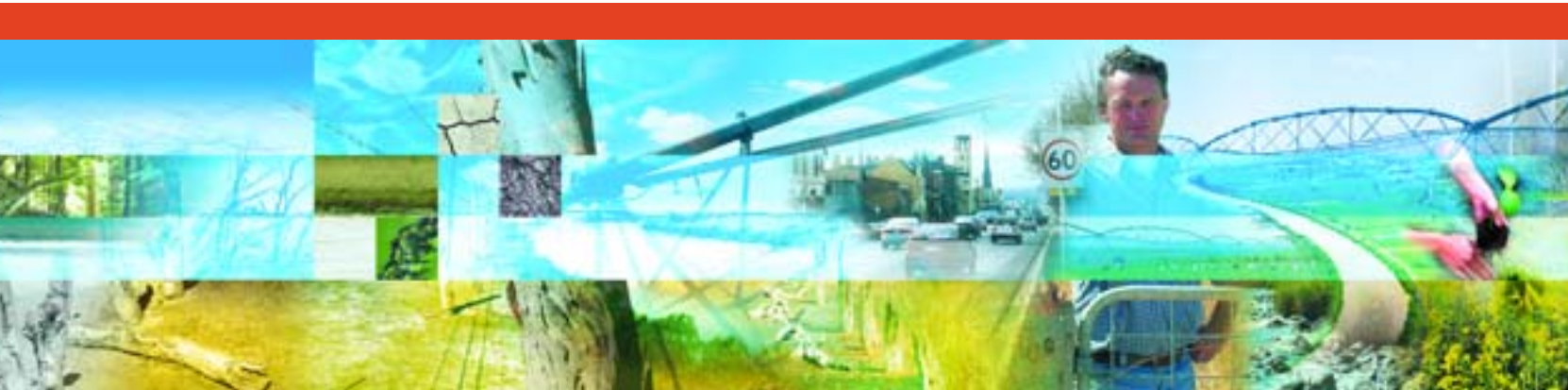


Dryland Salinity and Catchment Management

A Resource Directory and Action Manual for Catchment Managers



National
**DRYLAND
SALINITY**
Program

Know-how
to tackle salinity

Dryland Salinity and Catchment Management

A Resource Directory and Action Manual for Catchment Managers



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Australia's National Dryland Salinity Program is a collaborative research and development effort that is investigating the causes of, and solutions to, the national problem of dryland salinity. It was initiated by Land & Water Australia (formerly LWRRDC) in 1993 and has involved a wide range of funding partners and research organisations. It has been managed by Land & Water Australia since its inception.

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Finally, Dr Richard Price managed the National Dryland Salinity Program for 11 years from its inception to the production of these synthesis reports. For the first 10 years Richard worked as a program manager within Land & Water Australia and in this final year as a consultant to Land & Water Australia. Throughout this period, Richard's enthusiasm, drive, keen insights, extensive network and excellent program management skills have been fundamental to the success and impact of the NDSP. This has been an important contribution to salinity research in Australia, and to the wider understanding within the Australian community of the salinity challenge we face and how to manage it.

The National Dryland Salinity Program is jointly supported by the following organisations



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PLANT-BASED
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OF DRYLAND
SALINITY



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Research &
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DISCLAIMER: The information contained in this publication is intended for general use, to assist public knowledge and discussion and to help improve the sustainable management of land, water and vegetation. The information should not be relied upon for the purpose of a particular matter. Legal advice should be obtained before any action or decision is taken on the basis of any material in this document. The Commonwealth of Australia, Land & Water Australia, the authors or contributors, and the National Dryland Salinity Program and its partners do not assume liability of any kind whatsoever resulting from any person's use or reliance upon the content of this document.

FOREWORD

This report represents in part the culmination of an extraordinary adventure.

The National Dryland Salinity Program (NDSP) was established in 1993 by Land & Water Australia, the National Landcare Program, the Murray Darling Basin Commission and the State governments of New South Wales, Queensland, Victoria, South Australia and Western Australia, in recognition of the need for a coordinated approach to dryland salinity research in Australia. The NDSP has invested over \$40 million into new knowledge and understanding, technologies, decision-support systems and information products that are helping people across Australia to manage dryland salinity.

This investment has led a national shift in salinity research and policy, responding flexibly to the changing political environment and on-ground demands over this time. It played a major role in the report to the Prime Minister's Science, Engineering and Innovation Council, that provided a compelling case for establishment of the National Action Plan for Salinity and Water Quality (NAP). The NDSP had already brought the States and industry together under a national approach to salinity research and management. An independent review of the NDSP in 2003 confirmed the pre-eminent contribution it has made to developing solutions applicable at catchment and farm scales.

Over this past year, the 11th year of the program, the NDSP has invested a full year in harvesting and synthesising the efforts of over 300 researchers who investigated the causes, costs, consequences, solutions and management of dryland salinity in Australia over the past 10 years of the program.

This great portfolio of scientific and practical knowledge has been synthesised into three landmark reports, of which this is one. The three synthesis reports are designed to help people to make better decisions at farm scale, at catchment scale, and in developing policy respectively, based on the best available knowledge in Australia about salinity.

The foundation for these reports, and their companion resources, is solid science. This ground breaking research has brought together the contributions of hydrologists, economists, soil and plant specialists, ecologists, sociologists, biologists, agronomists, geologists, mathematicians, engineers, professional communicators and many others.

The synthesis process has been based on collaborative learning and analysis, spiced with vigorous discussion, debate and argument in public meetings and among partners. Drafts of the reports were road-tested in workshops in every State, involving catchment managers, farmers and their advisors.

The NDSP has been about more than just science. Indeed, it has been about professional communication developing solutions for farmers, catchment managers and others, backed by good science. This ambitious attempt to pull together a vast amount of scientific knowledge, and to package it to make it more useful for its end users, was made possible through funding from Land & Water Australia, the Department of Agriculture, Fisheries and Forestry (under the NAP), the Murray-Darling Basin Commission, Meat & Livestock Australia, the Rural Industries R&D Corporation, the Grains R&D Corporation, the Department of Natural Resources & Mines (Qld), the Department of Agriculture (WA) and the Department of Water, Land and Biodiversity Conservation (SA).

On behalf of the Governing Board and the NDSP partners that invested so much in this program, I commend these reports to you.

Kevin Goss, Chairman
National Dryland Salinity Program

HOW WAS THIS DOCUMENT PRODUCED?

This report was written and compiled by Lisa Robins (Robins Environmental Consulting), as Program Leader of the Catchment Team for the National Dryland Salinity Program (NDSP) Enhanced Communication Year 2003–04. The chapter on 'where to get help' was written and compiled by Dr Bruce Munday (Clear Connections). Report editing was by Georgina Wilson (NDSP Communication Coordinator, WA) and production coordination by Kim Mitchell (Currie Communications). Resource referencing was coordinated by Jo Curkpatrick (NDSP Communication Coordinator, Victoria) and Lisa Gray (NDSP Communication Coordinator, New South Wales).

The report was comprehensively reviewed by about 90 participants at focus groups in Queensland, New South Wales, South Australia, Tasmania, Victoria and Western Australia in February to April 2004. Dr Bruce Munday facilitated these events.

Development of the report was overseen by the NDSP Catchment Team, comprising:

- Peter Barker (Department of Infrastructure, Planning & Natural Resources, New South Wales)
- Dr Michael Crawford (Department of Primary Industries, Victoria)
- Dr Richard Cresswell and Peter Baker (Bureau of Rural Sciences)
- Jo Curkpatrick (NDSP Communication Coordinator, Victoria)
- Dr Sharon Davis, Dr Michele Akeroyd and Marie Waschka (Murray–Darling Basin Commission)
- Dr Richard George (Department of Agriculture, Western Australia)
- Lisa Gray (NDSP Communication Coordinator, NSW)
- Mike Grundy (Department of Natural Resources, Queensland)
- Dr Russell Haines (Rural Industries Research & Development Corporation)
- Alana Innes (National Land & Water Resources Audit)
- Daryl Richardson (CRC for Plant-based Management of Dryland Salinity)
- Dr Mirko Stauffacher (CSIRO Land & Water)
- Simon Veitch (Department of Agriculture, Fisheries & Forestry).

Input was provided by Dr Richard Price (Kiri-ganai, NDSP National Manager), John Powell (Optimal ICM), Dr Bruce Munday, and Melanie King (Land & Water Australia). Contributions were also made by NDSP Operations Committee member Cameron Allan (Meat & Livestock Australia) and NDSP Communication Coordinators (Mark Warnick, NDSP Communication Coordinator, Qld and Georgina Wilson, NDSP Communication Coordinator, WA).

The report was further provided to the following three committees of the Murray–Darling Basin Commission:

- Groundwater Technical Reference Group
- Basin Salinity Management Strategy Implementation Working Group
- Project Steering Committee of the 'Catchment Classification' project.

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Executive summary

Dryland Salinity and Catchment Management – A Resource Directory and Action Manual for Catchment Managers was prepared to assist strategic level planning and management about dryland salinity, with particular consideration to integrated natural resource management.

This directory consolidates the breadth of ground-breaking research commissioned by the National Dryland Salinity Program (NDSP) with significant research findings and resources on dryland salinity developed throughout Australia over the past 10 years. It captures research undertaken at the national, State and regional levels, and interprets the findings for the catchment manager.

It is framed around five vital questions for catchment managers, and each chapter starts by addressing why the particular question is important.

- Question 1 – *What is the current extent of dryland salinity and its risk of spread?*
- Question 2 – *What are the causes and processes of dryland salinity?*
- Question 3 – *What are the current and predicted impacts and costs of dryland salinity?*
- Question 4 – *What can we do and how do we measure progress?*
- Question 5 – *How do we integrate with other natural resource management issues?*

Advice from more than 150 people involved in salinity research or management was sought in developing the structure and content of this report.

Foremost, the directory is designed so that information to support decision-making can be readily accessed. A roadmap at the start of each chapter guides the reader to the information sought. Actions are highlighted in 'break-out' boxes, suggesting a way forward and interpreting the research and resources at the catchment level. Each action is rated on cost (high or low), time scale (long or short-term), and an indication of the level of confidence in success.

A comprehensive contact list and references are also provided.

The companion CD-ROM puts a library of research and resources within reach of the great variety of catchment managers seeking answers on dryland salinity management. While the directory itself will provide answers to many questions, the reports embodied in the CD-ROM, supported by a search facility, enable the user to access a wealth of information at the desired level of detail. It provides the first genuine repository of information on dryland salinity that transcends institutional and program boundaries.

All catchment managers throughout Australia will find something in this directory and its companion CD-ROM to improve regional planning and management. It is an essential reference for combining with regional and local sources.



Introduction

WHO IS THIS INFORMATION FOR?

This directory was prepared to assist strategic level planning and management about dryland salinity, with particular consideration to integrated natural resource management. It is designed to help you, as a busy catchment manager, to access information quickly that is relevant to you and your team following more than a decade of research. It is structured so that you can dip in and out rather than read from front to back. It is a resource directory, not a sequential 'how to' manual on developing a dryland salinity strategy. Suggested 'actions' are highlighted throughout, as well as summarised as a checklist at the end of the report.

This directory presents resources and research findings related to catchment-level decision-making on dryland salinity. It draws on research undertaken through the National Dryland Salinity Program (NDSP) and any other pertinent resources, research and investigations at the national, state and regional level.

It is structured around five major questions of interest to catchment managers. These questions are discussed under 'How do I use this document?'

The directory builds on and adds to the publication *Assessing the causes, impacts, costs and management of dryland salinity*,¹ which summarised the findings of NDSP Phase I (1993–98) and provided a general review of knowledge to that time. An outline of contents is provided in each chapter of this publication, as it remains a relevant reference for dryland salinity planning and management. You should consider it a companion text to this report.

Three general references on dryland salinity management are also recommended. The *Salinity Management Handbook*² comprises three parts (understanding salinity, investigating salinity and managing salinity) and provides a comprehensive and practical introduction to salinity. *Trees, Water and Salt*³ is a guideline on how to use trees in the Australian context to achieve healthy catchments and productive farms. The *Salinity Information Package*⁴ is a series of 40 technical information sheets (www.ndsp.gov.au) written in plain English for catchment managers on planning and managing dryland salinity addressing the following:

- Understanding dryland salinity
- Recognising dryland salinity
- Assessing dryland salinity risk
- Classifying biophysical and landscape processes
- Catchment planning and management options
- Implementing salinity management strategies
- Monitoring the effectiveness of salinity management strategies
- Assessing progress and reviewing plans.

Research outcomes relevant to leading producers and experienced advisors are available in the companion to this report: *Dryland salinity: on-farm decisions and catchment outcomes – a guide for leading producers and advisors*.⁵

Who is a catchment manager?

- Catchment and regional organisations
- Community-based NRM coordinators and facilitators
- Private service providers
- Governments (Local, State, Federal)
- Research purchasers and providers
- Non-government organisations
- Indigenous groups
- Industry and infrastructure managers
- Statutory authorities.

WHAT IS THE NDSP?

The National Dryland Salinity Program (NDSP) was established in 1993 and its first five-year phase focused on understanding causes of dryland salinity and establishing a national collaborative research and development effort. A larger second phase, completed in June 2003, involved new funding partners. Research projects were grouped into seven themes that aimed to address remaining gaps in understanding salinity and develop practical, profitable and sustainable solutions.

The seven themes related to understanding and managing salinity were:

- Audit and Monitoring
- Policy and Operating Environment
- Industry Solutions
- Productive Use of Saline Resources
- Environmental Protection and Rehabilitation
- Infrastructure Management
- Regional and Community Initiatives.

Ten years of research through the NDSP tells us:

- There is still much to be done
- The focus has shifted to include impacts on infrastructure – roads, bridges, buildings and other engineered structures
- Practical and economic solutions are not easy to find and their impact may not be felt for decades
- Salinity management should be integrated with other natural resource management strategies
- In some cases we will have to live with salinity and must find the institutional and practical means to make that possible.

In summary, the key messages described in the companion report *Breaking Ground – Key findings from 10 years of Australia's National Dryland Salinity Program*⁶ are:

1. Salinity costs are significant and rising: Protection must be strategic.
2. Profitable options for reversing the trend are lacking (but under development).
3. There is no one salinity problem: It challenges us to look beyond traditional policy instruments.
4. Integrated catchment management must be seen as only one approach to deal with dryland salinity.
5. Vegetation management remains the key to managing water resources, although the benefit-cost of revegetating catchments requires careful analysis.
6. Lack of capacity is an important, but secondary constraint, to managing salinity.

HOW DO I USE THIS DOCUMENT?

This directory is framed around the five vital questions for catchment managers, and each chapter starts by addressing why the particular question is important.

- Question 1 – What is the current extent of dryland salinity and its risk of spread?
- Question 2 – What are the causes and processes of dryland salinity?
- Question 3 – What are the current and predicted impacts and costs of dryland salinity?
- Question 4 – What can we do and how do we measure progress?
- Question 5 – How do we integrate with other natural resource management issues?

Each question provides an outline of what we knew in 1998 at the end of NDSP Phase I. This is drawn from the information presented in the report *Assessing the causes, impacts, costs and management of dryland salinity*, together with *Understanding dryland salinity*,⁷ which summarises the outcomes of some 27 projects, most within the Murray–Darling Basin Commission's Dryland Program for the same period.

The lessons from NDSP Phase II and other significant research and investigations at the national, State and regional scales that contribute significantly to answering the questions are then captured. 'Actions' are highlighted in break-out boxes, providing you with a suggested way to proceed.

Each action uses three codes on 'Cost', 'Time' and 'Confidence' to further inform your regional decision-making processes. The 'Cost' code refers to the cost of implementing the action. The 'Time' code refers to the time to undertake the action, not the time to achieve a result. The 'Confidence' code refers to the degree of confidence in achieving the anticipated result should you implement the action – if the confidence is low, it is generally a consequence of limited examples of implementation or of mixed results. The codes are only indicative and should be interpreted for your regional circumstances. While the coding system provides a useful function, it is not always possible to accurately reflect all catchments across Australia in this simplified manner.



While the review of information has been extensive, some local and regional research will be missing and you should be careful not to overlook these by consulting local experts and resource libraries. Examples are provided where possible to demonstrate advances in thinking and technology applied at a catchment level.

You will see that the answers to these five major questions are incomplete, and that there are gaps in our understanding to inform regional decision-making. The research findings are therefore used to look forward and ask 'Where to from here?' The ideas and directions provided here are intended to inform planning and management decision-making at the regional level. 'R&D Tips' are provided to direct you to institutions and programs that are major players in furthering research in the area.


What are 'the Audit' and 'the Atlas'?

The National Land & Water Resources Audit ('the Audit') conducted the first Australia-wide assessment of our natural resources from 1997 to 2002. The dryland salinity assessment focused on:

- Why dryland salinity is emerging now
- Impacts of dryland salinity
- How much dryland salinity exists in each State and Territory
- The risk and impacts of dryland salinity in 50 years time
- Dryland salinity management options.

The Australian Natural Resources Atlas ('the Atlas') is an internet-based 'one-stop-shop' for information on Australia's natural resources (www.nlwra.gov.au). The Atlas provides summary data and information at National, State and regional scales and the full *Australian Dryland Salinity Assessment 2000* report.

Its strategic plan covering 2002 to 2007 is available on the Audit web-page.



A checklist of the 'Actions' and 'R&D Tips' highlighted throughout Questions 1 to 5 is then provided, followed by a chapter on 'Where to get help', which compiles contacts, information, products and services. The contacts go beyond a list of institutions to helping you find the specific services you need to support catchment planning and management in addition to the 'R&D Tips'. A full list of references is provided in the concluding chapter.

This directory is available in hard copy and CD-ROM, with a summary brochure accessible on-line via the NDSP web-site (www.ndsp.gov.au). The CD-ROM provides electronic links to reports, including summary booklets, technical reports and NDSP *TechNotes*. These links plus a 'search' facility enable you to readily find the level of detail required. Maps, posters and a glossary of terms also feature on the CD-ROM.

WHY HAS THIS INFORMATION BEEN PROVIDED?

The NDSP has existed for 10 years, and has made a significant contribution to understanding dryland salinity across Australia. The States and the Australian Government have worked together in a coordinated way to address the problem, together with financial support from some rural industry groups. Research and development has been undertaken that would be beyond the scope of a single State or organisation, and we have moved from a state of little knowledge to having a more comprehensive understanding of the problems, the knowledge gaps and the actions needed to move forward.

There is far more activity in progress now to tackle dryland salinity than in 1993 at the genesis of NDSP. Regional models emphasising community engagement in priority-setting and resource allocation have developed across Australia. Regional planning needs to ensure that it continues to draw on the most up-to-date thinking, and this directory is pivotal in encapsulating the learnings from and beyond the NDSP at the catchment scale to-date.

Dryland salinity and its linkages to water quality and quantity and other natural resource management issues are very complex. We do not have the resources to investigate and develop a detailed understanding of these linkages and potential solutions in all areas where salinity occurs in Australia. We will always need to take the lessons from detailed studies in one part and apply them as best we can elsewhere. We will need to make 'best bet' judgements, and learn from both our achievements and mistakes.

We have relatively few experts to share across a vast landscape, so we need to be smart about allocating their time and our resources. Increasingly, investigations on dryland salinity are being initiated at the regional level to inform the implementation of catchment management plans. It will be important for regions to share information and think beyond the boundaries of their catchments if we are to succeed in managing dryland salinity and protecting our natural resources and other important assets at the continental scale.

The information provided here for catchment managers showcases the wealth of information available and encourages its application. It points out the gaps and where future investigations would yield significant benefits. Importantly, it also highlights the inter-dependencies between natural resource issues and between regions in tackling dryland salinity, and the benefits of on-going collaboration and cooperative research and information sharing.

WHERE IS THE INFORMATION APPLICABLE?

The information provided in this directory can apply across Australia to catchments with potential for dryland salinity, and has particular relevance to regional natural resource management groups. Dryland salinity, water quality, water yield and biodiversity issues rank highly in the on-going process of catchment planning and investment. This directory aims to support these regional planning and investment processes by pointing catchment managers to appropriate and cost-effective solutions.

The directory gives particular emphasis to the concept of a *Groundwater Flow Systems Framework*⁸ in transferring information and understanding between parts of Australia, as well as providing an integrating mechanism for better understanding the connections between natural resource management issues.

HOW CONFIDENT ARE WE IN THE INFORMATION?

The information presented in this directory is drawn from research and resources of varying detail, and therefore varies in how confident we can be in using it. Specific comments are provided throughout on issues of confidence, especially with respect to data and modelling outputs.

The issue of scale is important to highlight – while we can be confident about using certain information at one scale, it does not necessarily mean that it can be applied with the same level of confidence at a different scale. The *Groundwater Flow Systems Framework* is a typical example, where maps at various scales (1:5,000,000, 1:1,000,000, 1:250,000 and 1:100,000) are designed for different decision-making processes.

Our confidence in data, information and understanding varies significantly between regions. While most research investments at a regional level are based on the premise of being able to transfer the results elsewhere, this is often difficult in practice as the Australian landscape is so variable. This is why the *Groundwater Flow Systems Framework* offers great promise, as it provides a tool to extrapolate between well and poorly studied landscapes and improves our confidence in making management decisions. At the broad scale, it also informs the first cut process of prioritisation.

WHEN SHOULD THE INFORMATION BE USED?

While many catchments have finalised plans and investment strategies for managing dryland salinity, water yield, biodiversity and other natural resource issues based on the best available information, it will be important to keep abreast of new information and manage dryland salinity adaptively in this light.

The setting of salinity targets isn't the endpoint, but rather one measure of progress to inform the on-going process of decision-making. Information and understanding about dryland salinity and its relationship to other natural resource management issues will continue to grow and evolve, and you will need to embrace and adapt to new knowledge and technology along the way.

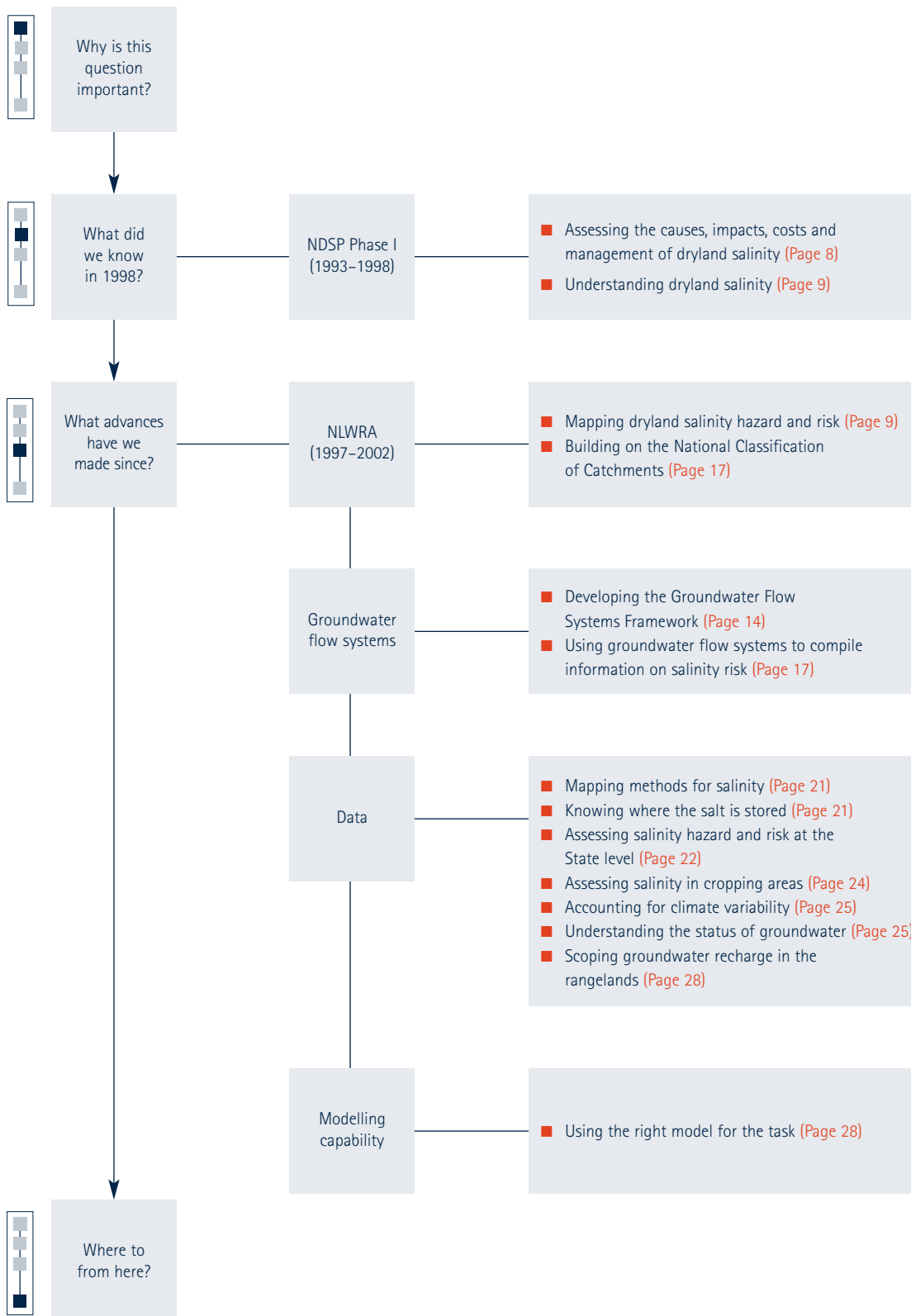
The planning cycle for catchment management is on-going – it's never too late for new information to inform your decision-making processes.



QUESTION 1

Roadmap

What is the current extent of dryland salinity and its risk of spread?



What is the current extent of dryland salinity and its risk of spread?

DEFINITIONS¹:

Hazard – Anything that can potentially cause harm to an asset. The word ‘threat’ is often used interchangeably.

Risk – The chance that hazard will cause harm to an asset at some time in the future. Risk is typically defined as an impact multiplied by its likelihood of occurrence at some given time in the future.



WHY IS THIS QUESTION IMPORTANT?

To address dryland salinity and its impacts, including in-stream salinisation, it is necessary to first understand how much salinity we have, where it occurs in the landscape and its risk of expansion. This question considers dryland salinity extent and risk at the landscape rather than property or paddock level.

Mapping of the extent and risk of dryland salinity at an extensive scale is used for strategic planning. It enables comparison between States or between major catchments. Finer scale assessment and mapping enables comparison between sub-catchments within each major catchment.

This sort of mapping and its associated information provide a ‘big picture’ view of where the serious dryland salinity problems are. This facilitates good planning and policy-making by enabling the setting of sensible targets to protect valuable resources at risk from salinisation, including cultural assets, and the efficient allocation of limited resources for both research investigations and on-ground investments.

It is important to use our understanding of dryland salinity extent and risk to guide investment in planning and management. The problem in Australia is considerable, and protection and remediation of all parts of the landscape where dryland salinity is an issue is not viable. In this light, a surgical ‘triage’ approach of better targeting public investment to protect the highest value assets is needed. Measures also need to be put in place to help communities where living with salinity, including the productive use of saline resources, is the only viable option.



WHAT DID WE KNOW IN 1998?

In 1998, when NDSP reported on the outcomes of its first phase of research and activities, it wasn’t possible to provide a comprehensive overview of the current extent and risks of dryland salinity and its risk of spread.

Chapter 2 in *Assessing the causes, impacts, costs and management of dryland salinity*² titled ‘What are the options for mapping the current extent and risk of dryland salinity in my catchment?’ focused on the available methods and tools for mapping salinity, rather than defining current extent and risk. While that chapter continues to be a relevant reference for understanding many of the methods and tools available for salinity mapping (albeit, with emphasis at property level), a more current user-friendly guide and associated technical report are described under ‘Mapping methods for salinity’ (section 1.3.1).

The following factors were considered:

- Defining the problem to be mapped
- Finding out what is already known
- Using visual observations
- Sampling your water and soil
- Checking out your water table

- Choosing suitable remote mapping techniques
 - Aerial photography
 - Satellite remote sensing
 - Airborne multi-spectral scanning (MSS)
 - Airborne geophysics
- Choosing ground-based mapping techniques
 - Electromagnetic techniques
 - Other ground-based methods
- Linking with groundwater information
- A case study of the Upper Kent River catchment in Western Australia.

