Healthy rivers
and catchments

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In Australia, the role of stewardship and the value of ecosystem services are being incorporated into new approaches to environmental planning that include both public and private investment.

Environmental damage is already costing Australians $AU3.5 billion each year. Soils, unique plants and animals, rivers and water supplies are seriously threatened by problems such as salinity, soil loss, pollution and habitat destruction. The cost of repairing the country is harnessing all sectors of the Australian community, government and industry to develop new integrated approaches to landscape and river management. Land care is about matching capacity to purpose. New water policy balances the needs of water users with those of healthy rivers and will protect those assets that are still unspoiled.

Opposite page: The Wollondilly river in the Warragamba catchment. Image courtesy of Sydney Catchment Authority

What drives innovation in Australia

A landscape that is unique

In its *Blueprint for a Living Continent*, the Wentworth Group of concerned scientists described in simple language the natural resource issues that confront Australia:

'Australia is the driest inhabited continent on Earth. It also has the most variable climate. Australia is also the most ancient continent. It is an old and weathered landscape and much of it is very flat, with a salt inheritance buried deep within it. Australian has been an island continent for over 40 million years.'

These three elements – an arid climate, ancient soils, and evolutionary history – make Australia unique and unsuitable for European agricultural practices. Over this unique environment has been superimposed the full gamut range of European agricultural practices supported by rapidly developing technologies and driven by changing global markets. It has become apparent that in many instances the existing agricultural practices are unsustainable and have led to large-scale damage to natural systems. Innovative approaches are needed to improve environmental sustainability and biodiversity.

Landscapes and rivers are damaged and need repair

The National Strategy for Ecologically Sustainable Development adopted by all Australian Governments in 1992 called for regular *State of the Environment* reporting. Land and water degradation in Australia was identified and regularly examined during the 1980s. However the spatial extent, trends and costs in lost production and environmental amenity, particularly biodiversity, remained very poorly documented until the publication of the *National Land & Water Resources Audit* report *Australians and Natural Resource Management 2002*.

ANZLIC – the Spatial Information Council and the Audit have prepared the *Natural Resources Information Management Toolkit* to assist managers and regional groups in discovering, accessing, visualising and managing their data and information.

Salinity and water quality problems need urgent attention because:

- At least 2.5 million hectares (about 5 percent of cultivated land) is currently affected by dryland salinity – modelling suggests that this could rise to 12 million hectares (22 percent) at the current rate of increase
- The *National Land & Water Rsources Audit* reports that one third of Australian rivers are in extremely poor condition
- Land and water degradation, excluding weeds and pests, is estimated to cost up to $AU3.5 billion per year. In addition, dryland salinity has adversely affected biodiversity, for example CSIRO estimates a resultant reduction in bird species of 50 percent in agricultural areas
- Infrastructure (such as buildings, roads) is being severely damaged in many rural urban centres

Current dryland agriculture is not sustainable

Over the past two hundred years, the success of Australian agriculture has driven the nation's economic development. The latest estimate from the *National Land & Water Reources Audit* for the gross value of agricultural production is $AU28 billion. Half of the profits came from irrigated agriculture, which takes up less than one percent of the agricultural land area.

However, in dryland agriculture, commodities are being produced in a world market with ever-declining terms of trade, and at significant cost to the environment. A different agricultural system is required – one that is in harmony with its environment and able to support viable rural communities.

While the problems are severe, progress is being made through commitment to change at the most senior (prime ministerial) level, by engaging regional communities in finding solutions, through science-based intervention, and through new funding mechanisms and incentives.

Wheat crop near Blyth in the mid north of South Australia. Image courtesy of ©CSIRO Land and Water

CSIRO Land and Water

Working with communities towards healthy rivers and catchments

Sustainable management of Australia's natural resources is critical to the health of our rivers and catchments. The challenges include allocating our limited water resources efficiently between the environment and other users, improving water use productivity and developing more efficient water delivery infrastructure.

These complex issues require integrated scientific solutions based on a whole-of-systems understanding of the impacts of land management and water use on rivers, catchments and estuaries – impacts that include groundwater recharge, salinity, erosion, water quality and altered flow regimes.

In tackling these challenges, CSIRO Land and Water harnesses expertise across disparate disciplines ranging from hydrological research to economics and social science. We recognise that strong economic drivers are also imperative, as are institutional, structural and social changes.

Our researchers work in partnerships with clients, collaborators and communities to provide the science capacity needed to underpin catchment-scale decisions, policy options and infrastructure investments.

Aerial view of Lyell Dam, Cox's River near Lithgow, New South Wales. Image courtesy of ©CSIRO Land and Water

Partnerships in research and development

Research and development effort is mostly co-investment with corporations and agencies such as the Murray-Darling Basin Commission, one example being the Murray-Darling Freshwater Research Centre. Active linkages include natural resource and environmental agencies in all Australian states, as well as the relevant Australian Government agencies, including the Departments of Agriculture, Fisheries and Forestry, and Transport and Regional Services, as well as the Department of the Environment and Heritage, and Land & Water Australia.

Partnerships include many Australian universities and twelve Cooperative Research Centres, including Catchment Hydrology; Coastal Zone, Estuary and Waterway Management; Freshwater Ecology; Irrigation Futures; Landscape Environments and Mineral Exploration; Sustainable Rice Production; and Plant-based Management of Dryland Salinity.

In delivering applied research to meet industry needs, CSIRO Land and Water collaborates with:

- Research and development (R&D) corporations – including the Grains R&D Corporation, the Grape and Wine R&D Corporation, Horticulture Australia, and the Rural Industries R&D Corporation
- Industry and non-government organisations such as the National Farmers' Federation, Canegrowers, Greening Australia and *Landcare Australia*
- Irrigation cooperatives – including Murrumbidgee Irrigation, Murray Irrigation Limited, Coleambally Irrigation Cooperative Limited and Goulburn Murray Water
- Water management authorities and regional catchment management agencies – including Sydney Catchment Authority, ACTEW, Melbourne Water, WA Water Corporation, WA Rivers and Waters Commission, North Burdekin Water Board, South Burdekin Water Board, and SunWater
- Private industry

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Innovation 1: Whole-of-system-thinking

The water cycle

An integrated approach is underpinned by recognition of interactions in the water cycle (Figure 3.01). Many of the actions that have damaged Australian water resources reflect failure to understand the complex nature of these interdependencies.

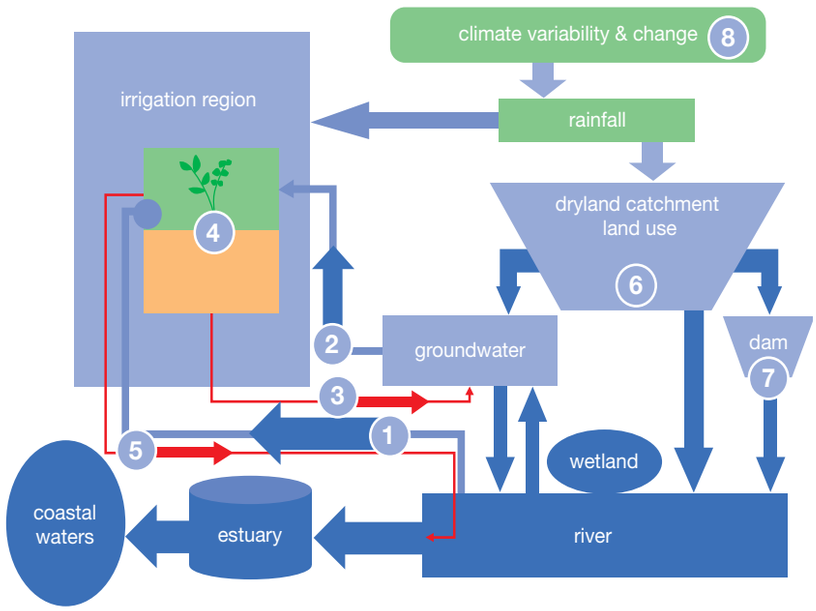
For example, rivers are stressed by being dammed and regulated, and by water extraction when the pattern of flow is changed. Over-extraction of water can endanger native fish, increase salinity and the incidence of algal blooms, and damage vegetation in wetlands and floodplains. These effects are compounded by stresses caused by release of cold water from storages, removal of snags (submerged timber) that are critical habitat for fish, and introduction of alien fish such as carp.

Some scientists believe that these non-flow stresses are more important than changes in flow regime, and this is causing substantial conflict between some scientists, water suppliers and conservationists.

A whole-of-system understanding for the River Murray – its groundwater systems, wetlands, billabongs and flood plains, linked to the extraction and return of irrigation waters – underpins the *Living Murray* initiative of the Murray-Darling Basin Commission (pages 21-22 and 96).

Many research groups are tackling the complex issues of river health and water for the environment. They include the Cooperative Research Centre for Freshwater Ecology (page 98), the Murray-Darling Freshwater Research Centre, The University of Adelaide, Griffith University, James Cook University, Murdoch University, Charles Sturt University and the University of Western Sydney (pages 63, 99, 120).

