and improve understanding to address the biophysical and socio-economic issues that have been highlighted as continuing to impede the development and implementation of best management practice for riparian lands and enhanced ecosystem services
5. to develop a visual conceptual framework that integrates knowledge of the most important riparian zone functions and their linkages in a form that allows ready development and testing of management principles
6. to develop practical and easy-to-use protocols for monitoring and evaluation of changes in riparian land practice
7. to improve riparian management by effectively communicating program findings and establishing a knowledge-exchange network to those involved in natural resources management.

Investment costs

The investment was made through a range of projects and research providers. Total program costs have been assembled and are shown in Table 1. LWA resources made up 60.2% of the investment (nominal terms).

Table 1: Resources Invested (nominal dollars) by Year and by Partner for the Riparian Lands Program

Year	LWA	Third parties	Researchers	Total
1993–94	141,555	48,000	116,000	305,555
1994–95	856,776	53,000	414,300	1,324,076
1995–96	820,169	128,500	399,670	1,348,339
1996–97	736,687	132,000	390,150	1,258,837
1997–98	636,666	123,000	447,670	1,207,336
1998–99	764,150	125,000	370,000	1,259,150
1999–00	687,032	71,830	204,934	963,796
2000–01	385,647	356,000	73,604	815,251
2001–02	809,320	356,000	364,723	1,530,043
2002–03	1,012,563	320,574	407,111	1,740,248
2003–04	547,197	28,654	370,153	946,004
2004–05	408,884	20,000	80,000	508,884
2005–06	359,318	0	0	359,318
Total	8,165,964	1,762,558	3,638,315	13,566,837

Source: LWA

Investment description

The program operated through selected sites across Australia that were established with State agencies and other regional and catchment groups. Much of the scientific research focused on understanding of processes that operated within riparian areas. A series of more-applied research investments focused on testing and evaluating principles of management.

A range of communication activities and products disseminated findings from the program including:

- fact sheets
- technical guidelines
- a website
- various workshops;
- a newsletter (RIP-RAP)
- scientific, technical and extension writings.

The fact sheets and technical guidelines are the principal extension products that have emerged from the program.

The program has been led and strongly funded by LWA. Co-lead R&D agencies early in the program were the Cooperative Research Centre (CRC) for Catchment Hydrology and the Centre for Catchment and In-Stream Research (Griffith University). No other partners committed to the program on a continuing basis, but many research organisations contributed funding in-kind. As well, financial contributions were forthcoming from commodity specific Research and Development Corporations (RDCs), on a specific project basis (e.g. Sugar RDC, Dairy RDC and Cotton RDC). Many of these shared projects were related to interpreting the knowledge produced in relation to particular industry circumstances.

There was a program advisory committee established by LWA and its membership extended to personnel from State agencies and the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) (formerly Agriculture, Fisheries and Forestry Australia/Department of Primary Industries and Energy).

A list of projects funded in the program is presented in Table 2.

Table 2**:** Riparian Lands Projects, 1993–94 to 2005–06

Code	Project Title	Organisation	Start Date	Finish Date
BCW1	Demonstration/evaluation of riparian restoration in the Blackwood Catchment	Blackwood Basin Group	01 Jan 1995	30 Jun 1999
BRC1	Gippsland dairy industry project—communications consultancy	Bradshaw Consulting	30 Apr 2002	30 Apr 2003
BVS1	Demonstration/evaluation of riparian restoration in the far south coast of NSW catchments	Bega Valley Shire Council	01 Jan 1996	14 Feb 2000
CCP1	Demonstration/evaluation of riparian management: Cooper's Creek, Queensland	Coopers Creek Protection Group	30 May 2000	30 May 2002
CLA1	Demonstration/evaluation of riparian management in the Clarence Catchment of NSW	Clarence Catchment Management Committee	01 May 1997	31 Jan 2000
CSU22	Livestock management and the monitoring and evaluation of management practices in riparian ecosystems	Charles Sturt University	01 Jul 2001	01 Aug 2006
CSU24	Gippsland riparian project	Charles Sturt University	15 Apr 2002	15 Apr 2003
CUL1	Investigating legislation re riparian management	Careers Unlimited	20 Jul 1998	30 Sep 1998

CWA14	Identification of priorities and methods for R&D on physical and chemical processes in Australian riparian zones	CSIRO Land and Water, Canberra	01 Nov 1993	31 Dec 1993
CWA15	Rehabilitation and management of riparian lands: aspects of physical and chemical processes (program A)	CSIRO Land and Water, Canberra	01 Oct 1994	01 Mar 2000
CWA16	Riparian zone modelling workshop consultancy	CSIRO Land and Water, Canberra	01 Nov 1994	31 Dec 1994
DAT3	Management of stock access to riparian zones	Department of Primary Industries, Water & Environment	01 Jan 1995	30 Jun 1998
DAV42	Gippsland dairy riparian project	Department of Natural Resources and Environment (Victoria)	21 Oct 2002	31 Jul 2003
DAW23	Using electronics to deny animal access to fragile vegetation	Department of Agriculture and Food, WA	31 Jul 1996	31 Oct 1996
DAW26	Feasibility of developing alternative grazing cattle control devices	Department of Agriculture and Food, WA	31 Mar 1998	30 Nov 1998
DEP5	Demonstration/evaluation of riparian management: South Australian mid north region and Mount Lofty Ranges	Department of Water, Land and Biodiversity Conservation	01 Mar 1999	25 Feb 2005
ECO3	Riparian Lands R&D Program: communication strategy	ECONNECT	07 Apr 1997	31 Jul 1997
ESC1	Streambank revegetation—Tranters Creek	Eacham Shire Council	15 Apr 1996	15 Apr 1998
GBC1	Demonstration/evaluation of riparian management: Victoria—Goulburn–Broken region	Goulburn–Broken Catchment Management Authority	01 May 1998	31 Oct 2001
GRU11	National Riparian Zone R&D Program: in-stream aquatic ecosystem research priorities	Griffith University	01 Aug 1993	30 Jun 1994
GRU12	Planing and conducting a workshop on ‘Ecology and management of riparian zones’	Griffith University	17 Mar 1993	30 Jun 1993