While maps and databases were available to varying degrees across catchments and for individual States in 1998, data custodianship was uncoordinated, and access to information was difficult. Piecing information together at a State and National scale, understanding the gaps and deficiencies, and making data more readily available was a major task that lay ahead.

Some progress with establishing datasets for the Murray–Darling Basin to inform dryland salinity management was made by 1998 with the *Basin-wide vegetation datasets*³ and *Murray–Darling Basin Soil Information Strategy*⁴ projects; however both datasets have significant limitations. The *NSW Dryland salinity hazard*⁵ project produced the first statewide dryland salinity map based on a 'weights of evidence' approach and GIS manipulation, and showed areas of major concern for more detailed investigations.

The importance of having a national perspective on dryland salinity to inform regional planning and management only emerged in the late 1990s. *Assessing the causes, impacts, costs and management of dryland salinity* discussed the notion of a 'National Catchment Categorisation System' or the 'National Classification of Catchments'⁶ to 'readily extrapolate management results from those more intensively studied catchments to assess salinity risk and determine appropriate salinity management options in other catchments'. The National Classification of Catchments approach was similarly conveyed in *Understanding dryland salinity*.⁷ This system became the building block for the *Groundwater Flow Systems Framework*⁸ (highlighted in the Introduction) – an operational framework now in use for assessing dryland salinity risk.

The groundwater and farming systems models described in *Assessing the causes, impacts, costs and management of dryland salinity* – FLOWTUBE, HARSD, MODFLOW, PERFECT, APSIM, WAVES, TOPOG – are still used to assess risk and management options, although further refinements have taken place. Water balance models are described in detail in Question 4.



WHAT ADVANCES HAVE WE MADE SINCE?

1.1 National Land & Water Resources Audit (1997–2002)

1.1.1 Mapping dryland salinity hazard and risk

The estimates of shallow water tables and salinity hazard brought together by the Audit⁹ presented the first comprehensive snapshot of extent and risk across Australia based on State studies. This was a great feat in combining data from a variety of sources, putting it on one map and providing a set of estimates for planners and policy-makers to work with. It highlighted the significance of dryland salinity as a natural resource management issue.

QUESTION 1

Salinity strategic planning and the development of action and investment plans at National, State and regional levels were given renewed importance by the findings of the Audit. In particular, this was reinforced by the National Action Plan (NAP) for Salinity and Water Quality launched in November 2000 by the Australian Government.

The Audit used regional-scale, dryland salinity risk or hazard assessments undertaken by State/Territory agencies drawing on:

- Information on groundwater levels and trends
- Known incidence of salinity
- Soil characteristics
- Topography.

The specific definitions of 'Hazard' and 'Risk' used in the Audit assessments vary between States. For example, the following definitions have been established in NSW:

Dryland salinity hazard is the extent to which natural physical characteristics, excluding land cover, predispose a landscape to salinisation. Relevant characteristics include topography, soils, geology and climate.

Dryland salinity risk is a measure of the likelihood of salinity occurring as a result of land use and other activities and of the severity of the impacts (economic, social and environmental costs) caused by that salinity (Risk = likelihood x consequence). A change in land use or management practice can either reduce or increase risk.

Risk assessments were undertaken for New South Wales¹⁰, Western Australia¹¹, South Australia¹² and Victoria¹³ where sufficient data enabled an understanding of shallow water table behaviour. However, a consistent approach was not always applied in these assessments.

In Queensland¹⁴ and Tasmania,¹⁵ *hazard* assessments were undertaken as data on groundwater levels and trends were sparse, requiring greater reliance on knowledge of dryland salinity incidence and land features. For the Northern Territory,¹⁶ the Audit used information from a hazard assessment of dryland salinity undertaken in 1994.

Areas considered to be of very low risk were not assessed, including most of the non-agricultural area in Western Australia, South Australia and western New South Wales.

Dryland salinity risk and hazard estimates for the year 2050 were compiled into a single map. It shows about 5.7 million hectares of agricultural and pastoral land with dryland salinity (through shallow water tables), increasing to 17 million hectares by 2050 in the absence of effective action (see Figure 1.1). Table 1.1 shows the breakdown of these estimates by States; however it should be noted that some States have undertaken finer resolution assessments since this time. These assessments are discussed in more detail in section 1.3.3.

The map shows large tracts in the Murray–Darling Basin in South Australia, Victoria and New South Wales at risk, together with the agricultural zone of south-west Western Australia. Over four million hectares of south-west Western Australia were assessed to be at risk. This area was predicted to double by 2050. These assessments were based on existing data held by States and constrained by financial resources and available time. Priorities for improving the groundwater data quality and coverage across States were exposed by the assessment process.

While confidence in different parts of the maps varies, it generally points to the need for land use change and management to address salinity, and where that change may need to take place. It is also helpful in targeting where more detailed assessments are needed. Confidence in the estimates is variable in southern Australia, but greater than in northern Australia where groundwater data is very sparse to non-existent.

Dryland salinity is an emerging problem in northern Australia. Water balance changes in catchments with high salt stores have the potential to mobilise salt. An estimated 3.1 million hectares in Queensland was assessed as facing a high hazard.

Figure 1.1

Forecasted areas containing land of high hazard or risk of dryland salinity in 2050

(Source: Commonwealth of Australia, 2001, *Dryland salinity in Australia: National Land & Water Resources Audit's Australian Dryland Salinity Assessment 2000 – Extent, impacts, processes and management options*. National Land & Water Resources Audit, Canberra ACT.)

**Table 1.1**

Areas at high risk from shallow water tables or with a high salinity hazard by State

(Source: Commonwealth of Australia, 2001, *Dryland salinity in Australia: National Land & Water Resources Audit's Australian Dryland Salinity Assessment 2000 – Extent, impacts, processes and management options*. National Land & Water Resources Audit, Canberra ACT.)

STATE*	1998–2000 [#] (ha)	2050 [#] (ha)
Western Australia	4,363,000	8,800,000
Victoria	670,000	3,110,000
South Australia	390,000	600,000
New South Wales	181,000	1,300,000
Tasmania	54,000	90,000
Queensland	not assessed	3,100,000
TOTAL	5,658,000	17,000,000

* The ACT and Northern Territory were excluded from the assessment on the basis of very minor salinity issues

[#] Finer resolution assessments have been made since this time and are discussed in section 1.3.3

The map-making facility provided on the Audit's web-site (www.nlwra.gov.au) can be used to generate dryland salinity maps of risk and hazard for individual States or catchments. An example for the midlands region of Tasmania is shown in Figure 1.2.

QUESTION 1

Figure 1.2

Predicted dryland salinity extent for the Midlands region of Tasmania in 1999–2000

(Source: www.nlwra.gov.au)



ACTION #1.1

Review data, information, reports and maps on the current extent of dryland salinity and its risk of spread compiled by the Audit relevant to your catchment, but with due consideration to work that has taken place since.



The key messages on dryland salinity risk and hazard arising from the Audit are:

- There is no quick fix – salinity can be managed by prevention, treating the cause, ameliorating the symptoms, living with it or a combination of these
- Salinity management requires knowledge about soil, salt, water and vegetation integrated with knowledge about groundwater flow systems
- Hazard assessment has confirmed that large areas of the tropics and sub-tropics have potential salinity problems if clearing occurs
- Broad-scale land clearing with little or no regard for the salinity hazard is a recipe to repeat the problems of temperate Australia
- Assessment of areas identified as having a hazard, particularly areas of extensive clearing in central and southern Queensland, is essential, and would underpin the development and implementation of vegetation management policies and guidelines
- Opportunity exists for a major national, well-focused investment in preventive action in northern Australia.

The availability of information on current extent and risk through the Audit has stimulated interest and debate around Australia about the importance of dryland salinity, the accuracy of data, the critical gaps in information and the need to more efficiently allocate resources. Water resources issues, such as The Living Murray Initiative (www.thelivingmurray.mdbc.gov.au) and the allocation of environmental flows, are also driving the need to better integrate dryland salinity management with other natural resource issues. While our understanding is still far from adequate, especially at the catchment planning level, managers and investors have a much better picture of where to focus their efforts and resources than in 1998.

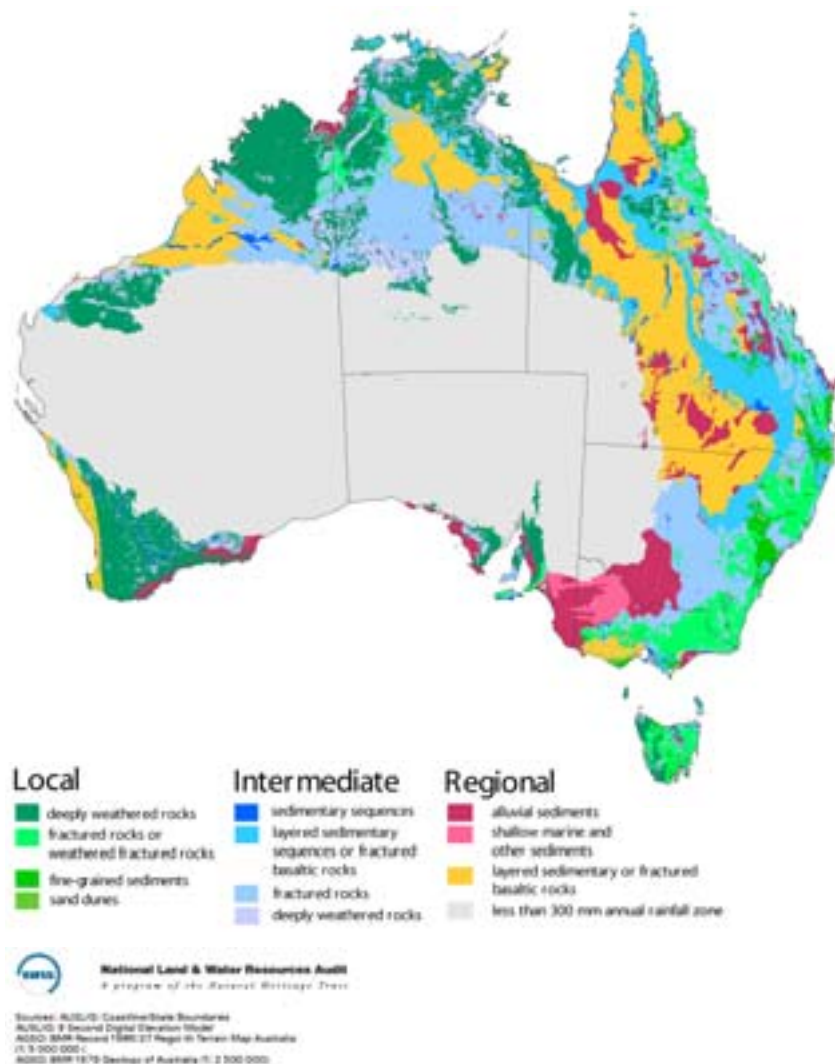
1.1.2 Building on the National Classification of Catchments

The Audit produced two 1:5,000,000 resolution maps of groundwater flow systems across Australia – the first representing the three major groundwater flow system types, and the second (see Figure 1.3) showing 12 sub-systems (3 of the 15 sub-systems described in the *National Classification of Catchments* could not be mapped at this scale). The three major groundwater flow systems are based on spatial extent and influence. A system with greater spatial extent has slower responsiveness to any changes in water balance and therefore presents a higher risk, as reversing the process is inherently more difficult.

Figure 1.3

Twelve major groundwater flow sub-systems in Australia at 1:5,000,000

(Source: Commonwealth of Australia, 2001, *Dryland salinity in Australia: National Land & Water Resources Audit's Australian Dryland Salinity Assessment 2000 – Extent, impacts, processes and management options*. National Land & Water Resources Audit, Canberra ACT.)



QUESTION 1

ACTION #1.2

Review data, information and reports on groundwater flow systems compiled by the Audit (www.nlwra.gov.au)



The mapping of groundwater flow systems embodies an understanding of the causes and processes of dryland salinity, as reflected in the five case study catchments outlined in Question 2 (section 2.1.2). The Audit describes the three major groundwater flow systems types accordingly:

- **Local groundwater flow systems** (<5 km in length) respond rapidly to increased groundwater recharge. Water tables rise rapidly and saline discharge typically occurs within 30 to 50 years of clearing native vegetation.
- **Intermediate groundwater flow systems** (5–50 km) have a greater storage capacity and generally higher permeability than local systems. They take longer to 'fill' following increased recharge. Increased discharge typically occurs within 50 to 100 years of clearing of native vegetation.
- **Regional groundwater flow systems** (>50 km) have an even higher storage capacity and permeability. They take much longer to develop increased groundwater discharge than local or intermediate flow systems – probably more than 100 years after clearing the native vegetation. The full extent of change may take thousands of years.

While a map of groundwater flow systems alone is not sufficient to assess dryland salinity risk or hazard, it provides an indication at the broadest level of potential exposure to risk from removing deep-rooted, perennial vegetation without further knowledge of catchment characteristics, such as the location of salt stores. Risk ratings can also be assigned to the various attributes that characterise a particular groundwater flow system (e.g. aquifer transmissivity, specific yield, catchment size), resulting in overall risk ratings for dryland salinisation, water salinity and salt load.

1.2 Groundwater flow systems

1.2.1 Developing the Groundwater Flow Systems Framework

Since the National Land & Water Resources Audit report on salinity, the 'Catchment Classification' project has produced a 1:1,000,000 resolution map of groundwater flow systems for the Murray–Darling Basin (see Figure 1.4) and drawn together and summarised the lessons from nine case study catchments across Australia (discussed in Question 2, sections 2.1.2 and 2.2.1) in the publication *Groundwater Flow Systems Framework – Essential tools for planning salinity management*.¹⁷

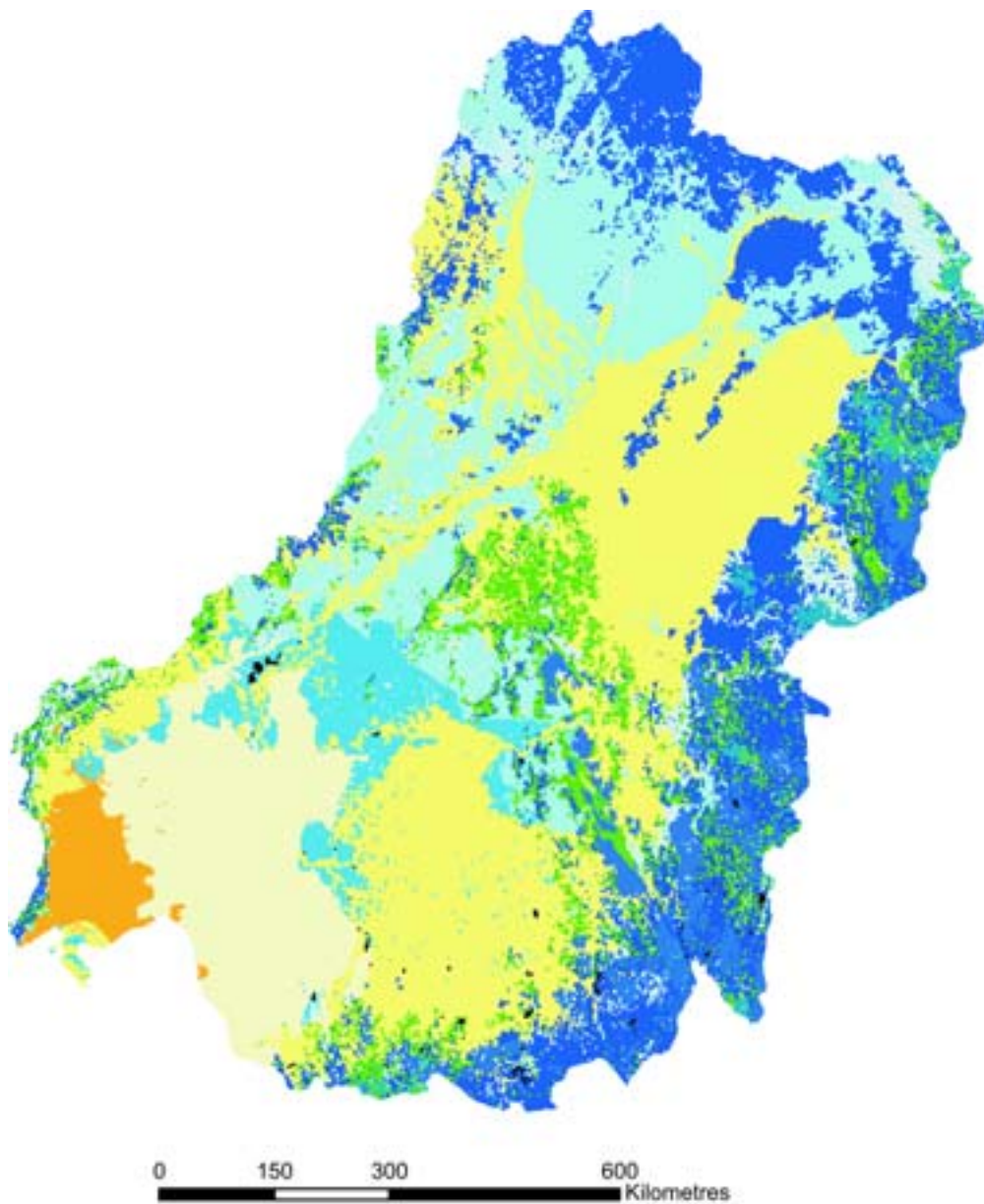
The framework provides all the key elements of a valuable and credible tool for salinity managers:

- An understanding of the causes of salinity – how groundwater recharges, mobilising salt, in response to changes in land use and management
- Conceptual models that describe groundwater processes leading to discharge
- Sound methodology for mapping the different groundwater flow systems
- Case studies where groundwater processes have been closely studied and model predictions tested and validated
- Groundwater and surface water data along with quantitative descriptions of hydro-geological features.

Figure 1.4

Murray–Darling Basin groundwater flow system map at 1:1,000,000 resolution

(Source: Walker G., Gilfedder M., Evans R., Dyson P., and Stauffacher M., 2003, *Groundwater flow systems framework: Essential tools for planning salinity management*, MDBC Publication 14/03, Murray–Darling Basin Commission, Canberra ACT.)



Salinity Provinces in the Murray–Darling Basin

- local flow systems in upland alluvium
- local flow systems in aeolian sands
- local flow systems in aeolian sands overlying regional flow systems in alluvial aquifers
- local flow systems in fractured basalts
- local flow systems in granitic rocks
- local flow systems in fractured rock aquifers
- Intermediate and local flow systems in fractured rock aquifers
- regional flow systems in unconfined marine sediments overlain by local flow systems in aeolian sediments
- regional flow systems in alluvial aquifers
- regional flow systems in limestone aquifers
- major water bodies

QUESTION 1

We now have a consistent method for mapping the landscape into distinct groundwater flow systems and associating these with conceptual models (see Figure 1.5). Importantly, we can describe in broad terms how groundwater functions in each part of the landscape. From this we can identify the typical processes leading to dryland salinity. In doing so, we can use the *Groundwater Flow Systems Framework* to prioritise catchments, propose options for managing them, and predict the most likely outcomes. These aspects of the framework are discussed in the chapters that follow.

The approach to using groundwater flow systems was modified in Western Australia to account for the dominance of salinity within local groundwater flow systems of similar geologic origin. Areas of like process, management action and risk have been grouped into 31 soil landscape zones¹⁸. These zones were used as the basis for assessing the impact of management options and quantifying the benefits of actions between zones (see further detail in section 5.2 – Salinity Investment Framework).

In catchments where there is a need and an established benefit, groundwater flow systems can be taken to paddock scale using airborne geophysics and associated systems of ground-based analysis¹⁹. Paddock-scaled resolution of soil, regolith, salt store and geology can be derived by use of these systems. Clear management objectives need to be established prior to planning for such levels of planning and action.

Groundwater flow systems may be 'nested'; for example, a local groundwater flow system may overlie a regional groundwater flow system, and these systems may or may not be connected. There are also very real limits to how reliably we can expect to transfer principles from one well-studied catchment to another that appears similar but is not well described.

This approach suggests that there is no 'one-size-fits-all' solution to dryland salinity. We should not be surprised to find, in such a vast and diverse landscape, that some catchments might not fit neatly into our catalogue of groundwater flow systems. But we now have a set of models that help us interpret and describe groundwater behaviour at a variety of scales.

In some instances we might find that the variability within a groundwater flow system is actually greater than the variability between different systems, providing a significant challenge to our classification scheme. Whilst we could remedy this by describing further catchment sub-systems, it comes at a price. The increasing detail and complexity negates the multiplier benefits of extrapolating knowledge from a few catchments to many that should be similar.

The current knowledge developed under the groundwater flow systems banner is a starting point that introduces the concept and places an approach in front of those charged with management. The classification of catchments allows for broad policy development and regional prioritisation of management options. However, we will require more complex tools as we focus in on key areas for more detailed assessment of options.

ACTION #1.3

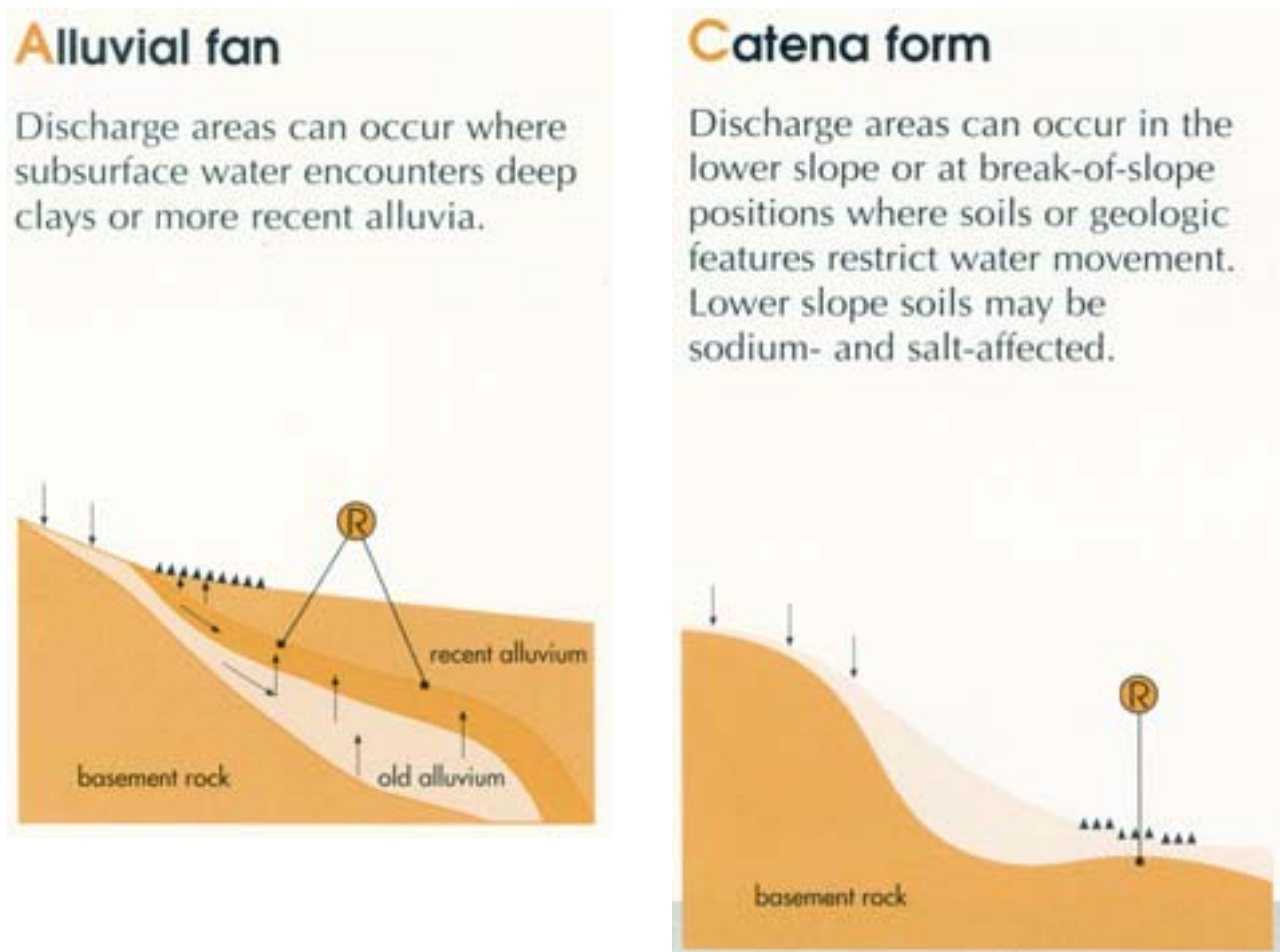
Read the six-page summary of the Groundwater Flow Systems Framework, and understand its strengths and limitations in guiding your salinity management planning.



Figure 1.5

An example of local groundwater flow systems where the movement of water is often occurring within the upper 2–5 metres of the soil profile – 'Alluvial fan' and 'Catena form' salinity types

(Source: Department of Natural Resources Queensland, 1997, *Salinity management handbook*. Scientific Publishing, Resource Sciences Centre, Coorparoo QLD.)



1.2.2 Using groundwater flow systems to compile information on salinity risk

Regional groundwater flow system maps at 1:250,000 resolution have been developed for the major catchments of the Murray–Darling Basin, with the exception of the rangelands (where their applicability is limited) and the Victorian and NSW Mallee. These maps were developed as a joint initiative of the *Catchment Classification* project and the *Tools*²⁰ project, a major communication and capacity-building initiative on planning and managing dryland salinity in the Murray–Darling Basin. Ongoing refinement of these maps continues, and some mapping at 1:100,000 resolution has also taken place in parts. Tasmania has just completed a 1:250,000 resolution map of groundwater flow systems for the State. Management options for the thirteen groundwater flow systems are described.²¹

QUESTION 1

Figure 1.6

Map of groundwater flow systems for Tasmania at 1:250,000

(Source: Latinovic M., Matthews W. L., Bastick C., Lynch S., Dyson P. and Humphries E., 2002, *Tasmanian Groundwater Flow Systems for Dryland Salinity Planning*, Mineral Resources Tasmania, Tasmanian Geological Survey Record 2003/02, Department of Infrastructure, Energy and Resources, TAS.)



The 'Tools' project used the *Groundwater Flow Systems Framework* to package information on salinity planning and management. The overarching *Salinity Information Package*²² comprising 40 technical information sheets was described in the Introduction (page 1). Ten *Regional Information Packages*²³ for the major catchments of the Murray–Darling Basin use the *Groundwater Flow Systems Framework* to describe the extent of salinity and a relative rating for salinity risk for each major groundwater flow system (see Table 1.2). These regional packages are specific to particular regions in the Murray–Darling Basin and represent an important achievement. They can also be used as a model for developing information packages for any region in Australia.

Each 'Tools' regional package considers the following:

1. Background
 - Location
 - Climate
 - Natural resources
 - Population
 - Industry
 - Heritage
2. People and the land
 - Land use
 - Trends in agriculture
 - Implications for salinity management planning
3. Salinity
 - Aspects of salinity
 - Extent of salinity
 - Costs of salinity
 - Implications for salinity management planning
4. Hydrogeology and salinity management
 - Background
 - Management options for each major groundwater flow system
5. Best management options
6. Further reading and references
7. Useful contacts.

Regional Information Packages are available for the following regions of the Murray–Darling Basin (www.ndsp.gov.au):

- Old Murray–Darling Basin
- Barwon, NSW
- Central West and Lachlan, NSW
- Murray, NSW (also see *Healthy Catchment guide*²⁴)
- Murrumbidgee, NSW
- Goulburn–Broken, Victoria
- North Central, Victoria
- North East, Victoria
- Wimmera, Victoria
- SA Murray–Darling Basin and the Victorian Mallee.

ACTION #1.4

Use the 'Tools' information packages. Rapid Catchment Appraisal findings or Catchment Management Handbook for your region (or review them as a model for developing your own information) as a guide for assigning salinity risks to each of your major groundwater flow systems.



ACTION #1.5

Access the best available groundwater flow systems map for your region, and consider investing in the development of smaller-scale maps at 1:250,000 and 1:100,000 for more detailed identification of risks.



QUESTION 1

Table 1.2

The Murray Regional Information Package provides an example of the decision-support table showing salinity risk categories

[Source: Murray–Darling Basin Commission, 2004, *Tools for improved management of dryland salinity in the Murray–Darling Basin – Murray regional information package*, Murray–Darling Basin Commission, Canberra, ACT.]