FIGURE 3.01 Catchment, Irrigation, River and Groundwater Management Cycles



Key intervention points for sustainability of irrigation systems are:

1 & 7. Reduce water extraction; improve river flow regime by trading, regulation of water use and improved dam management

2. Reduce water extraction from groundwater

3. Manage sub-surface drainage to avoid accumulation of salt in the root zone' and improve interception of subsurface drainage water and reuse through bio-concentration and extraction or evaporation basins

4. Improve water use efficiency on farm

5. Improve surface water drainage, improve reuse, reduce contaminants

6. Manage landscapes to maintain run-off while reducing amount of salt and pollutants to rivers and groundwater

8. Improve prediction of climate change over longer term on water availability

Image courtesy of CRC for Irrigation Futures

Salinity patches and scalds near Mount Torrens in the Mount Lofty Ranges, South Australia.
Image courtesy of ©CSIRO Land and Water

Australian Bureau of Meteorology

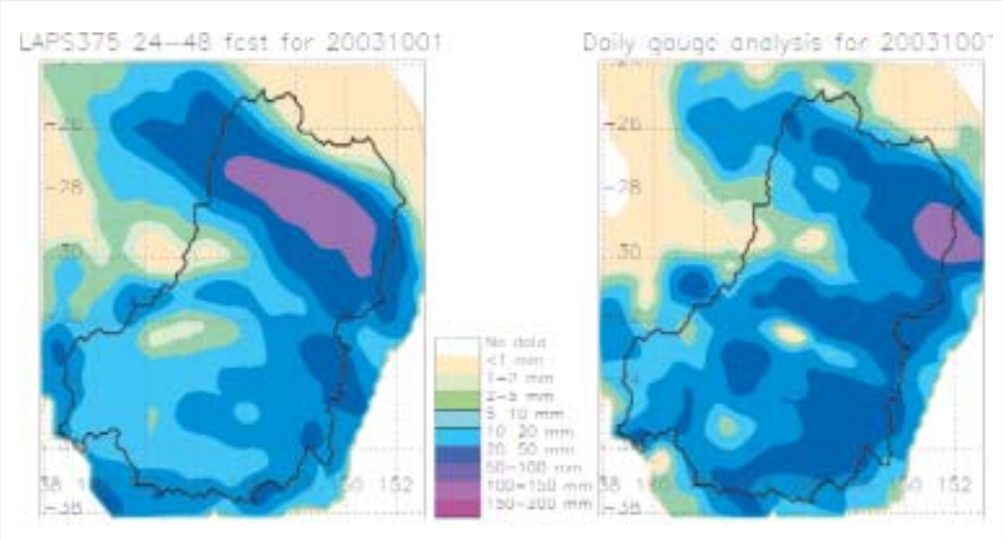
Improved weather forecasting

Sustainable water resources management requires accurate and timely information.

One way in which the Australian Bureau of Meteorology contributes to sustainable management is by an improved weather forecasting capability achieved through advances in numerical weather modelling and new observation systems such as Doppler radar.

Increasing pressure for more efficient management of water, for example through tighter controls on allocation and more competition for the resource across its different uses, places a higher value on accurate forecasts of both rainfall and evaporation. Innovations in the Bureau of Meteorology are meeting this need through improvements in forecasting at a range of scales from seasonal, through the medium term (1-4+ days ahead) and down to short term or 'nowcasting' (0-12 hours ahead).

Seasonal forecasts provide water managers with information on future rainfall (and through that river flow conditions) expressed in terms of the probability of, for example, above or below average conditions for a particular time of year. Water supply managers can use this information for decisions on water allocations, the timing of any water restrictions or managing releases for environmental purposes.



Accuracy of forecasts continually improving

Medium term forecasts from numerical weather prediction (NWP) models include predictions of hourly rainfall and evaporation sequences, out to four and more days, at space scales of several kilometres. The accuracy of this information is continually improving and is now available for most areas of Australia several times daily. Bureau researchers use supercomputers to estimate the reliability of predictions by running an ensemble of NWP calculations to produce probabilities of rainfall. Rainfall forecasts can be used with hydrological models to predict future streamflow conditions for flood warning and other purposes. They can also greatly improve water use efficiency in irrigation systems by reducing the volume of 'irrigation rejections' as well as assisting managers to manipulate their storage systems to optimise the availability of water to meet demand at different locations in the system.

Very short-term (0-3 hours) forecasts of rainfall are used to assist with flash flood warning. These forecasts are commonly made directly from observations by weather radar. Current practice is limited to generalised forecasts and warnings. However research is focusing on both increasing the lead time of the forecasts and improving the spatial resolution.

Above: Forecast of daily rainfall for 1 October 2003 made 48 hours in advance (left-hand box) using the Bureau numerical weather prediction model LAPS (Limited Area Prediction System) for the Murray-Darling Basin (dark outline), compared with observed daily rainfall for that date (right-hand box)

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Bureau of Meteorology

Integrated catchment management

The problems caused by current land use practices require a multi-faceted approach: fixing one problem while causing another is no solution. Relying on overly simple technical solutions will not do.

In Australia, these ideas have evolved to what is known as Integrated Catchment Management (ICM) (Figure 3.03), Total Catchment Management (TCM) and recently, Whole Catchment Planning (WCP). At the broadest level, integrated resource management involves the integration of environmental and economic considerations at management, planning and policy levels. This is argued to be an effective means of implementing the principle of sustainable development.

The publication *Farming Action – Catchment Reaction: the Effect of Dryland Farming on the Natural Environment* (Williams *et al.* 1998) provides a compendium of information about indicators of catchment health, effects of farming practices on land and water, and the tools and models available for bringing about change.

Setting targets

The goals of catchment planning in the Murray-Darling Basin are to achieve healthy rivers, innovative, competitive industries, and sustainable regional communities.

These goals incorporate targets for each of the Basin's major catchments as minimum requirements for catchment health. Usually, targets are set for water quality (salinity and nutrients), water sharing (consumptive and environmental flows), riverine ecosystem health, soil health and terrestrial biodiversity.

End-of-valley targets for each catchment in the Basin are needed to protect the health of the Basin as a whole (Figure 3.02).

Catchment Management Authorities have been established in Victoria and New South Wales. Similar planning groups are evolving in all other states.

FIGURE 3.02 • Targets for a catchment

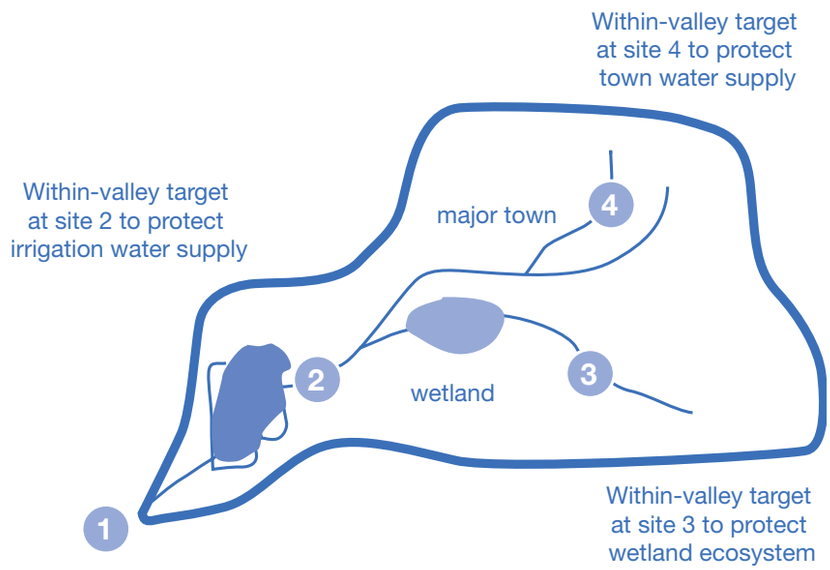
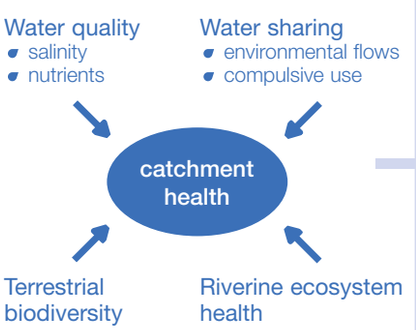
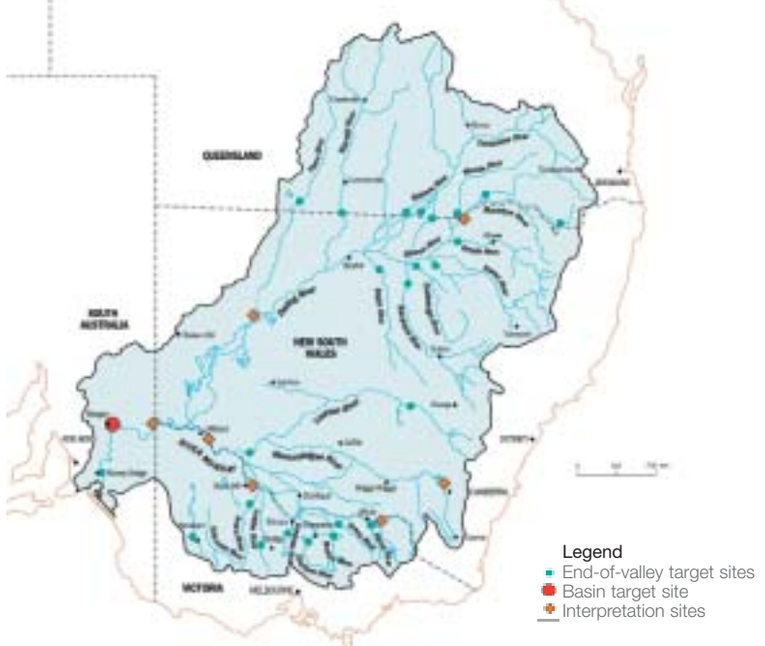


FIGURE 3.03 • Integrated Catchment Management (ICM) Principles – proposed target-setting in the Murray-Darling Basin





Above: proposed core signals of catchment health

Map: salinity targets in the Murray-Darling Basin. Electrical Conductivity Units (ECU) are a measure of salt concentration. Location of end-of-valley salinity target sites.