GRU17	Rehabilitation and management of riparian lands: ecological issues (program B)	Griffith University	01 Jul 1994	31 Dec 1999
GRU26	Flow-related responses of floodplain vegetation in arid, inland catchments	Griffith University	28 Feb 2000	27 Feb 2003
GRU27	National Riparian Lands Program (Phase 2): in-stream ecological issues	Griffith University	30 Jul 2001	31 May 2005
GRU29	Experimental reintroduction of large woody debris into rivers—geomorphic and habitat implications	Griffith University	30 Sep 2002	30 Sep 2003
JCU15	Stream stabilisation and restoration	James Cook University	29 Mar 1999	30 Sep 2002
JCU16	Livestock management and the monitoring and evaluation of management practices in riparian ecosystems	James Cook University	25 Jul 2001	31 May 2005
JCU9	Improved river bank stabilisation practices in the wet tropics	James Cook University	01 Jul 1993	30 Jun 1996
JOS1	Stock management in riparian areas—guideline	Jenny O'Sullivan	30 May 2005	30 Jan 2006
JRC1	Demonstration/evaluation of riparian restoration in the Johnstone River catchment	Johnstone River Catchment Management Association	01 Jan 1996	30 Dec 1999
LSR1	Assessing community capacity through riparian restoration	Landscape & Social Research	31 May 2002	31 May 2003
LSR2	Review of the capacity assessment tool	Landscape & Social Research	14 Oct 2004	03 Jan 2006
MAR1	Demonstration/evaluation of riparian management in the Mary River catchment	Mary River Catchment Co-ordinating Committee	01 Jan 1996	30 Nov 1999
MQU10	Environmental justice: a transdisciplinary framework for stream rehabilitation and management	Macquarie University	01 Jan 2002	01 Jun 2006
MQU9	Experimental reintroduction of large woody debris into rivers—geomorphic and habitat implications	Macquarie University	01 May 2000	30 Sep 2002

MWA2	Gippsland dairy riparian project—oral history	Michael Williams & Associates Pty Ltd	19 Aug 2002	31 Jan 2003
NHL1	Rehabilitation and management of riparian lands: seminar tour of Australia—consultancy	Newbury Hydraulics Ltd	01 Dec 1994	30 Apr 1995
NHT1	Production of a CD Rom on river restoration and management	Noble House Tasmania Pty Limited	04 Jan 1999	31 Jan 2001
OHW1	Demonstrate/evaluate practical methods of riparian rehabilitation on salinised lands	Oyster Harbour Catchment Group	01 Jan 1995	31 Oct 1999
PPM2	River ramblers	Pacific Projects Management Pty Limited	29 Oct 1999	30 Jun 2000
PWT1	Program C Coordinator—Rehabilitation and management of riparian lands	Parks and Wildlife Service, Tasmania	01 Jan 1995	31 Dec 1997
PWT2	Factors affecting the recruitment and regeneration of natural riparian vegetation on Tasmanian Rural Land	Parks & Wildlife Service, Tasmania	01 Mar 1995	30 Jun 1998
PWT4	Program C Coordinator—Rehabilitation and management of riparian lands	Parks & Wildlife Service, Tasmania	01 Jan 1997	31 Dec 1997
RMM2	River restoration and management—web design and site establishment	The Reef Multimedia Pty Limited	01 Mar 1999	30 Aug 1999
SIW1	Riparian Lands R&D Program Coordinator	Lovett Clarke Consulting Pty Ltd	04 May 1998	30 Jun 2006
SIW2	Preparation, editing and distribution of RIPRAP newsletter	Lovett Clarke Consulting Pty Ltd	01 Nov 1998	30 Jun 1999
SIW4	Capacity building and knowledge exchange methods for community-based river and riparian management	Lovett Clarke Consulting Pty Ltd	01 Mar 2004	06 Aug 2004
SIW7	Riparian program synthesis CD	Lovett Clarke Consulting Pty Ltd	01 May 2006	01 Oct 2006
SKP10	Evaluation of rivers programs	Sinclair Knight Merz	01 Aug 2004	25 Oct 2004
SRC7	Sugar industry riparian management guidelines	Sugar RDC	01 Oct 2000	17 Aug 2001

TUB2	Technical guidelines for the management of riparian lands	Wendy Tubman and Associates	20 Jan 1997	30 Apr 1998
TUB3	Publish the results of LWRRDC R&D project JCU9: Improved riverbank stabilisation practices in the wet tropics	Wendy Tubman and Associates	30 Sep 1997	31 Dec 1997
UME64	Riparian land management: concepts, floods and erosion	University of Melbourne	31 May 2001	31 Mar 2005
UMO32	To prepare an Australian manual of river restoration	Monash University	01 Mar 1997	30 Sep 1998
UOC21	Hydraulic habitat of inland rivers: the role of large woody debris	University of Canberra	01 Mar 2002	30 May 2006
UOC23	Biodiversity of riverine landscapes: the role of patches and connectivity	University of Canberra	01 Jul 2003	01 Dec 2006
UOC27	Biodiversity of riverine landscapes: the role of patches and connectivity	University of Canberra	01 Jul 2003	01 Dec 2006
UOG1	Visiting fellowship in holistic river restoration	University of Guelph, Canada	01 Sep 1999	31 Dec 1999
UWA25	National Riparian Lands Program (Phase 2): In-stream ecological issues	The University of Western Australia	30 Jul 2001	31 May 2005
UWA31	In-stream and modelled temperatures associated with riparian cover	The University of Western Australia	31 Jan 2003	20 Feb 2004
VIR7	Riparian program evaluation	VCG Australia Pty Ltd	29 Oct 1999	30 Nov 1999
WRC4	The importance of large wood debris in sandy river systems	Waters and Rivers Commission	31 Jul 1997	30 Jun 2000
Y576	Gippsland dairy riparian project—oral history	Michael Williams & Associates Pty Ltd	19 Aug 2002	31 Jan 2003

Source: Siwan Lovett, pers. comm. May 2006

Principal Outputs

The R&D findings from Phase One of the program included:

- the important role of vegetation roots in reinforcing and stabilising streambanks
- the minor contribution of trees to streambank slippage, contrary to previous positions
- the effectiveness of grass strips leading to riparian zones in trapping nutrients and sediment
- identifying the sources of sediments in streams and designing management responses
- design guidelines for laneways and tracks to minimise sediment release

