Stakeholders’ perspectives on Australia’s land and water resources research needs

CSIRO Land and Water Report 55/07
August 2007
Foreword

The mission of CSIRO Land and Water is ‘to undertake world-class research and technology diffusion that positions Australia as the acknowledged leader in land and water resources management’.

To achieve our mission, we must conduct science that stands out from the crowd, ensure that we have a tangible ‘offer’ for land and water managers, create sophisticated adoption pathways to ensure uptake by end-users, and to work with them to maximise the impact from our R&D. Clearly, understanding what our end-users need from R&D is a critical first step towards achieving these goals.

This document reports on a major consultation exercise that CSIRO undertook with its key land and water sector clients, collaborators and stakeholders. Over 170 people from more than 100 organisations were consulted to ascertain what they thought CSIRO should be working on in the land and water domain. This process resulted in a very rich set of perspectives that highlight stakeholder priorities for R&D in the land and water domain. We note that this study has been conducted at a time of significant land and water reform, exemplified by the National Water Initiative and the National Plan for Water Security.

Although this study was conducted for CSIRO’s internal planning purposes, we saw merit in publishing the findings so that we could share the wisdom of our clients, collaborators and stakeholders with the broader land and water sector. We are strongly of the view that the entire R&D sector will benefit by understanding the rapidly changing needs of land and water managers.

The senior leadership teams of CSIRO Land and Water and the Water for a Healthy Country Flagship will use this report to inform CSIRO’s research planning in the land and water domain. I thank Dr Michele Barson (seconded to CSIRO from the Bureau of Rural Sciences) for leading this study and the many interviewees who gave their time and wisdom so generously.

Further information on CSIRO’s R&D effort in the land and water domain can be obtained by contacting Mr Scott Keyworth Scott.Keyworth@csiro.au or Prof Jon Olley jon.olley@csiro.au.

Dr Neil McKenzie
Acting Chief
CSIRO Land and Water
August 2007
## Table of Contents

Foreword..........................................................................................................1  
Table of Contents.............................................................................................3  
Executive Summary.........................................................................................5  
Introduction ......................................................................................................7  
Methods ...........................................................................................................7  
Research needs identified ...............................................................................8  
  - Water quantity, yield and availability ............................................................8  
  - Managing surface and groundwater resources.........................................8  
  - The impact of climate change and climate variability on water availability9  
  - Understanding climate change risk...........................................................9  
  - Urban impacts............................................................................................10  
  - Climate change and agriculture ..............................................................10  
  - Climate change and environmental water provision ...............................10  
  - The effect of changes in land use on water yields ....................................11  
  - Managing water quality ...........................................................................12  
  - Agricultural chemicals.............................................................................12  
  - Nutrients and sediments .........................................................................12  
  - Salinity ....................................................................................................12  
  - Acidification.............................................................................................13  
  - Ground and surface water contamination and remediation ....................13  
  - Water supply quality issues ....................................................................14  
  - Managing Australia’s aquatic environments ...............................................14  
    - Quantifying the benefits of management changes..................................15  
    - Rivers ..................................................................................................15  
    - Estuaries and the near shore coastal zone.............................................15  
    - Wetlands ...............................................................................................16  
    - Groundwater dependent ecosystems .....................................................16  
  - Managing Australia’s soil and land assets..................................................16  
    - Improving the management of agricultural soils....................................17  
    - Managing land use change...................................................................17  
    - Ecosystem services ................................................................................18  
    - Land condition monitoring and assessment .........................................18  
  - Managing resources – social, economic and institutional challenges........19  
    - Engaging stakeholders and the community ..........................................20  
    - Methods to facilitate trade off decision making ......................................20  
    - Demographic change, water trading and structural adjustment ..........20  
    - Research for learning and communication ..........................................21  
    - Overcoming institutional barriers to change .........................................21  
    - Economic analysis and new management instruments ..........................22  
  - Water use...................................................................................................23  
    - Irrigated agriculture..............................................................................23  
    - Mining ..................................................................................................23  
    - Urban ....................................................................................................24  
    - Assessing alternative sources of water..................................................24  
    - Water sensitive urban design..................................................................24  
    - Asset management and maintenance ....................................................24  
    - Biosecurity and biovulnerability of urban supplies ...............................25
Executive Summary

- CSIRO land and water sector clients, collaborators and stakeholders were invited to outline their anticipated land and water resource research needs for the next five years. They were also asked to nominate the areas of research they thought would have the greatest impact nationally on land and water resources management.

- One hundred and seventy people from 100 organisations were interviewed, another 10 completed an online questionnaire. The interviews took place during a severe drought when there was a high level of concern about water scarcity. Thirty-six issues needing research were identified and analysed to establish their relative importance to: Australian and State government agencies, research and development corporations, regional organisations, universities and cooperative research centres, and the private sector.

- The following were nominated by more than 20 percent of respondents across all sectors:
  - managing surface and groundwater resources
  - the impact of climate change and climate variability on water availability
  - improving the management of agricultural soils
  - managing land use change
  - land condition monitoring and assessment
  - engaging stakeholders and the community
  - demographic change, water trading and structural adjustment
  - water use in irrigated agriculture
  - assessing alternative sources of water
  - new sensors to improve water and wastewater management.

- Research nominated as most likely to have a national impact includes managing surface and groundwater resources, the impact of climate change and variability on water availability, engaging stakeholders and the community, water use in irrigation, assessing alternative sources of urban water and new sensors and research which provides regional organisations with an improved understanding of landscape function as a basis for investing in integrated outcomes. There was a high level of congruence between the issues important to more than 20 percent of respondents and those most likely to have a national impact. CSIRO has identified some applied and basic research needs for these issues.

- Issues of particular concern to regional natural resources management groups interviewed include the impact of climate change on water availability, estuarine management and engaging stakeholders and the community. They noted the need for tools to prioritise their management actions and to relate on-ground actions to matters for target.
• About one third of interviewees identified the need for research to demonstrate that changes individuals and communities are asked to make in their resource use or management practices deliver the desired biophysical, social and economic outcomes. Relatively little research has been done into these issues although the continued funding of natural resources management programs depends on demonstrating real returns in these investments.

• A quarter of interviewees identified research needs for one or more soil or land issues. Some subsequently suggested that the report over emphasises water research needs at the expense of soil and land management issues. The interviewees’ focus on water issues may be attributed to concerns about water scarcity as well as their professional responsibilities. Land resources provide important services and need to be valued as infrastructure for the purposes of investment and management; an appreciation of this issue is developing.

• Some interviewees found it difficult to prioritise research needs across fields as broad as land and water. Some issues identified require resource assessment rather than or in addition to research, in some cases the research may have been done but not widely adopted.

• It is recommended that reviews which synthesise current understanding of major land and water issues be prepared and clients’, collaborators’ and stakeholders’ needs be analysed in the context of these reviews to identify researchable topics. This assessment will also need to consider the adoption of the potential research findings.

• A number of interviewees noted that a systems approach which brings together information from a range of biophysical disciplines, social sciences and economics is needed to develop an integrated understanding of the systems being managed, including the interactions between parts of these systems. CSIRO was seen as an organisation well placed to develop an integrated systems approach.

• Comparison of this study with the Australian Water Research Advisory Council’s 1988 national priorities suggests that progress has been limited on some issues. Those more recently identified and reported in this study as needing research include acidification of ground and surface waters, ecosystem services, groundwater dependent ecosystems, water sensitive urban design, the biosecurity of water supplies, new sensors, and mining industry water use efficiency.

• Participants made valuable suggestions for improving the land and water innovation system, including for communication and adoption of research. They also identified concerns about current and future science capabilities in land and water research, and suggested that a more coordinated approach to the research needed for land and water resources management be considered.
Introduction

CSIRO’s land and water sector undertakes research in a diverse range of fields, including hydrology, hydrogeology, aquatic ecology, water quality, soil and land resource management, agricultural, urban and industrial water use and the economic, social and institutional issues associated with land and water management. Much of this research is undertaken by the Division of Land and Water, increasingly delivered through the Water for a Healthy Country Flagship. Other Divisions within CSIRO, including Entomology, ENSIS, Exploration and Mining, Information and Communication Technologies, Livestock Industries, Marine and Atmospheric Research, Manufacturing and Materials Technology, Mathematical and Information Sciences, Molecular Health and Technologies, Plant Industry and Sustainable Ecosystems also contribute to CSIRO’s land and water research effort.

In 2006-07 approximately $ 59.98 m of appropriation funding was invested in land and water research through the Division of Land and Water and the Water for a Healthy Country Flagship. Clients and collaborators invested an additional $ 31.53 m in this work. Our clients are in the water industry, including irrigation, environmental, industrial, mining and urban organisations; the natural resources management sector and in the mining, manufacturing and processing industries that are concerned with environmental management. Most of our work is performed in partnership with co investors, including the rural research and development corporations, Australian and State government agencies, regional natural resources management groups, international organisations and collaborators in universities and Cooperative Research Centres. International work accounts for about 10 percent (by value) of our contracts, with major clients and co investors including the Australian Centre for International Agricultural Research, the American Water Works Association Research Foundation and mining and petroleum industry groups.

This study was undertaken to develop a comprehensive understanding of clients’, collaborators’ and stakeholders’ anticipated land and water research needs over the next five years. The results of this work will inform the development of priorities for CSIRO’s science investment process for land and water research, and provide a basis for planning and developing the scientific capabilities needed for future work.

Methods

Clients and collaborators who had co invested or participated in research undertaken by CSIRO Land and Water over the last 3 years, together with a number of research and industry leaders and stakeholder organisations, were invited to contribute to this review. Eighty three interviews were conducted over the period 9 August – 30 November 2006 with individuals and groups (see list in Appendix 1a). One hundred and seventy people from 100 organisations participated in the interviews. The semi structured interviews (Aslin and Brown 2004) of 1 - 2 hours duration were conducted by senior staff from CSIRO Land and Water and the Water for a Healthy Country Flagship.
The views of a further group (Appendix 1b) were sought through an online questionnaire (Appendix 2).

A draft of the report was provided to interviewees and questionnaire respondents who were invited to comment and to nominate 3 areas where they thought research could have the biggest impact at a national level, for example because of the cost of the problem, the hectares of land affected or the production implications of an issue. The research needs identified by interviewees and their comments on the potential impact of research were collated to prepare this report. The results of this analysis will be used to develop priorities for CSIRO’s land and water research effort for further discussion and refinement with clients and collaborators.

Research needs identified

The following pages summarise the issues raised in interviews and by questionnaire respondents. Table 1 (pages 43 - 45) summarises the relative importance (number of times the issues were identified) of these issues to client, collaborator and stakeholder interviewees from the following: Australian government agencies, State government agencies, Cooperative Research centres, Research and Development Corporations, regional organisations, Universities, and the private sector. Issues mentioned by more than a fifth of those interviewed are highlighted in the text.

Water quantity, yield and availability

Water scarcity, the current drought, the potential impact of climate change, concerns about over allocation of water resources and the increasing demand for water have raised awareness of the need for a better understanding of the available resources from all sources. Several interviewees noted the need to keep a watching brief on cloud seeding research.

Managing surface and groundwater resources

About one third of the organisations and individuals interviewed (see Table 1) noted the need for better data on the extent of groundwater resources and their connection to surface waters to improve resource management. They identified the need for research to provide improved techniques for quantifying and monitoring groundwater resources, particularly operational techniques for determining sustainable yields. They noted that this information is needed to help reduce uncertainties in the accounting, allocation and management of water resources. An improved capacity to model catchment water balances which accounts for the connections between ground and surface waters is also required.

Several interviewees noted that better information on the size of groundwater resources and their sustainable yields is necessary to identify opportunities for groundwater as an additional source for urban environments in South East Queensland and Western Australia. In South Australia and Western Australia
State agencies noted the need for better information about groundwater resources to facilitate the planning and management of water resources for anticipated resource industry expansion.