Source: Basin Salinity Management Strategy, MDBC, 2001

Innovation 2: Farming without harming

Landcare – a 'true blue' response

Australia has a long history of governments working with individual farmers and small farmer groups in soil conservation projects. The grass roots initiative *Landcare* was officially born with the formation of the first Landcare Group in Western Victoria in 1986.

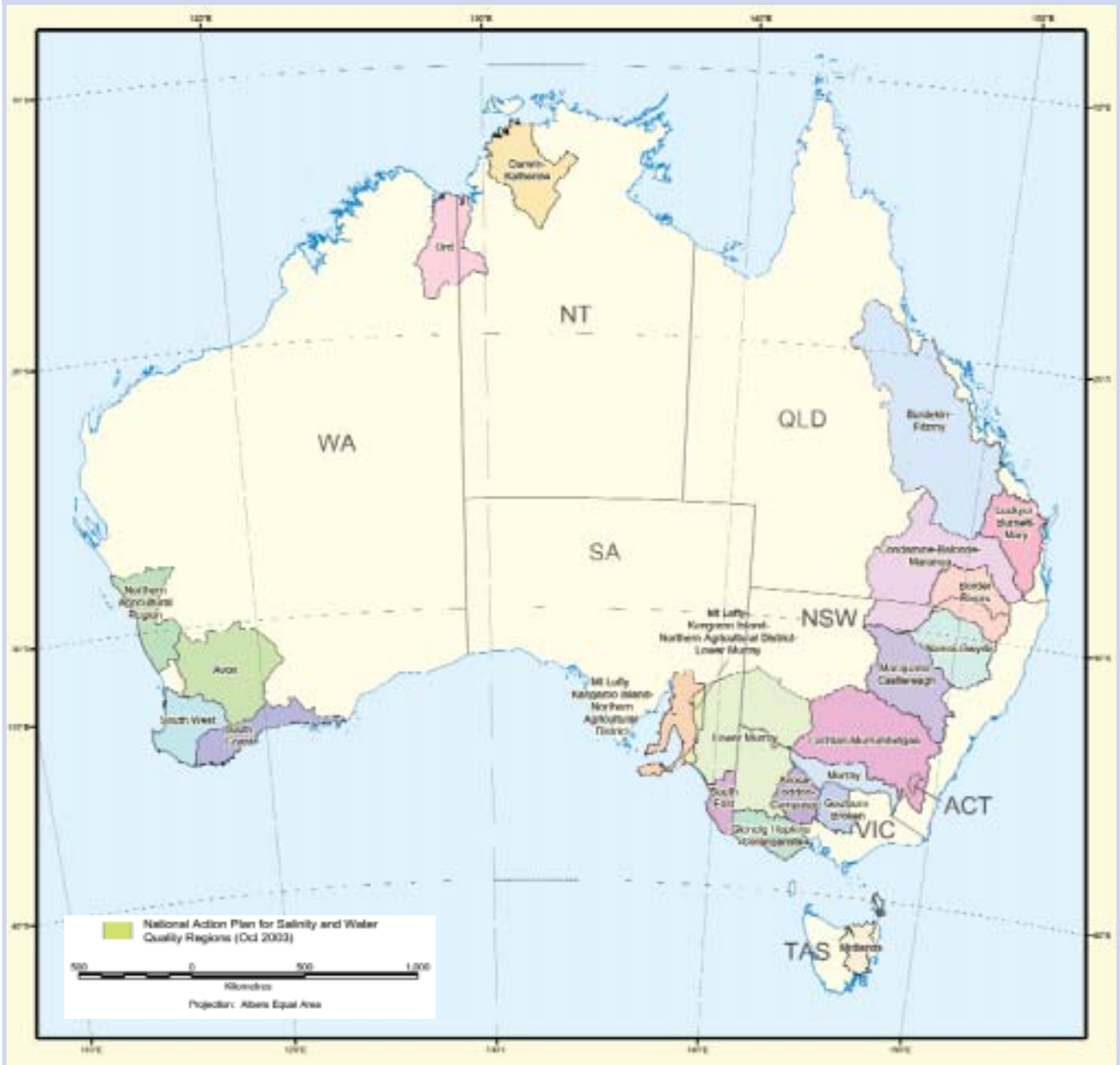
In late 1989, the Australian Government provided a national focus when it announced the *Decade of Landcare.*

Support funding was administered through the *National Landcare Program*. A joint submission by the National Farmer's Federation and the Australian Conservation Foundation was a major contribution to the national *Landcare* initiatives. Compared with the initial agency-led programs, this 'bottom up' approach has been very successful in involving farmers.

Landcare now includes more than 4,000 *Landcare* groups Australia-wide. Forty percent of farmers are members and they are influencing many more. The national body, Landcare Australia, builds partnerships with the corporate sector, conducts awareness-raising activities and administers Australian Government and state grants programs such as the *National Landcare Program*, the *National Action Plan for Salinity and Water Quality*, and the *Natural Heritage Trust*.

Source: Prime Minister's *National Action Plan for Salinity and Water Quality*

FIGURE 3.04 National Action Plan Priority Regions



The N*ational Landcare Program* continues to support the *Landcare* movement. In May 2003, the Australian Government committed a further $AU122 million to the program for the following three years, and agreed to review the program's effectiveness and possible future directions.

Landcare has played a major role in raising awareness of natural resource management issues. It has supported the adoption of changed farming practices such as no till, trash-blanketing and sustainable grazing; has improved the condition of land, water and vegetation on farms Australia-wide; and is a critical building block in catchment planning.

National Action Plan for Salinity and Water Quality

The *National Action Plan for Salinity and Water Quality* (funding $AU1.4 billion over seven years) was endorsed by the Prime Minister, state premiers and chief ministers at the COAG meeting on 3 November 2000. It identifies high-priority, immediate actions to address salinity, particularly dryland salinity, and deteriorating water quality in key catchments and regions across Australia.

Natural Heritage Trust

The plan complements the Australian Government's *Natural Heritage Trust (NHT)* ($AU2.7 billion), which is its chief environmental flagship program. The *NHT* has been successful in raising community awareness about a range of on-ground community action and monitoring programs, including *Landcare*, *Rivercare*, *Bushcare* and *Coastcare*.

New land uses

Australia needs suites of new land uses that are matched to its diverse climate, soils and geology, and which deliver water and nutrient flows below the root zone and across the land surface at rates that mimic pre-development conditions. Radical changes in land use are needed to achieve 'farming without harming':

- Commercial tree production systems and novel tree species are needed for large areas of current crop and pasture zones, including trees to produce nuts, oils, pharmaceuticals, bush foods, speciality timbers, charcoal and biomass. The Rural Industries Research and Development Corporation supports research in agribusiness trade and sustainable farming systems including agroforestry. CSIRO Forestry and Forest Products specialises in developing varieties and systems for profitable plantations in low rainfall areas. Specific breeding lines for radiata pine and software programs for genetic analysis that have been adopted in the USA, Japan, Canada and France
- New forms of cereals, oilseeds, pulses and forages are being selected or bred for characteristics that reduce deep drainage and nitrogen leakage. The Grains Research and Development Corporation, the Cooperative Research Centre for Plant-based Management of Salinity, CSIRO Plant Industry, and South Australian R&D Institute (SARDI), amongst others, are active in this area. Researchers from CSIRO Sustainable Ecosystems (contact: Ted Lefroy) and the University of Western Australia recently received the prestigious Eureka Prize for work on perennial native grasses that will reduce leakage of water into the water table while still providing commercial returns
- New land assessment tools are being used for best location of trees, other perennial plants, high-value annuals and native vegetation to meet water quantity and quality goals, as well as manage biodiversity in the landscape. The *Redesigning Agriculture for Australian Landscapes Program (RAAL)*, a joint initiative of Land & Water Australia and CSIRO, has developed precision farming methods, to 'double the yield in half the area'. (page 121) Mosaics of land use are combined with ecosystem services that are paid for by stakeholders and beneficiaries. This enables enterprises to derive income from a range of traditional world markets for wheat and wool, timber from agroforestry, and environmental credits for carbon, salinity, water supply and biodiversity. This approach is being tried in Western Australia where alley farming of native trees, legumes, cereals and oilseeds is being used, and in the *Heartlands Program* (page 93) in the Murrumbidgee and Murray region of South East Australia

Mount Lofty Ranges in mid summer near Mount Torrens, South Australia. Image courtesy of ©CSIRO Land and Water

Sydney Catchment Authority

Protecting the largest urban water supply in Australia

The Sydney Catchment Authority (SCA) protects over 16,000 square kilometres of catchments and the quality of bulk raw water in 21 dams and reservoirs including Warragamba Dam – the largest urban water supply in Australia. The SCA supplies bulk raw water to Sydney Water and other customers, who then filter, treat and distribute it to four million people in Sydney, Blue Mountains and the Illawarra.

This statutory authority was established in 1999 following a water quality incident in 1998 when high levels of pathogens were reported in Greater Sydney's water supply.

Catchment management

The SCA uses an internationally accepted model to assess pressure on the catchments, identify issues, and implement initiatives such as the *Healthy Catchments Program*. The program allows the SCA to maintain and improve the health of the catchments through grants and incentives. Examples of initiatives include improving the management of dairy effluents, carrying out riparian revegetation, and assisting local councils to upgrade sewerage infrastructure and storm water drains. The SCA, working with Sydney Water, has a 'catchment-to-tap' approach, enabling it to provide a reliable supply of the highest quality bulk raw water.