Attributes	Groundwater Flow System							
	Local				Local & Intermed	Local, Intermed & Regional	Intermed & Regional	Regional
	High Relief Fractured Rocks (Non-Granite)	High Relief Granites	Low Relief Granites	Fractured Sandstone & Surrounding Plains	Low Relief Fractured Rocks (Non Granite)	Upland Alluvium	Murray Basin Sediments (Shepparton Form)	Murray Basin Sediments (Calivil & Renmark Form)
	IV	V	VI	VII	I	III	II	VIII
Aquifer Transmissivity	20–50	<10	20–30	20–50	20–50	100–2,000	5–200	1500–2,500
Specific Yield	<5	10–15	10–15	<5	<5	15–20	15–20	15–20
Catchment Size (km ²)	<10	<10	<10	<20	100–200	500–1000	50	1,000
Annual Rainfall	650–1000	650–1000	450–650	600	450–550	450–700	350–450	350–500
Groundwater Salinity (dS/m)	0.2–3+	0.3–2+	1–20	1–3	1–10	0.4–12	0.5–60	0.4–50
Salinity Rating (soil)	S2	S2, S3	S2, S3	S2, S3	S2, S3	S2, S3	n/a	n/a
Temporal Distribution of Recharge	S	S	S, E	S	S, E	S	E	S
Spatial Distribution of Recharge	Hilltop	Slopes	Slopes	Slopes	General	General	General	Fan head
Type Areas	Holbrook Little Billabong	Mullengandra	Gerogery	Gerogery East	Lockhart	Upstream Corowa	Deniliquin	Deniliquin
Salinity Risk	L	L	L	L	M–H	L–M	M	L

Definitions of the relative ratings that apply to the characteristics of GFS (NLWRA 2001)

Aquifer Transmissivity	L	low (<2 m ² /day)	M	moderate (2–100 m ² /day)	H	high (>100 m ² /day)
Specific Yield	L	low (<5%)	M	moderate (5–15%)	H	high (>15%)
Catchment Size	S	small (<10 km ² ; <1,000 ha)	M	moderate (10–500 km ² ; 1,000–50,000 ha)	L	large (>500 km ² ; >50,000 ha)
Annual Rainfall	L	low (<400 mm)	M	moderate (400–800 mm)	H	high (>800 mm)
Groundwater Salinity	L	low (<2,000 mg/L; <3 dS/m)	M	moderate (2,000–10,000 mg/L; 3–15 dS/m)	H	high (>10,000 mg/L; >15 dS/m)
Salinity Rating (soil)	S1	loss of production	S2	saline land covered with salt-tolerant species	S3	barren saline soils, typically eroded
Temporal Distribution of Recharge	E	episodic	S	seasonal		
Salinity Risk Ranking	L	low	M	moderate	H	high

Similar information in the Western Australian context is available through the *Rapid Catchment Appraisal* (<http://agspsrv34.agric.wa.gov.au/environment>) (RCA) program. As part of the Western Australian Salinity Strategy²⁵, RCA provides regional catchment and local government authorities with current estimates of extent and risk, analysis of the impact of management options, and direction for salinity management in their region. Extent and risk analysis is driven by assessments of satellite-based salinity mapping, while management option assessments use established modelling tools such as FLOWTUBE and AgET. Analysis and reporting from projects spanning approximately six million hectares of the agricultural area has been completed.

For north-eastern Australia, the *Salinity Management Handbook*²⁶ comprising three parts – understanding salinity, investigating salinity and managing salinity – provides a comprehensive and practical introduction to salinity using groundwater flow systems concepts. The three major types of salinity are described and practical information for planning and carrying out salinity investigations is provided. Vegetation, irrigation and engineering applications are outlined, together with the process of developing an integrated plan of management.

1.3 Data

1.3.1 Mapping methods for salinity

Salinity mapping in a landscape can mean different things to different people. This has led to a comprehensive review on 'Salinity mapping methods in the Australian context and their applicability for assessing salinity hazard and risk'. A user-friendly guide²⁷ has been produced, supplemented by a technical report²⁸ with more detailed descriptions of approaches to salinity mapping, prediction, monitoring and risk management.

The guide looks at the information needs of three classes of user – at catchment, sub-catchment, and paddock levels. It explains the difference between hazard and risk, and briefly describes the origins of dryland salinity. It provides detailed information about methods to map dryland salinity, including the investment decisions that need to be made, the cost, skill level, applicability and limitations of each method. It is designed to help identify the optimal approaches that can be used to get more information about your salinity problem to help make better decisions about management options.

The review showed that tools such as air-photo interpretation, ground electromagnetics and satellite-based mapping systems could provide accurate maps of the current extent of existing dryland salinity. Acquiring these data require that they are first matched to the users landscape and their needs. All systems are only accurate if properly calibrated. Systems that are better equipped to assess hazard are tools such as airborne electromagnetics, magnetics and radiometrics. These tools map the spatial distribution of soils, regolith and deep salt stores that affect future risk. They do not map dryland salinity.

1.3.2 Knowing where the salt is stored

Techniques are available to map catchment attributes (soils, geology, regolith and salt stores), such as satellite, multi-spectral, hyper-spectral, terrain, radiometric, magnetics and electromagnetic systems. There are others that can map the expression of dryland salinity (satellite, air-photo, ground electromagnetics). Combinations of these systems have been used in hazard mapping. However, what is crucial is that none of these approaches directly maps the

ACTION #1.6

Consult the guide on salinity mapping methods to refine your thinking on future regional investments in salinity mapping, prediction, monitoring and risk management.



QUESTION 1

ACTION #1.7

Explore the various geophysical techniques (ground and airborne) available for locating catchment salt stores and undertake a cost-benefit analysis to guide effective investment in your region.



key parameters in salinity risk assessment, that is, land use and related changes to the catchment water balance.

Hazard maps require knowledge about the physical characteristics of the catchment, together with time trends in water and salt driven by climate and land use change. This approach drove the development of an assessment of current and predicted dryland salinity in Australia under the National Land & Water Resources Audit and, in part, the development of the groundwater flow systems approach. Since the Audit, various regions and States have taken differing approaches to resolve regionally-based assessment of hazard or risk by acquiring new datasets or assessing old datasets.

Salinity hazard maps have been produced for National Action Plan (NAP) catchments in Queensland. A state-wide salinity hazard dataset has been produced for New South Wales using a similar methodology to that used in Queensland. The overlay of three GIS datasets produces these maps: regolith salt store, recharge potential and discharge sensitivity. The resulting maps indicate the potential for salt to accumulate in a particular part of the landscape at sometime in the future.

If a finer resolution of risk and hazard is required, higher resolution datasets, such as airborne geophysics can be acquired. The *National Airborne Geophysics Project*²⁹ (NAGP) assessed the efficacy and application of airborne systems (SALTMAP, DIGHEM, TEMPEST) and interpreted products at five sites in four States. These products include salinity hazard, soil, groundwater target, salt store and geological maps.

The NAGP concluded that no others tools available provide the descriptive capacity for landscapes, or level of resolution available to assess salinity risk and hazard. However, it also concluded that the raw data was unusable by land managers and hence interpreted products were required. Assessments of those products showed that they could be significantly improved and that the major limitation to the technology was the lack of benefit developed from improvements in decision-making for land managers. The project also concluded that every dollar spent in the air should be matched by one on the ground (calibration and interpretation).

This conclusion was revisited in a further study that undertook analysis of the costs and benefits and adoption issues faced by land managers. They concluded that the majority of existing surveys had been poorly conceptualised and that only those who better understood the strengths of the technologies and needs of catchment managers would be valued³⁰. Recent surveys completed in South Australia (Riverlands)³¹ are evidence that the old logic of acquisition and testing (system trials) is giving way to products to test realistic applications and provide results.

1.3.3 Assessing salinity hazard and risk at the State level

The National Land & Water Resources Audit estimates of areas with shallow water tables and future hazard in Western Australia have been updated as part of the *Land Monitor*³² project, which provides farm-scaled, satellite-based estimates of the area of salt-affected land. Interpreted satellite images showed that 1.047 million hectares of land was classed as severely salt-affected, compared to the earlier estimate of 4.363 million hectares under the Audit shown in Table 1.1. Of this revised area of 1.047 million hectares, 0.821 m ha is farmland and the remainder is public land (mainly native vegetation). The time trends in the rate of expansion of

saline land were approximately 15,000 ha/yr. It is anticipated that satellite data will be continuously acquired on a 5–10 years timeline to update trends in salinity and native vegetation. The project also developed a surrogate system for assessing salinity risk into the future, after first failing to develop a system based on conventional groundwater data and modelling systems³³. The final hazard assessment tool used terrain analysis and decision rules derived to identify valley hazards for subsequent analysis. Between 4.4 million hectares (private) and 5.4 million hectares (plus public land) was identified using this system.

South Australia has salinity risk maps³⁴ for catchment managers, based on GIS modelling from soils, landscape, topography and existing salinity databases.

A major project under the NSW Salinity Strategy³⁵ is developing a *NSW Salinity Hazard and Risk Data Set*. This modelling is based on a range of data layers and provides a high-level strategic product for Catchment Management Authorities (CMAs) and government agencies to plan salinity actions.

The NSW Coastal Salinity Audit (in draft)³⁶, together with the Hunter River Salinity Audit³⁷, completes Action 1.3 of the NSW Salinity Strategy: to audit salt-affected areas outside the Murray–Darling Basin (MDB). The coastal audit focuses on the North and South Coast, plus the Manning River, Karuah River and Lake Macquarie and Tuggerah Lake basins, which were not included in the Hunter audit. The MDB and Hunter River audits assessed the impact of dryland salinity on stream salinity and river basin salt loads, and predicted future stream salinity based on groundwater level trends. The audits did not address land salinisation. Likewise, the coastal audit focussed on stream salinity, however, there was insufficient groundwater data for coastal river basins, except for the Hunter, to be able to make salinity trend predictions.

The general findings of the coastal audit are that:

- Median salinity values for most coastal rivers and tributaries are low
- Stream salt loads are not currently a major threat in coastal regions
- Agricultural practices currently present a low risk for stream salinisation across the coastal basins
- Major salinity problems on the coast are associated with urban development.

Urban salinity in Western Sydney is the subject of separate projects, as a part of the Local Government Salinity Initiative and the Urban Salt Action Team work, also established under the NSW Salinity Strategy.

The study *Salinity predictions for NSW rivers within the Murray–Darling Basin*³⁸ looks at the primary question of how much salt will be carried in the Murray and Darling tributary rivers of NSW as a result of dryland salinisation processes and rising groundwater during the coming century. Secondary questions regarding the impacts of salinity changes on river water uses such as irrigation, urban water supply and wetland ecosystems are also broadly addressed. On a whole catchment basis, the study calculated the total salt delivery in a range of from 0.3 to 26 t/km²/yr, with rates within catchments as high as 76 t/km²/yr in some geological units.

The Queensland Government has released a series of hazard maps covering priority catchments in Queensland, that is, over 40 per cent of the State³⁹. The maps use a composite index method in a GIS environment, developed from pilot studies of some seven million hectares in southern Queensland⁴⁰. The method captures the current knowledge of landscape salinity processes to identify vulnerable landscapes; a similar approach has since been used in New South Wales

ACTION #1.8

Use the results from assessments on the extent and hazard of dryland salinity to inform your decision-making processes with due consideration to the level of confidence in the underlying data sources applicable to your area.



QUESTION 1

hazard mapping. These maps provide a broad-scale regional overview; more detailed guidelines⁴¹ were developed for Queensland in 1997 for the identification, investigation and management of salinity based on site inspections and landscape observations. Broad-scale salinity risk mapping, salinity assessment tools and decision support tools are now being developed through the National Action Plan for Salinity and Water Quality and related activities.

1.3.4 Assessing salinity in cropping areas

The *Queensland cropping hazard*⁴² project assessed the potential of salinity issues in grain growing regions, using GIS-based hazard mapping, on-ground investigations of soil conductivity, and modelling of drainage associated with selected cropping systems. It showed that 21 per cent of all cropping land in Queensland faces a high hazard over the next 50 years. This area represents 4.5 per cent of all land within the Queensland agro-ecological zones defined by the Grains Research and Development Corporation (GRDC) (see Figure 3.4). A simplistic analysis would suggest that targeted management is need within an area of approximately 1.6 million hectares to protect the 21 per cent of cropping land falling within the high hazard category (see Table 1.3). Although this study used the latest advances in understanding and managing salinity, Queensland has major gaps in both data and knowledge of groundwater flow systems outside traditional irrigation areas, and therefore we need to use the information in a manner that reflects limited confidence in the results.

Table 1.3

GRDC agro-ecological zones in Queensland facing 'high salinity hazard'

(Source: Moss J., Gordon I., and Pearce B., 2002, *A description of the GIS based risk assessment methodology for salinity hazard assessment modelling in the Queensland Murray-Darling Basin*, Department of Natural Resources, Indooroopilly QLD.)

GRDC agro-ecological zone	High salinity hazard (ha)	Total cropping area (ha)	% of total in high hazard	Contributing catchment area (ha)
Old South-East	222,500	1,283,500	17	741,500
Atherton	2,300	7,300	31	7,500
Old South-West	6,000	186,800	3	20,200
Burdekin	200	1,800	9	600
Central	259,200	812,000	32	864,000
TOTAL	490,200	2,291,400	21	1,633,800

ACTION #1.9

Consider the results of specific studies on the extent and hazard of dryland salinity in cropping areas to inform your decision-making processes with due consideration to the level of confidence in the underlying data sources applicable to your area.



The *Economic evaluation*⁴³ project overlaid salinity extent maps from the NLWRA with the GRDC agro-ecological zones to assess the areas within each zone being impacted by dryland salinity in 2000 and 2020. Table 1.4 shows the estimated current extent of salinity within each GRDC agro-ecological zone by 2020. Zones with expected large increases include the WA Sandplain, SA Vic Bordertown Wimmera, NSW Vic Slopes, WA Central and Vic High Rainfall. Over 60 per cent of the additional saline area forecast to develop from 2000 to 2020 will be in the Western Region. About 1.1 million additional hectares of farmland in the cropping regions of Australia are forecast to become saline by 2020.

Table 1.4

Estimated current extent of dryland salinity in each GRDC agro-ecological zone and the anticipated growth in salinity area in each zone by 2020

(Source: Kingwell R., 2003, *Economic evaluation of salinity management options in cropping regions of Australia*, Grains Research & Development Corporation, Canberra ACT.)

GRDC zone	Saline Area ('000 ha)		Area Increase	
	2000	2020	('000 ha)	(x Area)
NSW Central	4	32	28	7.4
NSW Northeast-Qld Southeast	38	88	50	1.3
NSW Northwest-Qld Southwest	2	6	5	2.9
NSW Vic Slopes	61	203	142	2.3
Qld Atherton	1	2	2	2.2
Qld Burdekin		1	1	180.3
Qld Central	32	71	39	1.2
SA & Vic Mallee	108	145	37	0.3
SA Mid-North Lower York Eyre	118	118		
SA Vic Bordertown Wimmera	277	488	211	0.8
Tas Grain	18	24	6	0.3
Vic High Rainfall	72	228	155	2.1
WA Central	961	1,142	181	0.2
WA Eastern	374	374		
WA Northern	280	280		
WA Sandplain	275	522	247	0.9
TOTAL*	2,620	3,723	1,123	0.4

* No significant areas of salinity are recorded for WA Mallee or the WA Ord zones.

1.3.5 Accounting for climate variability

A project⁴⁴ in cropping areas on the south-west slopes of NSW showed that the main driver for water table change over the past 50 years has been climatic variability (at >80 per cent, compared to land use change at <20 per cent) and water tables over the past 30 years generally do not show a rise and in many cases have shown a slight fall. This suggests, for these catchments, that there will be minimal increase in land salinity over the next 50 years.

The marked rise relative to the initial level may be due to historic clearing of vegetation, but may be a consequence of bore development during dry periods and subsequent monitoring during wet periods. However, in Western Australia it has been demonstrated that rise in water levels is largely explained by vegetation clearance and the consequent adjustment in the water balance. The HARTT⁴⁵ model was used to discern changes and lags in water table response to rainfall and land use activities. These studies allow us to assess future likely trends in water levels, and consequent changes in salinity-affected areas.

1.3.6 Understanding the status of groundwater

The *Groundwater Status Report* project builds on the 1996 report on the status of groundwater in 1992 entitled 'Murray-Darling Basin Groundwater – A resource for the future'⁴⁶ and adds significantly to the body of data and knowledge used to inform the production of dryland salinity extent and risk/hazard maps by the Audit.

ACTION #1.10

Take into account climate variability (rainfall and evapotranspiration), where possible, when determining the risk of dryland salinity spread.



QUESTION 1

A plain-English report *Murray–Darling Basin Groundwater Status 1990–2000: Summary report*⁴⁷ is being prepared that will provide a strategic overview of the status of groundwater across the Basin, for each State and an individual status report on each major catchment based on the *Groundwater Flow Systems Framework* – using the 1:1,000,000 resolution map of the Murray–Darling Basin. A supporting comprehensive technical reference provides a detailed review of each groundwater flow system, and will be used to inform the production of the *Groundwater Status Report* itself.

The groundwater attributes considered include:

- Water table elevation
- Depth to water table
- Elevation of potentiometric surface (of semi-confined aquifers)
- Maximum drawdown
- Groundwater salinity (where data is available)
- Groundwater use, allocation and yield (for each groundwater management area)
- Analysis of groundwater trends as identified from analysis of hydrographs
- Identification of areas where groundwater resources are at risk.

For Murray–Darling Basin catchments, the *Groundwater Status Report* will represent the most up-to-date information available that consistently and accurately presents the attributes listed above. It will supercede comparative information presented in both the NLWRA and 'The salinity audit of the Murray–Darling Basin – A 100-year perspective, 1999'⁴⁸ and its associated State reports. However, as the 'Groundwater Status Report' is focused on groundwater, data on historical stream salinity trends and catchment salt balances⁴⁹ used in the 1999 Salinity Audit remain relevant.

Information is also presented as a GIS product. The GIS has been developed in ArcGIS Publisher and is delivered as a series of digital maps linked by a web style interface. The product may be viewed through ArcReader, a free product that is distributed with the GIS. The product allows maps to be printed at the scale required, with the ability to turn layers on and off to allow the user to tailor map outputs to specific requirements in addition to having hyperlinks to show representative hydrographs and salinity graphs (see Figure 1.7).

Three complementary reports reviewing *Groundwater management and property rights*,⁵⁰ *The origin of fresh groundwater in the SW Murray Basin and its potential for salinisation*⁵¹ and *Projections of groundwater extraction rates and implications for future demand and competition for surface water*⁵² in the Murray–Darling Basin are also available. The first publication considers the national framework for groundwater management and the Council of Australian Governments Water Reforms. On a State-by-State basis, it reviews groundwater legislation, institutional arrangements, implementation of approaches and dissemination of information, implementation and infrastructure issues and significant management initiatives. The second publication looks at the potential for salinisation of the large fresh groundwater reservoir in the Mallee region of the Murray–Darling Basin, which was mostly recharged 20,000 years ago and is not being replenished. The resource is drawn on for domestic, livestock and irrigation, and its expected life will be dependent upon the rate of extraction, but with the most immediate concern of the possibility of groundwater salinisation resulting from saline soil-water being displaced into the groundwater. The third publication considers water extraction in relation to the Murray–Darling Basin 'CAP on diversions' and recommends investigating and quantifying the groundwater resources of the Murray–Darling Basin and supporting their sustainable land use.

ACTION #1.11

Review the 'status report' for your region and State in the *Groundwater Status Report for the Murray–Darling Basin* (or as a model for developing your own in other parts of Australia) and use the CD-ROM to tailor your own regional maps.



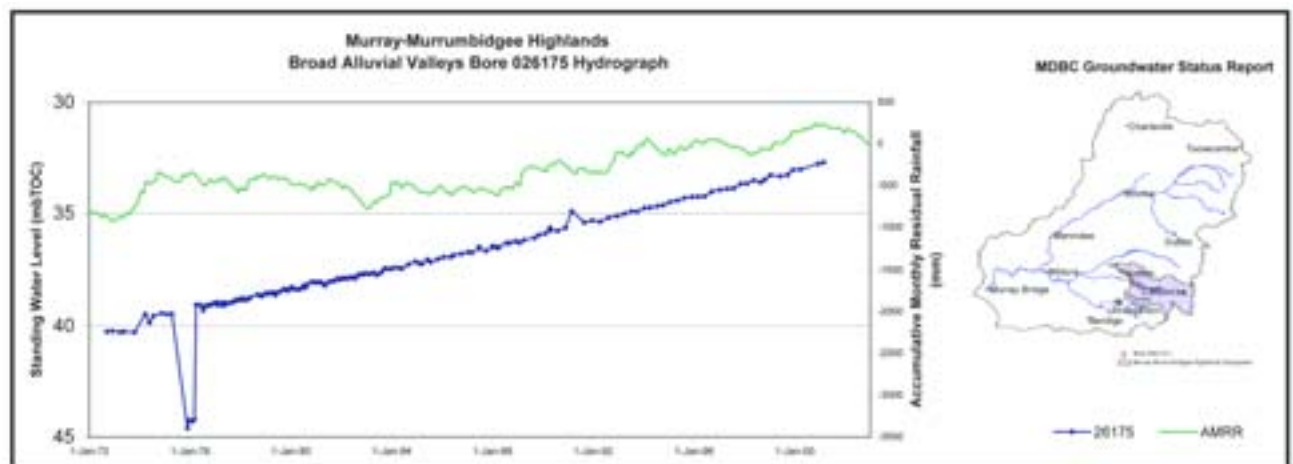
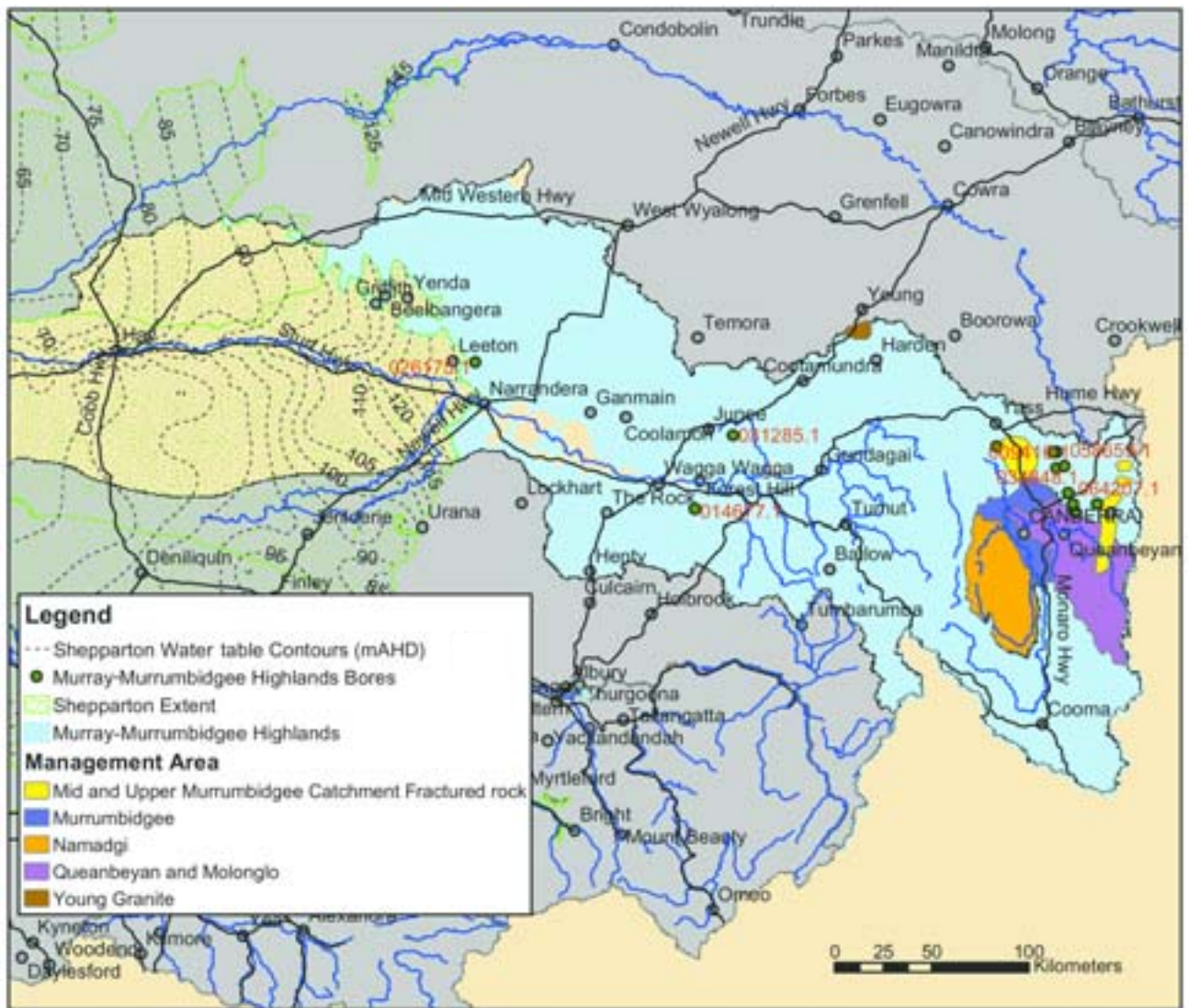
ACTION #1.12

Consider the concept of representative bores and the associated hydrographs for each groundwater flow system, and use this approach to guide future investments in bore installation and monitoring.



Figure 1.7

Example of a map of the Murrumbidgee Highlands showing groundwater management areas, with an example hydrograph showing rising groundwater levels from a representative bore near Leeton. (Source: Murray-Darling Basin Commission – Groundwater Status Report project.)



QUESTION 1

1.3.7 Scoping groundwater recharge in the rangelands

The *Rangelands recharge*⁵³ project scoped the risk of land and water salinisation in the rangelands of the Murray–Darling Basin from increased deep drainage from converting native vegetation to pasture land. The purpose of the salinity assessment was to identify areas for more detailed work, rather than to provide accurate predictions. The study used other data to extrapolate deep drainage, as recharge data in the rangelands was scarce.

For the southern rangelands (south of Wilcannia), increases in deep drainage would be unlikely to lead to significant increases in aquifer recharge within 100 years. Over this time-frame, the development of dryland salinity is expected to be limited to relatively small areas. Salt loads to the Darling River between Wilcannia and Pooncarie would not be expected to increase significantly.

For the northern half of the rangelands, significant areas of dryland salinity would be expected within 100 years after the increase in drainage. On this basis, the areas around Bourke and south of Charleville are potentially most at risk, and might be considered highest priority.

More extensive soil and stream salinisation would be expected following large irrigation developments, in both the south and north of these rangelands.

Two of the uncertainties in this salinity hazard assessment are water table depths and groundwater salinities of the aquifer in the northern rangelands. While detailed hydro-geological mapping of the Murray Geological Basin has been undertaken, the Darling Basin remains poorly understood.

ACTION #1.13

Investigate salinity risk in more detail before proceeding with conversion of native vegetation to pasture or irrigated agriculture in the rangelands of the Murray–Darling Basin, especially north of Wilcannia.



ACTION #1.14

Read the paper 'An overview of modelling techniques and decision support systems and their application for managing salinity in Australia', and consult the PRISM CD-ROM and 'Catchment Modelling Toolkit' (www.catchment.crc.org.au) to help refine existing information on the extent and risk of dryland salinity in your region.



1.4 Modelling capability

1.4.1 Using the right model for the task

A wide range of models has been developed to support salinity planning and management. These models draw on the understanding of experts and often local knowledge about salinity causes and processes. Many of these models have an element of risk assessment, but also salinity impacts and options for management – the topics of chapters to follow. The CRC for Catchment Hydrology is developing an on-line *Catchment Modelling Toolkit* (www.catchment.crc.org.au) with software and documentation on catchment modelling, supported by a *Catchment Modelling School* for professional training in model use.

The paper *An overview of modelling techniques and decision support systems and their application for managing salinity in Australia*⁵⁴ summarises some of the key models used to estimate salinity extent and risk. Table 1.5 is adapted from this paper, and provides some examples of salinity hazard and trend models. A description of these models is also on the PRISM (Practical Index of Salinity Models)⁵⁵ CD-ROM – a review of salinity models to support the implementation of the National Action Plan for Salinity and Water Quality. Also refer to section 4.3 'Models, frameworks and decision support tools'.