Tasmanian interviewees identified the need for better data to support the regulation of groundwater use in their State. The lack of surface and groundwater information for Northern Australia was noted by several Australian government agencies, an agency from the Northern Territory and some individuals interviewed; they suggested that research is needed to provide a better understanding of the functioning of these systems. One interviewee was concerned about drawdown in the Great Artesian Basin, whilst another identified the need to establish acceptable rates of exploitation for these fossil waters.

Groundwater mining was suggested by one interviewee as an option for short-term drought relief, who noted that this will require a better knowledge of groundwater recharge mechanisms and how to manage intake areas for recovery.

Several interviewees noted that integrated groundwater - surface water management systems will need to take into account both volume and quality, and a capacity to predict the movement of salt by groundwater will be required. Irrigation industry groups suggested that benchmarking of groundwater quality in agricultural areas, including nutrient content is needed so that the impact of management practices on quality can be quantified and understood. Mining industry interviewees noted that a better understanding of the effect of groundwater movements and groundwater surface water interactions on the movement and fate of point source contaminants at key localities will be needed to reduce the risk of pollution. Several agencies also suggested that some research is needed to understand the role of groundwater as a source of contaminants to surface waters.

The impact of climate change and climate variability on water availability

Understanding climate change risk

Climate change was identified by almost half of those interviewed (Table 1) as a key driver likely to affect water resource availability for many regions in Australia, and to complicate water allocation decision making. They emphasised the need to ensure that climate change risks are factored into planning and management decisions, including water sharing plans.

Many interviewees noted that the information currently available on the impacts of climate change at regional and local levels is generally inadequate for planning and management purposes and to prepare for adaptation. Research issues identified include the need to characterise the likely extremes of precipitation and temperature and their effect on run off and resource availability, a better understanding of the likely rates of change in climate and of the risks and uncertainties associated with climate change. The
need to communicate these uncertainties for planners, managers and users was emphasised.

Several interviewees mentioned the need for research to support contingency planning for worst case scenarios to deal with current concerns about water scarcity due to drought and longer term water resource availability due to climate change.

Urban impacts

Key areas of research needed by urban water managers included climate change related impacts on the total water cycle, including precipitation, storm events and stormwater, and sewage as a basis for future planning and analysing supply security issues. Climate change is viewed as a key issue, with the rate and extent of likely changes affecting how quickly research into strategies for managing water and wastewater systems under conditions of changed water availability will need to be developed. A better understanding of the likely impact of climate changes on demand is also needed. There is also a need to know what the impact of reduced water availability might be on urban water and wastewater infrastructure and the associated costs of managing potential problems.

Climate change and agriculture

More research is needed into the impacts of climate change on agriculture, especially the availability of water for irrigation and how to increase water use efficiency whilst maintaining productivity in both irrigated and dry land agriculture. Government agencies and industry groups are also interested in the potential for climate change scenario analyses and decision support tools to help identify the nature and significance of impacts on agricultural industries, for weighing up options for dealing with the likely changes and to identify opportunities for industry relocation. Development of improved seasonal forecasting tools for the cropping and grazing industries is needed to help farmers manage for climate variability. Better information for farmers on how to deal with climate change at the farm level is also needed; concern was expressed that understanding of the likely impacts of climate change and the risk to business is uneven across agricultural industries.

Climate change and environmental water provision

A better understanding of the implications of climate change for environmental water allocations is needed. Uncertainties in the level of water resources available are expected to complicate environmental flow decisions. Under these conditions what environmental values will communities want to see maintained? Can these values be maintained by using recycled water for environmental allocations? A capacity to model the consequences of lower rainfall, changes in water tables and surface water availability on biodiversity is important for planning purposes, particularly in relation to managing water dependent ecosystems and areas susceptible to acid soils.
Research is needed to understand the impacts of climate change on users’ entitlements and to develop methods to explicitly manage the trade offs needed to optimise water availability and security whilst delivering environmental allocations. Adaptive management approaches were seen as critical to the development of responses to climate change.

The need to understand the likely changes to water availability for the mining industry due to climate change was also identified.

**The effect of changes in land use on water yields**

The National Water Initiative (Council of Australian Governments 2004) identifies the potential that some land use change activities have to intersect significant volumes of surface and/or groundwater water. Parties to the Initiative have agreed to protect the integrity of water access entitlements from unregulated growth in interception through land use change. Implementation of measures to manage significant water interceptions will require an improved capacity for quantifying the impact of these activities on water yield. Some interviewees noted that this issue was likely to become particularly contentious.

Australian, State government agency and a number of industry interviewees noted the need to develop methods for quantifying the impact of changes in climate, land use (including rural residential developments) and vegetation cover (including fire related changes), and farm dams on interception and subsequent quantity, quality and timing of flows of water in catchments. This information will help to assess the risks of various interception factors to water entitlements and have them included in water sharing plans. It was also noted that existing information on interception impacts need to be factored into current water planning.

Quantifying the role of plantations in intercepting water was of particular concern, especially a better understanding of their impact on yield at catchment scale and the effects of different designs and placements, rotations and management practices on water quantity, quality and the timing of flows. This information will be an important input to processes to determine the trade offs between water for maintenance of vegetation for biodiversity, plantations for wood production, biofuels or carbon, and the availability of flows for other uses including salinity management.

Several Western Australian interviewees noted that research into methods for formulating allocations for users of water intercepted for plantations and farm dams will be needed.

Some interest was also expressed in the development of methods for enhancing runoff to increase water yields.
Managing water quality

Land and water resource contaminants that concerned interviewees included some pesticides and herbicides, fertilisers, sediment, acid drainage waters and wastes produced in mining processes and in the Northern Territory, high levels of naturally occurring nitrates and arsenic. One agency noted the need for research into the most effective methods for incorporating water quality issues into water entitlements.

Agricultural chemicals

Agricultural industry organisations generally did not identify water quality issues as a high priority for research. However, a number of interviewees, including some from this sector, noted the need for research to reduce the risk of contamination of surface and groundwater by agricultural chemicals. Benchmarking of levels of key contaminants in soils and water is needed, including an assessment of the relative contributions from different industries, as is a better understanding of the impact of management on changes in surface and groundwater quality. Improved pesticide spraying equipment is needed to help minimise spray drift. One State agriculture agency suggested that improved understanding of the fate of pesticides in the root zone of plants may lead to a reduction in pesticide inputs.

Nutrients and sediments

Nutrient losses from farms to surface and ground waters, particularly in drainage water, were identified as a concern by irrigation and grains industry groups who are looking for management practices to minimise these losses and improve the efficiency of fertiliser use. The dairy industry identified the need for further research to improve tools which can quantify nutrient sources, flows, amounts and impacts for nutrient loads from paddocks. The aim is to improve nutrient management and reduce fertiliser inputs.

Research into nutrient and sediment movement within catchments is needed by some State agencies and regional catchment management organisations who are interested in the use of models which can be validated in the landscape to predict the release, transfer, storage and fate of nutrients and sediments. Their major concern is to establish the extent to which catchment water quality targets can be met by proposed changes in agricultural management practices. The need for cost effective methods for managing algae in water storages was noted by one interviewee.

Salinity

State and one Australian government agency and several regional organisations noted the need for a better understanding of salinity issues. It was noted that under the current low rainfall conditions, salinity was not at the forefront of concerns. Agencies were aware that there were new techniques for mapping salinity [airborne electromagnetic mapping], but a number were
uncertain how the results from this work could be used to explore solutions. The need to integrate salinity work from soil, plant and hydrogeology disciplines was noted. A more robust understanding of the salinity problem will provide directions for future National Action Plan for Salinity and Water Quality investments. In Western Australia, concern was expressed about the lack of interest in salinity research and development.

**Acidification**

Acid rock drainage is a persistent and costly problem for the mining industry; a better understanding of sulphide oxidation rates and the movement of acid rock drainage water is required to develop predictive models which can be used to improve mine site operations.

Understanding the impacts of the acidification of surface waters associated with the unplanned drainage of soils in areas of the Western Australian wheat belt, urban areas and parts of the rangelands is of concern to Western Australian State agencies. One respondent noted that there is a reluctance to address the management of the acid drainage problem; the enormity of the problem makes the issue too daunting.

In Victoria several interviewees noted the increasing acidification of streams. The limited research undertaken to date has not provided an understanding of the mechanisms involved, and the impact of acidification on river health is not known.

**Ground and surface water contamination and remediation**

Methods for quantifying the relative effects of contaminants associated with different land uses as risk profiles for human or ecological health and exposures would provide a basis for prioritising and facilitating remediation decisions. Several interviewees noted the need for further research into processes for remediation, including bioremediation, combustion and phyto remediation.

There is much remediation of mining sites to be carried out worldwide, and a major need to develop clever and cost effective remediation techniques. Improved technologies are needed for contaminant assessment and clean up on mine sites. An improved capacity to model solute mass balances, ground water plumes and off site transport of mine wastes will assist the mining industry to remediate contaminated legacy sites, while a capacity to predict the transport and fate of chemically active solids from mine wastes and their impact on water quality will provide a basis for improving the disposal or containment of these wastes. A better understanding of the synergistic toxicological effects of some mixtures, e.g. metals and organics generated thorough mining processes, will also assist in dealing with these wastes. A quick and easy method of assessing the bioavailability of metals in liquids and solids is also needed.
Research is also needed to manage contaminated soils in vulnerable areas of the Gnangara Mound (Western Australia) where drinking water quality and groundwater dependent wetlands are at risk. A better understanding of the biogeochemistry of groundwater likely to be used for drinking water in the Northern Territory is needed. Water supplies for some Indigenous communities have low pH on extraction. In the Darwin rural area some groundwater contains high levels of arsenic; can this water be treated or should the use of water from specific aquifers be avoided?

Several organisations noted the need for research to support the development of standards (including critical loads and limits) for metals in air, soil, water and food.

**Water supply quality issues**

Several water supply authorities identified the need for development of rapid methods to detect pathogens and contaminants in water and wastewater. An improved capacity to predict the release, transfer, storage and attenuation of nutrients, organics, disinfection by products, endocrine disrupting chemicals and pharmaceuticals is needed. Some of these agencies are also concerned about the possibility of “super bugs” that withstand treatment processes and their impact on drinking water quality. There is also a need for better technologies to remove contaminants from water supplies.

Agencies concerned with managing counter terrorism threats have identified the need for new technologies to detect chemical, biological and radiological contaminants in aquatic systems including dams. An improved ability to quickly model the dispersal, transport and fate of these contaminants in rivers, reservoirs, irrigation systems and drainage networks is needed. Models are also needed for assessing the risks and threats associated with the transport of chemicals and contaminants. There is a major gap in understanding the risks associated with intentional release of toxins and the secondary impacts arising from decontamination processes.

Several interviewees noted that the current national water quality guidelines had been developed using the best available information at the time and that further research was needed to substantiate and update some of these guidelines. More reliable water quality guidelines are needed for contaminants.

Research is also needed to establish guidelines for the level of treatment for water being made available for re use, including guidelines based on the proposed re use options.

**Managing Australia’s aquatic environments**

The National Water Initiative identifies actions and outcomes needed to achieve the integrated management of environmental water in Australia. Interviewees identified research needed to ensure the effective management of rivers, springs, wetlands, estuaries and the near shore coastal zone.
Quantifying the benefits of management changes

Issues of particular concern to interviewees from many organisations include the need to quantify the economic, social and ecological benefits of providing water for the environment. It was noted that excellent science is needed to support the link between water allocation and environmental benefits, particularly under conditions of increasing competition and water scarcity.

Methods are also needed to demonstrate whether changes in policies and practices will or are having the desired impact; for example will sediment and nutrient load targets for a catchment be met by changes in agricultural land management practices? Investment returns for programs such as river restoration also need to be established.