Water quality risk management

The SCA is currently developing a *Water Quality Risk Management Plan*, which builds on its existing *Pollution Source Risk Management Plan*. The expanded plan will provide the framework for direct funding and resources to protect the water supply from pollutants. This risk-based approach to water quality management is consistent with contemporary water industry practices.

Research

Through collaboration with various universities, the SCA is conducting extensive research which includes:

- Developing a climate-forecasting model that will help detect drought ahead of time and assist the SCA plan its future water management
- Developing models about potential threats from erosion and sedimentation by researching catastrophic events which occurred over the last ten thousand years
- Identifying land practices that may result in high levels of nutrients getting into the water supply
- Estimating the amount and source of pathogens, *Giardia* and *Cryptosporidium*, in the catchments. This will allow the SCA to target problem areas and prioritise rectification plans to protect water quality

Above right: Warragamba Dam and auxiliary spillway

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SYDNEY CATCHMENT AUTHORITY

Innovation 3: Salinity management

As salinity is primarily a groundwater problem, an understanding of groundwater flow systems is essential to assessing the salinity risks in landscapes. The *Groundwater Flow Systems Framework* (Figure 3.05) describes and explains the behaviour of groundwater in response to recharge (water that infiltrates the soil and reaches the groundwater stores). The framework classifies three major types of flow systems – local, intermediate and regional – which respond differently to intervention such as tree planting.

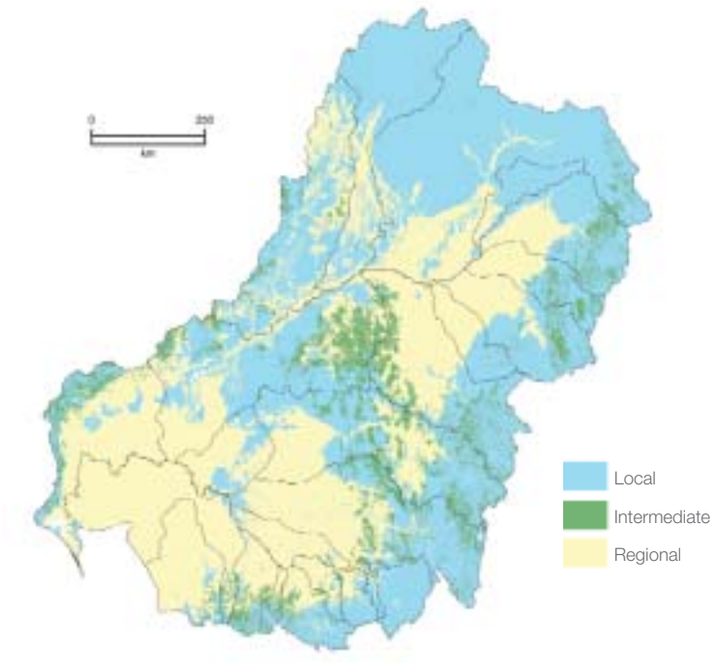
The system allows managers to set priorities for investment in landscape change based on the assets at risk, the time needed for change, and the locations best targeted for remedial action. The framework was developed by scientists from CSIRO Land and Water (Glen Walker, Mat Gilfedder and Mirko Stauffacher with Ray Evans of Salient Solutions Pty Ltd and Phil Dyson of Phil Dyson & Associates), and developed with support of the Murray-Darling Basin Commission and the *National Dryland Salinity Program*.

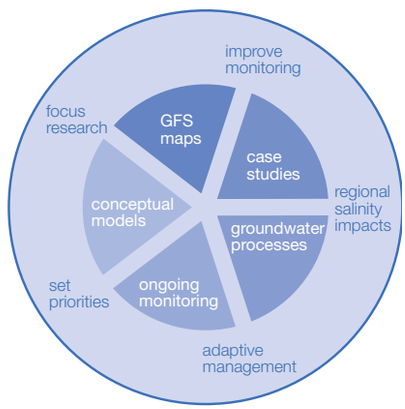
The *Salinity Investment Framework (SIF)* is a new system to help set priorities in investment in salinity repair. SIF identifies natural assets in four main classes – biodiversity, water resources, agricultural land, and rural infrastructure such as towns and roads. It then sets priorities based on three main criteria – the value of the natural asset, the threat to it, and the feasibility of options available to protect it. SIF was initiated by the Western Australia's Salinity Council and is coordinated by Department of Environment (contact: Tim Sparks) for the Natural Resource Management Council of Western Australia.

PRISM, the Practical Index of Salinity Models, is a product of the *National Action Plan for Salinity and Water Quality* and was prepared by consultants

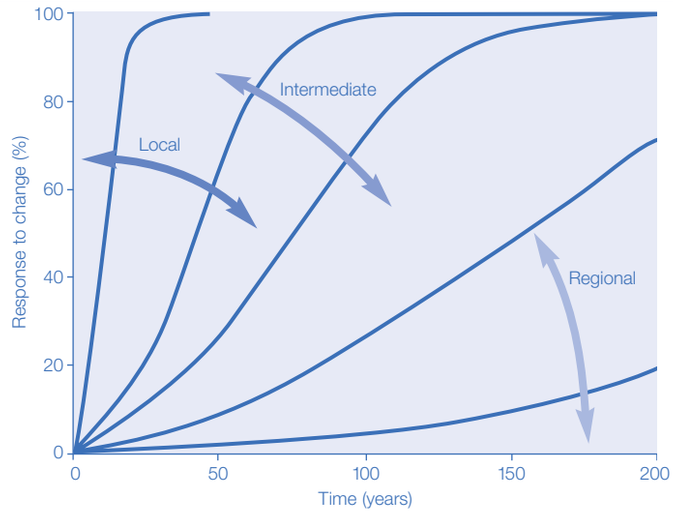
FIGURE 3.05

Groundwater flow systems map for the Murray-Darling Basin





Groundwater flow system framework



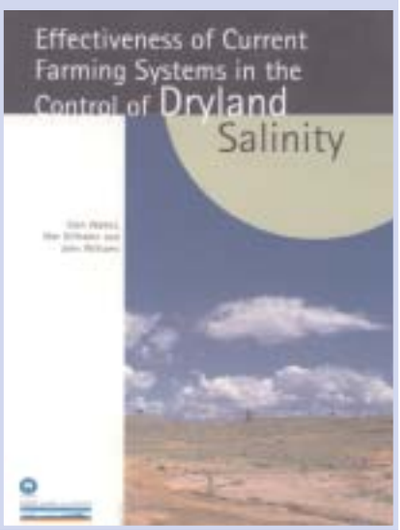
Source NLWRA 2000: Walker *et al*. 2003 and MDBC

URS Australia with support from Australia's *National Dryland Salinity Program* and Land & Water Australia. It is the most comprehensive collection of natural resource salinity and mapping tools available. The CD-ROM contains over 90 tools, models and frameworks.

Airborne geophysics, including magnetics, radiometrics and electromagnetics, have been evaluated for use in salinity management. The *National Airborne Geophysics Project* provides information on the economic benefits of airborne geophysics for salinity management.

The effectiveness of current farming systems in the control of dryland salinity was investigated in a review of different kinds of agriculture – grazing, cropping, native perennial grasses, agroforestry and plantation forestry – for several case studies covering different soils, geology and rainfall (Figure 3.06). APSIM was used to predict the effects of alternative farming systems on leakage of water below the crop root zone and calculate the allowable leakage from a catchment to avoid dryland salinity. Findings contradict the popular belief that plants are able to use large volumes of water from shallow groundwater tables, but conclude that vegetation can intercept water and minimise infiltration into the ground and so can prevent problems from becoming worse.

FIGURE 3.06 • Walker *et al*. 1999



Salt encrustation of fence line near Snowtown in the mid north of South Australia.
Image courtesy of ©CSIRO Land and Water

BOX 3.07

NATIONAL DRYLAND SALINITY PROGRAM

The *National Dryland Salinity Program* is supported by the following organisations: Land & Water Australia; CRC for Plant-based Management of Dryland Salinity; CSIRO; Rural Industries Research and Development Corporation; Meat and Livestock Australia; Grains Research and Development Corporation; Murray-Darling Basin Commission; Australian Wool Innovation Pty Ltd; Australian Government Department of Agriculture Fisheries and Forestry, through the *National Landcare Program*; *National Land & Water Resources Audit* and the State Governments of South Australia, Victoria, Western Australia, Queensland, New South Wales and Tasmania (contact: Land & Water Australia).

The National Dryland Salinity Program sponsors the annual W.E. Wood Award in recognition of outstanding scientific or technical excellence in research. Awards have been made to:

- Dr Ed Barrett-Lennard from the Western Australia Department of Agriculture, for demonstrating that land affected by dryland salinity could often be rehabilitated and used profitably, and for advocacy for the Productive Use and Rehabilitation of Saline Lands Group (PUR$L)
- Dr Glen Walker of CSIRO Land and Water, for work on basic research and modelling of groundwater quality, including FLOWTUBE, and for work on understanding salinity processes in floodplains
- Dr Richard George, Salinity Program Manager with Agriculture Western Australia for expertise in combining vegetation and engineering solutions and for his work on airborne geophysics for salinity mapping
- Dr Tom Hatton, CSIRO Land and Water for research into the use of water by trees at a landscape scale and for developing models to predict the impact of human land uses on whole catchments

Above: Past winners of the National Dryland Salinity Program's W. E. Wood Award for excellence in salinity research (from left) Dr Richard George, Dr Ed Barrett-Lennard and Dr Glen Walker. The annual award recognises a unique contribution to managing salinity over a sustained period of years.
Image courtesy of National Dryland Salinity Program

Innovation 4: Catchment management

Many catchment groups and regions have made excellent progress towards re-shaping agricultural enterprises to match land use capability while retaining profitability.