- in-stream productivity of streams is low under natural conditions due to low light, temperature and nutrient availability
- identifying nitrogen as the limiting factor in in-stream growth
- the role of shade in controlling growth of nuisance aquatic plants in waterways
- a canopy cover of about 70 per cent is usually required to prevent growth by aquatic plants—decision rules were developed to relate catchment area (stream width), latitude, orientation and percentage cover to control in-stream productivity
- the necessity to replant streambanks in the north with native species since aquatic organisms can not utilise C4 sources of carbon such as para grass and sugarcane
- showing the importance of in-stream habitats such as woody debris and root armouring of banks
- the deleterious nature of stock access to streams through urine and dung deposition, trampling and bank pugging
- strategic management of grazing can be used to improve productivity and recoup fencing and watering costs while improving environmental management
- improved livestock management can lead to natural revegetation and cost-effective direct seeding approaches are available
- practical methods developed for riparian fencing, alternative water point development, replanting and reseeding, re-armouring etc.

Major outputs in Phase Two of the program included the following:

CSU22: The project 'Livestock management and the monitoring and evaluation of management practices in riparian ecosystems' addressed the issue of uncontrolled stock access as a primary degrading force in riparian areas. The research produced a publication called *Stock and waterways: a managers guide*. The publication contains information underpinned by science about the range of options for stock management available to farmers.

UWA25 and GRU27: These projects investigated in-stream ecological issues and were carried out by Griffith University and the University of Western Australia. These projects addressed the updating of the earlier in-stream temperature work as well as that concerning managing wood in rivers.

UME64: This project concerned land management topics including concepts, floods and erosion and used modelling extensively. Two technical updates on these topics were produced.

CSU26: This project focused on a methodology for rapid appraisal of riparian condition.

The final year of the program (officially 2004–05) was extended to a synthesis or 'harvest' year (2005–06). This final year has focused on a series of nine workshops (one in each State and three at a national level) that have integrated many of the earlier outputs of the program. The workshops featured as presenters those researchers from some of the key projects (UME64, CSU26, and UWA25). These workshops were attended by State

agency personnel as well as personnel from the natural resource management regional groups.

Phase Two of the program has seen the strong communication effort continued and the demand for publications and CDs from the Riparian Lands R&D Program has been high.

The fact sheets and the technical guidelines were the vehicle for integrating and communicating the scientific knowledge produced in the program. Without the fact sheets and guidelines this knowledge would have been transferred by other means, perhaps less effectively and slower. However, the outputs for the investment should be seen as both the scientific knowledge generated and the communication products emanating from the program.

In the last six years of the program, there were a number of joint industry projects that assisted the translation of industry knowledge to specific rural industries including sugar, cotton and dairying. Guidelines for riparian management were produced for the sugar and cotton industries, with those industries contributing the majority of funding via their industry RDCs. The Gippsland dairy riparian project was co-funded by Dairy Australia and resulted in work being conducted locally and skilling up local scientists in a range of riparian assessment techniques, including the rapid appraisal of riparian condition.

Technical guidelines

The guidelines are user friendly but are strongly underpinned by scientific knowledge that has emerged from the program investment. Volume 1 of the technical guidelines presents principles of sound management, whereas Volume 2 provides on-ground tools and techniques to better manage riparian lands.

Some of the technical guidelines have been updated and all have been reprinted at least once and some twice. The technical guidelines available include:

- managing wood in rivers
- rapid appraisal of riparian condition
- managing high in-stream temperatures using riparian vegetation
- controlling willows along Australian rivers.

A *Stock and waterways managers' guide* has been published and is in demand from water authorities (e.g. Melbourne Water) and required a second print-run. Other recent publications from the program include a large woody debris manual; a contaminants publication; and a large synthesis publication.

Fact sheets

The first set of fact sheets was produced in 1995–96. The fact sheets were designed to link the scientific knowledge produced by the program with practical management issues. They were designed as a first step in raising knowledge and interest in managing riparian areas more effectively. The set of fact sheets has been revised/updated over time and extended to cover more management issues. A list of the fact sheets currently available on the 'Rivers' website follows:

- Managing riparian land
- Streambank stability
- Improving water quality
- Maintaining in-stream life
- Riparian habitat for wildlife
- Managing stock
- Managing woody debris in rivers
- Inland rivers and floodplains
- Planning for river restoration
- River flows and blue–green algae
- Managing phosphorus in catchments
- Riparian ecosystem services
- Managing riparian widths.

Program philosophy

The program has operated with a philosophy of the 'Five Ps'—profit, proof, people, place and promise—in facilitating behavioural change when benefits to the individual are sometimes minimal. Financial considerations of change have been taken seriously, high-class science behind the program has been considered essential, and a strong network of people working in riparian matters including the researchers, government personnel and industry has been developed and maintained. The program has built trust with industry and community groups by recognising the industry, social and catchment context and has been consistent in communication over a long period with outputs of credible and useful information.

Principal Outcomes

The information produced from this investment has filled a knowledge gap in the area of riparian land management. The information has reached a wide range of target audiences. Most importantly, the information is being used in practice.

The program and its products have raised awareness about the value of riparian lands. A review of the program in 1999–2000 found anecdotal evidence that the program had made land managers more aware of the importance and functions performed by riparian zones. This awareness had also been translated into action, and some land managers were adopting improved riparian management practices, often facilitated by government grants. Interest by Landcare groups and community projects was strong as was the inclusion of riparian issues in catchment plans and in Natural Heritage Trust (NHT) funding applications and uptake of grants (Virtual Consulting 2000). The number of projects at that time that had riparian management as a key focus in NHT projects under Bushcare, MDB 2000, the National Landcare Program, and the National Rivercare Programs was 530. This indicated not only a high level of awareness of the importance of riparian lands among those land managers but also active implementation of improved riparian practices (Virtual Consulting 2000, p. 20).

A review of the Riparian Lands R&D Program Phase Two was conducted as part of the River Arena evaluation in 2004 (SKM 2004). The review found that the standard of the

science was very high and was highly relevant to the management of riparian zones. The program had maintained a strong publication record and had a high level of ability to communicate to a wide range of audiences. The review reported that the Riparian Lands Program had a high profile and had a substantial potential to influence river management, planning, investigation and policy.