The need to improve the connections between catchment based research, particularly hydrology and aquatic systems research was also noted. A better understanding of the impact of sediments, nutrients and contaminants and the ecological response to these once they reach the aquatic environment is needed.

**Rivers**

Interviewees from a number of sectors noted the need to improve our understanding of the critical habitat functions and the environmental water requirements of riverine assets. This includes the relationships between flows and quality (including salinity) and the timing of flows, which will be needed to better manage water resources under conditions of increased scarcity and competition for water. This knowledge will improve the models needed to support environmental flow allocation decisions to ensure that water is provided where it will have the most benefit. Floodplain and wetland health also need to be considered in these decisions.

State agency and mining industry interviewees noted that the rapid expansion of the resources sector is accentuating the need for a better understanding of tropical rivers and associated aquatic ecosystems as a basis for pre-emptive and effective management, particularly in Western Australia. A mining industry interviewee also noted that the ecology of ephemeral streams in the arid zone is not well characterised.

There is also a need to develop operating rules for working rivers – what functions such as filtering do rivers which don’t contain ecologically significant habitats need to provide? Some urban water authorities are interested in an assessment of the suitability of treated wastewaters for use as environmental flows in streams.

**Estuaries and the near shore coastal zone**

State agencies and coastal regional natural resources management organisations noted the need for a better understanding of the link between
catchment based activities and downstream impacts, especially on estuaries. They are looking for improved approaches for the assessment of catchment land use impacts on estuaries and tools for the assessment of estuary health and near shore coastal zones. Methods for establishing environmental flows for estuaries are also needed. The management of coastal environments affected by salt water intrusion is also of concern, particularly since the area affected is likely to expand as sea levels rise.

**Wetlands**

One Australian and a number of State government agencies, agricultural industry groups, regional natural resources management organisations and one mining industry respondent identified the need for research to underpin the long term management of wetlands. This includes better information on the extent and distribution of wetland types, a better assessment of their condition and the need for baseline descriptions of ecological character, as well as determination of the limits of acceptable change from which to judge including the ecological implications of flow regulation and wetlands’ response to drier and more saline environments. Several organisations were interested in understanding the role that stormwaters and treated sewage could play in maintaining the environmental values of wetlands. Mining industry interviewees noted the need to be able to predict the impacts of mining developments on ecosystems including wetlands.

**Groundwater dependent ecosystems**

A number of interviewees noted that relatively little is known about groundwater dependent ecosystems, including wetlands and especially subsurface systems. These ecosystems need to be mapped, and methods developed for describing their ecological character and monitoring their condition. Several interviewees noted that the taxonomy of organisms and ecosystem processes in subsurface systems is almost unknown. Better information about these assets is required to make more informed decisions about aquifer management, groundwater utilisation (including aquifer recharge for storage) and the impact of changes due to allocation decisions.

**Managing Australia’s soil and land assets**

Natural resource management in Australia has changed with the shift to a regional model for planning and action. Robust scientific evidence is required to guide investment and monitor soil and landscape condition to ensure that the community’s resources are used, conserved and enhanced to maintain the ecological processes on which life depends and to increase the total quality of life for Australians.
Improving the management of agricultural soils

A quarter of those interviewed noted the need for research which will lead to improved management of agricultural soils (Table 1). State agency and agricultural industry groups identified the need for research which would produce technologies and practices to overcome the physical, chemical and biological constraints to agricultural production on some soils. Issues of particular concern include methods to reduce rates of soil loss, improve soil structure, improve soil fertility and control rates of soil acidification. One interviewee suggested that the offsite impacts of soil acidification could be very large. A better understanding of the relationship between pH and aluminium toxicity is needed to ensure the sustainable use of some Western Australian soils. More information about subsoil processes is required to manage subsoil constraints to agriculture and rehabilitate saline and sodic soils. Some work is also needed on the long term implications of the application of biosolids and wastewater to land and their effects on crops.

Irrigation industry groups also wanted better information about managing soil structure, particularly in relation to the long term impacts of drip irrigation, and some organisations suggested that predictive models would improve water use efficiency by taking into account soil profile type and irrigation application methods.

Agriculture and forestry industry organisations and some State agencies are interested in carbon trading and would like to have a better understanding of the opportunities for carbon storage. The need for long term carbon monitoring sites and the provision of methods to support carbon trading were mentioned. An Australian government agency identified the need for more research into the impact of climate change on carbon and nitrogen cycling, and the development of a capacity to predict the effects of different land uses and various climate scenarios on carbon and nitrogen cycling.

Managing land use change

Around one fifth of interviewees expect extensive land use change will be needed as a result of increased climate variability and climate change, as well as the movement of water entitlements to higher value uses (Table 1). For example, in Western Australia the limit to cropping has moved by more than 100 kms due to the drying climate, whilst the inappropriate management of land retired in the Shepparton (Victoria) irrigation district is causing concern.

Research needs identified include a better understanding of the impact of climate change on agricultural production, so that areas likely to be affected can be identified and management options developed for land that may become significantly less productive. Several interviewees noted the need for a better appreciation of the uncertainties associated with climate change, particularly in relation to the timescales for change. Agricultural industry organisations and some State agencies noted that new land use options will need to be developed for land retired from irrigated agriculture. Better land
capability and soils information will be necessary to manage these shifts in land use effectively. Rising fuel prices will also need to be taken into account. Some interviewees noted that in the longer term these changes were likely to lead to an intensification of land use, and that research into how to manage the resulting risks to the resource base would be needed.

Interviewees expected that managing land to maintain current levels of production without significant adverse environmental impacts under an increasingly variable climatic regime would be more difficult, and that research could be needed to identify the most appropriate management practices. Research will also be needed to develop a better understanding of how to manage land for extreme conditions, including the identification of thresholds beyond which ecosystems and landscapes can’t recover.

**Ecosystem services**

There was considerable interest in the potential for ecosystem services, where payments could be made to land managers for delivery of public good environmental benefits requiring a contribution over and above the expected duty of care.

A number of interviewees noted the need to identify, define and measure ecosystem services and to quantify their value so they can be factored into planning and development decisions. One organisation suggested that the ecosystems providing services should be treated as infrastructure to ensure appropriate levels of investment. A number of State agencies and regional organisations noted that primary producers played an important role in delivering ecosystem services; the value of this contribution needed to be quantified, particularly if farmers were to be paid for these services. It was suggested that payment for ecosystem services could enable the continued management of some lands which had become marginal for production due to changing climatic conditions. Research will be needed to develop land management prescriptions and appropriate practices for farmers being paid to deliver ecosystem services.

**Land condition monitoring and assessment**

More than a quarter of those interviewed identified the need for research into one or more land condition monitoring or assessment issues (Table 1).

State agencies identified the need to develop methods for producing an integrated assessment of landscape health/condition which can be monitored, and were interested in whether tipping points, an imminent change in the state of the resource, could be identified. It was suggested that Catchment or Landscape Health Strategies should be developed to match River Health Strategies. These should address issues such as agricultural inputs to catchments, matching land capability to land use, urbanisation of good quality agricultural land and the visual amenity of landscapes.
Several State agencies and agricultural industry groups suggested that methods should be developed to monitor the environmental performance of agriculture. These should include an assessment of the benefits and costs of agriculture on ecosystems and provide environmental and soil health indicators for different soils/landscapes to monitor effects of management systems. The results would help articulate the management changes needed and could provide the evidence needed (or changes required) to support a ‘clean, green’ image for agricultural products. A defence agency identified the need for research into indicators and management practices to assist in the sustainable management of defence training lands.

A number of interviewees noted the need for research that established monitoring and evaluation methods (to report on matters for target and resource condition – see Anonymous 2002) or developed other approaches to link land degradation processes to environmental health and management actions to catchment condition. Methods are needed to demonstrate the link between on farm land and water management practices and catchment outcomes, for example in relation to fertiliser and herbicide use, to demonstrate the benefits of land stewardship and identify whether landscape scale interventions were working to show return on investment in natural resources management.

A number of agencies noted that research was needed to identify land management practices, their economics and potential for uptake, that can help achieve catchment based targets for water quality improvements. This information is needed to provide catchment managers with a better understanding of what can be achieved at a practical level for catchment targets. State and regional groups noted the need for good science to underpin the development of regional plans.

Mining industry respondents noted the need for better criteria for land rehabilitation post mine closure and the development of more effective methods (including predictive modelling of constructed land form behaviour) for landscape reconstruction following mining operations. The need for methods to quantify sustainable development performance in the mining industry was also mentioned.

Managing resources – social, economic and institutional challenges

Interviewees noted that dealing effectively with water scarcity, the potential impacts of climate change on land and water management and the implementation of the National Water Initiative will require more effective and transparent ways of integrating biophysical, social and economic factors. Governments, management agencies and the community need a better understanding of the options and trade offs to enable resource sharing and manage the impact of environmental and land use change. Some existing governance arrangements will need review and more effective ways of involving stakeholders and the wider community in debate will be needed.
Engaging stakeholders and the community

Almost one third of those interviewed mentioned the importance of developing more effective mechanisms to empower people and groups to engage in the water debate (Table 1). Water industry interviewees thought that better stakeholder engagement would improve their understanding of how different groups use and value water. These insights are needed to help ensure the effectiveness of investments in demand management, improve the targeting of water conservation activities, and understand the incentives needed and the extent to which the community is prepared to change attitudes, especially to new sources of water, and their water behaviour.

The need for engagement with Indigenous groups was noted, with the comment that engagement is more about how advice is given. One agency noted that concern about regional changes often comes from people outside the location affected – are there ways of identifying and engaging with these people? There is particular interest in methods for involving communities in making decisions on the selection and management of water dependent icon ecosystems. It was suggested that stakeholder engagement could create the basis for adaptive learning by organisations and individuals, with management decisions regularly being informed by feedback.

Several State agencies noted the very different aspirations of urban and rural communities in relation to land and water use and suggested that research is needed to better understand these positions and how they impact on policy development.

Mining industry interviewees identified the need for better methods and frameworks for community engagement and consultation, especially in relation to social and economic factors associated with mine operations, mine closure and remediation strategies.

Methods to facilitate trade off decision making

Many interviewees mentioned the need for methods to integrate biophysical, social and economic information to understand complex natural resources management problems. These methods should provide a basis for dealing with the often competing needs of stakeholders, assessing the impact of various policy and management options and informing trade off decisions. They should include negotiation processes and address issues such as fairness, and provide a way of balancing local needs with those of the wider community. It was suggested these approaches were needed to manage trade offs such as those between catchment based targets for water quality and large scale land use change and assess the sustainability of different water supply, re use and demand management options, including rural urban water trading.

Demographic change, water trading and structural adjustment
One fifth of interviewees identified the need for research into the impacts of demographic change, water trading and structural adjustment on industries, communities and the environment (Table 1). Catchment management groups and farmer organisations noted that demographic changes in the farming population are expected to lead to major changes in agriculture and are interested in research into how agriculture will look in 10 - 50 years time. They are interested in the socio economic impact of these changes on regions. Catchment management groups want a better understanding of the drivers of population change; coastal groups are particularly concerned about population growth in their catchments and how to assess the capacity of catchments to support further growth.

Many agencies are concerned about the implications of water trading, including the inadvertent impacts on water quality, biodiversity and the stranding of assets. Research is needed into the multiplier effects that operate in water dependent agricultural communities and the socio – economic and environmental impacts of taking water out of communities. It was suggested that research to identify how irrigated agriculture will look in the future could help avoid larger adjustment costs. There was concern about the fairness of the proposed rules. A better knowledge of the social and economic implications of water sharing plans is also needed.