Table 1.5

Examples of salinity hazard and trend models in Australia

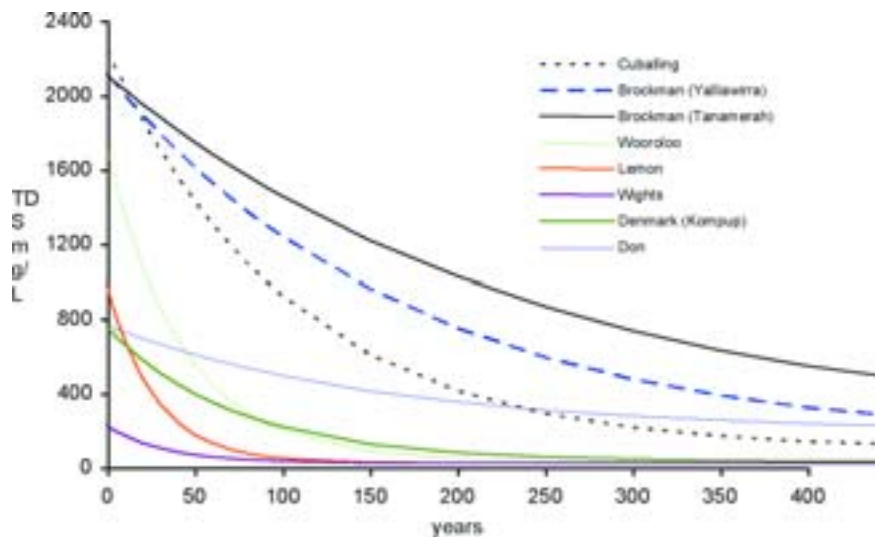
(Source: modified from Littleboy M., Vertessy R., and Lawrence P., 2003, *An overview of modelling techniques and decision support systems and their application for managing salinity in Australia*, PUR\$ 2003, CRC for Catchment Hydrology, Melbourne VIC.)

Model Type	Jurisdiction	Area	Focus	Summary
Hazard	BRS	Australia	Landscape	Composite index of climate and soil properties.
	Queensland	Qld Murray–Darling Basin & other Qld NAP regions	Landscape	Composite index of recharge potential, discharge sensitivity and salt stores.
	Western Australia	Catchment to sub-catchment	Stream	Catchment salt-flushing model ⁵⁶ – a simple storage and discharge model that estimates salt and water fluxes from catchments to estimate the time to reach a target salt load and flow concentration in a given stream, and the recovery of stream salinity to some useable level, as salt loads reduce over time. Eight catchments were modelled in south-west Western Australia under the 'Environmental Impacts' ⁵⁷ project (see Figure 1.8).
Trend	MDBC	Murray–Darling Basin	Stream	Used in the MDBC Salinity Audit. Linked rising groundwater model with current stream salinity trend to predict future stream EC and salt loads.
	NLWRA	Australia	Landscape	Identified current and future areas of shallow water tables. Linked to impact assessment on agriculture, urban and infrastructure.

Figure 1.8

Modelled reduction in-stream salinity through time for eight catchments in south-west Western Australia

(Source: Hatton T.J., Silberstein R.P., and Salama R.B., 2001, *Catchment salt balances and the future of river salinisation in Australia*, CSIRO Land & Water, Wembley WA.)



QUESTION 1



WHERE TO FROM HERE?

National Land & Water Resources Audit

The State assessments undertaken for the Audit resulted in a comprehensive analysis of groundwater data while exposing many limitations in quality, information management and fitness for purpose with respect to dryland salinity management. Most States have further refined these assessments since.

Some clear directions can be drawn from the Audit on understanding the current extent of dryland salinity and its risk of spread. The hazard assessments undertaken for central and southern Queensland were based on limited data and on-going refinement is better guiding the development of vegetation management policies and guidelines. Well-focused investment in preventative action in northern Australia is still needed, and this should be guided by the best available information.

The Audit has provided a mechanism by which users can determine what information is adequate and what is deficient for their particular purpose. Priorities for further research identified were improved methods of developing groundwater surfaces with distributed groundwater data, and improved methods for estimation of water balance targets, recharge and deep drainage with explicit links to groundwater system response.

Data records are accessible to catchment managers and funders to inform their investment decision-making processes, and we need to make sure that we use and build on this capability. This is particularly important given that the National Action Plan for Salinity and Water Quality has devolved a high proportion of resources directly to the regional level. Catchment managers and decision-makers need to be aware of the wealth of information that exists and where their investment choices can best add value at the regional level, and within the broader context.

The value of sharing information has been made apparent through both the Audit and the development of the *Groundwater Flow Systems Framework*. The Audit has played an on-going role in maintaining and updating the national database and ensuring its availability and accessibility. It is important that data collected at the regional level by catchment managers and funders continue to be made available and retrievable through this mechanism.

Groundwater flow systems

Where information on the current extent of dryland salinity and its risk of spread is limited, the groundwater flow systems approach has helped to fill the knowledge gaps. Understanding the type of groundwater flow systems provides an indication of the nature and size of the problem, and where it is likely to express itself in the landscape. From this, it is possible to rank catchments according to the nature and scale of their salinity problem or potential problem.

At National, State and regional scales the *Groundwater Flow Systems Framework* is guiding policy and investment decisions by identifying local, intermediate and regional groundwater flow systems, helping to determine broadly where the salinity risk is greatest and where management activities are most likely to be rewarded. In the Murray–Darling Basin and south-west Western Australia more detailed mapping and assessment allows regional predictions of salinity risk, guiding policy decisions and identifying broad management options. Further regional and sub-catchment scale mapping and interpretation are needed throughout Australia to support strategic and design level investment.

R & D TIP #1.1

Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au) and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.

R & D TIP #1.2

For information on further development of groundwater flow systems visit the NLWRA (www.nlwra.gov.au) and Bureau of Rural Sciences (www.brs.gov.au), and for the Murray–Darling Basin (www.mdbc.gov.au), as well as at individual State and regional levels.

Data

Studies in airborne geophysics indicate that specialised skills are required for salinity risk assessment and land management planning, and that targeted capture of airborne data is warranted in some circumstances. Realistic modelling of dryland salinity extent through time is achievable when combined with bore and climate data. Work needs to be expanded and explored further for different regions, where a cost-benefit analysis justifies the investment. There is also a need to collate metadata on existing datasets to maximise the benefits derived from multiple use of such data.

The *Groundwater Status Report for the Murray–Darling Basin* has used the *Groundwater Flow Systems Framework* to provide a statement on groundwater status for each system, major catchment, the Basin States, and the Basin as a whole. The approach used and the GIS tool are more broadly applicable and could be readily extended in other parts of Australia. Similarly, the identification of representative bores and hydrographs is an important step in rationalising data collection and reporting.

Plans are in progress for databases and associated information held by the Murray–Darling Basin Commission, including groundwater flow systems and those used in the *Groundwater Status Report*, to be made more readily available through an on-line GIS-based information facility. This system will complement the on-line NLWRA 'Atlas' facility and State-based web-sites.

Work on estimating recharge in the rangelands of the Murray–Darling Basin recommended that investigations be carried out in the north to provide more accurate data on water table depths, water table salinities and characteristics of the regolith, as well as field studies to better estimate rates of deep drainage beneath grazing land. It indicated that the monitoring network needs to be expanded, to ensure that rises in water tables of shallow aquifers beneath non-irrigated lands are detected. Particular attention should be paid to areas where time-lags between increases in deep drainage and increases in aquifer recharge are predicted to be relatively small.

Modelling capability

The tools, models and frameworks described in Table 1.5, on the PRISM CD-ROM and on the 'Catchment Modelling Toolkit' web-site provide very useful information for catchment managers. Furthermore, the 'Basin Salinity Management Strategy Operational Protocols' provide criteria for model assessment and review. However, tools, models and protocols are constantly under refinement, and it is difficult for potential users to keep abreast of such changes. Maintenance of these databases and information will require consideration. Investment in model and tool refinement should also consider the transferability of the model or tool between catchments and scales, and its data requirements. The overarching philosophy driving model and tool development should be that it is 'fit for purpose' (see section 4.3 for more details).

R & D TIP #1.3

Consider the National Airborne Geophysics project (www.affa.gov.au) to keep up-to-date with activities and advances in airborne geophysics mapping and research.

R & D TIP #1.4

The Groundwater Status Report for the Murray–Darling Basin is likely to be updated periodically, while accessibility of groundwater and other natural resource management information for the Basin will be progressively improved (www.mdbc.gov.au).

R & D TIP #1.5

Contact State agencies, NLWRA (www.nlwra.gov.au) or CSIRO Land & Water (www.csiro.au) for further information on development of programs or activities to collect data for salinity management in rangeland environments.

R & D TIP #1.6

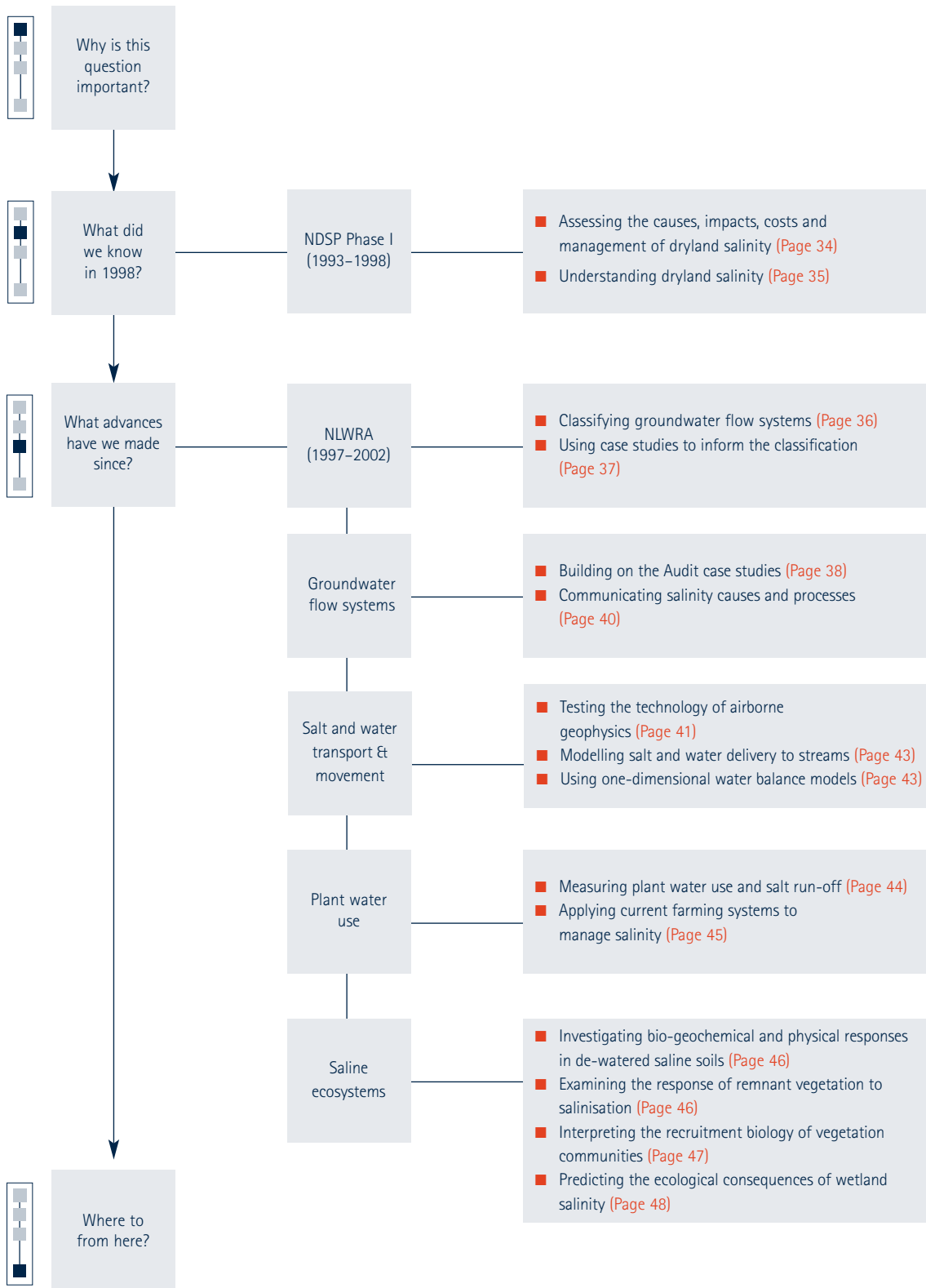
Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au), which is developing a Catchment Modelling Toolkit and consider the program of the Catchment Modelling School for training model users.



QUESTION 2

Roadmap

What are the causes and processes of dryland salinity?



What are the causes and processes of dryland salinity?



WHY IS THIS QUESTION IMPORTANT?

Understanding the causes and processes of dryland salinity will improve our ability to assess the likelihood of its expression in the landscape and its rate of spread, and to better manage the problem. This knowledge can be used to underpin basic or complex approaches to predicting the risk of salinity emergence or its spread. The more confident we are in understanding these factors, the more confident we can be in predictions and ability to take effective action.

Groundwater flow systems are at the core of this understanding as they vary from catchment to catchment and within catchments according to geology and geomorphology. Each system has key features that we must consider when assessing how that system operates and will respond to actions. This in turn helps regional and catchment planners address some of the questions that underpin their investment decisions.



WHAT DID WE KNOW IN 1998?

Our understanding of the causes and processes of dryland salinity in 1998 provided many of the foundations of today's advances. Chapter 1 in *Assessing the causes, impacts, costs and management of dryland salinity*¹ titled 'Where is the groundwater and salt in my catchment coming from?' looked at:

- Processes of salinisation
- Characterising a catchment
- Estimating recharge in a catchment
- Using recharge information for management of salinity problems
- A case study of the Liverpool Plains in NSW.

The section on 'processes of salinisation' acknowledged the importance of salt stored in the landscape. At the time, the importance of understanding the interaction between salt stores and groundwater movement was only just beginning to be more widely appreciated. In 1998, all leakage to groundwater exceeding natural rates was generally considered to be a problem, and appreciation of the need to maintain water yield and fresh water resources was limited.

The notion of 'characterising a catchment' was a new and promising concept in 1998, and a description of 15 conceptual models of groundwater related salinisation processes had just been published – known as the *National Classification of Catchments*.² This work provided the foundation for classifying groundwater systems under the Audit³, and the subsequent *Groundwater Flow Systems Framework*⁴ (discussed in Question 1, Section 1.2.1). Chapter 3 of *Understanding dryland salinity*⁵ on 'understanding salinity processes' looked at regional groundwater modelling, river catchment modelling (including the *National Classification of Catchments*) and farm scale modelling.

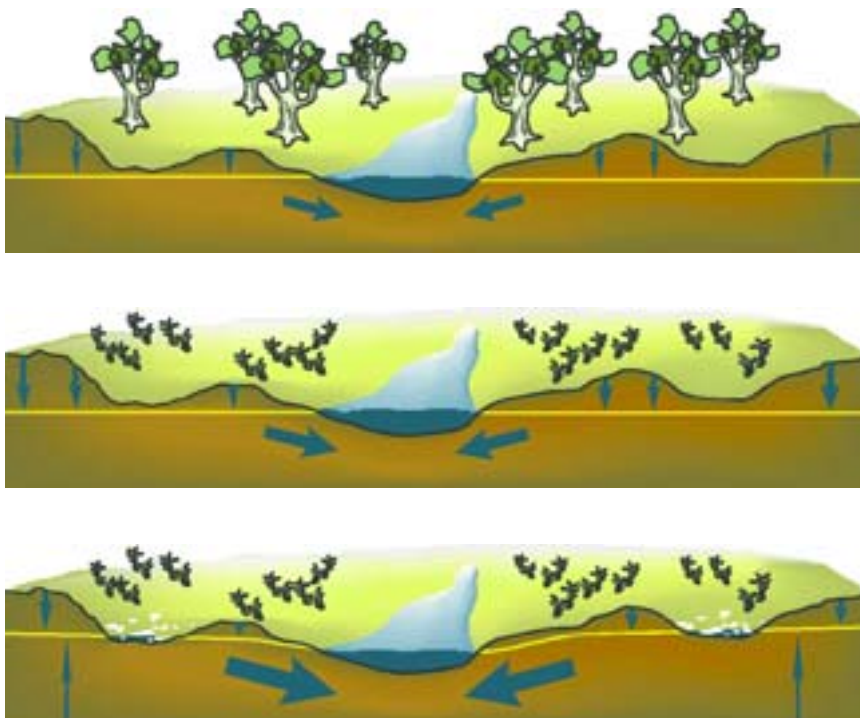
'Estimating recharge in a catchment' focused on the concept of groundwater balance. This is a simple concept where the inputs to the system need to match the outputs (i.e. the water that goes in must, eventually, come out). This approach still underpins modelling, except that our ability to measure the various inputs and outputs of water and salt is more accurate. Our understanding of these processes drives the groundwater models used to predict salinity risks. Many of the models used in 1998 have been further refined and are important tools for salinity managers today – FLOWTUBE, PERFECT, APSIM and WAVES. Water balance models are discussed in Question 4 under Section 4.3.1 'Selecting the right tool for the job'.

The Liverpool Plains case study was a seminal catchment-scale investigation, which informed later dryland salinity studies. The key findings are described in *Assessing the causes, impacts, costs and management of dryland salinity* and *Understanding dryland salinity*. Simple 'top down' catchment scale water balance modelling tools were developed and used for the first time (the FLOWTUBE groundwater model and Zhang curves – see Figure 2.3 – for catchment water yield under changed tree cover). These modelling techniques are less data intensive than the complex process-based models traditionally used in studies of large catchments and can therefore be applied more widely across Australia. In the Liverpool Plains, these new tools enabled an assessment of the relative contribution of different components of the catchment water balance to salinisation (run-off, sub-surface flow and groundwater) and highlighted the importance of whole catchment hydrology understanding for salinity management.

Figure 2.1

What causes dryland salinity? – A simplified dryland salinity scenario.

(Source: Commonwealth of Australia, 2001, *Dryland salinity in Australia: A summary of the National Land & Water Resources Audit's Australian dryland salinity assessment 2000 – Extent, impacts, processes and management options*, National Land & Water Resources Audit, Canberra ACT.)



QUESTION 2



WHAT ADVANCES HAVE WE MADE SINCE?

2.1 National Land & Water Resources Audit (1997–2002)

2.1.1 Classifying groundwater flow systems

The Audit added significantly to the understanding of dryland salinity by developing the *National Classification of Catchments* further by mapping the distribution of groundwater flow systems across Australia and providing detailed catchment case studies.

Measured data and expert knowledge were used to develop an understanding of the way a particular catchment will behave. These data include structural geology, geomorphology, aquifer properties and landscape topography, but the complexity of this task should not be underestimated given the spatial and temporal variability of catchments.

Groundwater systems are not the same across Australia and their contribution to dryland salinity also differs. The system of classification is based on recharge and flow behaviour. It uses measures such as length of flow paths through aquifers, aquifer permeability and driving pressure gradients to predict groundwater flow. Better understanding of how groundwater systems will respond to changing recharge under different land use scenarios, and what happens to the excess water is pivotal to managing dryland salinity effectively.

The Audit mapped and assessed 12 groundwater flow sub-systems. Three minor sub-systems of the 15 conceptual sub-systems defined in the *National Classification of Catchments* could not be mapped at continental scale. The assessment showed that:

- Groundwater processes in the deeply weathered landscapes of Western Australia are similar to those in the landscapes of Eyre Peninsula in South Australia and the Dundas Tablelands in western Victoria
- Groundwater processes in the sedimentary deposits of the Murray–Darling Basin are similar to those in the Perth and Bremer Basins in Western Australia
- Clear similarities exist between the groundwater processes underlying salinity on the northern and western foot-slopes of the Great Dividing Range in both Victoria and New South Wales.

The Audit produced continental and basin scale groundwater flow system maps and a series of fact sheets for each of the 12 groundwater flow sub-systems (see Table 2.1). Each fact sheet outlines the biophysical and landscape context in which salinity occurs, the attributes that determine groundwater responsiveness, and the processes that operate in the landscape to affect salinity. It is anticipated that the material will be updated as new information becomes available.

ACTION #2.1

Recognise that there is no one single approach to dryland salinity management, and start to understand the differences and similarities between each groundwater flow system in your region by reviewing the relevant fact sheets produced by the National Land & Water Resources Audit (www.nlwra.gov.au).



Table 2.1

Fact sheets describing major groundwater flow sub-system types

(Source: www.nlwra.gov.au)

Fact Sheet Name	
Fact sheet 1	Local flow systems in deeply weathered rocks
Fact sheet 2	Intermediate flow systems within sedimentary sequences infilling large valleys
Fact sheet 3	Local flow systems in fractured rocks
Fact sheet 4	Local flow systems in deeply weathered fractured rocks
Fact sheet 5	Local flow systems associated with colluvial fans
Fact sheet 6	Intermediate flow systems in fractured rock aquifers
Fact sheet 7	Local flow systems in fine grained unconsolidated sediments
Fact sheet 8	Regional flow systems in alluvial aquifers
Fact sheet 9	Regional flow systems within unconfined sediments
Fact sheet 10	Local flow systems associated with sand dunes
Fact sheet 11	Regional and intermediate flow systems within fractured basaltic rocks
Fact sheet 12	Intermediate and local flow systems in fractured basaltic rocks and layered sedimentary rocks

2.1.2 Using case studies to inform the classification

The Audit used intensive investigations of groundwater flow systems in five case study catchments in southern Australia to further understand the causes and processes of dryland salinity. The specific purpose of the case studies was to identify:

- Catchment areas where recharge changes significantly affects groundwater discharge and salinity
- How much recharge reduction is needed to reduce salinity
- Land use and farming system options for salinity management
- Information for a cost-benefit analysis, and the feasibility of options
- Constraints to achieving the change needed.

The catchments were selected on the basis of their salinity status and information availability, and because they were representative of the most salt-affected land types in Australia. The case studies built on the conceptual development and systems understanding gained through the NDSP Phase I focus catchments – in particular the Liverpool Plains (NSW)⁶, Upper South East (SA)⁷ and Loddon-Campaspe catchments (Victoria)⁸. The case study catchments were:

Kamarooka, Victoria⁹ – a local flow system in variably weathered fractured rock (groundwater discharge at break-of-slope)

Lake Warden, Western Australia¹⁰ – a local and regional groundwater flow system in alluvial sediments and deeply weathered rocks

Upper Billabong, New South Wales¹¹ – local and intermediate groundwater flow systems in variably weathered fractured rocks in connection to regional flow system in alluvial aquifers

Wanilla, South Australia¹² – a local to intermediate flow system in deeply weathered rock (groundwater discharge at break-of-slope and valley floors)

QUESTION 2

Great Southern, Western Australia¹³ – local and intermediate flow systems in deeply weathered rocks (this case study was not included in the *Groundwater Flow Systems Framework* publication).

The Audit studied data-rich catchments with well-documented information on many of the factors that affect groundwater recharge and discharge:

- Land clearing (when and where)
- Farming practices (what has been grown where)
- Deep drainage (leakage under various land uses)
- Seasonal rainfall, run-off and evaporation
- Piezometer and borehole data
- Landscape elevation
- Soil properties
- Regional geology.

Groundwater modelling using FLOWTUBE¹⁴ was undertaken to simulate the major processes driving the recharge and discharge of water in each of the groundwater flow systems studied. Data availability enabled researchers to simulate the groundwater behaviour exhibited by the catchment under the current salinity conditions using FLOWTUBE. The model was then used to predict likely behaviour under different land use and land management scenarios. These case studies gave confidence in the conceptual models, which may then be used to help prioritise actions in other similar catchments.

In keeping with earlier findings from the Liverpool Plains case study reported in *Assessing the causes, impacts, costs and management of dryland salinity*, the case studies highlighted the difficulties in reconciling outputs from the crop and pasture models with those from the groundwater models. While some further advances are described in this chapter under section 2.3.3 'Using one-dimensional water balance models', this remains a key gap in understanding and integrated modelling capabilities.

ACTION #2.2

Evaluate the availability of local data for each groundwater flow system in your catchment, and assess the likelihood of gathering additional data and the extent to which you will need to draw on understanding of like systems elsewhere to inform management decisions.



ACTION #2.3

Identify whether any of the groundwater flow systems in your catchment are of the same type as the 10 case study catchments investigated by the Audit and the Catchment Classification project. If so, review the relevant technical reports for more detailed information.



2.2 Groundwater flow systems

2.2.1 Building on the Audit case studies

Since the Audit report on salinity, the 'Catchment Classification'¹⁵ project has investigated a further five case studies:

- **Liverpool Plains, New South Wales**¹⁶ – a regional flow system in alluvial aquifers
- **Southern Loddon Plains, Victoria**¹⁷ – a regional flow system in alluvial aquifers
- **Kyeamba Creek catchment, New South Wales**¹⁸ – intermediate and local flow systems in fractured rock
- **Axe Creek catchment, Victoria**¹⁹ – intermediate and local flow systems in fractured rock
- **Brymaroo catchment, Queensland**²⁰ – a local flow system in fractured basalts.

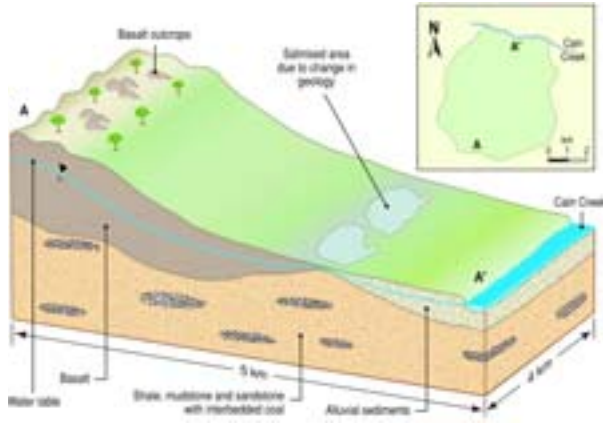
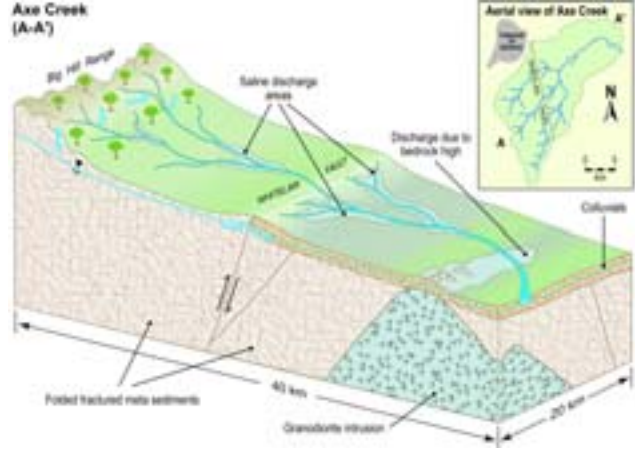
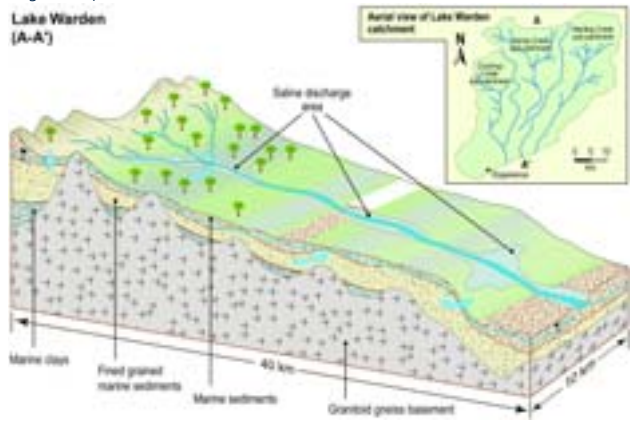
The value of the 10 case studies is much greater than just the light they shed on particular catchments if the lessons can then be extended to other catchments. The first and most important test made by the 'Catchment Classification' project was to check that the case studies represented the conceptual models developed by the *National Classification of Catchments* (NCC) (see Table 2.2).