The winners of the National Thiess River*prize*, presented at the International River*symposium* for 'an outstanding river repair success story' over the last three years are the Goulburn-Broken Catchment, Victoria; the Merri Creek Catchment Management Committee, Victoria; and the Hunter Catchment Management Trust, New South Wales. In 2001 the International Thiess River*prize* for excellence in river management was awarded to the Blackwood Basin Group, Western Australia.

Heartlands

Heartlands (page 93) is an exciting and innovative demonstration of large scale landscape change (coordinator Hamish Cresswell, CSIRO Land and Water).

The Blackwood Basin Group Chairperson Derek Dilkes with the Thiess River*prize* on the banks of the Blackwood River in Bridgetown Western Australia. Image courtesy of The Blackwood Basin Group. Photograph by Rebecca Harnett

Blackwood Basin

The Blackwood Basin Group started life in 1992 as the Blackwood Catchment Coordinating Group following community concern about declining water quality. Its objective was to coordinate the activities of local Landcare groups in order to restore the health of the river.

In 1995, the group acquired $AU2.5 million from the *National Landcare Program* to develop best-practice demonstration sites, provide landowners with grants for restoration activities, and develop a catchment information base. Over 1,600 hectares of remnant vegetation were protected, 1,200 hectares were revegetated and 750 kilometres of fencing was installed to protect sensitive areas. The government grant was particularly successful in stimulating private sector investment – over $AU1.4 million was used to augment the government funds.

The group has been awarded a second *Natural Heritage Trust* grant of $AU5.3 million, most of which will be used to continue the protection and restoration activities. The group's success in energising and coordinating the local community was recognised with the award of the 2001 Thiess International River*prize* at the Brisbane River*festival*.

Torbay

The Torbay Catchment near Albany in Western Australia, supported by Land & Water Australia's River Restoration Program, is a good example of community, whole-of government planning and on-ground action, with scientific support from the University of Western Australia. The status of remnant vegetation, groundwater pollution and remediation, and the dynamics of algal blooms, are features of targeted research and investigations.

A Geographic Information System (GIS) is of great value in assessing the implications of current and future land use planning. The Watershed Torbay project has a dedicated site within the Western Australian Land Information System (WALIS).

Focus catchments

Focus catchments of the CRC for Catchment Hydrology include:

- The Brisbane and Yarra Rivers – to reduce impacts of stormwater on Moreton Bay and Port Phillip Bay respectively
- The Fitzroy River – to manage high sediment and nutrient loads after rapid clearing, and water allocation for maintaining river health (page 99)
- The Goulburn-Broken River – to manage salinity and nutrient loads, afforestation and water allocation under tradeable water rights (page 116)
- The Murrumbidgee River – to manage dryland salinity in the middle reaches and afforestation in the mid and upper catchments

Estuaries and shore-line

The *National Land & Water Resources Audit* describes the threats to many estuarine and near-shore areas. The CRC for Coastal Zone, Estuary and Waterway Management conducts research in this area, including focused research in several estuaries including the Fitzroy River (page 99).

Protecting the Great Barrier Reef is a focus for CSIRO's *Water for a Healthy Country Flagship* (page 39). CSIRO Land and Water studies include the Gippsland Lakes, Port Phillip Bay and other estuaries throughout Australia (page 94).

LAND USE PLANNING – THE HEARTLANDS INITIATIVE

The *Heartlands* initiative aims to improve land use in the Murray-Darling Basin thereby preserving land and water resources and sustaining commodity production.

Integrated land use planning

Research guides on-ground works such as tree planting, protection of remnant vegetation, establishment of perennial pastures and erosion protection. There are project teams working in four different catchments in the Murray-Darling Basin.

Heartlands' outputs include maps to help rank revegetation activities in catchments, for use by catchment management authorities to increase the benefits derived from public investment.

The *Heartlands* land-use planning process recognises multiple objectives in the management of agricultural catchments, including ecosystem function (such as hydrology, nutrient cycling, and maintenance of habitat). This methodology provides an often-missing link between the different research disciplines. It affords a means of improving current catchment planning processes and therefore the effectiveness of investment in natural resource management.

Mosaic farming – a key to future agricultural landscapes

Mosaic farming creates agricultural landscapes comprising patches of annual crops and pastures interspersed with deep-rooted perennial vegetation such as lucerne or trees. Planting of deep-rooted perennial vegetation in carefully targeted locations could provide environmental benefits even though the vegetation may not be economically viable for use on a wider scale. A dryland farm in southern New South Wales has shown variations in paddock yield through several years, which are linked to possible management zones. Crop production in each of the zones was predicted for current and alternative land uses using a simulation model. The model incorporates climate data over several decades, soil properties and crop management practices. A useful feature of the approach is the ability to consider the impact of seasonal variability, which is difficult to assess from just a few years of yield maps.

Good planning, initial investment, early local participation and a sound scientific base are the ingredients that start positive on-ground action.

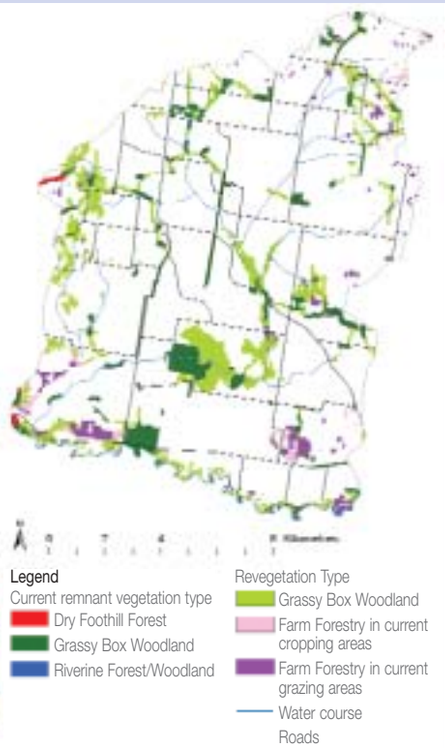
Partners

CSIRO Land and Water, CSIRO Forestry and Forest Products, CSIRO Sustainable Ecosystems; Murray-Darling Basin Commission; New South Wales Department of Infrastructure, Planning and Natural Resources; Victoria Department of Sustainability and Environment; Foundation for Rural and Regional Renewal; *Natural Heritage Trust*; Murray Riverina Farm Forestry; North East Catchment Management Authority; Murray Catchment Management Board; Murrumbidgee Catchment Management Board; Charles Sturt University; Goulburn-Broken Catchment Management Authority;and six Landcare Groups.

Heartlands is developing and applying the knowledge required to target revegetation works for maximum benefit. Image courtesy of MDBC. Photograph by Jiri Lochman

Murrumbidgee River with lucerne and wheat crops near Wagga Wagga, New South Wales. Image courtesy of ©CSIRO Land and Water

Heartlands land use planning photo of forestry mosaic



Example of an integrated land use planning scenario developed through *Heartlands* for Simmons Creek catchment, New South Wales. Image courtesy of ©CSIRO Land and Water and MDBC

BOX 3.09

CSIRO LAND AND WATER: REGIONAL PARTNERSHIPS

The *Lower Burdekin Initiative* is a partnership between CSIRO and some 15 organisations and research institutes, representing government, primary producers, the community and scientists. It provides a framework for coordinating water-related research activities in this major irrigation area. By better understanding the links between on-farm management practices and their impacts on underlying groundwater systems, this venture contributes to improved water management outcomes at both the regional and farm level.

CSIRO has led major collaborative projects aimed at sustainable management of coastal waters and their associated catchments:

- In South Australia, the Adelaide Coastal Waters Study is developing knowledge and tools for sustainable management by identifying causes of ecosystem modifications and the actions required to halt and reverse the degradation
- The *Western Port Bay Study* in Victoria pinpointed the sediment sources as the basis for action plans to improve the health of the Bay
- In Queensland, a study into the delivery of nutrients and sediments by the Fitzroy River has helped regional planners understand potential impacts on the estuarine system and the Great Barrier Reef
- As part of the *Ord-Bonaparte Program*, a 5-year multi-agency R&D program designed to support regional governance in the East Kimberley region in Western Australia, research has identified the role of tides and river flows on primary production in the estuary

Above left: Canola crop during harvest on a farm near Binalong, New South Wales.

Above: Check valve to control the flow of irrigation water to a sugar cane crop at Brandon (near Ayr) in the Burdekin Irrigation Area, South East of Townsville, Queensland.

Below: Aerial view of Euwen's Ponds discharge channel where it enters the Southern Ocean near Mt Gambier, South Australia.

Images courtesy of ©CSIRO Land and Water

Innovation 5: Water reform

Blueprint for a National Water Plan

Water is crucial to Australia's natural and economic wealth. Australians consume more than 24,000 gigalitres of water a year, of which more than 70 percent is used for irrigation. Many of Australia's rivers have highly variable flows. Droughts and floods are common, so Australian pioneers developed major dams for storage and regulation.