**Research for learning and communication**

Catchment based organisations identified the need for research that documents and explains the level of community understanding of the biophysical processes associated with land and water management and develops recommendations to improve this awareness. Research into communication mechanisms that help communities understand decisions made about water governance and provide insights into how communities react to policy changes is needed to help explain policy shifts. Capacity building at the regional level is also a significant issue – what are the best ways of organising large amounts of information and ensuring that knowledge is passed on?

Agricultural industry organisations are looking for research into how to present new information to farmers to facilitate their learning to deal with an increasingly complex environment for agricultural production. This issue will become even more pressing when responses to climate change and reduced water availability require further industry diversification.

Research is also needed into the best methods to train water supply operators to ensure that alternative water supplies, particularly indirect potable re use, meet public health standards.

**Overcoming institutional barriers to change**

A number of interviewees noted that institutional changes would be needed to facilitate the most effective planning and management for land and water
resources. They noted that research was needed to identify these barriers and recommend better governance models. Issues commonly identified included the need to integrate water and natural resources management plans, and integration of land and water planning – land planning is generally undertaken at local government level while water planning is centralised; better governance models are needed to bring these together. It was also suggested that current institutional arrangements would need to be modified to ensure the security of surface and groundwater supplies, integrate stormwater and sewerage management, and introduce water sensitive urban design effectively.

Several organisations noted that urban water and wastewater authorities are currently set up to manage centralised systems; institutional changes or new business approaches may be needed if there is a move to more localised service provision.

One interviewee noted the need for a common water language between States to progress national water issues. Research is needed to identify the institutional structures needed to deliver effective national solutions.

**Economic analysis and new management instruments**

Some Australian and State government agencies mentioned that more research is needed into the role market based instruments, incentives and offsets could have in improving environmental outcomes. They were interested in understanding how to get the best balance between planning, market and regulatory instruments. It was noted that economic instruments appropriate to ecosystem service provision would be needed.

The broader issue of who should pay for environmental outcomes was raised by several interviewees who suggested that the agenda for environmental change is driven largely by urban communities’ concerns. They noted the need for research to establish the integrated costs of change, and to recommend who should pay through which mechanisms.

A number of organisations commented on the importance of the link between water service provision and energy issues and the implications for future emissions trading. Research is needed to develop a life cycle approach to costing new sources and other water and wastewater supply and treatment interventions. For example, it was suggested that energy costs could make water trading impractical where pumping over long distances was needed.

It was suggested that new financial models need to be developed to help assess the optimum reliability and resilience of service levels in different cities appropriate to their circumstances. New models are also needed to quantify the water savings effected through non structural methods such as household water saving devices.
One interviewee noted that an analysis of how market failure affects natural resources management is required to provide a better framework for future investment.

**Water use**

Interviewees from all sectors identified the need for research to improve water use efficiency, assess the sustainability of potential alternative supply sources, investigate the issues associated with water reuse and recycling including the safeguarding of public health and the efficient and cost-effective operation and maintenance of water supply, wastewater and stormwater systems as water availability and water quality changes. A number of individuals interviewed noted the importance of establishing risk assessment approaches for the planning, allocation and management of water resources in quantity and quality terms.

**Irrigated agriculture**

More than a fifth of those interviewed noted that research was needed to improve the efficiency of water used for irrigation. Agricultural industry groups are looking for research that will improve on farm irrigation water use efficiency through understanding the effectiveness of alternatives to furrow irrigation, reducing evapotranspiration from storages, reducing drainage losses from storages, fields, channels, and how to target water applications spatially (within the root zone) and temporally. They also identified that science was needed to improve the capacity of irrigation industries to make informed decisions about how to deal with reduced availability of water. It was suggested by several interviewees that there were substantial opportunities to improve water use efficiency in the irrigation industry through system harmonisation. A better understanding of the potential impact of using grey water for irrigation of crops grown in peri-urban environments is needed.

A number of interviewees noted the need for research that would help improve the quality of irrigation drainage waters with respect to salt, nutrients and other pollutants. This would provide better quality water for reuse, and help reduce the environmental impacts of the industry.

**Mining**

Mining industry interviewees are keen to improve water use efficiency for mine sites, nominating the need for research to assess options for reduced water use, water reuse, the use of poor quality water in mining processes and ways of reducing evaporation losses. They are also interested in the potential for using grey water from sewage, understanding the impacts of this quality water on industrial processes, and the treatment needed to bring it to suitable standard for use, which will take into account the health aspects of grey water use. They are also interested in work which will identify opportunities to recover water from waste streams in refineries.
Urban

Assessing alternative sources of water

One quarter of those interviewed identified the need for research to provide improved methods for assessing alternative sources of supply for urban areas. Several interviewees noted the need for a risk assessment approach to the provision of urban water supplies. Urban sector interviewees noted the need for methods and processes to demonstrate and compare the sustainability (viability, energy and life cycle costs, acceptability and willingness to pay) of options for new resources for city supplies appropriate to their location. Options identified for study include desalination, aquifer storage and recharge, stormwater use, indirect potable use and rural – urban water trading. One interviewee noted the need for research into low energy membrane technology for desalination, and into the best approaches to disposal of desalination plant rejection water in inland areas and for reducing the potential for contamination of near shore coastal waters.

Public health issues requiring research include development of a risk management framework for alternative water sources and new guidelines for treated wastewater use underpinned by science. Issues of concern noted by interviewees included the presence of hormones, personal care products and pharmaceuticals in water being recycled for drinking and the risk of contaminants from industries in stormwater from some catchments.

Several interviewees identified that methods for predicting per capita usage over the next 10 - 50 years which could account for different use levels driven by changes in housing stock were needed to help set future demand management targets. Research is also needed into the use of plumbing regulations, leak management and pressure controls as demand management tools, including how to implement best practice.

Water sensitive urban design

Interviewees mentioned the role that water sensitive urban design could play in capturing stormwater for re use. It was noted that research was needed into the long term functionality of new methods of dealing with urban stormwater so that over engineering does not reduce the economic benefit of water savings. Developing a whole of water cycle focus for the design of new suburbs will be important in ensuring their resilience to extreme water events. A better understanding of the impact of new urban designs on catchment water quality and how designs can be used to improve environmental outcomes is also needed.

Asset management and maintenance

A number of interviewees noted that changes in the quantity and quality of water, wastewater and stormwater arising from decreased water availability
and increased use of recycled water would affect the management of water infrastructure assets. Water supply authorities noted the need for better technology and predictive models to maximise the life of assets, including research into pressure management, new rehabilitation methods, new and smart lining materials, and better sensors. Research is also needed into the effects of demand management procedures on infrastructure design and pipe selection, and into the impact of the quality of recycled water on pipes.

The development of improved control systems for water, wastewater and stormwater to provide information for scheduling maintenance activities more effectively and continuous monitoring systems to evaluate overall system performance and provide early warning of failures is needed. It was noted that a more strategic approach to the timing of sewerage and stormwater infrastructure (rather than on failure) could also deliver environmental benefits to urban streams.

Several interviewees identified the need for research into cost effective approaches to dealing with greater variability in sewer flows associated with climate change and infiltration. It was noted that the sewer system is critical in moving water resources to recovery plants; we need a better understanding of the interaction and control of micro organisms and biofilms to improve management and understand causes of sewer failure. Some authorities indicated that they were reviewing the role that existing smaller sewage treatment plants could play in producing water for re use; research is needed to improve their efficiency, and reduce energy use. It was also suggested that research into self containment approaches for septic tanks that are a suitable distance from waterways would help reduce the backlog in sewerage programs. Research is also needed to produce methods for cost effective delivery of water and sewage services to small country towns.

**Biosecurity and biovulnerability of urban supplies**

The biosecurity of drinking water supplies is of concern to several organisations; research is needed to identify whether and where there are weak links in the supply chain, and whether some of the risks can be overcome by design. It was suggested that if the future brings a less ordered society, we may need to consider the appropriateness of a piped supply model.

**Tools and technologies for land and water management**

Agricultural industry and some State agency interviewees identified the need for development of new, cheap sensors to provide more detailed and timely information for decision making by irrigators. Urban water supply authorities identified a number of sensor developments which would improve water quantity, quality and infrastructure management. Australian government and State agencies identified the need for improved catchment modelling and scenario planning tools. These agencies also noted the need for improved
data and better methods for accessing, analysing and integrating data, especially water data.

**New sensors**

A fifth of those interviewed suggested that research which led to the development of new (and preferably inexpensive) sensors would improve the management of Australia’s land and water resources (Table 1).

Agricultural organisations identified the need for improved whole farm water management tools which could provide much greater coverage than those currently available, and provide real time information on plant stress.

Several Australian government agencies identified the need for research into new sensors and techniques that would reduce the costs of acquiring land and water data at the catchment scale and increase the temporal coverage of data available, particularly for measurements of water in landscapes, including soil moisture, plant available soil water and evapotranspiration and for monitoring changes in condition such as soil erosion. One State agency noted the need for inexpensive automated meters for bores. There is also a need for the development of sensor specifications for unmanned vehicles proposed for the aerial collection of geospatial data, principally for defence use.

Urban water authorities provided an extensive list of opportunities for the development of sensors. These included sensors for pipe infrastructures to detect cross connections between potable and grey water reticulation systems due to leakage, sensors to help predict pipe failures and sensors to monitor in line water quality to eliminate problems associated with dead ends. Sensors are also needed to detect the location of valves, especially beneath roads. Simple cheap sensors are needed to alert urban authorities to the illegal use (usually for cleaning) of water from fire hydrants. Smart water meters could provide detailed information on individual components of household water use cheaply; this will help authorities target demand management activities more effectively. Wastewater sensing and measurement technologies, including on line measurement methods for pathogens and contaminants and sensors for microbes and contaminants would improve treatment efficiency.

**Models, scenario planning and monitoring tools**

The need for research which improved catchment modelling capabilities was identified by many Australian and State government agencies as well as some regional natural resources management organisations. Some State agency interviewees highlighted the need for simpler and more practical tools for catchment modelling. Other interviewees noted the need for better integrated catchment models which incorporate hydrological, social, environmental and economic factors to assist with allocation of water for water sharing plans in multiple use catchments. Tools are also needed for monitoring the hydrological and environmental impacts of water trading. One interviewee
noted that much of the value of integrated catchment modelling is in the forum created for discussion of system drivers and changes with managers.

Several interviewees noted the need for improved scenario modelling tools to enable exploration of alternative scenarios and management responses to changing climates, reduced water availability and increasing energy costs for regions. These should include tools for determining trade offs between carbon storage and water yield.

Mining industry interviewees noted the need for better tools for predicting and planning the likely impacts of proposed mines on land and water resources.

Models are also needed to improve the understanding of how microorganisms, carbon and other contaminants move in water supplies.

**Data collection, access and management**

State and several Australian government agencies and irrigation organisations noted the need for better and cheaper measurement techniques for collection of improved water data to support water sharing plans, environmental water registers, benchmarking for urban and rural water delivery and water trading. Improved ability to access and share land and water data via interoperable systems within and between State agencies is also needed, together with better processes for integrating and analysing these data. Given the costs associated with water quality monitoring, one interviewee suggested that risk assessment processes be developed to improve targeting of data collection.

Several organisations noted the need for research which improved the handling, storage and analysis of large data sets, including methods for data assimilation which enabled data of different types to be brought together for improved approaches to prediction and simulation.

Several urban water supply authorities identified the need for systems to optimise data transfer to and from field staff in an accurate format without the need for form entry, and a system to provide rapid customer feedback on the progress of works. A mining industry interviewee noted that the capacity to monitor water data remotely would improve the quality of information used for decision making.