At the broadest level of the *National Classification of Catchments*, our detailed understanding of the case study catchments matched the range of different groundwater flow systems types. This agreement gives confidence in the system, and in our ability to map groundwater flow systems.

Table 2.2

Comparison of generic predictions with modelled case studies

(Source: modified from Walker G., Gilfedder M., Evans R., Dyson P., and Stauffacher M., 2003, *Groundwater flow systems framework: Essential tools for planning salinity management*, MDBC Publication 14/03, Murray–Darling Basin Commission, Canberra ACT)

GFS	Predictions of NCC conceptual model	Case study modelling
<p>Local systems</p> 	<ul style="list-style-type: none"> ■ Farm-based solutions involving revegetation and perennial cropping in recharge areas and limited use of engineering treatments such as surface drains 	<ul style="list-style-type: none"> ■ 50% recharge reduction should reduce salinity by 30% in 20 years (Brymaroo catchment) ■ 50% recharge reduction should reduce salinity export by 50% (Kyeamba catchment)
<p>Intermediate systems</p> <p>Axe Creek (A-A')</p> 	<ul style="list-style-type: none"> ■ Surface appearance of salinity may be very limited, but there may be extensive salt export to local streams ■ Longer time lag between recharge reduction and impact on discharge ■ Groundwater pumping from fractured rock systems can be difficult to establish 	<ul style="list-style-type: none"> ■ Discharge predominantly into local streams ■ Discharge commenced 50–100 years after clearing; 90% recharge reduction over 500 years to stop discharge (Axe Creek catchment) ■ Groundwater pumping was not considered
<p>Regional systems</p> <p>Lake Warden (A-A')</p> 	<ul style="list-style-type: none"> ■ Amenable to groundwater pumping ■ Farm-based and vegetation strategies precluded by magnitude of system (long response times) ■ Productive use of salt is an option 	<ul style="list-style-type: none"> ■ Respond positively to pumping ■ 50% recharge reduction requires 75% of area revegetated with perennials, resulting in a reduced rate of groundwater rise by 2100 (Lake Warden catchment) ■ Productive use of salt is successful where discharge is not highly saline

QUESTION 2

ACTION #2.4

Refer to the Tools Information Packages, Healthy catchment guide, Salinity management handbook and Rapid Catchment Appraisal program to better understand the causes and processes of dryland salinity (or use them as a model), and consider developing conceptual diagrams for each major groundwater flow system using the Wimmera Regional Information Package as a guide.



2.2.2 Communicating salinity causes and processes

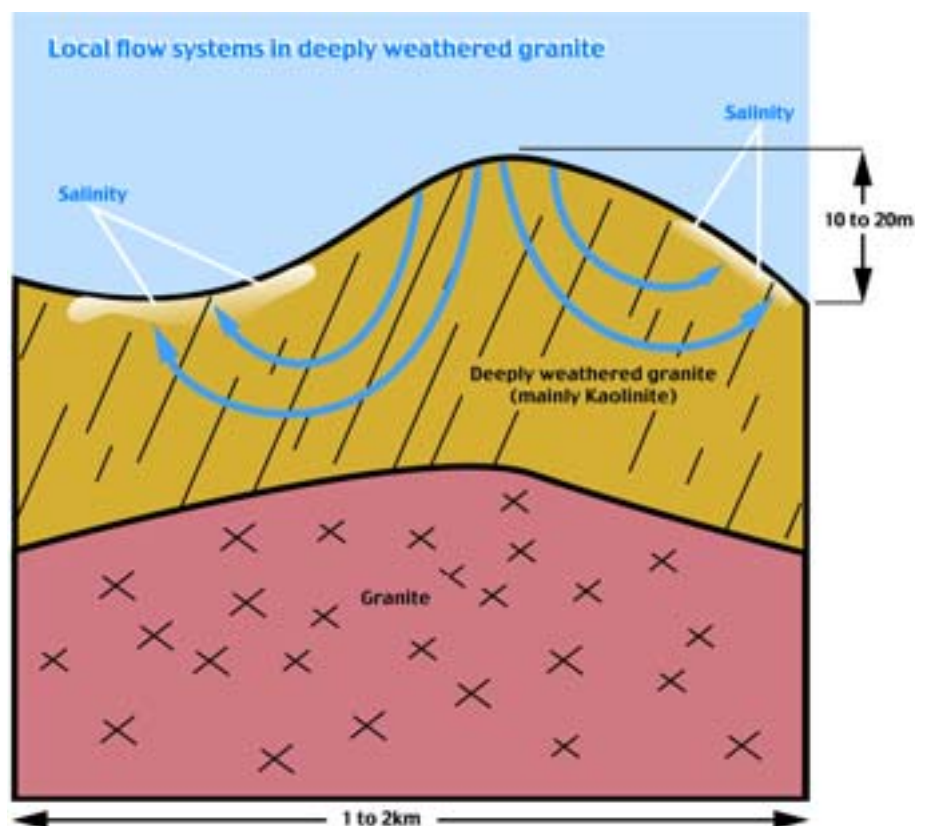
The Tools²¹ project developed an overarching *Salinity Information Package*,²² which was described in the Introduction. The 40 information sheets in this package include descriptions of the causes and processes of dryland salinity. Likewise, the 10 *Regional Information Packages*²³ for major catchments of the Murray–Darling Basin describe the causes and processes of salinity for each groundwater flow system type, and what this means for the management options. The packages were developed in consultation with regional stakeholders and technical experts, and incorporate local knowledge of groundwater processes and behaviour.

The Wimmera region in Victoria has progressed to developing a 'second generation' information package, building on the framework of the first version. The region has revised its salinity plan and investment strategy, and the outcomes of this process have been embodied in the new *Wimmera Regional Information Package*²⁴. The package is supported by diagrams of the conceptual models that inform each of the groundwater flow system types (see Figure 2.2). A list of *Regional Information Packages* for catchments of the Murray–Darling Basin is provided in Question 1 (page 17).

Figure 2.2

The Wimmera Regional Information Package provides an example of a conceptual diagram of groundwater flow systems

(Source: Murray–Darling Basin Commission, 2004, *Tools for improved management of dryland salinity in the Murray–Darling Basin – Wimmera regional information package* (Version 2), Murray–Darling Basin Commission, Canberra, ACT.)



A practical handbook entitled *Healthy catchment guide*²⁵ has also been published for the South West Slopes of the Murray Catchment (NSW). It looks at salinity processes relevant to the South West Slopes and discusses why this area is a 'salinity priority' in greater Murray River Catchment (NSW) context. It draws on the *Groundwater Flow Systems Framework*, the 'Tools' information packages and *Land Capability Classification* to provide a practical guide to priorities for vegetation placement for salinity, which can be applied at a property level.

For north-eastern Australia and as a model more broadly, the *Salinity management handbook*²⁶ has been developed that provides a comprehensive and practical introduction to salinity. It comprises three parts – understanding salinity, investigating salinity and managing salinity. 'Understanding salinity' describes the three major types of salinity and looks at salinity and hydrology management. 'Investigating salinity' provides practical information for planning and carrying out salinity investigations, considering geomorphic features, climate and land use. Indicator plant species and soil and water data are used to determine the extent of salting and the processes contributing to the problem. 'Managing salinity' considers vegetation, irrigation and engineering applications, and the process of developing an integrated plan of management.

In Western Australia, the *Rapid Catchment Appraisal* (RCA) program (<http://agspsrv34.agric.wa.gov.au/environment>) under the Western Australian Salinity Strategy²⁷ uses satellite-based salinity mapping to estimate current extent and risk, analyse the impact of management options, and direct salinity management at the regional level.

2.3 Salt and water transport & movement

2.3.1 Testing the technology of airborne geophysics

Airborne geophysics has been used to improve our understanding of the process by which salts move through the landscape from where they are stored to their discharge to land or water. Understanding these processes enables better prediction of risks and effective options for management.

The *National Airborne Geophysics Project*²⁸ (NAGP) comprised five pilot studies in four States included extensive field surveys to test several geophysical systems in airborne electromagnetics (salt), magnetics (geology) and radiometrics (soils). It analysed these systems and their ability to map salt, geology and soils. The work emphasised the value of airborne geophysics datasets in improving understanding of the landscape, sub-surface structure and hydrological process at catchment scale. It has provided a list of 12 core datasets required for salinity-related catchment planning (see Table 2.3), concluding that airborne geophysics is most beneficial when used in conjunction with other datasets when preparing detailed management plans at the catchment and paddock level.

The project concluded that airborne geophysical systems were accurate and that they provided an effective means of improving our understanding of the landscape, sub-surface structure and the hydrological process at catchment scale. However, airborne geophysical data are analytically complex, consume time, funds and test the capacity of researchers and providers alike. The future application of these systems depends on there being a clear cost and benefit statement and that the best systems are chosen to answer the specific question being posed. Regionally-based and generic tests of revised airborne electromagnetic systems are no longer required; emphasis on applications and delivering benefits to investors should be the major focus.

Table 2.3

Twelve key biophysical datasets required for salinity-related catchment planning

(Source: George R., Beasley R., Gordon I., Heislors D., Speed R., Brodie R., McConnell C., and Woodgate P., 1998, *Evaluation of airborne geophysics for catchment management*, The National Airborne Geophysics Project, Department of Agriculture, Fisheries and Forestry – Australia and National Dryland Salinity Program, Canberra ACT.)

1. Topography and drainage derived from a hydrologically sound Digital Elevation Model (DEM $<\pm 1$ m accuracy)
2. Orthophotos
3. Hydrological data (water table depth, salinity, hydraulic properties and trends)
4. Multi-spectral data (satellite: Landsat TM) and classifications (e.g. salinity, chemistry, vegetation)
5. Magnetics (to improve geology)
6. Radiometrics (to improve geology and soils/landscapes)
7. Field geology and related interpretations
8. Electromagnetics (ground and airborne; targeted application)
9. Meteorological data (rainfall, evapotranspiration, etc.)
10. Soils – Land Management Units (LMUs and other classifications)
11. Land use (spatial and temporal)
12. Cadastre and GIS data on related infrastructure

Analysis of the benefits and costs of airborne geophysics²⁶ suggest that it is more likely to be effective and economic where:

- There is relatively poor existing natural resource data available to assess the risks and options for management, and the relative importance of this knowledge in management is high
- The options for salinity management are understood (both impacts and costs) and cost-effective
- Specific management actions can be derived from the geophysics
- Off-site and on-site benefits are high (for example, protecting major public assets), and can be quantified.

These findings were supported by the *NSW Western Slopes cropping*²⁹ project, which concluded that:

- Salt mass-balance is hard to evaluate both within and between catchments due to the uneven distribution of salt stores and mobility. Recent improved modelling of airborne electromagnetic (AEM) data enables us to determine salt stores in landscapes. Subsequent understanding of groundwater movements will assist to provide quantitative estimates of salt fluxes through the landscape.
- The commonly used salt input/output ratio does not consider the dynamics of salt mobility. Accession of salt to the landscape is mostly via precipitation (cyclic salt) and dry deposition of wind-blown salts from inland lakes. Some weathered and re-mobilised salt will also leave, but most salt is relatively young in origin.
- Use of the *Groundwater Flow Systems Framework* approach to understanding dryland salinity should be developed to account for the interactions between stacked or overlain systems.

A number of airborne geophysical studies across the country have shown the applicability of the technologies to salinity such as in Honeysuckle Creek (Goulburn–Broken catchment, Victoria) and Upper Billabong Creek (Murrumbidgee catchment, NSW). The *South Australia Salinity Mapping and Management Support*³⁰ project was the first to target specific questions related to salinity, rather than purely mapping the distribution of salt, soils and sub-surface features. This covered the Riverland and Tintinara (investigating a clay-rich layer that reduces recharge rates to the underlying aquifer and the subsequent rates of discharge of salt to the Murray); around Jamestown (the underground network of palaeo-channels defined the causes for salinity without directly mapping salt); and beneath the Angas–Bremer Plains (the extents of the lower salinity aquifer were defined with improved accuracy and storage estimates made from the airborne electromagnetics).

2.3.2 Modelling salt and water delivery to streams

The paper *Mobilisation of Salts in Australian Landscapes*³¹ considers an integrated understanding of catchment surface water flows, groundwater dynamics, salt distribution and salt transport processes within different parts of the landscape. It summarises contemporary techniques used to describe and predict catchment water balances and salt mobilisation, including the *Groundwater Flow Systems Framework*. It concludes that we generally lack the critical biophysical data and integrated modelling approaches needed to define the timeframes and specific management requirements of individual catchments.

The *Salt Delivery*³² project sought to develop an understanding of landscape processes in areas at high risk of waterlogging and salinity using an integrated approach to interpreting landscape function, including airborne geophysics. The study focused on the Simmons Creek sub-catchment (177 km²), located in the Billabong Creek catchment near Walbundrie in southern New South Wales and was aligned with the *Heartlands*³³ initiative.

It incorporated the disciplines of pedology, hydrology, hydrogeology, terrain analysis and modelling. Data collection, monitoring and modelling activities included:

- A soil and regolith survey, with spatial modelling of soil properties
- Groundwater monitoring
- Stream gauging (water quantity and quality)
- Weather observation
- Conceptual modelling of hydrology and salt movement
- High resolution terrain analysis
- Hydrological modelling of water and salt movement.

The project has developed an understanding of the hydrological function of the Simmons Creek catchment, determined the salinisation processes and suggested management options.

2.3.3 Using one-dimensional water balance models

One dimensional water balance models are widely applied in crop production simulations. These models do not, however, predict lateral sub-surface flow of water. Any water draining below the root zone is assumed to move vertically and recharge the groundwater system. This limits their relevance in a salinity context which requires a more robust conceptualisation of excess water partitioning (2–3 dimensions). Water balance models and the methods used to improve the prediction of recharge are described in more detail in Question 4 (section 4.3.1 – Selecting the right tool for the job).

ACTION #2.5

Use airborne geophysics in a strategic way to help understand the process by which salts move through the landscape where available information supports its application.



ACTION #2.6

Consider the relevance of the sub-catchment scale approach used in the Salt Delivery project and the Heartlands initiative to understanding hydrological function and the mechanisms of salt transport within parts of your region.



ACTION #2.7

Be aware that using the outputs of one-dimensional models for dryland salinity planning and management and water allocation in hilly terrain has limitations and that decision-making processes should take reasonable account of sub-surface lateral flow and vertical drainage.



QUESTION 2

2.4 Plant water use

2.4.1 Measuring plant water use and salt run-off

Woody vegetation retention and increasing the perennials in a landscape through planting trees or perennial pastures are key strategies of many salinity management plans. Advances have been made in plant water use processes and their implications for catchment water yield and salinity.

The publication *Plantations, farm forestry and water: A discussion paper*³⁴ considers water balance in the landscape, planted forests and water issues, and the effects of afforestation on water and on salt mobilisation. Case studies for the Murray–Darling Basin southern high-rainfall region, the Green Triangle, Macquarie Valley and south-west of Western Australia are provided.

The following four review papers are presented in the report 'The ways trees use water'³⁵:

- Tree water use and its implications in relation to agroforestry
- Does leaf water efficiency vary among eucalypts in water-limited environments?
- Relationships between water use efficiency and tree production
- Root distributions and water uptake patterns in eucalypts and other species

A recent publication called *Planning for Change – Understanding the impacts of afforestation on catchment runoff and river salinity*³⁶ considers the amount of water used by plants and the effects of afforestation on the catchment water balance, with particular reference to effects on seasonal flows and changes in low flows and the implications for in-stream salt concentrations. It demonstrates that reforestation targeted at medium rainfall zones (500–800 mm/yr) is more beneficial for dryland salinity management than in the higher rainfall zone, as it has less impact on runoff quantity (dilution flows) but similar benefits in recharge reduction.

It builds on the report *Predicting the effect of vegetation changes on catchment average water balance*,³⁷ documenting the so-called 'Zhang curves' (see Figure 2.3), and particularly draws on the work of the 'Environmental impacts'³⁸ project and its related 'Impacts and land use change'³⁹ project. The report summarises the current state of knowledge as:

- Mean annual run-off from catchments will decrease following land use change from grass to trees; the reduction can be estimated using a simple water balance model.
- Reduction in mean annual run-off is dependent on the kind of revegetation carried out. In south-eastern Australia, pine plantations yield less run-off than native eucalypt plantations, primarily due to the greater interception of rainfall by pines. Productive hardwood plantations probably yield as much water as pine plantations, though little data is available to support this assertion.
- Run-off reduction following afforestation is generally proportional to the percentage of tree cover. In small catchments, it is difficult to detect a yield change if less than 20 per cent of the catchment has experienced a change in land cover.
- Groundwater recharge under forest is lower than under pasture and crops and is often close to zero. Hence plantations can lower groundwater levels. This may or may not be a good outcome, depending on the utility and salinity of the groundwater system underlying the plantation.
- While afforestation has the greatest impact on absolute flow in high rainfall areas, the greatest *proportional* reduction is in the low rainfall areas or at times of low flow.

- The number of low or zero flow days is likely to increase following afforestation. Complete afforestation of small headwater catchments with mean annual rainfall of c. 900 mm can reduce the number of zero-flow days from 0–50 to 175–225 days per year.
- Run-off reductions are minor for the first five years after afforestation and are greatest 10–20 years after planting.
- Water yields from forests slowly increase after 30 years of age as water use starts to decline in association with reduced growth rate.
- Thinning forest and forest clearing can also lead to increased water run-off. The magnitude of the run-off increase depends on the proportion of the forest cleared and the age of the trees.

ACTION #2.8

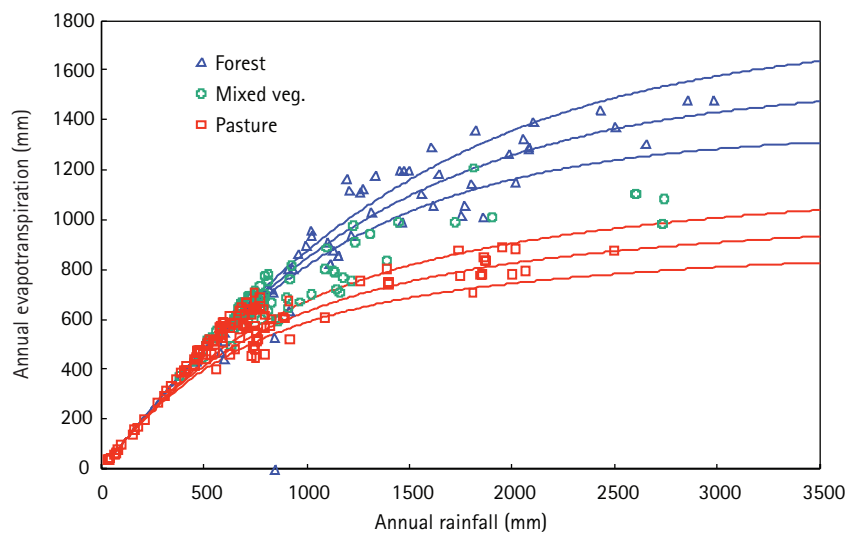
Inform yourself about the trade-offs between managing the movement of salt versus the movement of water in the landscape before considering large-scale afforestation in any part of your region, and refer to Australian case studies where large-scale afforestation has taken place.



Figure 2.3

The Zhang curves show the relationship between annual evapotranspiration and rainfall for different broad vegetation types. The middle blue curve indicates the relationship for *forested* catchments, and the middle red curve for *pasture* catchments, with *mixed vegetation* catchments somewhere between the two. The lines either side indicate 95% confidence intervals.

(Source: Zhang L., Vertessy R., Walker G., Gilfedder M., and Hairsine P., (in press), *Planning for change – Understanding the impacts of afforestation on catchment runoff and river salinity*, CRC for Catchment Hydrology Industry Report, CRC for Catchment Hydrology, Clayton VIC.)



2.4.2 Applying current farming systems to manage salinity

The report *Effectiveness of current farming systems in the control of dryland salinity*⁴⁰ and its companion document *A revolution in land use: Emerging land use systems for managing salinity*⁴¹ show that farming systems based largely on shallow-rooted annual crops and pastures simply cannot control leakage to groundwater where rainfall exceeds 600 mm – even when adopting current recommended practices (the 'Landmark'⁴² project has produced a directory⁴³ of industry current recommended practices for traditional dryland broadacre agriculture).

QUESTION 2

ACTION #2.9

Identify where woody perennial vegetation will be of greatest benefit in your catchment with due consideration to the location of salt stores.



ACTION #2.10

Establish the extent to which dryland salinity management is reliant on the development of alternative farming systems in your catchment.



ACTION #2.11

Use the classification system developed by the Saline Soils project to identify the types of saline soils amenable to de-watering in your catchment.



There is very sound evidence that lucerne⁴⁴ has potential to provide significant soil water deficits and contribute to reduction of recharge, although establishment and persistence are limited by soil constraints, particularly acidity and aluminium toxicity. Alley farming and phase farming systems may be effective in reducing groundwater levels but variable profitability limit their application at this stage.

Widespread leakage below traditional farming systems which mobilises salt stores through increased hydraulic pressure is the fundamental cause of our expanding dryland salinity problem. While groundwater recharge contributes flows to rivers and downstream water users, we need profitable solutions for turning off the unwanted groundwater recharge driving dryland salinity. At present, alternative farming systems are largely confined to lucerne, forestry and farm forestry options.

2.5 Saline ecosystems

2.5.1 Investigating bio-geochemical and physical responses in de-watered saline soils

The *Saline Soils*⁴⁵ project aimed to improve understanding of the chemical, physical and biological changes in soil after salinisation. Prior to this project, uncertainties existed on the bio-geochemical processes involved in saline soils and being able to predict the physico-chemical changes that occur when they are drained or disturbed, partly because saline soils have been considered to have little agricultural value.

A classification system was developed identifying 22 types of dryland saline soils in farming regions of southern Australia with differing properties.

Seventeen paired sites were studied in eight different groundwater flow systems. The researchers found that progressive development of saline environments is caused by different physico-chemical processes when land is drained or disturbed.

Three generic conceptual models have been developed to summarise the processes involved in the changes leading to different soils or poor water quality when a saline landscape is drained or disturbed. The three models include saline soils progressively affected by:

- sodium and chloride from groundwaters (halite-dominant)
- sulphur, sodium and chloride from groundwaters (sulphidic-, gypsic-dominant)
- transient salinity in the root zone (dry saline land), restricted permeability within sodic subsoil layers.

It was found that saline soils do not always return to their former state after being drained or disturbed, and that tailored management is needed.

2.5.2 Examining the response of remnant vegetation to salinisation

While the physiological processes of salinity and/or waterlogging tolerance on native species are well understood, few studies in Australia have focused on how native plant communities respond to the development of secondary salinity. Given that remnant vegetation on Australian agricultural land is often small in extent, highly fragmented and likely to be degraded by grazing, weeds and other factors, rising water tables may deliver the final blow to maintaining their ecological integrity.

Because of the availability of pre-existing data, the *Restoring Native Vegetation*⁴⁶ project was conducted in the upper and middle Blackwood Basin in Western Australia. One reason for choosing this location was that the south-west of Western Australia has been designated one of 25 world 'hot spots' for biodiversity and the only one in Australia.

The investigations concluded that all remaining native vegetation is valuable in terms of conserving diversity and providing ecosystem services to surrounding farmland. It is difficult, if not impossible, to determine clear eco-hydrological tolerances for plant communities due to the temporal and spatial variability of water levels and flows and the variability in species compositions across small distances (at least in south-west Western Australia).

The project findings also question the relevance of determining such tolerances. Plant communities seem to collapse, often due to unusual or infrequent events and, within this context, tolerance of 'average' conditions may not be relevant.

Investigation of the interactions between groundwater characteristics and dynamics, soil characteristics, micro-topography and vegetation responses elucidated opportunities for managing vegetation at the micro-scale. For example, where micro-topographic differences influence vegetation health, then opportunity exists to maintain some elements of the current vegetation in areas of higher micro-topography, with the rest planted with salt-tolerant species, thus creating a new ecosystem mosaic.

Two papers presented at the 9th Murray–Darling Basin Groundwater Conference on *Groundwater lowering and environmental flow options for Chowilla*⁴⁷ and *The floodplain impacts model: A tool for assisting the assessment of groundwater inflows to the floodplains of the lower River Murray*⁴⁸ provide detailed background and references on the extensive research effort on floodplain salinisation and the health of River red gums. A simple, one-dimensional analytical model⁴⁹ has been developed that distributes floodplain groundwater discharge as seepage at the break-of-slope, evapotranspiration across the floodplain and as groundwater flow into and out of the river. The model has been applied using regional scale GIS data to the lower River Murray in south-eastern Australia. It can be used as a planning tool to assess potential impacts to floodplain and wetland vegetation and the river from irrigation developments and river management. The report *Spatial modelling of groundwater discharge patterns to predict floodplain salinisation and impacts on vegetation health*⁵⁰ looks at using the quasi-three dimensional groundwater model MODFLOW 96 to simulate regional groundwater flow through a floodplain on the lower River Murray, achieving good accuracy for total volumes of evapotranspiration and seepage on a floodplain scale.

2.5.3 Interpreting the recruitment biology of vegetation communities

The *Recruitment Biology*⁵¹ project aimed to develop a greater ecological understanding of vegetation affected by dryland salinity and waterlogging at plant community scale. Salinity levels in riparian wetlands and the groundwater under adjacent plant communities are rising and destroying large areas of remnant vegetation. Remnants along drainage lines are particularly vulnerable to hydrological change. Many of south-western Australia's rivers are associated with low gradients and deeply weathered landscapes in which salt has accumulated over tens of thousands of years. Plant communities, such as those associated with yate (*Eucalyptus occidentalis*) woodland, persist along these naturally saline rivers in the upper tributaries of the Gairdner River in Western Australia, where this project was based.

ACTION #2.12

Apply a precautionary principle in the management of remnant vegetation affected by, or at risk of, dryland salinity, recognising that plant communities can collapse due to unusual or infrequent events, and consider opportunities for managing vegetation at a micro-scale.



ACTION #2.13

Identify remnant vegetation on riparian land, along drainage lines and in wetlands vulnerable to hydrological change or in need of restoration, and use the findings of the 'Recruitment Biology' project to support your management decisions.



QUESTION 2

ACTION #2.14

Study the relationship between increasing salinity and the health of wetland ecosystems in your region, using results of the Wetland salinity project as a guide.



R&D TIP #2.1

Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au), the Catchment Modelling Toolkit (www.catchment.crc.org.au) and the 'National Evaluation Framework' project for information on proposed data and model development.

R & D TIP #2.2

Further development of the Groundwater Flow Systems Framework will take place at several levels – nationally through the NLWRA and the National Evaluation Framework project (www.brs.gov.au); for the Murray–Darling Basin through the MDBC (www.mdbc.gov.au); as well as at State and regional levels.

Interim results confirm that a greater understanding of vegetation response to changes in soil/water regimes is necessary to identify the key processes driving changes to plant community health, structure and diversity in saline lower landscapes. Soil and water regime thresholds need to be identified to maintain biodiversity in remnant riparian systems and restore sites affected by hydrological change. Even plant communities adapted to naturally saline conditions are not immune to change when critical thresholds are exceeded.

2.5.4 Predicting the ecological consequences of wetland salinity

The *Wetland salinity*^{52,53} project is investigating the relationship between increasing salinity and the structure of biological communities that develop from aquatic plant seeds and zooplankton eggs stored in the sediments of wetlands and rivers. The first stage of this project has been completed. Preliminary results indicate that salinity above 1500 EC units reduces the diversity and abundance of aquatic plant and invertebrate communities. However, plant and animal communities from different wetlands responded to different salinity levels in different ways. The effects of increasing salinity were more obvious in edge plant communities than those more frequently flooded.

WHERE TO FROM HERE?

National Land & Water Resources Audit

The Audit concluded that further integration of groundwater models with farming systems models is needed to more accurately predict the effectiveness of individual farming systems on managing salinity. To do this, the processes that underpin the models need to be better understood. This will require more detailed data about the land systems characteristics of those groundwater flow systems, which is not yet available in most catchments at risk of dryland salinity.

Groundwater flow systems

We can claim to broadly understand the causes and processes of dryland salinity, and have developed the *Groundwater Flow Systems Framework* to extend what we know about one part of the landscape to other parts in some instances. The level of detail we need about dryland salinity processes will depend upon the management and investment decisions in question. For most parts of Australia, what we know about dryland salinity processes, particularly guided by the type of groundwater flow system (local, intermediate, regional), is adequate for some broad-scale prioritisation decisions. Getting down to the design phase will require more specific investigations about processes.