In 2003, Australians were confronted with a serious drought. Simultaneously, the need for environmental water to maintain river health was confirmed by the CRC for Freshwater Ecology in a report for the Murray-Darling Basin Commission's *Living Murray* initiative (pages 21-22, 96). Industry groups, such as the irrigation water suppliers, commodity and grower organisations, were also working towards significant change and reform.

The Wentworth Group of concerned scientists published *A Blueprint for a National Water Plan* to inform the national debate on the balance between the needs of consumptive users and the environment. The Group proposed the following three principles for water sharing between consumptive users and the environment to ensure the long-term health of river systems:

- Protect river health and the rights of all Australians to clean water
- Establish a new, nationally consistent water entitlement and trading system that provides security to both water users and the environment
- Engage local communities and ensure a fair transition

COAG developed and agreed on the *National Water Initiative* (page 19-20) which sets the scene for a revolutionary change in water management.

River classification

Preventing environmental damage is much cheaper than remediation. A national program, comparable to the national reserve system, is being developed to classify the rivers and groundwater systems that remain unspoilt and to develop management strategies to protect them.

The Wentworth Group described the benefits of such a program. They include giving future generations the opportunity to enjoy healthy Australian rivers; supporting recreation and tourism; providing a baseline for assessing working rivers with altered flow regimes; and protecting native plants and wildlife that can be reintroduced elsewhere to improve the health of other rivers.

It is proposed that:

- Rivers with less than 5 percent of their water extracted for human use should be classified as Heritage Rivers
- Rivers with 5-15 percent water extracted should be classified as Conservation Rivers
- Rivers with more than 15 percent extraction will require large interventions to restore their ecological health to pristine condition, even if extraction were reduced, but could earn the status of Healthy Working Rivers

Rivers and estuaries of tropical Australia need special consideration because many are important fisheries and are internationally significant for conservation.

Heritage Rivers

Many of the concepts for heritage and wild rivers proposed by the Wentworth Group are built into the reform program for the recently-elected Beattie government in Queensland. Some seventeen wild rivers will come under legislated protection.

Australia's greatest river systems lie in the northern half of the continent and nurture at least 70 percent of Australia's water resources including wetlands, estuaries and coastal ecosystems. Methods to assess and manage rivers of high conservation value are being developed through the National Rivers Consortium of Land & Water Australia.

The Snowy River

The Snowy River is an icon of Australian folklore. Its natural flow south-eastwards to the ocean was diverted inland to the west by the Snowy Mountain Scheme, and its waters used for hydroelectricity and irrigation. The *Snowy Water Inquiry* and other reports led to a Government agreement to restore 21 percent of the Snowy's original flow within ten years – the minimum flow that scientists say is needed to restore the river to a sustainable condition. The first 210 gigalitres of environmental entitlement will be shared – two thirds to the Snowy River and one third to the River Murray. The adjustment will be expensive – estimated to cost $AU600,000 per kilometre of river bank – and indicates the strength of Australian commitment to restoration and conservation.

A working river – the Living Murray

One of the greatest challenges for Australians is to return the River Murray to the status of a healthy working river. Since development of the Murray for water supply in the early 1900s, the amount of water diverted for consumptive use has steadily increased.

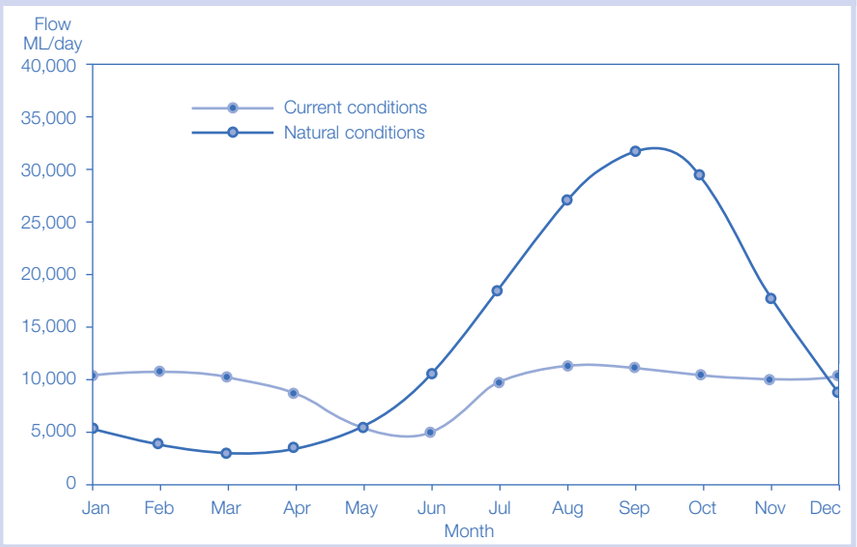
An audit of water use in the Murray-Darling Basin was conducted in 1994 to assess the long-term sustainability of ever-increasing development and water diversion. An interim moratorium on water diversions (the 'Cap') from the rivers of the Murray-Darling Basin was introduced in 1995 in response to findings of the audit. A long-term 'Cap' is now in place to arrest declining sustainability of the water resources and to balance the needs of industry and communities that depend on the rivers of the Basin.

At the time that the audit was being conducted, it became widely acknowledged that the health of the River Murray and its environs had degraded to a precarious state. Of particular concern was the destructive impact that modified flow patterns (Figure 3.10) were having on the riverine environment. Some scientists believe that cold water released into the rivers from the storages, and other non-flow factors are prime causes of stress for native fish and aquatic ecology.

The Murray-Darling Basin Commission responded to these concerns by asking a working group of state representatives to develop a flow management plan for the River Murray that considered the long-term sustainability of the riverine environment and the needs of existing users. Striking a balance between consumptive demand and the demands of the environment would not be a trivial exercise. Only through the cooperative efforts of the states, river operators, water users, the community and environmental groups can a balance be struck to achieve a sustainable River Murray.

Central to restoring river health has been the identification of six significant ecological assets or icon sites (page 22) that are the priority targets for restoration activity, particularly the use of increased environmental flow. The assets are of regional, national and international importance for their ecological values.

FIGURE 3.10 Median monthly flows River Murray downstream of Yarrawonga Weir



In the mid reach of the River Murray current flow conditions are much less than before development (natural) and the spring seasonal increase in flow has been dampened. Source: Interstate Working Group on River Murray Flows.

Water-sharing in New South Wales

Water-sharing plans are a critical component of integrated catchment plans prepared in New South Wales under the *Water Management Act 2000*. Other states have similar arrangements. The water-sharing plans establish:

- Environmental water rules
- Requirements for basic landholder rights
- Requirements for water extraction under access licences
- How much water will be available for extraction by licenced water users

The plans must consider:

- The effect of climatic variability on the availability of water
- Water sharing measures for the protection and enhancement of the quality of water in the catchments and their dependent ecosystems
- Operation of water accounts for the area involving monitoring and reporting requirements for the catchment
- Types of water supply works that could be constructed, such as fish ladders to improve environmental benefits, or that need to be removed, such as redundant weirs

This comprehensive approach to water planning aligns well with the innovative policy work of state and national governments in developing the *COAG Water Reform Framework* and aligns well with the Wentworth Group *Blueprint for Water Reform*.

WATER-SHARING

The Murrumbidgee and irrigation demand

Water sharing in the Murrumbidgee catchment is particularly contentious because the river is highly regulated to provide water for irrigation that underpins regional wealth and employment. Water is also required to maintain the ecological function of the river and its floodplains, to support a Ramsar convention wetland and endangered fisheries, and to provide water for catchments downstream. The issue is not simply one of more water for the environment but of 'anti-drought', with a reversal in the pattern of natural flow. The river flows bank-full in summer to supply the needs of irrigation areas and districts several hundred kilometres downstream.

A hierarchy of rights to water access

The *Murrumbidgee Water Sharing Plan* establishes a hierarchy of rights for access to shares of the available water resource. Environmental water has priority, followed by holders of basic landholder rights, then stock, domestic and utilities, then high security, and lastly, general security licence holders. Native title claims, still to be registered, are part of basic rights. Under the plan town water supply (local water utilities) can be varied every five years to reflect changes in population and associated commercial activities, but water for new industry must be purchased.

The actual volume or share of consumptive water depends on the announced allocation, storage volumes and climatic conditions. Consequently, any reduction in supply, for example as a result of reduction of catchment run-off through afforestation or climate change, is reflected in a reduction of share to general security licence holders, as they have the lowest priority of access.

Environmental flow rules

Environmental water is managed through a series of flow rules which include:

- A minimum low flow from the two major storages
- Dam 'translucency' that returns some of the natural variability in the release pattern to scour build-up of sediment, prevent algal blooms caused by low flow, and restore some of the early spring flows that are important for fish breeding
- An environmental health allowance – a volume of water set aside in storage for opportunistic release for environmental benefit
- Water for 'end-of-system' flow to ensure connection with the River Murray downstream

Novel aspects of the flow rules include:

- The use of the environmental health allowance to raise river height to inundate wetlands, especially in the middle reaches of the river, by supplementing or 'piggy-backing' dam releases onto surge peaks from tributary inflows
- The use of 'provisional storage', a volume of water that is retained in the dam and increases with general security water allocation. This increases the probability of dam spill in winter and spring, and the level of storage at the start of the following year, effectively sharing environmental water in wetter times to reduce the highest year impact on irrigators and improve early season allocation levels

CASE STUDY 3.11 CONTINUED

Market forces and water security

The need for investment security is a strong and consistent message during public consultation. The Wentworth Group have proposed a 'robust separation' of entitlement, allocation and use licence and a nationally consistent approach to trading – potentially a way out for those farmers who are no longer profitable and who wish to cash in licences or consider retirement.