The fact sheets and technical guidelines have been utilised throughout Australia by a range of users since they were released, and are strongly linked to adoption of improved management practices associated with riparian areas on private land. The regional groups established under NHT2 and the National Action Plan for Salinity and Water Quality (NAP) have been strong users of the material. Users of the information products generated include government and non-government agencies, community-based organisations including NHT recipients, Greening Australia, catchment management staff, individual land managers, industry organisations, and consultants. A range of government agencies has endorsed the guidelines.

The program became the principal R&D program in Australia associated with riparian land science and management. The material has influenced and is influencing the priorities that are placed on riparian management in catchments and throughout natural resource management planning.

The major changes in riparian land management that have been observed in the past few years have been:

- fencing off waterways and limiting livestock access
- establishing water sources outside the fenced areas
- enhancing vegetation within the riparian areas.

For example, 21,084 km of waterways protected was reported in the final evaluation NHT1 (Hassall and Associates 2005). So far under NHT2 and NAP (to 30 June 2005) the length of riparian waterways protected by fencing was 1,640 km (James Austen, pers. comm. April 2006).

It is quite probable that the increased awareness of the importance of the riparian zone has increased the length of waterways that has been fenced off and protected. In addition to enhanced adoption, there may have been an improvement in the effectiveness of riparian land management for waterways that may have been fenced off anyway without the program.

Apart from fencing and vegetation enhancement either through natural regeneration or new plantings, other management practice changes that have been supported by evidence produced from the program include providing alternative shade sources for livestock, use of alternative water sources such as troughs, and limited short grazing episodes on riparian areas.

Communication

The Riparian Lands Program has been well communicated through its life. The *RipRap* Magazine was the third-most frequently used communication product/mechanism from 15 used by LWA stakeholders as reported in the 2005 stakeholder survey. Only the LWA website and the *Salt* magazine were reported as being used more frequently (Pearson and Amber 2006). Its performance rating was second, only behind face-to-face meetings. It is interesting to note that, in 2005, it was rated (statistically significantly) higher by the local government sector, compared with all stakeholders. There are currently about 5,500 people on the mailing list for *RipRap* which has widened its coverage to a range of issues associated with rivers.

In previous stakeholder surveys *RipRap* also had rated consistently highly. For example, in 1998, *RipRap* was the highest ranked of five LWA newsletters. In 2001, *RipRap* was nominated as the most recent communication product (of 19 products) used by LWA stakeholders (Carma International 2001). In the stakeholder survey in 2004, *Rip Rap* was again rated highly and valued by participants in 2003 and 2004 (Carma International 2003, 2004).

A recent summary of sources of river management information in Australia produced by Greening Australia (Greening Australia 2005) recognised the wealth of information produced by the Riparian Lands Program. Of the 36 pages devoted to the two chapters on 'Community engagement' and 'Protection, rehabilitation and management', the Riparian Program publications make up 22 of these pages.

Also, the rivers website at <www.rivers.gov.au> has a large range of information and has been recording increasing site visits from a range of public and private sectors. In the six months to February 2003, the site received on average of 92 visits per day. In the following six months, the site visits had increased to 151 visits per day. The Riparian Program products (including research activities, fact sheets, manuals and *RipRap*) contributed significantly to the site visits and downloading.

The nine integrating workshops held in 2006 were rated highly by the more than 200 participants, with 87 per cent rating the usefulness of the workshops as very or extremely useful. The highest subgroup ratings (97–100 per cent) were obtained from landholders, extension officers and group facilitators (e.g. Rivercare/Landcare), together who made up nearly half of all those attending (LWA 2006).

Benefits Associated with the Investment

The major benefits from improved management of riparian lands include:

- potential improvement in biodiversity, both fauna and flora, and both terrestrial and aquatic
- reduced nutrient and sediment export to streams from the stabilising of stream banks and trapping of nutrients by grass strips and other vegetation
- reduced fouling of waterways by livestock, resulting in improved water quality
- aesthetic improvements for the land manager as well for the wider community in many instances

- improved water quality in the waterway and downstream, as a result of lowered sediment and nutrients potentially leading to enhanced recreational amenities and lower water-treatment costs
- improved livestock management and performance, and lower inspection and mustering costs for stock
- other benefits to the agricultural systems from the adjacent healthier waterway ecosystem such as improved pollination for horticultural plants, and enhanced windbreak protection
- increased carbon sequestration from revegetated areas.

The benefits are a mixture of those that benefit the land manager and those that fall to the wider community and the public in general.

The economic costs of the poor management of riparian lands are significant. It is estimated that 10 per cent of the $450 million spent each year on water quality treatment for human use may be attributed to the degradation of riparian lands (Rivers website, June 2006). Remedial works, such as protective infrastructure and flood mitigation measures designed to prevent or reverse riparian degradation are estimated to cost $100 million per year (Rivers website, June 2006). These estimates take no account of production losses, nor the environmental services provided by riparian lands and healthy riparian vegetation.

High costs can be incurred in protecting riparian areas. For example, the cost of fencing and off-stream infrastructure such as watering facilities and shade that may need to be developed can be high. Particularly costly is the opportunity foregone of not using the land fenced into the waterway area, as this is often highly productive land for cropping or grazing. Hence, there is not only the initial capital cost of fencing and watering, but also the ongoing loss of land and any ongoing management costs such as weed control and any additional costs outside the riparian area caused by the changes made.

Most studies have indicated that the private benefits gained by the land manager from improving riparian land management are generally less than the private costs incurred. Notwithstanding the previous knowledge gap therefore, the past decisions of many land managers not to fence off waterways would appear financially rational.

The value of total public and private benefits associated with improved management of riparian areas is driven by the extent of adoption of the improved management practices and the valuation of those benefits that cannot be captured privately by land managers. The extent of adoption is affected by the magnitude of private benefits and costs and any incentives to adopt that may be provided.

Private benefits and costs

Sillar Associates (2001) provide some key statistics from a series of case studies investigating the extent of private benefits and costs for riparian land management. They reported that for only 19 per cent of sites the private benefit–cost ratio was greater than 1. Even then there were questions over some of the benefits such as timber harvesting from

the riparian land (this may have compromised environmental benefits) and the attribution of benefits arising from adjacent land to any riparian enhancement.