We need to continue to refine the *Groundwater Flow Systems Framework* and its associated groundwater dynamics by better understanding how individual systems function – their hydraulic gradients, specific yields, etc. – and the linkages between stacked or layered groundwater flow systems. Further case study investigations are needed to unravel the complexities of these systems and understand their similarities and differences. There are no case studies for some sub-system types.

The 1:250,000 resolution regional groundwater flow systems maps and supporting 'Tools' information packages developed for the Murray–Darling Basin are more detailed than for most other parts of Australia; however 1:100,000 resolution maps will be needed to design activities

in priority areas. The development of regional information packages could be extended outside of the Murray–Darling Basin, especially to high priority areas for dryland salinity management. Within the Murray–Darling Basin, catchments could progress to developing second generation packages similar to that developed in the Wimmera Region (Victoria).

Salt transport & movement

The application of airborne geophysics technology should be closely aligned with the *Groundwater Flow Systems Framework*. Airborne geophysics can deliver three of the 12 critical data sets for salinity planning identified in Table 2.3. It should both be guided by and inform the refinement of the *Groundwater Flow Systems Framework*, ensuring that mechanisms are in place to transfer relevant information between regions. As an expensive technology that generally requires interpretation in the light of other biophysical data, it should be strategically targeted within priority areas.

Further understanding of processes governing the delivery of salt and water to streams requires good quality, strategic monitoring of stream flows, groundwater levels and salt concentrations. These are essential for developing a sound conceptual model and subsequent quantitative model of catchment function. Investment in a program of field investigation should be followed up with critical monitoring as the most cost-effective means of resolving remaining uncertainty.

The knowledge that potential water yield and stream flow could be adversely affected under certain treatments (e.g. tree planting) suggests that catchment managers need to proceed with caution when implementing certain treatments that, in the past, have been considered as best-bets.

Plant water use

Understanding plant water use and the movement of water and salt in the landscape remains a hurdle in understanding dryland salinity processes, and consequent ability to model water balances accurately. The coupling of groundwater and farming systems models to adequately account for the lateral movement of water in the landscape both across and beneath the surface is an important area for further investigation.

Improved understanding of the movement of water and salt in the landscape will assist in refining estimates of seasonal flow (and zero flow) and the associated salt loads and concentrations. More refined estimates are necessary for ensuring water security in terms of both quality and quantity of supply, and in setting and meeting end-of-valley salinity targets.

The potential for lucerne and other perennials to manage groundwater recharge requires further evaluation for various groundwater flow systems and climatic regions. In addition, management constraints due to soil characteristics need to be addressed.

Native grasslands occupy a significant part of the landscape, supplying substantial fresh water to aquatic ecosystems and downstream users, and representing important ecosystems in their own right. More detailed understanding about the role native grasslands play in water delivery processes and as part of our terrestrial biodiversity estate is needed, and their protection from large-scale conversion to sown pastures or woody perennials.

R & D TIP #2.3

Keep abreast of activities and advances in airborne geophysics mapping and research findings (www.affa.gov.au).

R & D TIP #2.4

Follow up on the progress of the Heartlands initiative (www.clw.csiro.au/heartlands)

R & D TIP #2.5

Consider the on-going development and measures in place to implement and monitor the agreed end-of-valley targets under the Basin Salinity Management Strategy (www.mdbc.gov.au).

R & D TIP #2.6

Review the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au) to keep abreast of improvements in modelling to account for plant water use and lateral movement of water in the landscape.

R & D TIP #2.7

Consider the CRC for Plant-based Management of Dryland Salinity (www.crcsalinity.com) Program 3, Subprogram 5, which includes research on native grasses and lucerne.

QUESTION 2

R & D TIP #2.8

Consider the CRC for Plant-based Management of Dryland Salinity (www.crcsalinity.com) Program 2 on 'Function of natural ecosystems', which includes research on how ecosystems function in recharge zones, and how ecosystems function in soil affected by salinity and waterlogging, and Program 7 on opportunities for enhancing biodiversity in salinising landscapes.

Saline ecosystems

There is a need for a coordinated national framework of dryland saline soils sites to provide long-term data on changes in saline soils. Datasets are scarce or non-existent in groundwater flow systems outside southern Australia and there is little monitoring of long-term changes in saline soils anywhere. In particular, datasets are scarce for Western Australia and New South Wales, and no data exist for Tasmania, Queensland and Northern Territory.

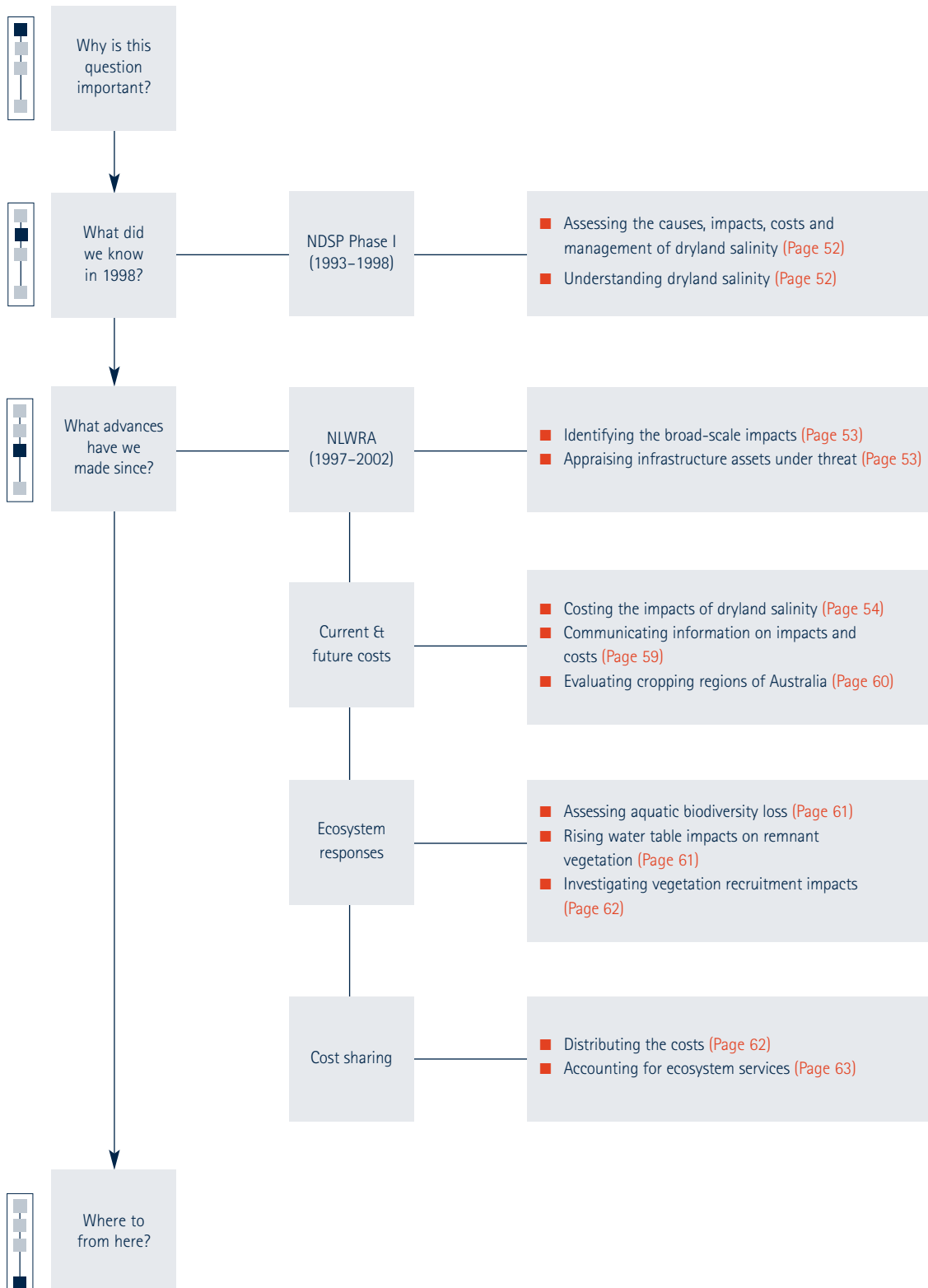
We need much better information on the responses of remnant native vegetation communities at risk from salinisation to extreme events that cause their collapse. Remnant vegetation needs to be managed so that the natural system is well within its buffering capacity for extreme events, and this may not be achieved if we aim to manage vegetation at the upper end of its tolerance limits.

Information on plant communities existing on naturally occurring saline soil, and their regeneration and restoration potential is limited. Vegetation response to salinity along saline drainage lines has also received little attention. An understanding of recruitment strategies and vegetation health, structure and diversity of plant communities in saline soils will help improve restoration plans for land affected by secondary salinity and waterlogging.

QUESTION 3

Roadmap

What are the impacts and costs of dryland salinity?



What are the current and predicted impacts and costs of dryland salinity?



WHY IS THIS QUESTION IMPORTANT?

Dryland salinity has ecological, economic, social and cultural impacts and costs. Understanding the breadth of these impacts and costs, and how they may change through time, is needed to inform investment priorities and on-ground actions.

Information on the ecological, economic, social and cultural dimensions of dryland salinity impacts and costs is needed at different scales to inform decision-making at different levels – National, State, regional, catchment, sub-catchment and property.

Foregone agricultural production was thought to be the main impact and cost of dryland salinity throughout the 1980s, together with declining river health from rising salt concentrations. The extent to which salinity impacted on in-stream, wetland and riparian health and on terrestrial ecosystems, particularly remnant vegetation stands, was not fully appreciated.

A realisation that the off-farm impacts on and costs to individuals, rural communities and the nation exceeded on-farm lost agricultural production emerged in the mid-1990s. These impacts include damage to rural and regional assets such as roads, railways, bridges and culverts, and damage to urban assets such as street paving and guttering, parks and gardens, and domestic and commercial buildings.

Quantitative and qualitative data on the impacts and their associated costs is important for informing the community and policy-makers about the scope of dryland salinity issues. The information can be used to encourage more strategic investment in salinity management, taking into account their salinity-related impact costs. It could also be expected to improve collaboration between farming and urban communities in working together to address salinity; and bring authorities with an interest in infrastructure and environment together to more holistically address the dryland salinity problem.



WHAT DID WE KNOW IN 1998?

*Understanding dryland salinity*¹ explains that in 1994 a long-term project was initiated to develop a method to estimate the full range of dryland salinity impact costs across the Murray–Darling Basin. In particular, the method needed to enable comparison of salinity impact costs on agriculture with off-farm costs on rural and regional infrastructure, urban infrastructure, and cultural heritage and the environment.

Chapter 4 of *Assessing the causes, impacts, costs and management of dryland salinity*² – ‘What are the costs of dryland salinity in my catchment and who bears them?’ – reported on the progress of this work and described the research activities to follow. While the case study information on the Loddon–Campaspe (Victoria)³ and Upper South-East (South Australia)⁴ catchments presented remains relevant, much of this chapter has been superseded by more recent work. Descriptions of the types of impacts and costs are valid, however reports discussed here provide more up-to-date information. This is especially so for the costs figures stated, with the national cost of dryland salinity of \$270 million (including environmental costs) calculated in 1998 now estimated at \$305 million for the Murray–Darling Basin alone (excluding environmental and cultural heritage costs).

WHAT ADVANCES HAVE WE MADE SINCE?

3.1 National Land & Water Resources Audit (1997–2002)

3.1.1 Identifying the broad-scale impacts

Assessments of dryland salinity and its impacts were undertaken through the Dryland Salinity Theme of the National Land & Water Resources Audit, published in 2001⁵. It was estimated that about 5.7 million hectares of Australia's agricultural and pastoral zones had high potential for developing dryland salinity through shallow water tables.

Predictions based on groundwater trends, field surveys and landscape characteristics indicate that unless effective solutions are implemented, the area could increase to 17 million hectares by 2050. Serious impacts have been identified for agricultural land, important wetlands and other habitats, flora and fauna, quality of water resources, and farm and community infrastructure.

The largest areas of concern are in the Western Australian agricultural zone, water resources of the Murray–Darling Basin (MDB) – especially for South Australia, wetlands of the MDB and south-western Victoria. Queensland assessments highlight potential impacts within 3.1 million hectares considered to have high salinity hazard.

The NLWRA showed that the economic impacts of salinity on dryland agriculture are relatively small when viewed in the context of total agricultural profits. The present value of agricultural profits is estimated to decline by 1.5 per cent over the next 20 years due to salinity, without allowing for farmers' adaptive behaviour.

The project provided a frame of reference (in time and space), a spatial basis to assess impact costs at catchment and continental scales; context for assessing structural adjustment implications for salinity management (discussed in Chapter 4 section 4.2.3); and was influential in the decision to implement a National Action Plan (NAP) for Salinity and Water Quality.

3.1.2 Appraising infrastructure assets under threat

The *Infrastructure Assets*⁶ project aimed to answer the question 'What is the cost of land and water degradation, including salinity to the economy?' It focused on cash flow impacts, rather than non-market impacts such as biodiversity. The project used data produced by the National Land & Water Resources Audit.

The results indicated that a best-bet estimate of future 'off-site' damage costs to local infrastructure was around \$89 million per year in Australia in the year 2000, potentially rising by \$62 million or 70 per cent over the next 20 years. This included damage to general urban infrastructure, roads, railways, bridges and so on.

The net present value of the increases in damage costs up to the year 2020 was estimated to be \$561 million for salinity; \$786 million for turbidity; and \$86 million for erosion/sedimentation. This was conservatively based on an across-the-board five per cent increase in levels of salinity, turbidity and sedimentation in rivers across Australia, and assume a five per cent discount rate.

Estimation of the current and future size of the cost to the environment was not undertaken in this analysis. Significant impacts on the environment due to salinity will continue to be among the key off-site impacts of land and water degradation. At a national scale, off-site and downstream damage costs caused by salinity are probably more important than on-farm yield losses.

ACTION #3.1

Identify the resources in your catchment that may be adversely affected by the current extent of dryland salinity and its risk of spread and list these assets in order of priority for action.



QUESTION 3

ACTION #3.2

Use the Audit data to make a preliminary calculation of what dryland salinity is costing your regional economy, and the relative importance of off-farm versus on-farm costs, except where your catchment was part of the 'Costs' project (see Action #3.3).



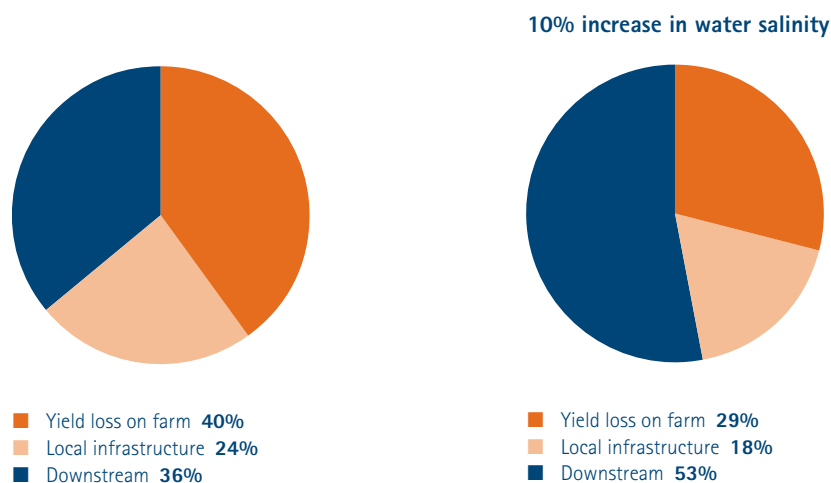
Figure 3.1 shows an estimation of the relative size of future costs imposed by salinity on agriculture, local and downstream infrastructure over the next 20 years.

About two-thirds of the total increase in damage costs is anticipated to be off-farm with a five per cent increase in salinity, turbidity and sedimentation, excluding environmental damage. If water salinity levels were to increase by 20 per cent, then off-farm costs are calculated at more than 81 per cent.

Figure 3.1

Comparison of national salinity cost increases from 2000 to 2020 (net present values of increase at five per cent discount rate).

(Source: Young M., 2001, *Appraisal of infrastructure assets under threat*, National Land and Water Resources Audit, Commonwealth of Australia, Canberra ACT.)



3.2 Current & future costs

3.2.1 Costing the impacts of dryland salinity

In 1994, a project to estimate dryland salinity impact costs was initiated. The method is documented in the 'Costs Guidelines',⁷ and was applied across the Murray–Darling Basin from 1999 to 2002 under the 'Costs'⁸ project. The methods described can apply across Australia, and have been tested outside the Murray–Darling Basin in the Mt Pleasant catchment (SA)⁹ and Lower Fitzroy catchment (Qld),¹⁰ and in a separate project in the Glenelg–Hopkins¹¹ catchments (Victoria).

The 'Costs' final report details the causes of dryland and urban salinity, identifies types of salinity impacts, and estimates the current impact costs being incurred by stakeholders for each major catchment of the Murray–Darling Basin. The 'Costs Guidelines' provide methods for estimating marginal costs and predicting future costs, although only current costs were estimated in this research project. The Glenelg–Hopkins Catchment Management Authority in Victoria has used the 'Costs Guidelines' to predict costs over the next 30 years.

Dryland salinity impacts fall into two categories: impacts from saline water; and impacts from high saline water tables. Saline water can affect urban domestic, municipal and commercial users. High saline water tables can affect urban and rural assets. Some urban areas, as well as the natural environment, can be affected by both saline water supplies and high saline water tables.

The 'Costs' project estimated total impact costs incurred by: urban households and businesses; municipal councils; State Governments and public utilities; and dryland farmers (see Figures 3.2 and 3.3). Key findings were:

- Impact costs across the Murray–Darling Basin total about \$305 million per annum. This figure is much higher than the previous 1993 estimate of \$22 million per annum for seven case study areas. The true cost is much larger because the figure excludes salinity impacts on irrigated agriculture, cultural heritage, the natural environment and the city of Adelaide, South Australia
- Estimates of total impact costs are expected to rise as levels of awareness about the types of salinity impacts increase, as ways of measuring impact costs improve, and as the negative effects of salinity continue to outweigh the positive effects of amelioration activities
- At least 220 towns and rural centres in the Murray–Darling Basin are affected by urban salinity. This number contrasts with the NLWRA report *Australian Dryland Salinity Assessment 2000*¹² which estimated that only 68 towns across Australia were affected in 2000 and that 219 towns could be affected by 2050
- The cost of dryland salinity identified in the context of this report totalled \$305 million dollars per year, split between commerce, industry and households (46 per cent), dryland agricultural producers (33 per cent) and Local and State Government agencies and utilities (21 per cent)
- A number of cultural heritage sites, heritage-listed buildings and some environmentally significant terrestrial and wetland areas are at risk.

Awareness of these findings is expected to influence consideration of the rural and urban dimensions of salinity during development and implementation of regional resource management plans and government salinity management programs.

ACTION #3.3

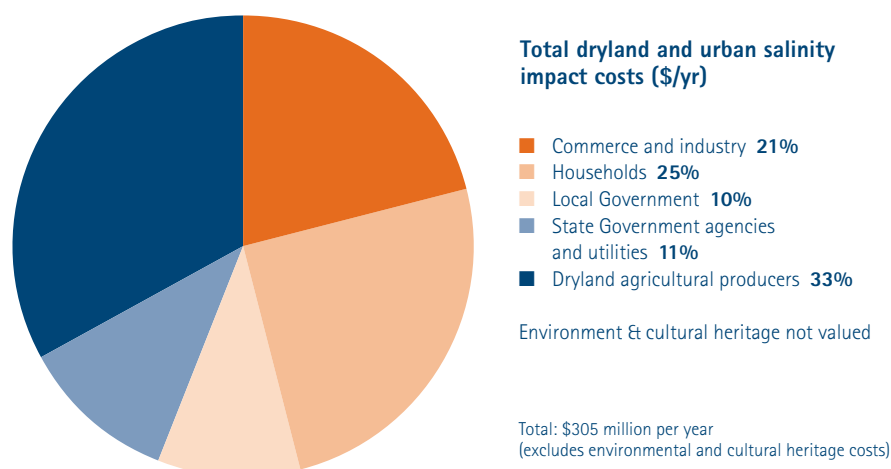
Use the Costs Guideline to estimate current, marginal or future predicted costs for any region in Australia, but start by reading the 'Costs' final report to see what work has already been done and what sort of results you can expect.



Figure 3.2

Breakdown of current dryland and urban salinity costs across the Murray–Darling Basin by major stakeholder group

(Source: Wilson S.M., 2004, *Determining the full costs of dryland salinity across the Murray–Darling Basin: Final project report*, Report to the Murray–Darling Basin Commission and National Dryland Salinity Program, Murray–Darling Basin Commission, Canberra ACT.)

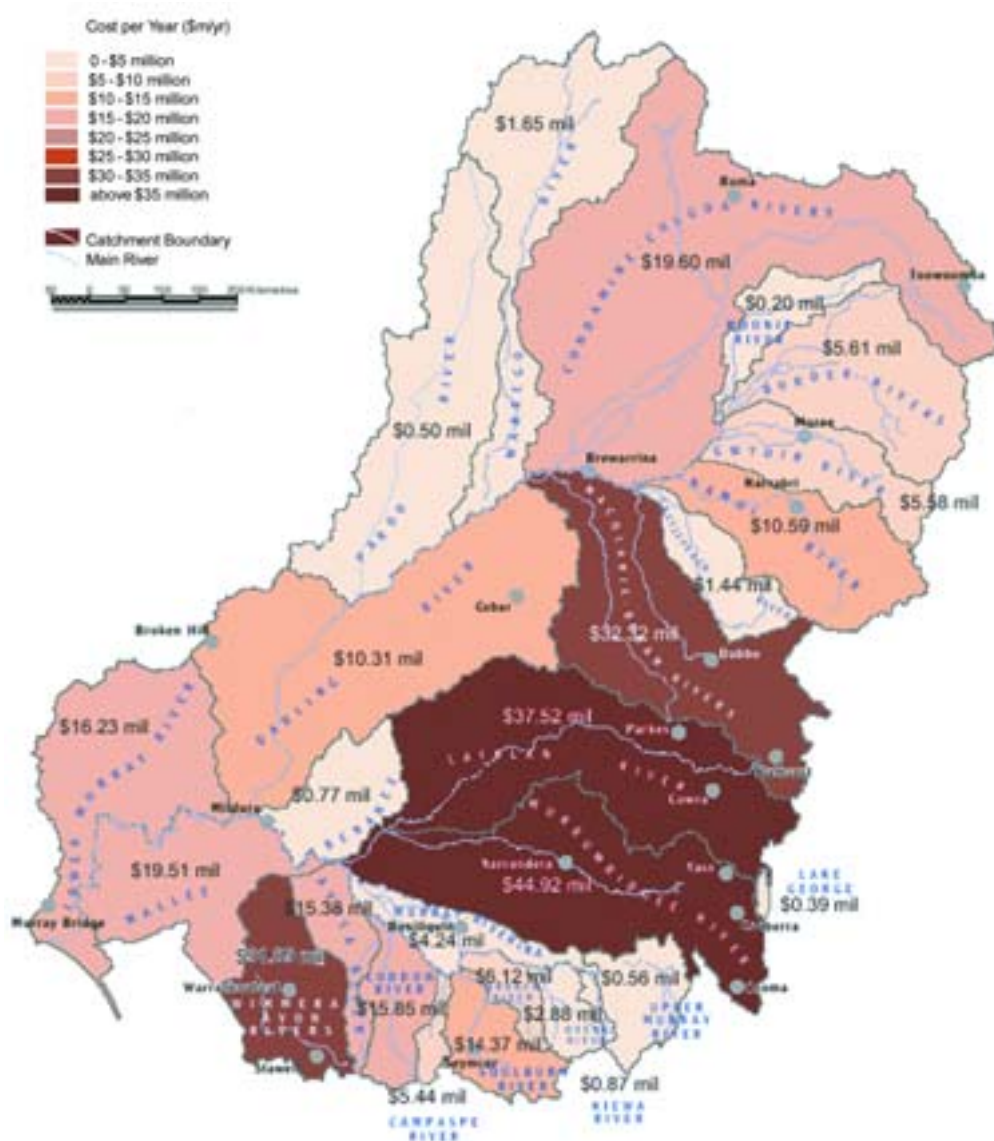


QUESTION 3

Figure 3.3

Total current annual cost of dryland and urban salinity to key stakeholders across the Murray–Darling Basin (\$mil/yr)

(Source: Wilson S.M., 2004, *Determining the full costs of dryland salinity across the Murray–Darling Basin: Final project report*, Report to the Murray–Darling Basin Commission and National Dryland Salinity Program, Murray–Darling Basin Commission, Canberra ACT.)



Notes: Figures include all estimated current impact costs to urban and rural households, commerce and industry, Local Governments, State Government agencies and utilities and dryland agricultural producers, but exclude all costs of salinity to agricultural producers in irrigation areas, and to the natural environment and cultural heritage. Estimates also exclude any costs of salinity to Adelaide (which sources much of its water from the Murray River), as this city is located outside the Murray–Darling Basin.

In Western Australia the impact of salinity on agricultural land, infrastructure, biodiversity and water resources has been undertaken as part of the Salinity Investment Framework¹³. For agriculture, the Framework shows that investment in salinity management is estimated to eventually generate a stream of additional profits (and losses avoided) for farmers that, in present value terms, equates to \$716 million. The analysis can be used to speculate that the annual cost to farmers of forgone profit is around \$300 million (that is, if farm operations are completely and permanently unconstrained by salinity) and the present value of those annual impacts (losses) is around \$4 billion. In terms of infrastructure, assessments based on salinity impacts on highway and local road maintenance (costs of \$19,840 and \$6614 per kilometre), indicated a total combined recurrent costs of \$21 million. However, when the length of roads at risk are considered this increases to a combined cost of \$175.5 million. Importantly, the costs are likely to accrue to Local Government. The present value of future repairs to highways, main and local roads are estimated to be \$1355 million. An assessment of the current annual and potential costs to railways ranges from \$0.5 m to \$7.0 million per year. The present value of in-perpetuity costs was estimated to be \$176 million.

The Rural Towns Program (RTP)¹⁴ (http://agspsrv34.agric.wa.gov.au/environment/townsite_salinity/index.htm) was an initiative of the 1996 WA Salinity Action Plan and developed in response to the recognition that salinity has a significant impact on rural infrastructure and communities. Approximately 38 communities are now involved in this program (see Figure 4.8 in Question 4), 15 of which are considered a high priority for future action. Detailed hydrological studies are conducted in all participating towns, involving drilling, aquifer tests and modelling to determine the impact of applicable management tools. From these studies a salinity management plan is prepared and, in some cases, implementation has commenced.

In six of the rural towns where implementation plans were established (Brookton, Corrigin, Cranbrook, Katanning, Merredin, Morawa) detailed economic analyses were conducted¹⁵ (see Table 3.1), with separate reports published for each town. The reports show that, typically, roads were the infrastructure item most affected by the impact of rising water tables and salinity, representing about two thirds of the total cost in each town. Housing represented about 20 per cent of the total cost, with public buildings, commercial buildings and other infrastructure, such as recreation areas, representing the remaining 15 per cent. However, economic modelling revealed that the benefit–cost ratio of investing in these towns was relatively low. The low benefits were the result of the relatively low value of the asset base, the long time to impact (which devalues the need to invest now) in some cases and the relatively high cost of treating and disposing groundwaters. An electronic decision support tool called *Urban Salinity Economic Analysis Package* (USEAP) and an associated operating manual were also produced.

Current work is aimed at reducing the cost of water management strategies and value adding the saline water generated from pumping systems established or proposed in the towns. In addition, detailed hydrologic assessment tools are being developed to improve the efficiency of locating pumping bores. Desalination and related water management systems are being developed in conjunction with the *Healthy Country*¹⁶ project.

QUESTION 3

Table 3.1

Damage and control costs for six towns participating in the Rural Towns Program, in Western Australia

(Source: Department of Environment, 2003, *Salinity Investment Framework Interim Report – Phase 1*, Salinity and Land Use Impacts Report No. 32, Resource Science Division, Perth WA.)