A reduction in run-off is foreshadowed as a result of catchment revegetation and forestry and recent analysis suggests that rainfall variability is increasing in the Murrumbidgee. These factors are foreshadowed in the *National Water Initiative (NWI)* which is explicit about assignment of risks and reductions in future water availability. Water access entitlement holders are expected to bear the risks associated with natural events, such as climate change and drought, whereas governments are to bear the risks for new policy such as increased environmental allocations.

A framework will be established for coping with water interception through changes in land use. The *NWI* also promises to return over-allocated surface and groundwater to environmentally sustainable levels of extraction. In the Murrumbidgee, this will be important in managing the previously unused 'sleeper' and seldom used 'dozer' licences that are likely to be taken up as the value of water increases.

The move to water trading and the recent drought have highlighted the measurement of water-use efficiency in Australia (for example by Aquatec consultants and the Warren Centre, University of Sydney). There is an increasing emphasis on the concept of virtual water (water required to produce a given product) and on valuing water through accounting that includes generation of wealth and measures of human, manufacturing and natural capital.

The Australian Bureau of Statistics (Trewin, 2004) have recently used the System of Integrated Environmental and Economic Accounting to compile one of the few water accounts that exists world-wide.

BOX 3.12

CRC FOR FRESHWATER ECOLOGY: INNOVATIVE APPROACHES IN LARGE-SCALE RIVER MANAGEMENT

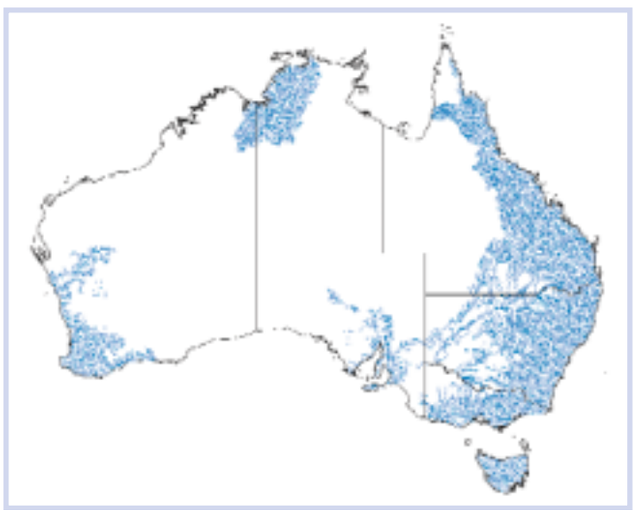
Teamwork and extensive ecological knowledge contributed by river scientists across eastern Australia enable the Cooperative Research Centre for Freshwater Ecology to bring innovation to the large-scale management of rivers.

An international first

An Australia-wide comparison of the condition (or 'health') of rivers and streams was the challenge taken on by the CRC for Freshwater Ecology, with CSIRO Land and Water, for the *National Land & Water Resources Audit*. A team led from the University of Canberra used creative thinking and the experience and data-access that result from cooperative partnerships to achieve an ecology-based assessment of key aspects of river condition in all river reaches in the 3.3 million square kilometres used for intensive agriculture – in a little over one year. The team's approach is an international first, and highly relevant to the many countries of the world that are now focusing on river health.

Guiding the sustainable management of the River Murray

In another first, a team of over 60 scientists led by the CRC for Freshwater Ecology applied a new decision-support tool to predict expected habitat responses by birds, fish and plants to potential 'environmental flow' allocations across the River Murray System in eastern Australia. The Murray-Darling Basin Commission contracted the CRC for Freshwater Ecology to lead a scientific reference panel comprising river ecologists and geomorphologists from six Australian jurisdictions to achieve the objective. The panel used CSIRO-built software, the Murray Flow Assessment Tool, to assess river flows and ecological outcomes to guide the sustainable management of the river. The panel's appreciation of managers' needs resulted in an innovative, thorough and transparent process, interpreting decades worth of scientific data on the Murray.



All rivers (blue) assessed for the first *National Land & Water Resources Audit* by a team from CRC for Freshwater Ecology and CSIRO Land and Water. Image courtesy of the river assessment team.

BOX 3.13

UNIVERSITY OF WESTERN SYDNEY: ECOLOGY OF RIVERS

Historically, a range of animals played a role in the maintenance of wetlands and water quality. For example, thousands of mussels were natural cleaning agents in our waterways, syphoning turbid water in and releasing it as clean water.

Other species that helped to maintain water quality (eg turtles), or those that provided food for others (eg frogs that provide a super-abundance of eggs and tadpoles to be consumed by others) are also in decline. Their demise signals the degradation of waterways, while their loss may increase the rate of degradation of local ecosystems.

Associate Professor Shelley Burgin and her team from the University of Western Sydney, focus on the ecology of waterways. Studies investigate the use of aquatic species (eg macroinvertebrates, turtles, mussels and frogs) as bioindicators of water health. A greater understanding of the ecology of these species will provide the basis for their incorporation into constructed wetlands or degraded water bodies to act as natural cleaning agents and monitors of the ecosystem's health.

Currently the team is surveying the ecology and distribution of mussels so that they can be introduced to constructed wetlands in the Penrith and Hawkesbury local government areas of Sydney to act as natural bioremediators.

Images courtesy of Water Futures Institute, University of Western Sydney.
Photograph by Associate Professor Shelley Burgin

BOX 3.14

CRC FOR COASTAL ZONE, ESTUARY AND WATERWAY MANAGEMENT: FITZROY RIVER STUDY

The Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC) partnered with the Fitzroy Basin Association (FBA) and other stakeholders to understand and mitigate the impacts of variable water flows on coastal areas and communities in central Queensland's Fitzroy River Catchment.

Their aim was to develop solutions for managing variable water flows in Australia's second largest coastal catchment.

Understanding of nutrient dynamics within the Fitzroy estuary has been enhanced through intensive monitoring and the development of water quality models. Research on water quality, complemented with studies on water flows, has shown that the estuary requires large floods in summer to maintain stocks of aquatic species such as barramundi and prawns.

This information, combined with that published in a *Central Queensland Information Paper*, was used by the FBA to prepare regional resource targets in a strategy for sustainability. It has also been reported in a *Healthy Waterways* community awareness campaign driven by the Coastal CRC. The campaign's success was demonstrated by a survey showing most residents valued waterways and catchments very highly.

A remotely sensed imaged of the Fitzroy River entering the Great Barrier Reef region.
Image courtesy of CRC for Coastal Zone, Estuary and Waterway Management

Innovation 6: Ways of sharing the cost

Catchment care principle

Australia faces major challenges in making the transition to sustainable natural resource management. Many regions need significant changes in land use and new income strategies that support social and environmental sustainability. Unfortunately, progress has been blocked by disagreement over who should bear the cost.

CSIRO economist, Steve Hatfield Dodds, has proposed a possible solution (Figure 3.15) that moves beyond the conflicting approaches of 'beneficiary pays' and 'polluter pays' to a burden-sharing approach. The catchment care principle combines disincentives, cost sharing by landowners, transitional assistance for mandatory public-good conservation, and incentives for voluntary conservation, resulting in higher overall environmental standards than could be achieved by land-holder cost-sharing alone.

Ecosystem services and stewardship

Currently in Australia, 'ecosystem services' (such as the production of clean water, sequestration of carbon dioxide, and production of oxygen) are not valued, let alone paid for. The challenge is to define ecosystem services that could be paid for by stakeholders and beneficiaries, both private and public.

The approach has developed rapidly in Australia. In Victoria, the *Rural Land Stewardship Program* is led by the Victoria Department of Sustainability and Environment and the Victorian Catchment Management Council and funded by the *National Action Plan for Salinity and Water Quality*. The project is exploring ways of managing private rural land in Victoria by rewarding landholders for providing ecosystem services.

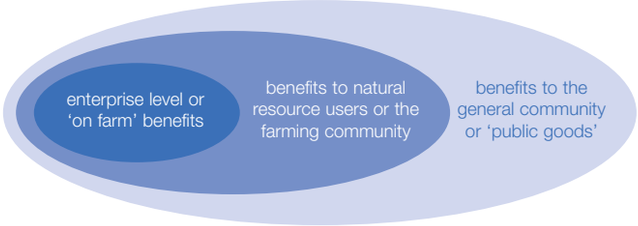
The *Rural Land Stewardship Program* is an innovative approach aimed at bringing about sustainable agricultural activity, increasing environmental outcomes and invigorating rural communities. Images courtesy of Victoria Department of Sustainability and Environment

FIGURE 3.15 Catchment care principle

The catchment care principle (diagram below) focuses on the shared interest of the users of renewable natural resources in the maintenance of ecosystem integrity. This approach improves investment security for landholders by:

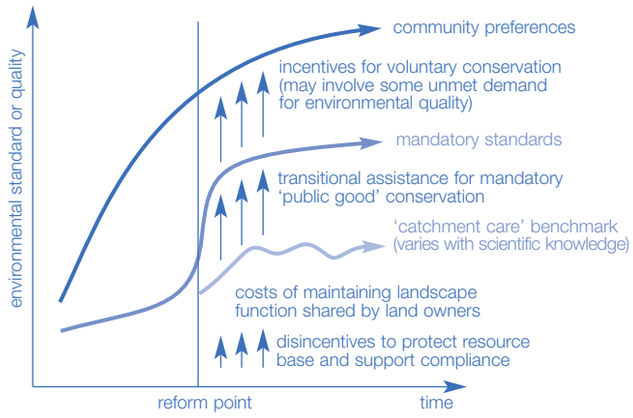
- Separating their personal responsibilities from changes in community attitudes
- Preventing one farmer's actions from undermining the overall value of the natural resource base

Classifying the potential incidence of benefits from resource management policies



The principle was a critical part of the Wentworth Group's model for vegetation management in New South Wales, which resulted in the protection of all remnant native vegetation and selected regrowth.