Australian government, State agencies and some regional natural resources management organisations were particularly interested in developments that could improve monitoring and evaluation of resource condition. These include the underpinning systems science and a framework for natural resources management monitoring and evaluation and improved standards and methods for data collection and analysis for use in multiple applications. There is a strong interest in developing an approach that could be used to meet multiple reporting requirements.
Managing biodiversity

While a detailed consideration of biodiversity issues was beyond the scope of this report, the interaction between land and water management and biodiversity values was noted by several interviewees. Most State agriculture and natural resource management agencies, several regional organisations and two industry groups interviewed noted the need for research to underpin the management of biodiversity. Issues identified included cost effective monitoring strategies for broad scale vegetation clearance, managing for biodiversity in agricultural environments, and optimal methods and social and economic mechanisms for replacing vegetation to improve biodiversity outcomes. Several State agencies suggested that research was needed to establish how to manage for biodiversity under changing climatic conditions and to understand the impact of climate change on the management of pest plant and animal species.

A defence agency identified the need for research which would assist them to manage for and maintain certain vegetation structural types in landscapes used for defence training purposes without compromising biodiversity values.

Research Impact

Interviewees and questionnaire respondents were invited to nominate land and water management issues for which they thought that research could have a national impact (for example because of the cost of the problem, the hectares of land affected or the production implications of the problem). Twenty percent of participants responded, nominating seven issues. The policy context for each issue is outlined, and the major areas where CSIRO believes research is needed are discussed briefly.

Research which improves our biophysical knowledge of ground waters and surface waters, including their connectivity, to manage for water supply security and to inform the negotiation and review of water sharing plans.

CSIRO notes that the desktop analyses completed for the Murray Darling Basin indicate that a serious water scarcity problem is emerging for southern Australia. These analyses are revealing that managers have not properly understood the impact of groundwater use on surface water flows. For example, the cap on surface water diversions in the Murray Darling Basin did not take into account the reduction in surface water flows arising from groundwater use. It has been estimated that groundwater pumping has reduced annual stream flow by 327 gigalitres (GL), with a further reduction of 253 GL expected by 2012-13 (Resource and Environmental Management unpublished).

The problem is well recognised in the National Water Initiative (Council of Australian Governments 2004), and under the National Plan for Water Security (Australian Government 2007) a new cap on diversions that takes into account the connectivity between surface and ground waters will be
developed. An objective quantification of the groundwater resource is needed to help set the cap at the appropriate level.

CSIRO believes that improved quantification of Australia’s groundwater resources, and their connectivity to surface water systems, is essential. This will require improved characterisation of aquifer properties through a combination of geophysical methods, tracing and empirical water balance studies. This information is required to adequately parameterise surface water - groundwater models needed for each aquifer/basin, so that the effects of climate and management options can be properly examined. The Murray Darling Basin Water Assessment project will bring together current understanding and the available data to identify where the major knowledge deficiencies exist.

Our understanding of groundwater resources can be greatly enhanced by new methods to directly measure the rate and direction of groundwater flows; these have previously been inferred by combining measurements of groundwater levels in bores and using models. Likewise, some new tracing and water dating techniques will provide better information on the origins and residence times for groundwaters. This understanding will provide the evidence base for establishing sustainable levels of extraction.

**Climate change research which examines the impact on water resource availability and supports adaptive management of land and water resources at a regional level.**

Hydroclimate is continually changing over a variety of time scales, and this has significant implications on the management of land and water resources and environmental systems. For example, all water resources projects take into account seasonal and inter-annual variability, some water authorities now use ENSO-based forecasts for operational water resources management, and everyone is concerned about the impacts of climate change on water resources. The management challenges for Australia are compounded by the recent prolonged drought and by Australian streamflow being more variable than elsewhere in the world.

Climate is the key driver of hydrological and environmental processes, and improved quantification of hydroclimatic variability and climate change impact is essential for realistic land and water resources planning. This is well recognised by government and water management agencies, with very significant resources invested on assessing climate impacts on catchment water yield and different water users throughout river systems (urban, irrigation and environment).

CSIRO believes that the key applied science needs in the climate impacts on water area include: improved characterisation of hydroclimatic variability (based on instrumental record and paleodata); improved climate change projections (mainly interpretation of global climate model simulations); methods to provide stochastic climate inputs to drive hydrological models (including statistical and dynamic climate downscaling models); methods for
assessing climate change impact on water and environmental systems (from simple rule of thumb to complex modelling methods); improved seasonal hydroclimate forecast; and adaptive water resources and environmental management to respond to climate variability and change.

The basic science needs in the climate impacts on water area include: climate research (process understanding and modelling) to improve future climate projections; surface-atmosphere feedbacks and land surface processes in enhanced CO₂ climate (forest water use, bushfire impacts on water); continental scale hydrologic and environmental system sensitivity to climate; and assessing the combined impacts of climate and other drivers on water users across river basin systems (urban, irrigation and environment).

Research which provides regional organisations with an improved understanding of landscape function as a basis for investing in integrated outcomes, including biodiversity, water yields, water quality goals and sustainable land management practices, and making informed trade offs.

Australian, State and Territory governments have invested around $ 2.4 billion in a collaborative regional approach to natural resources management since 1999 through the National Heritage Trust and the National Action Plan for Salinity and Water Quality (Agriculture and Food Policy Reference Group 2006). Through these programs, on ground natural resource management activities and funding have been devolved through 56 regional groups which coordinate activities within catchments across Australia.

The Australian government is funding a third major natural resources management program which will begin in 2008. This program will seek to embed regional planning as the tool for generating wider investment in natural resources management. These investment decisions will need to be based on sound science (Agriculture and Food Policy Reference Group 2006; Keogh et al. 2006). The provision of knowledge in this domain is complex and current arrangements are in need of reform (Campbell 2006). The severity of the current drought, the spectre of climate change, pressures to relocate or develop major industries (e.g. irrigation development in northern Australia), the development of schemes for stewardship payments, and trading systems for water, carbon and other services, will all increase the need for good quality information on landscape function across the country.

Much of our hard won scientific understanding of landscapes will remain unused until we have good spatial information on the functional properties of landscapes at a range of scales along with carefully designed systems for monitoring selected components (e.g. soil organic carbon, acidification, water quality). CSIRO notes that the applied science needs range from developing far more effective systems for rapid measurement (e.g. new sensors for water quality and soil spectroscopy), improved environmental sensing (e.g. temporal remote-sensing) through to the design and implementation of web-based systems for acquiring and analysing natural resource information (e.g. as
embodied in the proposed Water Resource Observation Network, although expanded to address landscape processes and management more generally).

There is a need for a restricted number of substantial long-term scientific studies of ecosystem and landscape processes in catchments that represent, in the first instance, the main regions used for agriculture, urban development and forestry in Australia. These studies need to measure and model the dynamics of water, sediment, nutrients, contaminants, biological production and related processes. Such studies are essential for an improved understanding of processes controlling the sustainability of current and planned systems of land use. In particular, it is important to understand the impacts of changing land use (e.g. urbanisation, revegetation, acidification, increasing use of fertilisers, intensification of farming systems) on nutrient loss from soil systems, catchment water balance and the ecology of waterways and land management systems.

**Research which will provide, reliable, safe and cost effective water supplies to growing cities in sustainable ways.**

Due to population growth and increasing demands from industry, Australia’s cities are expected to have a shortfall of 850 GL of water per year by 2030 if demand continues to grow at its current rate (Water Services Association of Australia 2005). It is possible that this prognosis of reduced water availability could become considerably worse due to climate change. Plentiful water of high quality is required by our cities, to support the well-being of the population and the industries on which the economic base of our cities depend. A single urban supply water quality incident, such as the outbreak of Cryptosporidium which occurred in Sydney in 1998, can cost as much as $350 m, justifying investments in treatment and distribution water quality research to improve the management of potable water supplies and the protection of source waters.

The adoption of integrated urban water management is required for the provision of safe and cost effective water supplies to our growing cities. New sources are being explored (Indirect Potable Reuse in South East Queensland; new groundwater resources in Sydney, Toowoomba and Perth) and in some cases are being implemented (desalination and interregional water trading in Perth; demand management in most of our cities). There is no single optimal approach for the provision of new water resources for each of our cities. Each urban precinct will need to be evaluated on a case by case basis, and the final decision on how to provide new water resources will need to take into account the economics and the political and environmental implications of securing those resources. “Each recent election has seen proposals for significant water infrastructure projects that have not been seriously designed, planned or assessed. Political focus groups are not a substitute for detailed technical assessment” (Cullen 2007). The decisions must be based on sound scientific, economic and social analysis. In collaboration with state governments, major urban water utilities and university researchers, CSIRO hopes to play a role in the provision of the
science and technology that will support informed decision making with respect to safe and secure urban water supplies.

The Natural Resource Management Ministerial Council, the Environmental Protection and Heritage Council and the Australian Health Ministers’ Conference have produced the National Guidelines for Water Recycling: Managing Health and Environmental Risks in 2006. For the supplementation of drinking water supplies from alternative sources, particularly if wastewater is to be recycled into the drinking water supply chain, many researchers, including those at CSIRO, consider that the key to managing water quality from any source will be the Drinking Water Management Framework of the Australian Drinking Water Guidelines. Evaluation of the different treatment options for the safe inclusion of treated wastewater into the potable supply is of national interest, and it is expected that CSIRO will contribute to that evaluation through national demonstration projects.

As water quality for treatment and distribution is closely linked to water quality in the urban environment and its catchments, improved understanding of the fate and transport of contaminants (chemical and microbial) in surface and ground waters is required. New and more cost effective treatment systems such as lower cost and more effective membranes for desalination and treatment of recycled water will benefit the industry. As water deteriorates between the treatment plant and the tap, often due to corrosion, chemical reactions between disinfectants and organic matter, and through biofilm processes, applied science that details the interactions of those processes, and how treatment processes can affect those interactions, are major research topics for national and international water utilities. The high cost of corrosion and deterioration of urban infrastructure will require strategies for its renewal and timely replacement.

CSIRO notes that an overarching modelling package that integrates the many different urban water models that deal with quality issues in catchments, demand management, distribution, waste treatment and environmental release is required to implement integrated urban water management. Harnessing and treatment of stormwater for alternative optimal usage in the urban environment remains a challenge for many cities. New sensors and modelling of systems are required for defining and responding to risks associated with the breakdown of multiple barriers in treatment systems, cross connections and for the maintenance of water security against potential bioterrorism treats. Finally, understanding of community responses to water quality and treatment systems will be required for their acceptance and successful implementation.

Infrastructure replacement programs will depend upon a basic understanding of how infrastructure materials corrode or decay in distribution systems. The physiological responses to the physico-chemical conditions in distribution systems of opportunistic pathogens and biofilm generally will assist in the design of applied systems for their control for provision of safe drinking water. Investigation of parameters that control the transport and decay of chemicals of concern and micro organisms is required for improvements in the
management of urban water quality, and especially in the design of systems for managed aquifer recharge. The development of new sensors for water quality parameters will improve on-line and real time measurement for hazard identification and critical control of water quality hazards.

On farm research and irrigation system harmonisation to improve water use efficiency; several participants suggested that this was low risk work, with the results likely to be readily adopted to provide significant water savings.

In an average year irrigated agriculture uses 14,000 GL of water; over 70 percent of Australia’s consumptive use. Water resources in irrigation basins are close to fully allocated, or over-allocated in some catchments, and there is increased competition for water from urban and industrial needs. Irrigation water is not used as efficiently as it could be: 10 - 30 percent is lost before it reaches the farm gate, up to 20 percent may be lost from on-farm distribution channels and more than 10 -15 percent of water applied to crops is lost through over watering. Around 60 percent of water used for irrigation on farms in Australia is applied using high volume, ineffective gravity irrigation methods (Khan et al. 2005).

The effective operation of water markets and the $5.9 billion to be provided through the National Plan for Water Security (Australian Government 2007) provide a major opportunity to modernise Australia’s irrigation industries. Science is needed to underpin the Prime Minister’s Water reform package to modernise irrigation infrastructure both on and off-farm to save water, increase water productivity and retire inefficient irrigation schemes. This will lead to more efficient, productive and profitable rural water use and maintenance of the value of irrigated production in the face of declining water availability.