Town (timescale of estimates)	Damage costs (7%)	Timing of onset of major costs (years)	Total cost of potential options to control rising groundwater (7%)	Cost of abandoning land and infrastructure (7%)
Brookton (60 yrs)	\$0.618m	4	\$0.275m ¹	\$0.678m
Corrigin (60 yrs)	\$0.210m	2	–\$0.105m ²	\$0.09m
Cranbrook (60 yrs)	\$0.611m	22	\$5.742m evap \$1.554m (\$2.251m ³)	\$0.889m
Katanning (30 yrs)	\$6.865m	1	\$7.609m evap \$3.422m	\$13.8m
Merredin (60 yrs)	\$0.384m	26	\$4.565m evap \$0.922m (\$1.827m ⁴)	\$0.698m
Morawa (30 yrs)	\$0.248m	1	\$0.900m	N/A

1. assumes reduced need to purchase scheme water.

2. shown as a negative cost because of benefit due to reduced need to purchase scheme water.

3. if pumping and drainage implemented in Year 16.

4. if pumping and drainage implemented in Year 20.

The report *Financial costs to Local Government of dryland salinity*¹⁷ provides a method for Local Government to assess the cost of salinity and develop appropriate responses to these financial implications. The method includes a financial model, which is described in *Salinity impact model: Impact of salinity on rate revenue and land values – Urban fringe and provincial centre fringe*¹⁸. The model was applied to five municipalities to estimate the increase in infrastructure expenditure costs due to salinity and the affect of these increased costs on rate income. It also takes the existing rate income by different land use types and shows the impact that reduced land values due to salinity will have on the rate base over time. The work found that dryland salinity will financially affect Local Government through the infrastructure that it maintains and renewal costs on behalf of its community, and through its property value based rating system. The case studies investigated included:

- A rural municipality with limited urban areas and a low value infrastructure base
- A rural municipality with a number of small towns and urban areas with a diverse but not high value infrastructure
- A provincial centre, primarily urban municipality with a diverse and moderately high value infrastructure base
- A metropolitan fringe municipality with a high value infrastructure base but low infrastructure maintenance budget
- A municipality on the fringe of a large provincial centre with a low value infrastructure base but a relatively high infrastructure maintenance budget.

3.2.2 Communicating information on impacts and costs

The *Salinity Management Handbook*¹⁹ and the Western Australian program *Rapid Catchment Appraisal* described earlier in sections 1.2.2 and 2.2.2 are significant sources of information on dryland salinity, together with resources from the Tools²⁰ project. The overarching *Salinity Information Package*²¹ (described in the Introduction) considers both dryland salinity impacts and costs, and the ten detailed *Regional Information Packages*²² for major catchments of the Murray–Darling Basin include the specific impacts and costs findings from the 'Costs' project described above.

The *Local Government*²³ project raised awareness of the risk of dryland salinity among 450 Local Governments within rural Australia via the dissemination of an information kit on CD-ROM²⁴ and focus group discussions. It was supported by financial modelling case studies, providing councils with an easy-to-use tool to determine the financial implications of salinity on infrastructure. Case studies of successes and failures by local government in Australia including urban councils are documented and analysed. The report outlines the economic rationale for Local Government getting involved and investing in dryland salinity control.

Under the NSW Salinity Strategy²⁵, the Urban Salt Action Team works with Local Government to provide training, education and technical support on urban salinity issues. As part of the Local Government Salinity Initiative a series of booklets are being produced. At present these include:

- *An Introduction to Urban Salinity*²⁶ – an overview of the processes, impacts and management options for urban salinity
- *Indicators of Urban Salinity*²⁷ – contains information on a range of salinity indicators and explains the causes of salinity
- *Broad Scale Resources for Urban Salinity*²⁸ – discusses some of the resources available to determine the nature of salinity issues in a particular region
- *Site Investigations for Urban Salinity*²⁹ – provides a framework for assessing the impact of salinity on a proposed development and the impact of a development on salt and water processes
- *Roads and Salinity*³⁰ – describes how salt and water processes can affect road structure as well as strategies to prevent road damage and minimise the role roads play in salinity problems
- *Building in a Saline Environment*³¹ – explains how salt damages buildings and how to build structures that are less susceptible to salt damage
- *Waterwise Parks and Gardens*³² – contains information on creating and managing sustainable, water-efficient landscapes.

Ten workshops/training sessions based on the contents of these booklets have been held in regional New South Wales. The Local Government Salinity Initiative (LGSi) is supported by the Local Government and Shires Associations of NSW. A *Western Sydney Salinity Code of Practice* has been developed that uses the level of salinity hazard, riskiness of the land use and size of the development to determine whether a level 1, 2 or 3 investigation and management response is appropriate. The Code of Practice was supported by training sessions and an information resource kit, which includes the LGSi booklets. At least one staff member from 22 per cent of councils in New South Wales attended training sessions in urban salinity between October 2002 and July 2003.

ACTION #3.4

Refer to the Tools Regional Information Packages for summary information on the findings of the 'Costs' project in your region, and consult the Salinity Information Package for more general information on salinity costs.



ACTION #3.5

Refer to the 'Local government' project information kit on CD-ROM and the series of booklets on urban salinity to guide salinity identification and management for urban areas in your region.



QUESTION 3

ACTION #3.6

Consider the estimates for current and predicted impact costs on farm profits for GRDC's agro-ecological zones for individual grain growers and the grains industry in your management response to dryland salinity.



ACTION #3.7

Ascertain whether an assessment of the current and predicted impact costs on farm profits for beef, sheep meat, wool or other industries is needed to inform your management response to dryland salinity.



3.2.3 Evaluating cropping regions of Australia

The *Economic Evaluation of Salinity Management Options in Cropping Regions of Australia*³³ project was inspired by the findings of the National Land & Water Resources Audit, which estimated 2.6 million hectares of GRDC's agro-ecological zones (see Figure 3.4) to be salt-affected, with an additional 1.1 million hectares predicted to be affected by 2020.

The five agro-ecological zones facing large salinity increases are the WA Sandplain, SA Vic Bordertown Wimmera, NSW Vic Slopes, WA Central and Vic High Rainfall. Over 60 per cent of the additional salt-affected area will be in the Western Region, in particular the WA Sandplain and WA Central zones. Some zones, such as the WA Sandplain and WA Central, are already major grain growing regions so their forecasted large increases in salt-affected areas toward 2020 will impact on national crop production.

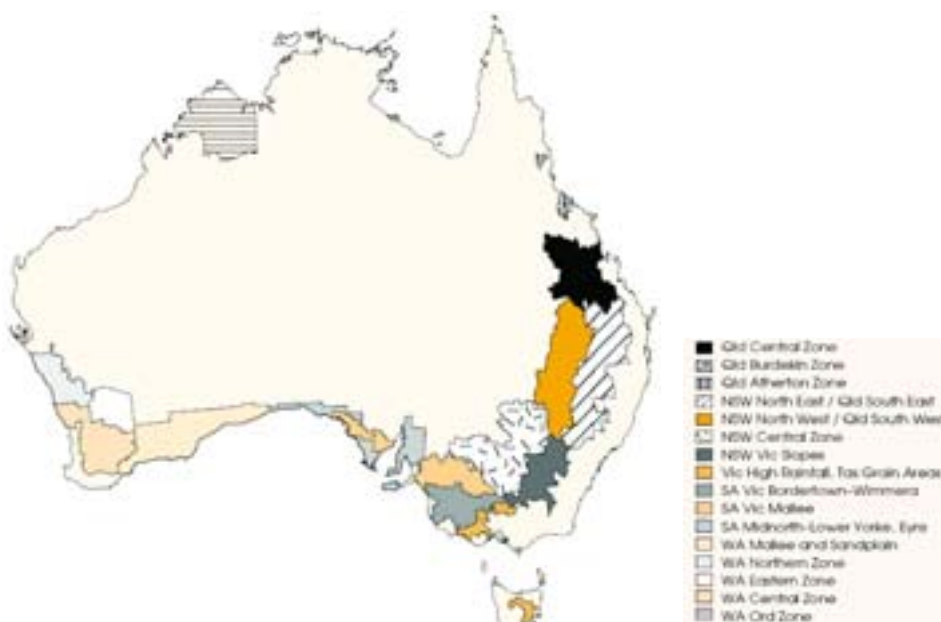
Across all the zones, if half the forecast additional area to become salt-affected is normally sown to crops, this represents, at worst, a potential loss around half a million hectares of crop land.

The five agro-ecological zones forecast to experience large salinity problems over the next 20 years are, with the exception of the Vic High Rainfall zone, also the major consistent sources of Australian farm profit. Declines in farm profit due to salinity within these zones could have damaging consequences for overall grain industry profits and for regional economies. The impact of salinity, measured as the present value of the decline in farm profit from 2000 to 2020 due to worsening salinity, is around \$238 million. Including impacts beyond 2020 increases this cost to \$387 million. This equates to an annual cost of around \$29 million in foregone farm profit.

Figure 3.4

GRDC agro-ecological zones

Source: ABARE (1999), Australian Grains Industry Performance by GRDC Agro-ecological Zone, April 1999. Page 19.



3.3 Ecosystem responses

3.3.1 Assessing aquatic biodiversity loss

The *In-stream health*^{34,35} project undertaken in the Barwon River catchment (south-west Victoria) set out to trial the development of a system that will predict the loss of aquatic biota caused by a rise in salinity. Methods were developed to rapidly test the relative salinity tolerance of a large number of species (57).

In order to construct a predictive system the frequency distribution of the relative salinity tolerances of the species tested was assessed – this distribution approximated log-normal and can therefore be used as the basis of a predictive system. A log-normal distribution means that most species are slightly tolerant, while some are very sensitive and some are very tolerant. This suggests that initial salinity increases will affect only a minority of aquatic macro-invertebrate species. However, further salinity rises will affect many species, and progressive increases will affect the few more tolerant species remaining.

Short-term or acute lethal tolerance was used as an indicator of the macro-invertebrates' relative tolerance. The relative salinity tolerance of specific macro-invertebrate taxa was also assessed and found that mayflies and non-arthropods (snails and worms) were the most salt-sensitive and macro-crustaceans were the most tolerant. Rare species tended on average to be more tolerant than common species. To assess the tolerance of a wide range of species and taxa that comprise natural communities there is a need for testing of both common and rare species. However, rare species are difficult to test because it is hard to collect them in large numbers.

This research has shown that it is feasible to develop a system to predict the loss of aquatic biota caused by rises in salinity and that acute lethal tolerances do relate to field occurrences. It has identified which specific taxa are sensitive/tolerant and that there is a need to consider rare species. The project has given an indication of spatial variation in salinity tolerance and provided preliminary information on sub-lethal and critical life-stages.

3.3.2 Rising water table impacts on remnant vegetation

The *Restoring Remnant Vegetation*³⁶ project developed a decision-tree approach to predict likely ecosystem response to changes in hydrologic balance. The research was conducted in the upper and middle Blackwood Basin in Western Australia.

At landscape scale, hydrological modelling of the future groundwater surface was linked with the distribution of plant community types in vegetation remnants. This identified those remnants most at risk from rising groundwater.

The work demonstrated that broad-scale estimates of losses from salinisation may over-estimate the actual impact, as fine-scale variation in micro-topography mediates the broad-scale risk from water table rise, such that some locations escape impacts, at least in the short-term.

The hydrological information derived for the upper Blackwood is being incorporated into a regional predictive analysis of salinity impacts for the major rivers of the WA wheatbelt (including the Blackwood) under the WA Engineering Evaluation Initiative.

ACTION #3.8

Estimate the loss of aquatic biota from a rise in salinity in your catchment using the preliminary methods developed by the 'In-stream health project' project to rapidly test the relative salinity tolerance of a large number of macro-invertebrate species.



ACTION #3.9

Test the decision-tree approach developed by the 'Restoring Remnant Vegetation' project in your catchment to predict likely ecosystem responses to changes in hydrologic balance.



QUESTION 3

ACTION #3.10

Use waterlogging and elevation as an initial indicator of the capacity of primary saline ecosystems to persist in a secondary saline environment.



3.3.3 Investigating vegetation recruitment impacts

The *Recruitment Biology*³⁷ project investigated the recruitment biology of vegetation communities, in the south-west of Western Australia near Jerramungup. The Gairdner River is naturally saline and the woodland of yate (*Eucalyptus occidentalis*) trees, melaleuca shrubs and sedges observed, grows in shallow soils above a hypersaline water table, in many places twice as salty as the ocean.

The research found that the current structure, species abundance and diversity along primary saline rivers did not persist in secondary saline environments. Waterlogging and elevation are useful initial predictors of a site's fate, particularly in the lower parts of the landscape. Waterlogging duration, soil chloride and soil type increase the predictive power higher in the landscape.

Information on the impact of salinity and waterlogging on yate woodland will ensure that management strategies can be developed that consider specific soil and water thresholds necessary to maintain functioning ecosystems.

3.4 Cost sharing

3.4.1 Distributing the costs

The report *Robust separation – A search for a generic framework to simplify registration and trading of interests in natural resources*³⁸ considers how to establish a robust, economically efficient and equitable system of defining, allocating and managing use of natural resources. Such a system defines interests, rights and use obligations that sit within an economically efficient trading system. The report does not consider pricing, charging or how to convert from existing systems (these are proposed for reports to follow).

The report *Cost-sharing for on-ground works*³⁹ considers the rationale for adopting cost sharing, including the role of government. It explains the principles of cost-sharing and how these may be applied to action planning at the regional level. Four examples of cost-sharing frameworks are described. *Investment programs and institutional arrangements for effective natural resource management*⁴⁰ reports on the application of the 'Cost-sharing for on-ground works' approach in the Liverpool Plains (NSW).

The following four economic reports on conserving native vegetation are summarised in the publication *Managing the bush*⁴¹:

- *Motivating people – using management agreements to conserve remnant vegetation*⁴²
- *Beyond roads, rates & rubbish – opportunities for Local Government to conserve native vegetation*⁴³
- *Opportunity denied – review of the legislative ability of Local Governments to conserve native vegetation*⁴⁴
- *Talking to the taxman about nature conservation – proposals for the introduction of tax incentives for the protection of high conservation value native vegetation.*⁴⁵

Policy options for how to encourage sustainable land use are described in a discussion paper⁴⁶ that outlines 18 suggestions. The options come under five major categories – Make plans (e.g. Define property holders' rights and responsibilities); Find resources (e.g. Offer tax

ACTION #3.11

Investigate opportunities for cost-sharing arrangements to inform the development and support the implementation of your regional dryland salinity plan.



incentives); Gain knowledge and skills (e.g. Extend landholders' skills); Encourage change (e.g. Pay farmers for environmental services); and Monitor progress (e.g. Monitor for adaptive management).

3.4.2 Accounting for ecosystem services

The 'Ecosystem Services'⁴⁷ project studied the services people obtain from the natural environment, the economic and social value of these services, and the opportunities that can arise from considering them more fully in land management policies and decisions. Some examples of natural ecosystem services include provision of clean and pure water; maintenance of liveable climates and atmospheres; pollination of crops and native vegetation; fulfilment of cultural, spiritual and intellectual needs; and provision of unforeseen options for the future.

The *Ecosystems Services* project investigated case studies in the Goulburn-Broken catchment (Victoria), the Atherton Tablelands (Qld), the Rangelands and Gwydir catchment (NSW), the Blackwood catchment (WA), the Onkaparinga catchment (SA), the Brigalow (Qld) and Brisbane (Qld). The analysis framework used in these studies and further discussion is provided in section 5.10. The research provides a better understanding of the benefits and beneficiaries of ecosystem services, and direction on more equitable sharing of the costs and benefits of natural resource management.

A report⁴⁸ on the contribution of mid to low rainfall forestry and agroforestry to greenhouse and natural resource management outcomes identifies opportunities to help deliver carbon sequestration and more sustainable natural resource management in conjunction with regional economic development and agricultural diversification benefits.

The key findings of this work are:

- Revegetation and land use change over large areas in mid to low rainfall regions of southern Australia using commercial forestry and agroforestry is vital to sustainable natural resource management. Carbon sequestration from these activities could make a significant contribution to meeting Australia's greenhouse goals.
- There are good opportunities to use tree crops to modify agricultural systems in the mid and low rainfall zone of southern Australia.
- Revegetation at the required scale is unlikely to occur with either public or private investment alone at present market values.
- The current market value of greenhouse and other ecosystem services is unlikely to be sufficient to fully fund revegetation at the scale required.
- Wherever possible, market signals should be used to guide investment in tree crops.

Two complementary studies on the opportunities for ecosystem services in Australia are outlined in the summary report *Making farm forestry pay – Selling the environmental services of farm forestry*⁴⁹. The first study, *Making farm trees pay*⁵⁰, assesses why existing incentives for farm forestry are not adequate, and whether markets for environmental services could be developed to make farm forestry economically attractive. The second, *Emerging markets for environmental services*⁵¹, reviewed several case studies of environmental markets in the USA and United Kingdom, focusing on elements that were critical for the success of the trading programs. These reports concluded that opportunities exist in Australia to develop markets for ecosystem services.

ACTION #3.12

Develop opportunities to market ecosystem services in your region to make sustainable land management more economically viable, and maintain a watching brief on the progress and relevance of programs and activities taking place elsewhere.



QUESTION 3

The NSW Government's Environmental Services Scheme⁵² focuses on land use changes that will produce economic and ecological benefits for individual properties and the State as a whole. The scheme provides financial incentives for landholders to change to 'environmentally-friendly' land uses such as the establishment of deep-rooted perennial pastures on land currently used for cropping or annual pastures, commercial tree planting and establishment of saltbush pastures. Information from this scheme will eventually be used to develop markets through which a range of environmental services can be traded.

R & D TIP #3.1

Review the strategic plan for the National Land & Water Resources Audit Phase II (2002–07) and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.



WHERE TO FROM HERE?

National Land & Water Resources Audit

The NLWRA identified that information on the impacts of dryland salinity on biodiversity is scant and that detailed assessment of impacts will need to be undertaken as part of all regional planning. The priorities for further research highlighted were the assessment of the ecological impact of elevated salt loads in streams, and improved methods for the application and integration of social and economic data in the setting of salinity control targets.

Current and future costs

Some costs of salinity may be recoverable, such as using saltland agronomy,⁵³ while others are not. We need to particularly focus on preventing future damage to high value assets, using cost-effective treatments. Close attention will need to be paid to the cost-benefit of protecting private assets versus public assets (e.g. wetlands and heritage buildings), which may be more efficient than efforts to protect agricultural land. Cost-benefit analysis of the major dryland industries – wool, beef, sheep meat, grains – is needed to inform this decision-making. It will also be necessary to account for the value of saline land as an agricultural resource, increasingly highlighted through research of the Sustainable Grazing on Saline Lands (SGSL) Sub-Program.

Planning could be further supported by reinterpreting the current findings of the 'Costs' project within the *Groundwater Flow Systems Framework*⁵⁴ to establish the distribution of impact costs across groundwater flow system types. A high proportion of the impact costs in local groundwater flow systems compared to intermediate and regional systems would provide a broad indication of our capacity to remedy impact costs through vegetation-based versus engineering-based solutions in the shorter-term. This is especially important for managing impacts on important environmental and cultural heritage assets.

The results of the 'Costs' project could be improved by additional investigations to overcome data and information limitations with respect to the current area of salinised, urban impacts and their costs, damage to cultural heritage, and damage to wetlands.

More thorough knowledge of the existing area of salinised land, as well as a consistent measure of its severity, is required. This requires further work to record, in digital form, the location, area and severity of all salinity outbreaks. The report *Economic Evaluation of Salinity Management Options in Cropping Regions of Australia* identified the GRDC agro-ecological regions of WA Sandplain, SA Vic Bordertown Wimmera, NSW Vic Slopes, WA Central and Vic High Rainfall as priority areas for further investigation.

The 'Costs' project suggests that urban areas experience the greatest impact of the costs related to dryland salinity, at least within the scope of this study. It must be recognised that this work is not exhaustive of all towns and cities and does not include the costs related to

river salinity, irrigated agriculture or the environment and cultural heritage. All estimates of urban salinity costs are therefore indicative only and require further refinement.

Notwithstanding general acceptance that dryland and urban salinity is having adverse effects on places, buildings, archaeological sites, gardens and trees with cultural and Aboriginal significance, there is limited documentation of these impacts. A systematic assessment is required. The *Salinity Investment Framework* and the *Rural Towns Program* in Western Australia provide leading examples.

There is an urgent need to improve monitoring of salinity levels of high-value wetlands at risk from salinity, and to improve understanding of salinity impacts on in-stream plants and animals, and on riparian vegetation.

A further advance in understanding impact costs would be achieved by using the 'Costs Guidelines' to predict future impact costs. This could be undertaken using the digitised datasets from the National Land and Water Resources Audit and *The Salinity Audit of the Murray–Darling Basin 1999*,⁵⁵ which show the likely extent of high water tables and salinity concentrations in rivers in 2020, 2050 and 2100. Where improved datasets are available, such as the Groundwater Status Report for the Murray–Darling Basin,⁵⁶ they should be used in this analysis.

In the longer term, the design of salinity programs and collaboration between stakeholders could be enhanced by assessing the costs of salinity at regular intervals, preferably under the direction of regional organisations preparing and implementing salinity plans. This has the potential to:

- Further increase community, industry and government awareness of the nature of salinity impact costs, and the level of costs being incurred by stakeholders
- Assist in attracting levels of investment in salinity management appropriate to the levels of costs being incurred or predicted
- Assist in strategic allocation of investment across urban, rural, environmental and cultural heritage issues
- Contribute to regular monitoring, reporting and evaluation processes introduced to facilitate the longer-term development of salinity management programs.

Ecosystem responses

Research on aquatic biodiversity loss indicated a need to extend studies to ascertain the degree to which the findings from the Barwon catchment (Victoria) apply to other locations. Further studies on sub-lethal effects, longer-term lethal effects and tolerances of critical life-stages (such as eggs and young) of a sub-set of species are necessary, as is knowledge of the relationship between these effects and field distributions. Consideration of whether other biological groups (e.g. micro-invertebrates, some life-stages of fresh water fish, etc.) are more sensitive than macro-invertebrates should also be considered.

The decision-tree approach to provide likely ecosystem response to changes in hydrologic balance and the recruitment biology investigations of yate communities were both undertaken in Western Australia. Further trials are needed to determine the extent to which these research findings are relevant elsewhere. The hydrological information from the Blackwood catchment is being applied in the WA wheatbelt under the Engineering Evaluation Initiative, and this will provide further testing of the methods and findings.

R & D TIP #3.2

Consider the on-going activities of the Salinity Investment Framework, Rural Towns Program and the implementation of the Basin Salinity Management Strategy (www.mdbc.gov.au)

R & D TIP #3.3

Consider the outcomes of research from the Sustainable Grazing on Saline Lands (SGSL) Sub-Program (www.lwa.gov.au) and PUR\$L (www.ndsp.gov.au) on the changing value of saline land as an agricultural resource.

R & D TIP #3.4

Consider the research portfolio of the Land & Water Australia (www.lwa.gov.au), particularly the Contaminants Program, the CRC for Freshwater Ecology (www.environmentdirectory.com.au/research/crcfw.html) and the WA Engineering Evaluation Initiative (www.wrc.gwa.gov.au/protect/salinity) for further information.

QUESTION 3

R & D TIP #3.5

Follow the progress of investigations by CSIRO Land and Water (www.clw.csiro.au) on efficient trading systems and on ecosystem services under the NAP (www.napswq.gov.au).

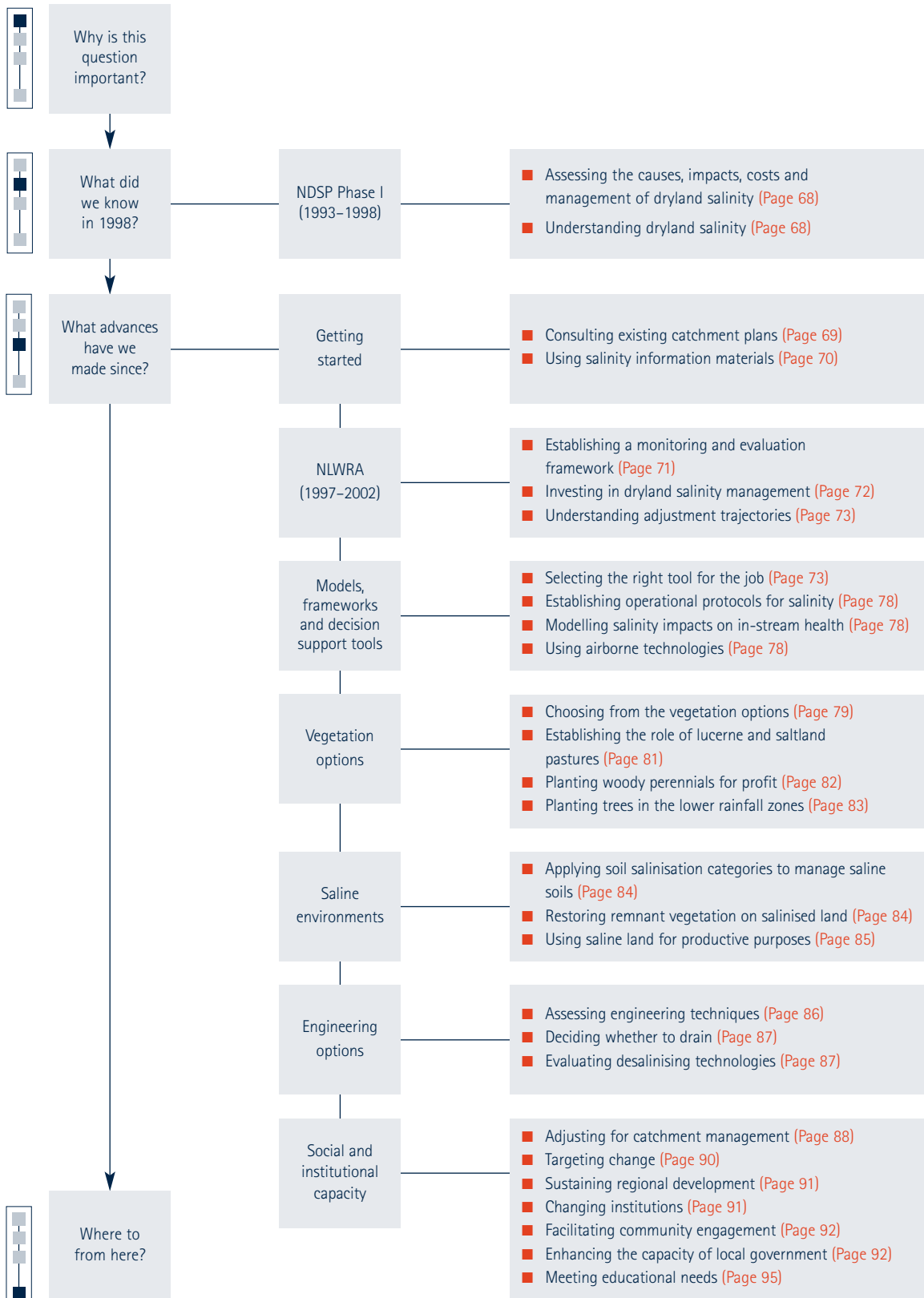
Cost sharing

Investigations are required to more clearly define interests, rights and use obligations within an economically efficient trading system. Supporting research on pricing, charging and how to convert existing systems is in progress. This system must be supported by equitable cost-sharing arrangements to support on-ground works in natural resource management with a public good component. The provision of ecosystem services should be fully accounted for in any trading system and associated cost-sharing mechanisms.

QUESTION 4

Roadmap

What can we do and how do we measure progress?



What can we do and how do we measure progress?



WHY IS THIS QUESTION IMPORTANT?

Deciding what to do about dryland salinity is perhaps the most important question. It is underpinned by our knowledge of the extent of dryland salinity and its risk of spread, our understanding of the causes and processes of dryland salinity, and the ecological, economic, social and cultural dimensions of the impacts and costs.

We need to consider the nature and timing of the problem, what society is wanting to protect or live with, and how much it is willing to pay, before deciding on the options for action and their appropriateness.

While our understanding of all of these aspects of dryland salinity has significant gaps, decisions about investments and actions are on-going, and we need to make decisions using the best available knowledge. In doing so, we will invariably make mistakes, but we need to have an adaptive approach to learning and management so that we can learn and improve over time.