Cost sharing and transitional assistance under the Catchment Care Principle



Source: Steve Hatfield Dodds (2003)

BOX 3.16

CSIRO LAND AND WATER

Providing innovative tools to support resource management decisions

As regional communities and catchment managers around Australia decide how to meet water quality and other environmental targets, CSIRO Land and Water is contributing vital expertise, and a range of predictive models and Decision Support Systems to guide decision making and investment. These toolkits enable regions to evaluate land-use options, assess water allocation strategies and tradeoffs, identify ecosystems at risk and set targets for water quality.

Burdekin River south of Townsville in far north Queensland.
Image courtesy ©CSIRO Land and Water

- The SedNet (Sediment Network) suite of computer programs was developed by CSIRO, with support from the *National Land & Water Resources Audit (NLWRA)*, to help assess the movement of sediment and nutrients across Australia. In a joint industry and government initiative in the 130,000 square kilometre Burdekin Catchment in Queensland, SedNet has been used to identify and target erosion hotspots, and predict the impacts of different management strategies
- The Murray Flow Assessment Tool (MFAT) was built by CSIRO, with inputs from a broad network of Australian aquatic ecologists, to provide a Decision-Support System for evaluating the potential ecological benefits and impacts of different environmental flow scenarios for the River Murray System. MFAT is being used in the Murray-Darling Basin Commission's *Living Murray* initiative
- A new risk assessment tool – the *Groundwater Flow Systems (GFS) Framework* – has provided a breakthrough for salinity science and management. By better predicting the behaviour of groundwater in response to recharge, resource managers working at local and regional scales now have a means for achieving a consistent approach to managing and preventing salinity. The GFS was developed with collaboration and support from a host of agencies, including Geosciences Australia, the Murray-Darling Basin Commission, the *National Dryland Salinity Program* and the *National Land & Water Resources Audit*

TABLE 3.17 • Consultants

Agricultural Business Research Institute	University of New England. Livestock and international consultants
Australian Association of Agricultural Consultants	A membership register assists clients in choosing a consultant most appropriate to their needs
Birchip Cropping Group	Membership of 500 farmers across four states
FarmStar	Comprehensive precision farming software
FM 500	Aims to create a global network of farmers using the Internet to access quality information
FSA Consulting	Agricultural, environmental and engineering services
Jonathon Sobels & Co	Precision farming with satellite imagery
Kondinin Group	Publisher of *Farming Ahead*
Otto Agribusiness	Whole-farm planning, risk management and advice through the Farm Help Program
Planfarm	Farm management and agronomy in Western Australia
Rinex Technology	Specialists in precision farming and global positioning applications
Scholefield Robinson Horticultural Services Pty Ltd	Viticulture, horticulture and agribusiness
Smart Viticulture	Viticulture
SST Australia	Precision farming. Joint venture with SST Development Group Oklahoma USA
University of Sydney	The Australian Centre for Precision Agriculture
Wesfarmers Landmark	Leading suppliers of agronomic products and services operating from more than 400 outlets

Market-based instruments and investment leverage

In recent years, the Australian Government has encouraged the development of markets that demand goods be produced in environmentally benign ways and has invested in a range of pilot programs (Table 3.18).

The urgent need for funds for repairing landscapes has brought together industry and the environmental movement to find the optimum mix of public investment and market-driven approaches.

The Allen Consulting Group identified strategies to release nearly $AU13 billion over ten years from the private sector. The recommended package includes improved access to private capital through tax-preferred statutory investment vehicles, a land repair fund to administer a range of programs and tax concessions, and accreditation for plans to ensure coincidence with national priorities. The group was commissioned by the Business Leaders Round Table and included Southcorp, Elders Ltd, Berri Ltd, ABN AMRO, Macquarie Bank, the Australian Conservation Foundation and CSIRO.

In another approach, Greening Australia and CSIRO are piloting an investment fund or 'green bank' with a mix of public and private capital. The fund brokers invest in enterprises that provide an environmental dividend to public and altruistic investors.

Table 3.18 Use of market-based instruments

Project	Lead Organisation	National Action Plan Region (page 87)
Using an auction approach to valuing intervention in the landscape (including salinity, water quality, water quantity and biodiversity)	Department of Primary Industries, Victoria	Goulburn-Broken, Victoria
Tradeable net recharge contracts in Coleambally Irrigation Area	CSIRO Sustainable Ecosystems and CSIRO Land and Water	Lachlan-Murrumbidgee, New South Wales
Farming finance: creating positive land-use change with a natural resource management leverage fund	Greening Australia	Lachlan-Murrumbidgee, New South Wales/ South Coast, Western Australia
Auction for landscape recovery (south-west Australia)	WWF (formerly World Wildlife Fund) Australia	Avon, Western Australia
Adoption of new land management practices through conservation insurance	South Australia Department of Water, Land, and Biodiversity Conservation	Lower Murray, South Australia
Cap and trade for salinity: property rights and private abatement activities, a laboratory experiment market	Victoria Department of Primary Industries	Lower Murray, Victoria/South Australia Mount Lofty, Kangaroo Island
Catchment care: developing an auction process for biodiversity gains and water quality outcomes	Onkaparinga Catchment Water Management Board	South Australia Nmoi-Gwydir/Macquarie-
Green offsets for sustainable regional development	New South Wales Environment Protection Authority	Castlereagh/Murray, New South Wales Burdekin-Fitzroy, Queensland
Establishing east-west landscape corridors in the southern desert uplands	Desert Uplands Build-up and Development Committee	Burdekin-Fitzroy, Queensland
Establishing the potential for offset trading in the lower Fitzroy River	Central Queensland University	

Source: DEH/DAFF September 2003

Innovation 7: Aids for better decision making

A range of technologies, models and Decision Support Systems underpin better decision making and investment.

Weather forecasting

Agricultural practice and planning depends on the weather. The Australian Bureau of Meteorology (page 62) provides weather forecasting, short and long-term predictions, warnings of storms and drought, and information tailored to specific regions.

Predictive models and Decision Support Systems

A range of software packages has been developed, most of which are publicly available. They are used by a range of consultants and agronomists. Examples include the Catchment Modelling TOOLKIT from the CRC for Catchment Hydrology, the Environmental Management Support System (EMSS) used successfully in South East Queensland to optimise land-use planning, and the Agricultural Production Systems Simulator (APSIM) and Pesticide Impact Rating Index (PIRI) from CSIRO.

PIRI assesses the risk of water pollution from run-off, spray drift or leaching and has been used by several Australian agencies, including the South Australia Department of Water, Land and Biodiversity Conservation, the Goulburn Murray Rural Water Authority and

Forestry SA. Overseas it has been used by ACIAR in partnership with the University of the Philippines and in Ecuador by the *IAEA/FAO Pesticide Program*.

Several other useful Decision Support Tools are described by CSIRO (page 101). SedNet has been used in several catchments including the Burdekin and the Murrumbidgee to target 'hotspots' for erosion control and to optimise investments when establishing riparian vegetation for intercepting eroded sediments and associated nutrients.

Tracer methods

Fallout radionuclides (Caesium 137 and Lead 210) are used to determine the origin of sediments in streams. The radionuclides are concentrated in the soil surface so that sediments derived from surface soil through sheet and rill erosion have high concentrations of nuclides, while sediments from gullies, channels and riverbanks contain low concentrations. These techniques can aid the management of catchment remediation by revealing the source of the sediments. For example, in a recent study on the Wingecarribee sub-catchment for the Sydney Catchment Authority (SCA) it was found that gully and stream erosion dominated, rather than surface run-off. The study of contaminant budgets was coordinated by ECOWISE Environmental using a multi-disciplinary team from CSIRO Land and Water (contact: Jon Olley), The Australian National University and SCA (page 89).

The CSIRO Land and Water Isotope Analysis Service (contact: Fred Leaney) provides stable isotope analysis and hydrological expertise to track surface water and rainfall retention times in catchments. Chlorfluorocarbons have only been in the atmosphere for the past fifty years, so their presence in groundwater reflects recent recharge from rainfall. Uranium decay isotopes can be used to identify groundwater entry into streams.

Tracer isotopes have been used by Ann Henderson-Sellers of the Australian Nuclear and Science Technology Organisation (ANSTO) to track the effects of deforestation and climate change on water resources.

Mapping technologies

Environmental remote sensing expertise available in CSIRO Land and Water enables high resolution mapping of sensitive coastal ecosystems, such as forest and crop condition, using satellite and airborne systems.

The Australian Government Office of Spatial Data Management, located in Geoscience Australia, supports the growth of a private sector spatial information industry and facilitates community access to spatial data.

Late afternoon. River Murray at Renmark, South Australia. Image courtesy of ©CSIRO Land and Water

Summary

Australian rivers and landscapes face a slowly emerging crisis – but crisis also spells opportunity, resilience and imaginative solutions. In barely twenty years one third of human kind will face severe water shortages through soil erosion, salinisation and pollution of rivers and groundwater. Food production and freshwater and estuarine fisheries, which provide much-needed protein, are also at risk. Australians are developing solutions to these complex matters and are keen to share their experience internationally. Shared solutions can alleviate poverty and contribute to a peaceful and secure future.