Applied science needs include the development of rapid assessment techniques to identify channel leaks to bring water conveyance efficiency up to 90 percent, and tools to enable irrigators and irrigation managers to increase returns per unit of water and optimise water use efficiency at the farm and irrigation scheme level. These tools include aerial based evapotranspiration data to estimate crop water needs in the context of short and medium term climate forecasts, and tools to more precisely match water application to crop water needs. The development of system wide real time water balance information at the bulk delivery system level will also improve water use efficiency.

Other research needs to link water savings information with the economic analysis at the farm and irrigation area level to help farms and irrigation companies decide on infrastructure investments. To benchmark progress towards real water savings there is a need to include system wide networks to monitor evapotranspiration, soil moisture and climatic conditions for water balance under the present and future conditions. The water use efficiency improvements will also require short term weather forecasts to predict the water balance in soils and crops. Combining the on-farm water management
data with system models will provide better decisions about when to irrigate and how much water to apply.

**Research into the most effective ways of obtaining active engagement of stakeholders and communities in contributing to decision making about resource allocation and use and encouraging the adoption of sustainable practices.**

CSIRO has noted the increasing emphasis placed on social analysis and public involvement in decision making in natural resource management (e.g. Australian Government 2006, Dovers and Hussey 2007, Western Australian Government 2003). While there is some Australian based literature which can assist in providing effective social analysis and process evaluation, this is fragmented and therefore appropriate professional practice is neither well justified nor understood. If sustainable decision making is to be encouraged, more systematic attention will need to be given to this area.

There are a host of initiatives both nationally and internationally that have the stated objective of engaging the public in decision making and in encouraging behavioural change. Water reform, regional natural resource management, the introduction of demand management programs in both urban and rural contexts all have a stated requirement of public and stakeholder involvement. While there is much available literature on issues such as procedural justice, fairness in allocation and the social psychology of behavioural change, practice varies widely across Australia. Further, comprehensive evaluation programs which would enable social and behavioural input into land and water management issues in an adaptive learning paradigm, are almost totally lacking.

There is great variety in the potential methodological and theoretical approaches to the evaluation of professional practice in the areas of social assessment and public involvement processes. Evaluations to date have been rather anecdotal and have rarely had a systematic approach. There is a need for a national best practice guide document that adapts current evaluation paradigms to the Australian natural resource management situation. This could be illustrated by successful Australian evaluation projects.

In the area of behaviour change it has become apparent that existing attitude behaviour models have some limitations in terms of their breadth of predictive variables and in how they operate in a longitudinal sense. That is: how does behaviour change occur over time? In addition there is generally no theoretical integration of social psychologically based models with a network understanding of how community change can occur at a regional or metropolitan level to effect real environmental change. In the area of allocation it is evident that while there have been significant developments in our understanding of the components of procedural and distributive justice these paradigms have largely been developed in non environmental areas. It is important that understanding of these issues is improved as the conflict for resources increases.
Research which identifies methods for cost effective environmental repair.

There is an increasing recognition that there are a multitude of land and water degradation issues that require remediation or repair. Those associated with water include surface water quality and quantity issues resulting in damage to ecosystems unacceptable to the community at large. Groundwater dependent ecosystems have also become threatened because of over allocation and use for many significant aquifers. Salinity in areas such as the WA wheat belt is continuing to advance and significant tracts of land are now unsuitable for agriculture. There are also many chronic land management problems causing erosion, soil degradation and pollution in both rural and urban landscapes. For this reason a host of remediation policies and programs have been put in place at national, state and regional levels. Often these rely on voluntary contributions or private investment. The potential investment in remediation is huge. It is important therefore to ensure that the investments we are making are as effective and efficient as possible. This will require both biophysical understanding of alternative methods of repair and socio economic understanding of what is most valued and why and the economic and social costs of landscape remediation.

This issue underpins almost all of environmental policy in Australia. It is particularly important however in guiding priorities for implementation and in creating feasible solutions for landscape problems.

Applied research will be required from the socio economic perspective to understand the extent to which remediation is required and for what purpose. For example, in the case of wetland restoration how much of the original biodiversity is seen to be of value and over what range of wetlands? Can any or many of society’s wetland values be maintained using artificial wetlands? How can we get an economic valuation of existence value or aesthetics to guide decision making in this area? There will also be the need to answer questions from a biophysical perspective such as what are the biodiversity consequences of increasing groundwater levels by a certain amount on maintenance of biodiversity in groundwater fed wetlands. Both biophysical and socioeconomic investigations will need to be integrated within an overarching systems based sustainability assessment (Mitsch and Gosselink 2000).

The underlying and difficult research dimensions for all researchers in this area will be that of dealing with uncertainty in decision making and managing that issue when deciding on which area of repair to invest (Rettinger and Hastie 2001). For example, are there certain thresholds that will govern the cost effectiveness of remediation programs? How does one deal with issues such as climate change in which variability in climate could have a massive effect on the reality of repair being achieved? How resilient is the remediation or repair likely to be in social and ecological terms (Walker et al. 2006)? Can complex systems approaches help identify key areas of intervention?
Discussion

The issues identified by clients, collaborators and stakeholders include some which require investigations or resource assessments rather than research. For example, many noted the need for better information on the extent of groundwater resources. Other issues will need resource assessment as well as research - groundwater mining for short term drought relief will need better data as well as research into groundwater recharge mechanisms and the most effective methods for managing intake areas for recovery. In some cases the research needed may have been completed but not adopted.

Several interviewees noted the difficulties associated with identifying and prioritising research needs across fields as broad as land and water. They suggested that there was a significant need for preparation of reviews to synthesise current understanding of major issues to guide where future investments in research should be made. These independent reviews of the knowledge base could include both synthesis of current understanding within disciplines and the bringing together of understanding from several disciplines to address major management issues. The resulting publicly available reports would provide an up to date overview of the issues for clients as well as informing research planning. A number of interviewees thought that CSIRO was well positioned to undertake this work, and that these reviews could have a significant national impact.

It is suggested that the next step in the process of identifying land and water research priorities for CSIRO is to review the clients’, collaborators’ and stakeholders’ needs summarised in this document against the detailed understanding of science needs developed through review and synthesis of the existing knowledge base to identify researchable topics. This assessment will also need to consider the adoption of the potential research findings – the suitability of adoption pathways, and the presence of economic, social or institutional issues which could affect adoption, or reduce the impact the research findings could have on the management of Australia’s land and water resources.

A number of interviewees noted that a systems approach which brings together information from a range of biophysical disciplines, social sciences and economics is needed to develop an integrated understanding of the systems being managed, including the interactions between parts of these systems. The outputs from such an approach will provide the overviews needed by decision makers, as well as a strong basis for the development of adaptive management approaches. CSIRO was seen as an organisation well placed to develop an integrated systems approach to land and water management issues.

About a third of interviewees, including Australian and State government agencies, mentioned the need for research to demonstrate that changes individuals or communities are asked, or in some cases may be required, to make in their resource use or management practices are delivering the desired biophysical outcomes, and to demonstrate the social and economic
benefits of these changes. Areas of particular concern identified by interviewees include:

- quantification of the benefits of environmental flow provisions
- catchment and resource condition targets – the extent to which these can be met by proposed changes in land management practices
- the benefits of land stewardship – can we demonstrate that landscape scale interventions are working?

Relatively little research into these issues has been undertaken to date, despite the fact that the continued funding of natural resources management programs will depend on demonstrating a real return on investment in these programs.

The shift to the regional model for natural resources management has led to the establishment of 56 regional organisations with responsibilities for planning and action. Representatives from 11 of these organisations based in New South Wales, Queensland, Tasmania and Victoria provided input to this report. Issues of particular concern to most of the regional natural resources management groups interviewed include the impact of climate change on water availability, estuarine management and engaging stakeholders and the community. Several also noted the need for tools to help prioritise their management actions and to relate on ground actions to matters for target. Interviewees from Australian and State government agencies also noted the importance of a strong technical and scientific basis for the development of future regional plans. Several interviewees suggested that research which provides regional organisations with an improved understanding of landscape function as a basis for investing in integrated outcomes would have a significant impact at a national level on the management of land and water resources.

There is a high level of congruence between the issues identified by more than twenty percent of all respondents as needing research (Table 1) and those nominated by the 20 percent of interviewees/questionnaire respondents who offered views on the areas of research most likely to have an impact on land and water resources management at the national level (see pages 29 - 36). These issues include managing surface and groundwater resources, the impact of climate change and variability on water availability, engaging stakeholders and the community, water use in irrigated agriculture and assessing alternative sources of urban water and new sensors.

Some who commented on the draft report suggested that it over emphasises water research needs at the expense of soil and land management issues. Factors which contributed to the interviewees' focus on water issues are likely to include the timing of the interviews, which took place during drought and at a time when there was a high level of concern about low river inflows in southern mainland Australia and the resultant water scarcity, as well as the interests and responsibilities of the interviewees. A significant proportion of the interviewees are either responsible for delivering water services or use water directly in their business operations. About a quarter of interviewees
identified research needs for one or more soil or land issues. Land resources provide important services and need to be valued as infrastructure for the purposes of investment and management; however, a wider appreciation of this issue is still developing.

Comparison of the findings of this study with the national water research priorities published by the Australian Water Research Advisory Council in 1988 (Commonwealth of Australia 1988) suggests that progress has been slow in improving our understanding and management of some land and water issues. The 1988 priorities were developed from 13 position papers commissioned by the Council (Australian Water Research Advisory Council 1987) and discussed at the Council’s 1987 Water Research Seminar. Priority areas for research in 1988 and also nominated in the present study include:

- improved understanding of catchment behaviour, including the effects of land management practices on water quantity and quality and the effects of soil, vegetation and meteorological factors on infiltration, recharge, evapotranspiration and stream flow, and the below ground phase of catchment water movement; in particular the effect of hydro geological controls on the movement of groundwater and dissolved chemicals, regional scale estimation of recharge and the development of more remote techniques for the evaluation of groundwater systems

- assessment of the implications for the water industry of short term climatic variability (including drought) and long term climatic changes

- ecological knowledge aimed at developing sound management practices for catchments and surface waters

- mechanisms and management strategies for incorporation of users’ needs and attitudes into decision making in the water industry

- integration of land and water management, encompassing development of a framework for assessing competing demands for catchment land use and water resources and mechanisms for resolving conflict; and analysis of the economic, legal and organisational constraints to integrated land and water management

- investigation of efficiency promoting changes in irrigation practices at the farm level which have implications for water resources and their management

- the implications of alternative irrigation policies for farm structure, resource use and structural change and the effects of structural changes in the irrigation industry on regional economies

- development of a total systems approach to State wide water facility planning and management for ground and surface waters which includes development and application of standard measures of risk, reliability, robustness and vulnerability of water supply systems
• development of improved technology for the management of ageing water supply and treatment systems

• development of standardised terminology and classification systems for the measurement and description of catchment topography, land use, hydrology, hydrogeology, natural environment values and existing water resources commitments to assist in State and nation-wide planning.

Land and water management issues more recently identified as needing research and reported in this study include acidification of ground and surface waters, ecosystem services, groundwater dependent ecosystems, water sensitive urban design, the biosecurity of water supplies, new sensors, and water use efficiency in the mining industry.

Some interviewees noted the need for research into methods to improve the adoption of research findings, particularly the improved uptake of better management practices by farmers and land holders. Many commented that the ultimate users of the results of CSIRO’s land and water research are a much wider group than the clients and collaborators working directly with CSIRO. They suggested that researchers need to develop a good understanding of the users’ needs and operating environments and engage them together with clients and collaborators in the planning and development of research and the delivery of outcomes. Other ways suggested to improve adoption include early identification of users and planning for adoption pathways, industry based advisory committees for projects, secondment of clients’ and collaborators’ staff to CSIRO to work on projects, the preparation of summary reports for users written in plain English, workshops and road shows for users, and engaging peak industry bodies and forums in disseminating outcomes.