On the other hand these analyses did not include private benefits the land managers may have derived from improved aesthetics on farm and other interactions between the productivity and long-term health of the agricultural system and a healthy riparian area.

For example, the PMEIC (2002) reports the value of pollination to agriculture has been calculated as $1.2 billion per annum. Pollinators are mainly bees and native insects, and horticultural crops and lucerne depend on them to set seeds and grow fruit. Riparian and other remnant vegetation can be important in ensuring a continuing habitat for the pollinators. Moreover, Australia is one of the last major beekeeping countries free of the parasitic mite that has caused major declines in feral and managed honeybee populations elsewhere in the world. Hence, pollination services in future may need to rely increasingly on pollination by native insects such as native bees (see Cunningham et al. 2002).

Martin and Green (2002) state that:

> … in terms of pest control and pollination, the mobility of animals allows them to have beneficial effects beyond the boundary of the conservation areas. Sensitive species may not be able to survive long-term or breed in the wider landscape, but they may be able to forage or under certain conditions live beyond these protected areas, consuming pests or pollinating trees, pastures and crops.

The presence of a diversity of native vegetation types can assist biological control of non-beneficial insects by birds and other animals. For example, about two thirds of respondents in a survey of north-eastern Victorian and southern NSW landholders identified the provision of habitat for animals that control pests as a benefit from native vegetation (Miles et al. 1998).

Some of the contributions of native fauna to pest control have been documented in fact sheets produced by some agencies (Sheahan 1998; DNRE 2002). Examples include:

- ibis consuming locusts and grasshoppers
- magpies consuming scarab larvae
- insectivorous bats consuming in one night half their body weights of moths, beetles and bugs and some spiders, mosquitoes, grasshoppers and crickets
- sugar gliders consuming up to 18,000 scarab beetles per ha per season
- between 40 and 60 per cent of the diet of crows and ravens is insects
- a variety of small birds (such as robins, fantails, weebills, pardalotes, honeyeaters, and butcherbirds) will control thrips, scale, lerps, flies and locusts.

An attempt to attribute private–public benefits in several prospective benefit–cost analyses has been made in the past by Agtrans Research, for sugar and dairy industry projects associated with riparian vegetation. The dairy industry projects were related to streambank management in Gippsland and western Victoria (fencing off plus

revegetation), and on riparian management on dairy farms in coastal Queensland and northern New South Wales. From an overall societal viewpoint, the economics were assumed dependent on the improvement in water quality. Estimates were that the community would need to provide at least 20 per cent of the capital costs associated with the implementation of the management changes in order for the farmer to gain a positive return as indicated by the net present value of the investment. Risky variables for the land manager included the extent of any drop-off in milk production due to loss of grazing capacity (Agtrans Research 1998).

The sugar industry project was associated with establishment of riparian vegetation to control rats through shading out of their grass habitat and improve sediment/nutrient trapping. This resulted in less rat damage to the cane, a reduction in use of rat poison, suppressed development of aquatic weeds and increased biological activity in the rivers, together with reduced sediment and nutrient export. The environmental benefits were measured through assumptions on increased fisheries productivity in estuaries and coastal waters. However, in this case it was shown that the privately captured sugar industry benefits more than outweighed the costs of revegetation for those regions and farms where rats were significant (Chudleigh et al. 1997). A conclusion of private benefits outweighing private costs on this topic was also evident in another study carried out by Wendy Tubman (Canegrowers, undated).

These examples illustrate the difficulties of attempting to develop general conclusions about the magnitude of private and public benefits from enhanced riparian lands due to:

- difficulties in quantifying values of environmental benefits, not only due to the absence of markets, but also due to the inadequate knowledge about the relationships between a supposed best practice and the magnitude of the environmental impact
- different resource situations of farmers, so that the share of costs that might be appropriately paid by the public will differ from farm to farm
- different financial circumstances between farmers, so the level of costs paid by the public may need to differ between farmers in order to encourage adoption, with associated equity implications
- different risk attitudes of farmers to the specified investment or practice and the uncertainty of reaping private benefits.

Carbon sequestration

Any benefits for carbon sequestration due to improved regeneration and/or new plantings enhancing riparian vegetation are not likely to be captured privately due to the difficulty of identification and validation, and the absence of a formal carbon credit trading scheme across Australia. However, given the increasing certainty of climate change and the role of carbon dioxide, sequestration of carbon is assumed to constitute a community or public benefit. It is assumed that carbon will be sequestrated permanently from any enhancement of riparian vegetation as it is not likely to be removed due to the increased community recognition of its value and local government restrictions.

Type of benefits
A summary of the principal types of benefits associated with the Riparian Lands R&D Program is shown in Table 3.

Table 3**:** Categories of the Benefits from the Riparian Lands R&D Program

Benefits
Productivity and Profitability • Improved pollination for horticultural plants and other benefits to agricultural systems (e.g. retention of nutrients on farm, enhanced windbreak protection) • Improved livestock management and performance and lower inspection and mustering costs • Reduced need for and expenditure on remedial works downstream (e.g. erosion) • Less breakouts from creeks, and lower maintenance of creek crossings
Environmental • Biodiversity improvement in riparian areas • Reduced sediment and nutrient export and improved water quality • Increased carbon sequestration
Social • Aesthetic improvements

Public versus Private Benefits
As indicated above, there are both public and private benefits generated by the Riparian Lands R&D Program. Private benefits are in the form of productivity increases and saved costs to agricultural producers, and some environmental and social benefits that accrue on farm (e.g. aesthetics, improved water quality). Public benefits accrue in the form of improved biodiversity in riparian zones; reduced sediment and nutrient export, and therefore water quality; increased carbon sequestration; and aesthetic improvement.

Benefits to Primary Industries
Benefits from addressing the health of riparian lands in Australia will accrue to all agricultural industries. Benefits to industry will mostly be in the form of some productivity improvements or avoided costs on-farm, as well as benefits of water quality improvements to downstream irrigators. There may also be some increased costs associated with adopting some solutions recommended by the program.

Distribution of Benefits Along the Supply Chain
As the research investment will result in benefits to a wide range of primary industries, as well as the public, it is difficult to draw conclusions regarding the distribution of benefits along the supply chain. However, as the ratio of private benefits and costs will vary from farm to farm around a ratio of 1, there is not likely to be any significant change in average cost of production at an industry level.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 3.