Several Australian government, State agency and university sector interviewees identified current and expected skill and capability shortages in aquatic ecology, hydrogeology, systems modelling, quantitative landscape scale ecology, quantitative pedology and soil physics and remote sensing. Some of these agencies would like to formalise collaborations with CSIRO to improve access to our skills. Two agencies suggested that consideration be given to developing a more coordinated approach to natural resources management research to help address the skills shortage, referring to the nationally coordinated approach to grains research and development which has helped reduce fragmentation and duplication to ensure maximum leverage for research and development expenditure.

Conclusions

Contributors to this study have identified a wide range of resource assessment, investigation and research activities needed to improve the management of land and water resources in Australia. Further refinement of these issues is needed to develop priorities for CSIRO research that will have
significant impact on resource management at the national level. This process should be informed by preparation of syntheses of our current understanding of major issues which bring together knowledge from a range of disciplines.

Participants made valuable suggestions for improving the land and water innovation system, including recommendations on improving adoption, the need for a systems approach to land and water management issues and the importance of demonstrating a return on investment in changes in management practices adopted as a result of research findings. They also identified concerns about current and future science capabilities in land and water research, and suggested that a more coordinated approach to research for land and water resources management be considered. Many of the issues identified as being of national importance and requiring research in 1988 are still of major concern to CSIRO's land and water sector clients, collaborators and stakeholders.

Acknowledgments

Thanks to the agencies and individuals listed in Appendix One who shared the ideas for this report and to Neil McKenzie, Ian Prosser and Geoff Syme (CSIRO Land and Water) who helped develop the methods for the study.

The assistance of the following CSIRO staff in conducting the interviews is acknowledged: Andy Steven, Anthony Ringrose-Voase, Anu Kumar, Arnold Dekker, Ashok Sharma, Barbara Robson, Bradley Patterson, Chris Smith, Clare Diaper, Damian Barrett, Dan Walker, Don McFarlane, Francis Chiew, Gary Caitcheon, Geoff Podger, Geoff Syme, Glen Walker, Grace Tjandraatmadja, Graeme Batley, Greg Davis, Hamish Cresswell, Iain Gordon, Ian Prosser, James Moody, Jeff Baldock, Jeff Connor, Jenet Austin, Joel Rahman, Jon Olley, Keith Bristow, Kris Broos, Lorraine Bates, Mac Kirby, Michael Warne, Michele Barson, Mike Grundy, Mike McLaughlin, Neil McKenzie, Nicky Grigg, Olga Barron, Paul Davis, Peter Dillon, Peter Franzmann, Peter Hairsine, Rai Kookana, Rebecca Bartley, Rob Vertessy, Sarah Ryan, Scott Keyworth, Scott Wilkinson, Shahbaz Khan, Shiroma Maheepala, Simon Apte, Steven Kenway, Stewart Burn, Stuart Minchin, Stuart Simpson, Sue Cuddy, Tim Ellis, Tom Hatton, Trevor Bastow, Wendy McIntyre, Wendy Proctor and Zoe Levistion.

Thanks to Angela Gardner, Anna Lukasiewicz, Anthea Brecknell, Brendan Speet, Jan Mahoney and Tanya Jacobson for assistance with data base and questionnaire development and report preparation.

References


<table>
<thead>
<tr>
<th>Issue</th>
<th>Australian Government Agencies (14)</th>
<th>State Government Agencies (16)</th>
<th>Research and Development Corporations (9)</th>
<th>Regional Organisations (9)</th>
<th>Universities &amp; Cooperative Research Centres (15)</th>
<th>Private Sector Organisations (25)</th>
<th>Other (5)</th>
<th>Total No. of Respondent s (93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Managing surface &amp; groundwater resources</td>
<td>43%</td>
<td>56%</td>
<td>22%</td>
<td>22%</td>
<td>27%</td>
<td>32%</td>
<td>20%</td>
<td>34%</td>
</tr>
<tr>
<td>The impact of climate change &amp; climate variability on water availability</td>
<td>43%</td>
<td>56%</td>
<td>44%</td>
<td>78%</td>
<td>40%</td>
<td>36%</td>
<td>60%</td>
<td>47%</td>
</tr>
<tr>
<td>Urban impacts</td>
<td></td>
<td>13%</td>
<td>22%</td>
<td></td>
<td></td>
<td>12%</td>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Climate change &amp; agriculture</td>
<td>7%</td>
<td>19%</td>
<td>33%</td>
<td></td>
<td></td>
<td>4%</td>
<td></td>
<td>9%</td>
</tr>
<tr>
<td>Climate change &amp; environmental water provision</td>
<td></td>
<td>13%</td>
<td></td>
<td></td>
<td>7%</td>
<td></td>
<td></td>
<td>3%</td>
</tr>
<tr>
<td>The effect of changes in land use on water yields</td>
<td>14%</td>
<td>38%</td>
<td>22%</td>
<td>11%</td>
<td>7%</td>
<td>16%</td>
<td></td>
<td>17%</td>
</tr>
<tr>
<td>Agricultural chemicals</td>
<td>7%</td>
<td>6%</td>
<td>33%</td>
<td></td>
<td>7%</td>
<td>4%</td>
<td></td>
<td>8%</td>
</tr>
<tr>
<td>Nutrients/ sediments</td>
<td>7%</td>
<td>13%</td>
<td>44%</td>
<td></td>
<td>11%</td>
<td>13%</td>
<td>12%</td>
<td>14%</td>
</tr>
<tr>
<td>Salinity</td>
<td>7%</td>
<td>38%</td>
<td></td>
<td></td>
<td>22%</td>
<td>20%</td>
<td>4%</td>
<td>14%</td>
</tr>
<tr>
<td>Acidification</td>
<td>7%</td>
<td>25%</td>
<td></td>
<td></td>
<td>20%</td>
<td>8%</td>
<td></td>
<td>11%</td>
</tr>
<tr>
<td>Ground/surface water contamination</td>
<td></td>
<td>19%</td>
<td></td>
<td></td>
<td>32%</td>
<td></td>
<td></td>
<td>12%</td>
</tr>
<tr>
<td>Water supply quality</td>
<td>7%</td>
<td>6%</td>
<td></td>
<td></td>
<td>13%</td>
<td>16%</td>
<td>20%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Legend: 0% 2-9% 10-19% 20-29% 30-39% >40%
<table>
<thead>
<tr>
<th>Category</th>
<th>0%</th>
<th>2-9%</th>
<th>10-19%</th>
<th>20-29%</th>
<th>30-39%</th>
<th>&gt;40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantifying management benefits</td>
<td>29%</td>
<td>11%</td>
<td>11%</td>
<td>13%</td>
<td>16%</td>
<td>20%</td>
</tr>
<tr>
<td>Rivers</td>
<td>21%</td>
<td>38%</td>
<td>11%</td>
<td>11%</td>
<td>7%</td>
<td>12%</td>
</tr>
<tr>
<td>Rivers</td>
<td>21%</td>
<td>38%</td>
<td>11%</td>
<td>11%</td>
<td>7%</td>
<td>12%</td>
</tr>
<tr>
<td>Estuaries</td>
<td>7%</td>
<td>19%</td>
<td>33%</td>
<td>7%</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>Wetlands</td>
<td>7%</td>
<td>19%</td>
<td>11%</td>
<td>8%</td>
<td>40%</td>
<td>10%</td>
</tr>
<tr>
<td>Groundwater-dependent ecosystems</td>
<td>21%</td>
<td>25%</td>
<td>4%</td>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improving management of agricultural soils</td>
<td>7%</td>
<td>19%</td>
<td>66%</td>
<td>33%</td>
<td>20%</td>
<td>24%</td>
</tr>
<tr>
<td>Managing land use change</td>
<td>21%</td>
<td>38%</td>
<td>44%</td>
<td>11%</td>
<td>7%</td>
<td>16%</td>
</tr>
<tr>
<td>Ecosystem services</td>
<td>7%</td>
<td>25%</td>
<td>11%</td>
<td>22%</td>
<td>7%</td>
<td>12%</td>
</tr>
<tr>
<td>Land condition monitoring &amp; assessment</td>
<td>36%</td>
<td>31%</td>
<td>44%</td>
<td>22%</td>
<td>13%</td>
<td>20%</td>
</tr>
<tr>
<td>Engaging stakeholders &amp; community</td>
<td>21%</td>
<td>25%</td>
<td>44%</td>
<td>13%</td>
<td>28%</td>
<td>40%</td>
</tr>
<tr>
<td>Facilitating trade off decision making</td>
<td>21%</td>
<td>25%</td>
<td>11%</td>
<td>11%</td>
<td>13%</td>
<td>4%</td>
</tr>
<tr>
<td>Demographic change, water trading &amp; structural adjustment</td>
<td>21%</td>
<td>19%</td>
<td>22%</td>
<td>11%</td>
<td>20%</td>
<td>24%</td>
</tr>
<tr>
<td>Research for learning and communication</td>
<td>6%</td>
<td>33%</td>
<td>22%</td>
<td>7%</td>
<td>4%</td>
<td>20%</td>
</tr>
<tr>
<td>Overcoming institutional barriers to change</td>
<td>21%</td>
<td>19%</td>
<td>11%</td>
<td>13%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Economic analysis &amp; new management instruments</td>
<td>7%</td>
<td>25%</td>
<td>22%</td>
<td>33%</td>
<td>7%</td>
<td>24%</td>
</tr>
<tr>
<td>Irrigated agriculture</td>
<td>14%</td>
<td>13%</td>
<td>55%</td>
<td>22%</td>
<td>20%</td>
<td>20%</td>
</tr>
<tr>
<td>Mining</td>
<td></td>
<td>7%</td>
<td>16%</td>
<td></td>
<td></td>
<td>5%</td>
</tr>
<tr>
<td>Tools and Technologies for land and water management</td>
<td>0%</td>
<td>2-9%</td>
<td>10-19%</td>
<td>20-29%</td>
<td>30-39%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td>--------------------------------------------------</td>
<td>----</td>
<td>------</td>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>------</td>
</tr>
<tr>
<td>Water sensitive urban design</td>
<td>0%</td>
<td>13%</td>
<td>44%</td>
<td>7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset management &amp; maintenance</td>
<td>7%</td>
<td>6%</td>
<td>11%</td>
<td>13%</td>
<td>24%</td>
<td>20%</td>
</tr>
<tr>
<td>Biosecurity &amp; bio-vulnerability of urban supplies</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>New sensors</td>
<td>21%</td>
<td>13%</td>
<td>33%</td>
<td>33%</td>
<td>13%</td>
<td>20%</td>
</tr>
<tr>
<td>Models, scenario planning &amp; monitoring tools</td>
<td>14%</td>
<td>25%</td>
<td></td>
<td>13%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Data collection, access &amp; management</td>
<td>29%</td>
<td>50%</td>
<td></td>
<td>7%</td>
<td>16%</td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- 0% - 2-9%
- 10-19%
- 20-29%
- 30-39%
- >40%
## Appendix 1 – List of contributors

### 1a Interviewees

<table>
<thead>
<tr>
<th>Australian Government Agency</th>
<th>People Interviewed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Australian Centre for International Agricultural Research</strong></td>
<td>Dr Christian Roth, Dr Ian Willett</td>
</tr>
<tr>
<td><strong>Australian Federal Police</strong></td>
<td>Mr Herman Metz</td>
</tr>
<tr>
<td><strong>Australian Greenhouse Office</strong></td>
<td>Mr Ian Carruthers, Ms Jo Mummery, Dr Gary Richards</td>
</tr>
<tr>
<td><strong>Bureau of Rural Sciences</strong></td>
<td>Dr Stephen Bygrave, Dr Colin Grant, Dr Kim Ritman</td>
</tr>
<tr>
<td><strong>Defence Imagery and Geospatial Organisation</strong></td>
<td>Dr Elizabeth Milne, Mr Charles Vagi</td>
</tr>
<tr>
<td><strong>Department of Agriculture Fisheries and Forestry</strong></td>
<td>Mr Tom Aldred, Ms Fiona Bartlett, Ms Angela Robinson</td>
</tr>
<tr>
<td><strong>Department of Agriculture Fisheries and Forestry and Department</strong></td>
<td>Mr Mike Lee</td>
</tr>
<tr>
<td><strong>Environment and Heritage Joint Team</strong></td>
<td>Mr Colin Trinder, Mr Rick Zentelis</td>
</tr>
<tr>
<td><strong>Department of Environment and Heritage</strong></td>
<td>Ms Christine Schweizer</td>
</tr>
<tr>
<td><strong>Murray Darling Basin Commission</strong></td>
<td>Dr Sharon Davis, Mr Tony McLeod</td>
</tr>
<tr>
<td><strong>National Land and Water Resources Audit</strong></td>
<td>Mr Blair Wood</td>
</tr>
<tr>
<td><strong>National Water Commission</strong></td>
<td>Prof Peter Cullen, Mr David Trebeck, Dr Colin Chartres, Ms Paula Hahesy</td>
</tr>
</tbody>
</table>

### State Government Agencies

| ACT Department of Territory and Municipal Services                | Mr Stewart Chapman, Mr Peter Ottesen, Mr David Shorthouse                        |
| **NSW Department of Environment and Conservation**               | Dr Klaus Koop                                                                     |
| **NSW Department of Natural Resources**                          | Mr Neil Bennett, Ms Jacqui Tracey, Dr Ross Williams                               |
| **NSW Department of Primary Industries**                         | Dr Nick Austin, Mr Barry Buffier, Mr Rob Young                                     |

* Commissioners and staff interviewed separately
NSW Natural Resources Commission
NT Department of Natural Resources, Environment and the Arts
Dr David Leece, Dr John Williams
Mr John Gilmour, Mr Ian Lancaster

QLD Department of Natural Resources, Mines and Water
Mr John Mullins, Mr Satish Choy, Dr Ken Brook, Mr John Ruffini

SA Department of Water, Land and Biodiversity Conservation
Mr Paul Jupp, Mr Peter Butler, Mr Neil Power, Mr Fraser McLeod

TAS Department of Primary Industries and Water
Mr Greg Pinkard, Mr Alasdair Wells, Mr David Nicholls, Mr Martin Read, Mr Ludovic Schmidt, Ms Catherine Murdoch (Tasmanian NRM North Ltd), Dr Tony Norton (Tasmanian Institute of Agricultural Research)

VIC Department of Primary Industries
Ms Kimberley Dripps, Mr Ron Prestidge

VIC Department of Sustainability and Environment
Mr Kevin Love, Mr Scott Rawlings

WA Department of Agriculture and Food
Mr David Hartley, Dr Bob Nulsen

WA Department of Environment and Conservation
Mr Neil Burrows, Mr Keiran McNamara, Mr Ken Wallace

WA Department of Premier and Cabinet
Ms Meredith Blais, Ms Andrea Leverington

WA Department of Water
Ms Hazel Kural, Mr John Ruprecht

Co-operative Research Centres
Cotton Catchment Communities CRC
Mr Guy Roth

CRC for Irrigation Futures
Mr Ian Atkinson, Prof Wayne Meyer

CRC for Landscapes, Environments and Mineral Exploration
Dr Steve Rogers

eWater CRC
Prof Gary Jones

Research and Development Corporations
Cotton Research and Development Corporation
Mr Bruce Finney

* Interviewed separately
Dairy Australia
Ms Catherine Phelps, Mr Stephen Coats

Forests and Wood Products Research and Development Corporation
Dr Glen Kile

Grains Research and Development Corporation
Dr Martin Blumenthal, Dr Greg Fraser

Grape and Wine Research and Development Corporation
Dr James Fortune, Mr John Harvey, Mr Keith Hayes, Ms Sarah Warner

Horticulture Australia Ltd
Ms Alison Turnbull

Land and Water Australia
Ms Cate Andrews, Mr Andrew Campbell, Mr Michael Lester, Dr Nick Schofield

Meat and Livestock Australia
Mr Rod Dyer, Mr Wayne Hall

Rural Industries Research and Development Corporation
Dr Caroline Lemerle, Dr Peter O'Brien

Regional Organisations

Armadale Redevelopment Authority
Mr John Ellis

Community Advisory Committee to the Murray Darling Basin Ministerial Council
Mr Lee O'Brien

Indian Oceans and Climate Initiative
Mr Brian Sadler

Moreton Bay Waterways and Catchments Partnership
Ms Eva Abel, Mr David Allworth, Mr Rob DeHayr, Mr Graham Phegan, Ms Diane Tarte

NSW Catchment Management Authorities’ Council
Mr Bob Crouch (Border River Gwydir Catchment Management Authority), Ms Pam Green (Southern Rivers Catchment Management Authority), Mr John Klem (Hawkesbury Nepean Catchment Management Authority), Dr Wej Paradise (Hunter Central Rivers Catchment Management Authority), Mr Jim McDonald (Namoi Catchment Management Authority), Ms Judy Henderson (Northern Rivers Catchment Management Authority), Ms Kerryn Richardson (Secretariat)

Reef Water Quality Partnership
Mr Adrian Jeffreys (Premier and Cabinet), Ms Jane Waterhouse (Far North Queensland NRM Ltd), Ms Rachel Eberhard (Far North Queensland NRM Ltd), Mr Colin Creighton (Mackay Whitsundays NRM Group), Mr Don Begbie (Dept of Natural Resources and Water), Ms Julia Playford (Environment Protection Agency)
### Universities

<table>
<thead>
<tr>
<th>University</th>
<th>Professor/Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian National University</td>
<td>Prof Mick Dodson</td>
</tr>
<tr>
<td>Central Queensland University</td>
<td>Dr Leonie Andersen</td>
</tr>
<tr>
<td>Charles Darwin University</td>
<td>Prof Robert Wasson</td>
</tr>
<tr>
<td>Griffith University</td>
<td>Prof Stuart Bunn</td>
</tr>
<tr>
<td>Monash University</td>
<td>Prof Barry Hart</td>
</tr>
<tr>
<td>University of Canberra</td>
<td>Prof Bill Maher</td>
</tr>
<tr>
<td>University of Melbourne</td>
<td>Prof John Langford</td>
</tr>
<tr>
<td>University of Tasmania</td>
<td>Prof Graham Harris</td>
</tr>
<tr>
<td>University of Queensland</td>
<td>Prof Clive Bell, Prof Jurg Keller</td>
</tr>
<tr>
<td>University of Western Australia</td>
<td>Prof Bob Gilkes</td>
</tr>
</tbody>
</table>

### Private Sector Organisations

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Contact/Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcoa World Alumina Australia</td>
<td>Dr Ian Harrison</td>
</tr>
<tr>
<td>BP Refinery (Kwinana) Pty Ltd</td>
<td>Dr Rod Lukatelich</td>
</tr>
<tr>
<td>G Kelleher &amp; Associates Pty Ltd</td>
<td>Dr Graeme Kelleher</td>
</tr>
<tr>
<td>Mackellar Consulting Group Pty Ltd</td>
<td>Dr Phil Price</td>
</tr>
<tr>
<td>Melbourne Water</td>
<td>Mr Peter Scott, Mr Bruce Rhodes</td>
</tr>
<tr>
<td>Murrumbidgee Irrigation (Murray Irrigation Ltd)</td>
<td>Mr Dick Thompson</td>
</tr>
<tr>
<td>National Biosolids Partnership</td>
<td>Mr Allen Gale</td>
</tr>
<tr>
<td>National Farmers' Federation</td>
<td>Dr Vanessa Findlay</td>
</tr>
<tr>
<td>NSW Irrigators’ Council</td>
<td>Mr Doug Miell (CEO), Mr Murray Shaw (Murrumbidgee Private Irrigators), Mr Lee Furness (Murrumbidgee Private Irrigators &amp; Murrumbidgee Groundwater Pumpers), Mr Richard Stott (Murrumbidgee Groundwater Pumpers), Mr Robert Black (Coleambally Irrigation Cooperative Limited), Mr Michael Murray (Gwydir Valley Irrigators Association), Mr Andrew Watson (Cotton Australia), Mr Ian Cush (Gwydir Valley Irrigators Association), Ms Mary Ewing (Lachlan Valley Water), Mr Bruce McCollum (Border Rivers Food &amp; Fibre), Mr Matt Linnegar (Murrumbidgee Irrigation), Mr Ralph Leutton (Cotton Australia), Mr Daryl McDonald (Murray Private Diverters), Mr Arthur Burns (Hunter Valley Water Users Association), Mr Les Hellyar (Richmond Wilson</td>
</tr>
</tbody>
</table>
Oil Search Limited
Plastics Industry Pipe Association
South East Water
Rio Tinto*
Rio Tinto Technical Services (UK)
SA Water
Sydney Catchment Authority
WA Water Corporation
Water Services Association of Australia
Yarra Valley Water

Other
Office of Hon Malcolm Turnbull MP - Member for Wentworth
Prof Don Bursill
Mr Roger Wickes

**1b Questionnaire respondents**

**State Government Agency**
NSW Department of Environment and Conservation

**Respondent**
Dr John Chapman

**Regional Organisations**
City of Port Adelaide Enfield
Irrigated Cropping Forum and Irrigation Research and Extension Committee
Port Phillip and Westernport Catchment Management Authority

**Respondent**
Ms Verity Sanders
Mr Bryan Clark
Mr David Buntline

**Private Sector Organisations**
Australian National Committee on Irrigation and Drainage Mr Kim Russell
Australian Water Association Mr Chris Davis
EWL Sciences Pty Ltd (Division of ERA & Rio Tinto) Dr Tony Milnes
European Copper Institute Ms Ilse Schoeters
International Copper Association, Ltd Dr Robert Dwyer
Saltgrow Pty Ltd Mr Glenn Dale
Other
World Wildlife Fund Mr Jamie Pittock.
Appendix 2 – On line questionnaire

Relevance and Impact

Enhancing the relevance and impact of CSIRO’s land and water research.

The survey will take approximately 15 minutes to complete.
* We are especially interested in your responses to questions 3 and 6.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Your name</td>
</tr>
<tr>
<td>2.</td>
<td>Your position</td>
</tr>
<tr>
<td>3.</td>
<td>Your organisation*</td>
</tr>
<tr>
<td>4.</td>
<td>Please list the top 4-5 water and land management issues of current concern to your organisation.</td>
</tr>
<tr>
<td>5.</td>
<td>Is research needed to improve decision making on these issues or are there other factors, such as institutional barriers affecting the resolution of these problems?</td>
</tr>
<tr>
<td>6.</td>
<td>What do you think will be the most important land and water management issues that will need research in the next 5 years? Please list these in order of importance to your organisation.*</td>
</tr>
<tr>
<td>7.</td>
<td>For which of these future issues could research have a national impact (for example because of the cost of the problem, the hectares of land affected or the production implications of the problem) on how land and water is managed?</td>
</tr>
<tr>
<td>8.</td>
<td>Can you suggest what CSIRO could do to improve the rates of adoption of its findings for the issues you have identified as needing research in the next 5 years?</td>
</tr>
</tbody>
</table>
For further information:

**CSIRO Land and Water:**
Neil McKenzie, Acting Chief  
Phone: (02) 6246 5922  
Email: neil.mckenzie@csiro.au  
Web: www.clw.csiro.au