Table 3: 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 research within the Riparian Lands R&D Program is largely aimed at improving sustainability and natural resource management (National Research Priority 1 and Rural Research Priority 3). There are potentially some productivity implications of this investment (Rural Research Priority 1).

Quantification of benefits

Framework
An appropriate framework for considering costs and benefits for the R&D investment in the Riparian Lands Program is shown in Table 5.

Table 5: Categories of Benefits from the Riparian Lands R&D Program

Costs	Benefits
A. R&D costs	A. Private benefits to landholder
B. Capital costs of works on ground	B. Incentives gained by landholder
C. Ongoing additional management and opportunity cost of the riparian area protected	C. Public benefits including biodiversity, water quality (fishing, recreation implications) etc
D. Any public cost to encourage adoption	

A reasonable assumption is that the benefits A plus B should equate to or be greater than costs B plus C for adoption to occur. The challenge is then to value the public benefits.

Few attempts have been reported to value the range of public benefits from improved riparian land management defined earlier. The assumptions used in the current quantitative analysis focus on three public benefits only:

- the public's willingness to pay (WTP) for restoration of water quality
- enhanced biodiversity as influenced by improved riparian land management
- carbon sequestration benefits.

Restoration of water quality

It is assumed the riparian program has contributed to improved water quality in two ways.

- by encouraging a greater length of waterways to be protected
- by lifting the success rate of riparian enhancement.

Extent of riparian improvement

The length of waterways protected in the five years to 2001–2002 due to the fencing of waterways is assumed to be at least 13,000 km as recorded under the NHT program (NHT 2002; DEH undated). This approximated 2167 km per annum over six years. However, an estimate of 21,084 km of waterways protected was reported in the final evaluation of NHT1 (Hassall and Associates 2005). This is equivalent to 3,514 km per annum.

Since that time, information has been assembled for the Regional Programs Report summarising the achievements of the NAP and the regional component of the continuing NHT. The data are supplied by the regional natural resource management bodies. To 30 June 2005 the length of riparian areas protected by fencing was 1,640 km (James Austen, pers. comm., April 2006). Over three years this approximated 547 km per year.

Additional riparian land improvement would also have occurred due to the LWA program outside of NHT and NAP funding. This was not accounted for in the analysis as it is difficult to estimate the extent of activity. However, given the general principle that private benefits are usually less than private costs, the length of waterways protected is assumed smaller than that produced under public programs such as NHT.

The technical guidelines, fact sheets and other communication activities of the program raised awareness of riparian issues and stimulated added activity and adoption over what would have happened without the program. It is assumed that without the riparian program some 90 per cent of the length of waterways protected would still have been protected and the riparian guidelines would have directly stimulated the other 10 per cent being protected.

Success rate of riparian enhancement/extent of protection

The degree of protection from enhanced riparian lands management (reduction of nutrients and sediment entering the waterways through natural regeneration and tree planting providing bank stabilisation, grass buffer strips etc.) will vary considerably from each length of waterway that is protected.

It is assumed that for the 90 per cent of waterways that would have been protected anyway, 80 per cent of this protection would have been effective without the guidelines and 90 per cent with the guidelines. The lack of effectiveness would have been due to such factors as planting the wrong species, fencing too close, higher level of access for livestock than with the guidelines etc. For the other 10 per cent of fencing that was directly stimulated by the program, the effectiveness is assumed to be 95 per cent.

Value of waterway health improvement
The WTP by households in the community for improved river condition was derived from Van Bueren and Bennett (2004). This was the WTP estimate of 8 cents per 10 km per annum for 20 years of river restored to fishable or swimmable as defined by the Environmental Protection Agency in NSW. This benefit was adjusted by a series of factors to equate it to a WTP component attributed to the extent and effectiveness of the improved riparian land management.

The proportion of households where the above WTP is assumed representative is assumed to be 45 per cent. The value of the additional length of waterways protected is therefore estimated as 45 per cent of 7 million households each willing to pay 8 cents per 10 km per annum for 20 years of waterways protected. This is equivalent to $25,200 per km per annum of waterways restored.

The probability that the riparian zone enhancement by itself would have effectively restored the water quality is estimated at 5 per cent.

It should be noted, however, that there may be significant thresholds (e.g. proportion of a waterway to be protected) before a significant water quality improvement or remedial cost is changed. For example, if all the kilometres of 'protection' represented only 5 per cent of each waterway in Australia, any impact may be substantially reduced as it may be so small as to not influence treatment costs or recreational opportunities for any specific waterway. This is accounted for in the 5 per cent probability assumed.

Enhanced biodiversity
A WTP 'surrogate' for improving biodiversity was estimated from data from a specific government initiative in Victoria, the BushTender trial. Here $400,000 was spent via an auction for the supply of services to protect biodiversity on private land. The resulting agreements included riparian land, and most spending was on fencing, enhancement plantings etc. The average cost to government was approximately $125 per ha of land protected, which was the incentive needed for the landholders to take action. It could be argued that the Victorian Government, acting on behalf of the public, viewed the public benefits actually higher than this price and therefore that the $125 per ha was a conservative estimate of public benefits. It is assumed that the riparian zone components of these biodiversity-enhancing activities were worth four times the average, or $500 per ha of riparian areas improved.

If it is assumed that a 30 metre width of land is protected with riparian enhancement, the area protected per kilometre of waterway is 3 ha. The improvement in effectiveness of

the riparian protection for waterways is also assumed to apply for biodiversity enhancement.

Carbon sequestration

It is possible to impute values to carbon sequestration by enhanced riparian vegetation based on existing carbon sequestration rates and carbon sequestration values.

The value of carbon sequestration for the NSW Greenhouse Gas Abatement Scheme for carbon is around $15 per tonne and its penalty rate is $10.50 per tonne (Michael Robinson, pers. comm. 2006). This is lower than the value of sequestering carbon (carbon dioxide equivalent) of about $48 per tonne as indicated by the European Union Emissions Trading Scheme in early April 2006 (as reported on Point Carbon website, April 2006). The Australian value is preferred in the current analysis.

It is assumed that the rate of sequestration will be around 2 tonnes per ha per year due to the usually good growing conditions around riparian land. At 2 tonnes of carbon per ha per year and at an imputed value of carbon of $15 per tonne, this is equivalent to $30 per ha per annum. It is assumed that 80 per cent of land protected regenerates naturally or is subject to new plantings.

A summary of all assumptions made is presented in Table 6.

Table 6: Assumptions for the Valuation of Benefits from Protecting Riparian Lands

Variable	Value	Source
Restoration of water quality		
Length of waterways fenced off per annum from 1996–97 to 2001–02	3,514 km per annum	Hassall and Associates (2005)
Length of waterways fenced off from 2002–03 to 2004–05	547 km per annum	James Austen, pers. comm., April 2006
Willingness to pay (WTP) per household	8 cents per annum for 20 years per 10 km of waterway restored to 'fishable or swimmable'	Van Bueren and Bennett (2004)
Number of households in Australia	7 million	Australian Bureau of Statistics
Proportion of households where the above WTP is assumed representative	45%	Van Bueren and Bennett (2000)
Length of waterways that would have been fenced of in absence of Riparian Lands Program	90%	Agtrans Research

Success rate or effectiveness of protection to water quality improvement for the 90% of waterways fenced off without and with the Riparian Lands Program	80% and 90%, respectively	Agtrans Research
Success rate or effectiveness of protection to water quality improvement for the 10% of waterways fenced off due to the Riparian Lands Program	95%	Agtrans Research
Probability of waterway protection raising water quality to desired level	5%	Agtrans Research
Enhanced biodiversity		
Value of biodiversity protected in riparian areas	$500 per ha	Agtrans Research, based on Victorian BushTender Trial
Width of land area protected in riparian area	30 metres	Agtrans estimate
Area protected per km of waterway protected	3 ha	Deduced from above assumptions
Carbon sequestration		
Width of waterways protected	30 metres	Agtrans estimate
Percentage of area sequestering carbon	80%	Agtrans estimate
Rate of carbon dioxide equivalent sequestered	2 tonnes per ha per annum	Agtrans estimate
Value of carbon dioxide equivalent sequestered	$15 per tonne	NSW Greenhouse Gas Abatement Scheme for carbon

Results

All past costs 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 (2005-06) to the final year of benefits assumed (2030-31).

Investment criteria were estimated for both total investment and for the LWA investment alone. Each set of investment criteria were estimated for different periods of benefits. As well as for the 25 year benefit period, each set of investment criteria were estimated for different periods of benefits. Benefits for LWA investment criteria were estimated as 60.02% of the total benefits, 60.02% representing the proportion of total costs contributed by LWA. The investment criteria are reported in Tables 7 and 8.

Table 7: 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 ($m)	94.5	124.8	148.6	155.6	161.0	165.4
Present value of costs ($m)	24.4	24.4	24.4	24.4	24.4	24.4
Net present value ($m)	70.1	100.4	124.2	131.1	136.6	140.9
Benefit:cost ratio	3.9	5.1	6.1	6.4	6.6	6.8
Internal rate of return (%)	86.3	86.4	86.4	86.4	86.4	86.4

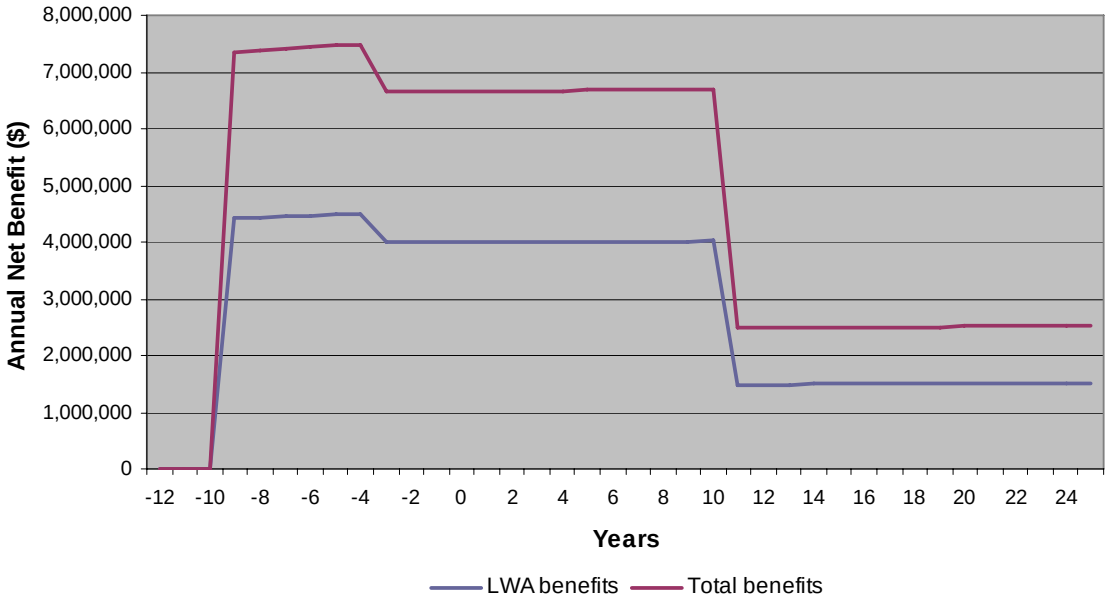
Table 8: Investment Criteria for LWA Costs and Benefits (discount rate 5%)

Criterion	0 years	5 years	10 years	15 years	20 years	25 years
Present value of benefits ($m)	56.7	74.9	89.2	93.4	96.6	99.2
Present value of costs ($m)	14.6	14.6	14.6	14.6	14.6	14.6
Net present value ($m)	42.1	60.3	74.6	78.8	82.0	84.6
Benefit:cost ratio	3.9	5.1	6.1	6.4	6.6	6.8
Internal rate of return (%)	87.4	87.5	87.5	87.5	87.5	87.5

For the 25 year analysis, the contributions to total benefits in the analysis are the assumed water quality improvements (89 per cent), biodiversity (6 per cent) and carbon sequestration (5 per cent). Since LWA contributed a large part of the investment in the program (60 per cent), the return to LWA in terms of the net present value is high.

Figure 1 demonstrates the rate at which net benefits accrue.

Figure 1: Annual Net Benefit Flow



Sensitivity Analysis

The sensitivity of the investment criteria to four key assumptions was tested (for the 20 year analysis; LWA benefits only). All other assumptions remained the same when the one factor was varied. The four key assumptions tested were:

1. Adoption (post-2004-05, as prior to that year actual data from NHT is used)
2. Willingness to pay for improvement in water quality
3. Willingness to pay for biodiversity improvement
4. Value of carbon credits

Table 9: Sensitivity of Investment Criteria to Level of Adoption after 2004-05 (LWA benefits and costs only)

Criterion	Discount rate 5%		
	50% of base value	**Base value (547km per annum)**	**150% of base value**
Present value of benefits ($m)	85.1	96.6	108.1
Present value of costs ($m)	14.6	14.6	14.6
Net present value ($m)	70.5	82.0	93.5
Benefit:cost ratio	5.8	6.6	7.41
Internal rate of return (%)	81.3	87.5	93.5

Table 10**:** Sensitivity of Investment Criteria to Willingness to Pay for Improvement in Water Quality (LWA benefits and costs only)

Criterion	Discount rate 5%		
	50% of base value	**Base value ($0.08 per household per 10km)**	**150% of base value**
Present value of benefits ($m)	53.0	96.6	140.3
Present value of costs ($m)	14.6	14.6	14.6
Net present value ($m)	38.4	82.0	125.7
Benefit:cost ratio	3.6	6.6	9.6
Internal rate of return (%)	49.5	87.5	117.2

Table 11: Sensitivity of Investment Criteria to Willingness to Pay to Improve Biodiversity (LWA benefits and costs only)

Criterion	Discount rate 5%		
	50% of base value	Base value ($500 per ha)	150% of base value
Present value of benefits ($m)	93.2	96.6	100.1
Present value of costs ($m)	14.6	14.6	14.6
Net present value ($m)	78.6	82.0	85.5
Benefit:cost ratio	6.4	6.6	6.9
Internal rate of return (%)	92.4	87.5	92.6

Table 12: Sensitivity of Investment Criteria to Carbon Price (LWA benefits and costs only)

Criterion	Discount rate 5%		
	50% of base value	Base value ($15 per tonne)	150% of base value
Present value of benefits ($m)	95.4	96.6	97.9
Present value of costs ($m)	14.6	14.6	14.6
Net present value ($m)	80.8	82.0	83.3
Benefit:cost ratio	6.5	6.6	6.7
Internal rate of return (%)	87.3	87.5	87.8

Table 13 presents the net present value (NPV) for low, expected and high adoption assumptions (post 2004-05), for each of the 0, 5, 10, 15, 20 and 25 year timeframes (for all investment).

Table 13: Net Present Value Sensitivity to Adoption (all investment)

NPV	Project Horizon					
	0 years	5 years	10 years	15 years	20 years	25 years
Low (50% of expected)	62.2	89.4	110.8	114.5	117.4	119.7
Expected (547km per annum)	70.1	100.4	124.2	131.1	136.6	140.9
High (150% of expected)	77.9	111.3	137.6	147.7	155.8	162.1

It needs to be kept in mind that this analysis relies on some non-market valuations that have relied on a benefit transfer (water quality) and an indirect valuation (biodiversity). Hence, both the relative and absolute magnitude of benefits should be viewed with some caution. The gross assumption of neutral private costs and benefits (private benefits as defined here include any incentive or transfer payment) also remains.

One of the more important motivations for improving native vegetation on farms is aesthetics (Miles et al. 1998). This is mainly a private benefit, but there would also be a public benefit in the outcome. Improved aesthetics is not valued in the current analysis.

As mentioned earlier, the extent of riparian areas protected is based only on NHT records. There are likely to have been other riparian land areas restored to date outside of the NHT grant process. For example, as of 2000, a survey showed that 57 per cent of dairy farmers with waterways have all or most of them fenced off from livestock. Improved information needs to be assembled by industry to enable an improved estimate of the increasing extent of riparian protection.

As some benefits as defined earlier have not been represented in the analysis, the results are likely to show an underestimate of the total benefits from this investment. The improved aesthetics and the likely downstream remedial works avoided, have not been accounted for. Any potential private benefits above the costs of restoration (uncertain but not often not understood or defined) have not been included.

Summary of Adoption Information

The major benefits from improved management of riparian lands are a mixture of private and community benefits. Most studies have indicated that the benefits gained by the land manager from improving riparian land management are generally less than the private costs incurred. Different resource and financial situations of farmers and their different attitudes to risk differ from farm to farm and therefore different farmers will respond differently to public incentives to manage riparian lands. The extent of actual adoption is

not only affected by the magnitude of private benefits and costs but also by the magnitude and nature of incentives to adopt that may be provided by government.

The uptake of management practice changes is supported by the statistics reported for protection of waterways in the past 10 years via NHT1, NHT2 and NAP. For example:

- the length of waterways protected in the five years to 2001–2002 due to the fencing of waterways is assumed to be at least 13,000 km as recorded under the NHT program (NHT 2002; DEH undated).
- an estimate of 21,084 km of waterways protected was reported in the final evaluation of NHT1 (Hassall and Associates 2005).
- to 30 June 2005 the length of riparian areas protected by fencing was 1,640 km (James Austen, pers. comm., April 2006).

It was not possible to identify the length of waterways protected in the past 10 years where landholders have taken action on their own without public assistance.

It is likely that the NHT and NAP programs have been the major drivers of adoption over the past 10 years. The awareness-raising and guidance provided by the Riparian Lands Program has most likely enhanced this adoption to some extent by building capacity and confidence. In addition, the program will have increased the effectiveness of riparian practices.

Conclusion

The investment in this program produced a highly integrated program in terms of topics and between high level science and communicating practical guidelines for action. There was also a positive link between R&D and policy, where management guidance available was backed up by scientific knowledge and incentives to promote actions by land managers and administrators.

There have been significant benefits associated with this investment with economic, environmental and social benefits all emerging in some form. The quantitative analysis provided a net present value of $82 million and a benefit:cost ratio of 6.6 to 1, for the LWA investment alone. However, such investment criteria need to be treated with some caution due to the use of benefit transfers of non-market values from other studies, and the omission of some benefits from the analysis. For example, private benefits and costs to landholders have not been addressed in detail due to their variations by site, enterprise and management systems. The likely reduced costs of sedimentation and avoided costs of river remedial work due to improved riparian lands management have also been excluded.

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