Catchment managers in some areas have recently set targets for salt loads and salinity concentrations in-stream to protect identified assets and values. While measuring progress against these targets is a requirement for accountability reporting, it is important to better understand whether the targets themselves are accurate, feasible and desirable within the scope of the management responses available and the capacity of communities to implement the type and scale of change needed.



WHAT DID WE KNOW IN 1998?

Chapter 3 of *Assessing the causes, impacts, costs and management of dryland salinity*¹ considered the question 'What are the land use options for managing my recharge?'

The following factors were considered:

- Understanding the constraints and setting realistic objectives for salinity management
- Selecting land use options for managing salinity, including models for predicting outcomes of salinity management options
- Management options for reducing recharge
- Management and protection of remnant vegetation
- Agronomic solutions
- Engineering solutions
- A case study of the Brymaroo catchment in Queensland.

The first section on 'constraints and objectives' looked at the ecological, economic and social dimensions of dryland salinity management. It provided a cursory discussion about how suggested land management and land use change scenarios might affect society, the economy and the environment. It also questioned whether social and economic capacity is adequate to implement the scenarios proposed. It was supported by the 1996 publication *Cost-sharing for on-ground works*² described in *Understanding dryland salinity*³ that advocated a need for a principled and objective approach to cost-sharing arrangements.

Selecting land use options discussed the models that were available for comparing alternative land use change options in 1998. Some of the models discussed have been superseded, have limited data availability or public access issues, or have been absorbed into more dynamic forms. Others have been refined and are key modelling tools used today.

The section on 'management options for reducing recharge' provided a table of land use options – management and protection of remnant vegetation, agronomic options and engineering solutions. While the options and descriptions remain broadly applicable, advances through the *Groundwater Flow Systems Framework*⁴ and other projects described in this chapter provide more up-to-date and detailed information.

Our understanding of the importance of the 'management and protection of remnant vegetation' has developed significantly since 1998. The advantages, limitations and cost-benefit discussion detailed in *Assessing the causes, impacts, costs and management of dryland salinity* provided little information to guide land use options for salinity management as, at the time, information about the extent of salinity and its risk of spread was very patchy. The body of knowledge about plant water use and salt storage and movement was also scant.

'Agronomic solutions' discussed both land use change and improved management under current farming systems – annual crops and pastures, traditional perennial species, changing to new perennial species (oil mallees, broombush, jojoba), trees and ecosystem mimicry. Several research activities on agronomic solutions undertaken between 1990 and 1998, notably 'Pasture management for recharge control', 'Community grasses', 'Episodic recharge under crops and shrubs in the Mallee', and 'Planting strategies for recharge management' are discussed in *Understanding dryland salinity*. At the time, the potential scope of the land use change needed was not appreciated, nor the limitations of current farming systems to reduce recharge and the likely scale of living with salinity and the potential for productive uses of saline land.

Drainage of surface water, surface and sub-surface drainage of groundwater, and groundwater pumping were considered in 'engineering solutions'. Significant investigations have taken place since 1998 to scope the range of engineering options, including their applicability in different parts of the landscape and associated costs and impacts.

The five case study catchments in NDSP Phase I – Brymaroo (Qld)⁵, Liverpool Plains (NSW)⁶, Upper Kent River (WA)⁷, Loddon-Campaspe (Victoria)⁸ and the Upper South-East (SA)⁹ – provide important resource information on considering the questions of management options and monitoring progress for dryland salinity management. These case studies are described in *Assessing the causes, impacts, costs and management of dryland salinity* and more detailed technical reports on these investigations are available.



WHAT ADVANCES HAVE WE MADE SINCE?

4.1 Getting started

4.1.1 Consulting existing catchment plans

Many catchments in Australia have a salinity management plan and/or an integrated catchment management strategy. These plans must meet any regional obligations associated with higher order strategies and regulations, such as the requirements of the National Action Plan for Salinity and Water Quality¹⁰ and under Schedule C of the Basin Salinity Management

QUESTION 4

ACTION #4.1

Undertake a comprehensive review of all relevant regional plans in the light of current dryland salinity research outcomes, and assess the need to align the plans, with particular consideration to the suitability and feasibility of management options and measuring progress.



ACTION #4.2

Access the Tools Salinity Information Package, Salinity Management handbook, Rapid Catchment Appraisal or similar resource to understand the broad salinity options available.



ACTION #4.3

Refer to the table on 'Suitability of options for managing dryland salinity' in the Tools Regional Information Package for your region (or as a model to develop your own) to identify broad management options and ratings for each groundwater flow system type.



Strategy.¹¹ Catchment plans and the reports that underpin them are important sources of information for further planning and management. Other regional plans that may impact on dryland salinity management, such as those prepared by economic development organisations, irrigation authorities, regional private forestry development committees and Local Governments, should also be considered in future strategic planning activities.

It is important that all regional plans that impact on dryland salinity management are broadly compatible and account for current understanding and knowledge, especially water sharing and groundwater allocation and management plans. Reviewing plans from outside of your region can also provide insights about different approaches to planning and management.

4.1.2 Using salinity information materials

The Tools¹² project is a good starting point for understanding the broad options for salinity management – using remnant vegetation, agronomic changes, engineering and living with salinity, including the productive use of saline lands. The *Salinity Information Package*¹³ provides 40 information sheets that consider all aspects of salinity management, supported by the more specific *Regional Information Packages*¹⁴ for the major Murray–Darling Basin catchments. The *Regional Information Packages* use the broad groundwater flow system types, their related attributes and local knowledge of groundwater behaviour to develop tables of broad management options, with a ranking (High, Moderate, Low) to determine the effectiveness of different options, as shown in Table 4.1.

Table 4.1

An example of ranking the effectiveness of management options for different groundwater flow systems used in the Tools *Regional Information Packages* showing the North Central region (Victoria).

(Source: Murray–Darling Basin Commission, 2004, *Tools for improved management of dryland salinity in the Murray–Darling Basin – North Central regional information package*, Murray–Darling Basin Commission, Canberra, ACT.)

Section	Groundwater Flow System	Priority
I	Regional GFS in alluvial (riverine) plains	High
II	Local and intermediate GFS in deeply weathered and fractured sedimentary rock	High
III	Local and intermediate GFS in Cambrian volcanic and sedimentary rock	Moderate to high
IV	Intermediate GFS in fractured rock	Moderate
V	Local GFS in fractured rock	Moderate
VI	Local GFS in colluvial fans within granitic rock	Moderate to low
VII	Local and intermediate GFS in upland alluvium	High
VIII	Local and intermediate GFS in fractured basalt	Moderate

The *Salinity management handbook*¹⁵ provides a comprehensive and practical introduction to salinity. It comprises three parts – understanding salinity, investigating salinity and managing salinity. 'Understanding salinity' describes the three major types of salinity and looks at salinity and hydrology management. 'Investigating salinity' provides practical information for planning and carrying out salinity investigations, considering geomorphic features, climate and land use. Indicator plant species and soil and water data are used to determine the extent of salting and the processes contributing to the problem. 'Managing salinity' considers vegetation, irrigation

and engineering applications, and the process of developing an integrated management. The Appendices include:

- Landscape features diagnostic chart
- Plant salt-tolerance data
- Pasture species for saline soils
- Tree species for salinity management
- Useful software packages
- Salinity publications for further reference

The *Rapid Catchment Appraisal* (RCA) program (<http://agspsrv34.agric.wa.gov.au/environment>) under the Western Australian Salinity Strategy¹⁶ provides current estimates of extent and risk, analysis of the impact of management options, and direction for salinity management in their region. Extent and risk analysis is driven by assessments of satellite-based salinity mapping, while management option assessments use established modelling tools such as FLOWTUBE and AgET.

A practical handbook entitled *Healthy catchment guide*¹⁷ has also been published for the South West Slopes of the Murray Catchment (NSW). It looks at salinity processes relevant to the South West Slopes and discusses why this area is a 'salinity priority' in the greater Murray River Catchment (NSW) context. It draws on the *Groundwater Flow Systems Framework*, the 'Tools' information packages and *Land Capability Classification* to provide a practical guide to priorities for vegetation placement for salinity, which can be applied at a property level.

For the Upper South East of South Australia, the publication *Managing dryland salinity in the Upper South East: Implications of some recent groundwater studies*¹⁸ should also be consulted.

4.2 National Land & Water Resources Audit (1997–2002)

4.2.1 Establishing a monitoring and evaluation framework

The *Evaluation Framework*¹⁹ project resulted in a system for adaptive updating of knowledge, guidelines for monitoring key biophysical attributes for defining the current and future risk of dryland salinity, and recommendations about the spatial and temporal design of monitoring programs in each groundwater flow system type.

The adaptive framework provides a means for State agencies to carry out management, monitoring and research activities that systematically build on existing knowledge. The evaluation framework balances the need to use imperfect information to support on-going decision-making processes, with the need to learn and adjust as we go. Figure 4.1 shows the adaptive management cycle developed by the project.

Guidelines were developed for systematically monitoring key biophysical attributes critical to defining the current and future risk of dryland salinity. These include groundwater levels and salinity concentrations, stream salinity concentrations and salt loads, extent of land salinisation, land cover and land use, and other contextual data. Recommendations are made for the spatial and temporal design of monitoring programs in each groundwater flow system type.

ACTION #4.4

Use the National Evaluation Framework guidelines to plan how to systematically build on existing knowledge for each groundwater flow system type through coordinated management, monitoring and research. Refer to Participatory evaluation for landcare and catchment groups – A guide for facilitators for background information on monitoring and evaluation.

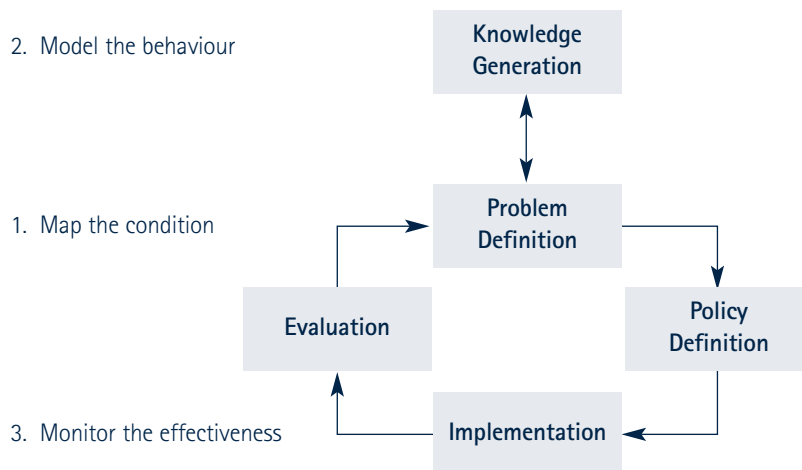


QUESTION 4

Figure 4.1

The adaptive management cycle developed by the *Evaluation framework* project

(Source: Coram J.E., Dyson P.R., and Evans W.R., 2001, *An evaluation framework for dryland salinity*, A report prepared for the National Land and Water Resources Audit Dryland Salinity Project, Bureau of Rural Sciences, Canberra ACT.)



This approach will align management, monitoring and research activities. We can also begin to identify suitable, cost-effective management and monitoring requirements for relatively unstudied areas. We are now better placed to answer:

- What attributes will enable cost-effective mapping of current effects?
- What attributes will assist in cost-effectively predicting future effects?
- Where should these attributes be measured and how frequently?
- How adequately have management activities been implemented?
- How effective have management activities been?
- Where are other areas that are likely to behave in a similar manner?

The basic principles of monitoring and evaluation, together with ways to engage the community in the process, are explained in the plain-English guideline *Participatory evaluation for landcare and catchment groups – A guide for facilitators*.²⁰

ACTION #4.5

Consider the broad scope of options available to manage dryland salinity – plant-based, engineering, saline industries, living with salinity – and select those that optimises the benefits to your region considering the short-term and long-term costs and benefits.



4.2.2 Investing in dryland salinity management

The work undertaken by the NLWRA on groundwater flow systems and the associated case studies provided the broad suite of management options available to manage dryland salinity and their applicability in different parts of the landscape. It highlighted the inter-generational nature of dryland salinity – with time-scales for investment and management up to hundreds of years. This has broadened the debate on actions to manage salinity from tree-based solutions to a wider range of interventions including engineering, plant-based solutions, saline industries and 'living with salt'.

Catchment case studies undertaken as part of the Audit showed that large-scale tree planting would represent a poor investment in many cases under current market conditions. The analyses concluded that engineering options and/or saltland production systems would be more economic than catchment-wide changes involving agroforestry and perennials.

4.2.3 Understanding adjustment trajectories

The *Social adjustment*²¹ project reports on four NLWRA regional case studies and examines the capacity of the local and wider communities to change in a manner that might achieve improved salinity control. It uses the outcomes of the biophysical, economic and social modelling undertaken within other projects of the Audit. The case study catchments²² are:

- Wanilla catchment, South Australia
- Kamarooka region, Victoria
- Lake Warden catchment, Western Australia
- Upper Billabong Creek catchment, New South Wales.

The case studies revealed a number of instances where the 'cure' for salinity was worse than the 'disease' in terms of the impact upon the regional farming communities. An understanding of regional adjustment trajectories may explain why salinity control strategies are not being implemented. Some parts of the rural community are in a trajectory out of commercial farming. In these cases, solutions based upon intensification of agricultural management will have little chance of implementation.

This research has produced a modelling tool that improves our understanding of the potential social impacts of policy change and is applicable beyond dryland salinity management (e.g. water allocation).

The key lessons derived from the case studies are:

- There is no simple, broadly applicable paradigm with which to conceive a response to salinity
- Expectations of farm-based change leading to salinity control need to be tempered by social and economic realities
- Broad-scale reforestation will often be a poor economic and social investment in current market conditions
- A lack of profitable, technically feasible options is the major constraint to capacity to control salinity
- 'Capacity for change' is really the capacity of our communities to make informed decisions about investment in salinity control
- Integrated catchment management strategies need to operate within an adaptive management framework
- Public investment in salinity control should be based upon a triage model, where protecting healthy, more valuable parts of the landscape takes precedence over less tractable, degraded environments
- The 'on-ground works' imperative should be tempered by a 'least regrets' investment approach
- Landscape change must be seen as a multi-generational challenge.

4.3 Models, frameworks and decision support tools

4.3.1 Selecting the right tool for the job

Finding the 'right' model(s) to support catchment scale planning is a difficult task when confronted with the myriad of options available addressing different processes and aspects of salinity. Models operate at a range of scales – property, sub-catchment, catchment, river basin, regional, State and National – all of which have relevance for answering particular questions

ACTION #4.6

Use the surveys and modelling tools developed by the Audit to examine potential social impacts of your proposed management approach to dryland salinity, and develop a better understanding of the social trajectory of your community.



QUESTION 4

ACTION #4.7

Read the paper An overview of modelling techniques and decision support systems and their application for managing salinity in Australia and the booklet Groundwater models – A community guide to better understanding to get an overview of salinity modelling, and then consult the PRISM CD-ROM to help inform the choice of an appropriate modelling approach for your region.



ACTION #4.8

Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au) to view the 'Catchment Modelling Toolkit' and consider the benefits of attending the 'Catchment Modelling School' to improve modelling capacity in your region.



for salinity planning and management. The available data and the level of certainty needed from the modelling outputs will also play a large role in determining model suitability.

Table 4.2 provides some examples of prominent models used to test alternative land use change scenarios, together with case study examples where the models have been applied, while Table 4.3 provides examples of river basin models and decision support systems. These tables have been adapted from the paper *An overview of modelling techniques and decision support systems and their application for managing salinity in Australia*²³ and informed by the paper *A review of hydrologic models for salinity management*²⁴, which summarise many of the key salinity models and decision support tools used in Australia.

A project to review salinity models has produced the PRISM (Practical Index of Salinity Models)²⁵ CD-ROM, developed primarily to support the priority regions identified under the National Action Plan (NAP) for Salinity and Water Quality. A user guide describes the types of tools, models and frameworks used in planning and the current activities in natural resource management planning in the States and Territories. It provides information on more than 90 tools, models and frameworks.

A complementary guideline *Groundwater models – A community guide to better understanding*²⁶ is designed specifically for catchment communities and natural resource managers as a guide to understanding and developing groundwater models. A more detailed 100-page version is also available.²⁷

The on-line *Catchment Modelling Toolkit* (www.catchment.crc.org.au) is developing a repository for software and supporting documentation intended to improve the efficiency and standard of catchment modelling. It is a resource for the land and water management industry and the research and development community supporting that industry. Its purpose is to enable prediction of the multiple impacts of land and water management decisions at a whole-of-catchment scale. The 'Toolkit' is supported by a 'Catchment Modelling School' for professional training.

*Studies in catchment hydrology – The basics of recharge and discharge*²⁸ is a 10-part series on measuring and modelling recharge and discharge to inform the management of water catchments. The series covers developing sustainable land use practices, estimating time scales for salinisation to occur or recede, impacts of proposed land uses on catchment behaviour, and ensuring that remediation activities aimed at modifying the hydrological behaviour of a catchment are targeted at the appropriate part of the catchment. The target readership is identified as landholders, integrated catchment management groups, Landcare groups, extension officers, hydrologists, agronomists, Local Government engineers and planners, soil and agricultural scientists, academics and students. The 10 parts in this series comprise:

- Physical and chemical techniques for discharge studies²⁹
- Groundwater chemical methods for recharge studies³⁰
- Soil physical methods for estimating recharge³¹
- Catchment scale recharge modelling³²
- Using groundwater responses to infer recharge³³
- Groundwater processes and modelling³⁴
- Using soil water tracers to estimate recharge³⁵
- Electromagnetic induction techniques³⁶
- Surface water balance for recharge estimation³⁷
- Plot-scale models and their application to recharge studies³⁸

Table 4.2

Examples of salinity scenario models in Australia

(Source: modified from Littleboy M., Vertessy R., and Lawrence P., 2003, *An overview of modelling techniques and decision support systems and their application for managing salinity in Australia*, PUR\$ 2003, CRC for Catchment Hydrology, Melbourne VIC.)

Model Name	Focus	Summary	Applications
Biophysical Capacity to Change (BC2C)	Stream	Uses a groundwater flow systems approach to predict regional scale impacts of afforestation and other land use changes on mean annual water yield, recharge and stream salinity. It is designed for assessing multiple groundwater flow systems, and where little information exists about the individual groundwater systems ³⁹ and was developed by the 'Environmental impacts' ⁴⁰ project. It allows the model to operate across large vertically dominated GFS systems and smaller laterally dominated GFS systems within the one framework.	It has been used to investigate variation in salinity response to afforestation ⁴¹ in some of the upland catchments of the Murray–Darling Basin and test alternative land use scenarios in the Little River catchment, NSW ⁴² in a more detailed application of the model. The water yield and salt load component draws on the earlier Goulburn–Broken catchment ⁴³ (~24,000 km ²) case study.
CATSALT	Stream	A modelling framework that combines rainfall-run-off modelling techniques with climate variability, land use efficiency, topographic modelling, salinity hazard and salt outbreak mapping to investigate the effects of land use on water and salt balance. Evaluates impacts of land use changes in a catchment (500 to 3000 km ²) on daily time series of water yields, salt loads and salinities exported from the catchment. CATSALT is calibrated to actual streamflow and salinity data and is directly compatible with IQQM.	CATSALT version 1 was used to examine a no land use change scenario and subsequent incremental reforestation in the Kyeamba Valley ⁴⁴ (602 km ²). CATSALT version 1.5 was applied to nine case study catchments in NSW, including the Boorowa catchment ⁴⁵ (1550 km ²) and the Mandagery Creek catchment ⁴⁶ (1688 km ²) where CATSALT together with HYDRUS 2-D and FLOWTUBE were used to consider land use change scenarios. CATSALT has also been applied to 119 priority catchments in the New South Wales portion of the Murray–Darling Basin and the Hunter Valley, and some other coastal catchments.
Catchment Analysis Tool (CAT)	Surface to groundwater processes	Integrates a range of models operating across scales. Estimates changes to water partitioning from land use change, engineering works, and management change. Explicitly links surface processes to groundwater.	The model was applied in the four priority NAP catchments in Victoria (Wimmera, North Central, Goulburn–Broken, Mallee) ⁴⁷ . The 'Landmark' ⁴⁸ project modelled current land use and the broad-scale adoption of current recommended practices for the Upper Goulburn–Broken (Vic), Upper Billabong (NSW) and Upper Condamine (Qld) catchments (see section 4.4.1).
MODFLOW ⁴⁹	Groundwater	Complex two-dimensional model. Evaluates the effects of management options on aquifer behaviour including effects of water usage patterns and changes in recharge regime due to land use changes.	Five major modelling studies were undertaken to assess land and water management options and estimated impacts on groundwater resources, river and aquifer interaction and salinity – Lachlan Block, Southern Riverine Plain, Lower Murrumbidgee, Lower Darling, and South Australian and Victorian Mallee. Also used as a component of the CAT model.
HYDRUS 2-D	Groundwater	Complex two-dimensional model. Partitions excess soil water into horizontal and vertical pathways to evaluate land use change options on recharge.	To improve the prediction of recharge from 1-D models, a simplified lateral flow algorithm ⁵⁰ to partition excess soil water into horizontal and vertical pathways was determined using HYDRUS 2-D and PERFECT. It was used to produce recharge maps for the NSW portion of the MDB ⁵¹ under current land use and a generic land use change scenario.
Framework for Land Use & Spatial Hydrology (FLUSH)	Surface water (with groundwater connection)	Enables the combination of farming systems models simulating commodity production, with catchment scale hydrological process (surface water movement and groundwater connection). Changes in farm management (eg. modified crop rotations) can be explored as they impact on catchment hydrology.	Has been verified against measured data in the Tarrararra research catchment (Vic), and has been applied in the Simmons Creek (NSW), Hughes Creek (Vic) and Liverpool Plains (upper Mooki River, NSW) catchments as part of the 'Salt delivery' ⁵² project, and the 'Landmark' project (see section 4.4.1).
FLOWTUBE ⁵³	Groundwater	A simple groundwater model for examining the effects of a range of recharge and discharge options on catchment groundwater. It is designed for assessing individual groundwater flow systems, where adequate information exists to support and justify the modelling. It is not suitable for modelling particular sites or whole farm planning.	The FLOWTUBE model is well tested, using data from the case study catchments in the NLWRA and the 'Catchment Classification' project. Version 2 ⁵⁴ is freely available at www.civag.unimelb.edu.au/~argent/flowtube/ or www.agric.wa.gov.au (search on 'flowtube')

QUESTION 4

Table 4.3

Examples of salinity river basin and decision support models in Australia

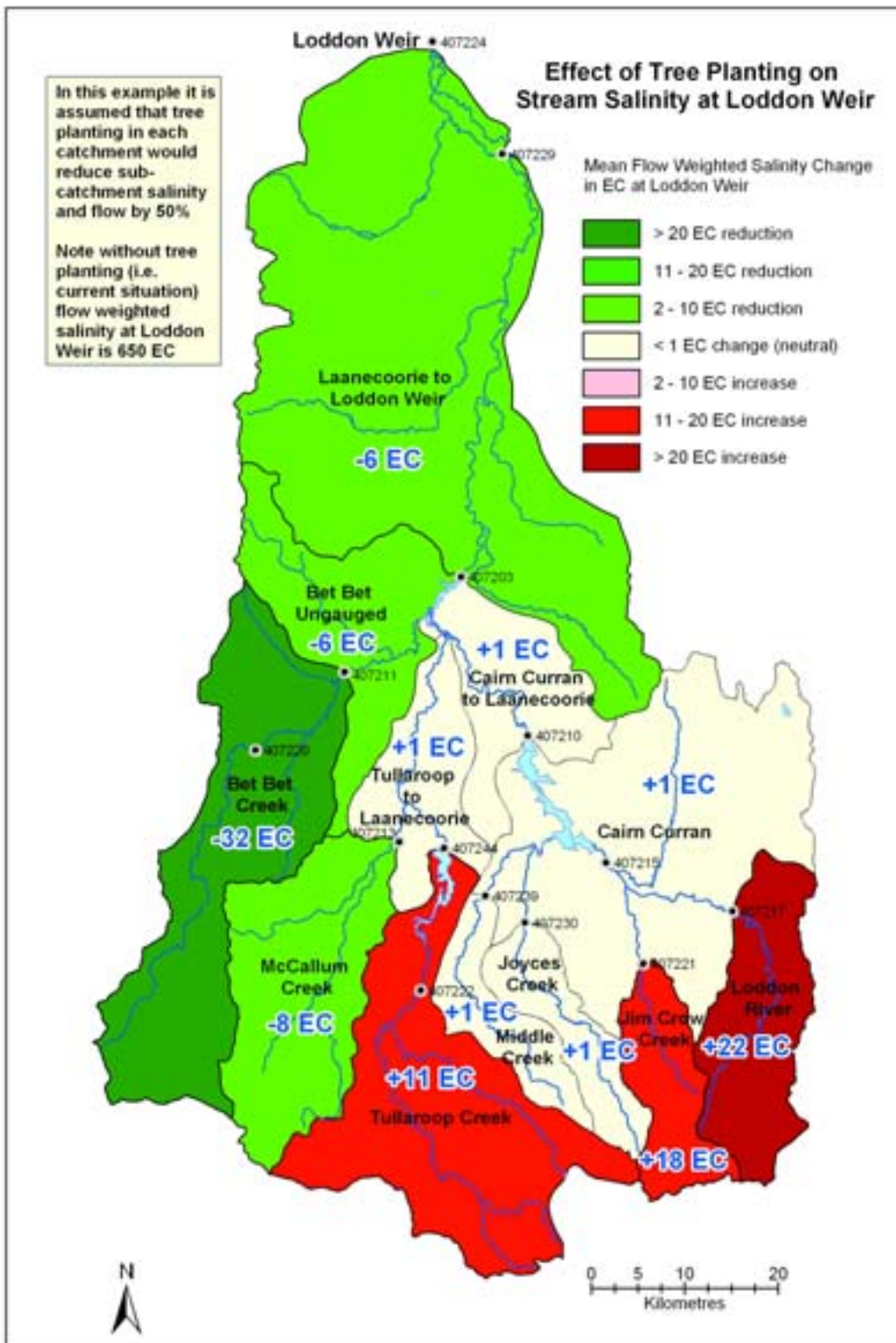
(Source: modified from Littleboy M., Vertessy R., and Lawrence P., 2003, *An overview of modelling techniques and decision support systems and their application for managing salinity in Australia*, PURSL 2003, CRC for Catchment Hydrology, Melbourne VIC.)

Model Type	Model Name	Area	Focus	Summary
River basin	Integrated Quantity-Quality Model (IQQM)	River valleys (NSW)	Stream	Salt transport model linked to NSW water allocation model (IQQM) to route salt through river networks.
	REALM	River valleys (Vic)	Stream	Salt transport model linked to Victorian water allocation model (REALM) to route salt through river networks. A poster ⁵⁵ on 'where to plant trees' has been developed for the Upper Loddon catchment based on this work (see Figure 4.2).
	SIMRAT	Mallee	Stream	Evaluates the salinity impacts of interstate water trade. It outputs salinity impacts and costs for a 100-year time-frame.
Decision support	Land Use Options Simulator (LUOS) ⁵⁶	Property to catchment	Property planning	Evaluates impacts of land use changes at a site on water yields and salt loads exported from the catchment. Evaluates benefit indices for six additional environmental services via a set of analytical toolkits.
	Salinity and Landuse Simulation Analysis (SALSA) ⁵⁷	Regional	Regional planning	Compares the costs of alternative land use scenarios in the Murray-Darling Basin. The first application of groundwater flow systems was in applying the SALSA model across the Basin, linking the landscape and river and providing the first approach which could justify a salt and water balance. Used to simulate the impact of climate change for two scenerios in the Murray-Darling Basin. ⁵⁸
	Facilitator ⁵⁹	Regional (Qld)	Regional planning	A multi-criteria analysis tool to provide a simple,transparent decision framework to integrate multiple objectives, multiple stakeholders and varied data sources and bodies of knowledge. The outcomes provide a prioritisation of options.

Figure 4.2

Output from the application of the Dryland Rapid Assessment Tool on where to plant trees for salinity control in the Upper Loddon catchment (Vic)

(Source: Murray-Darling Basin Commission, 2003, *Where to plant trees for salinity outcomes*, (Poster), Murray-Darling Basin Commission, Canberra ACT)



QUESTION 4

ACTION #4.9

Ensure that your regional salinity management plan complies with the requirements of higher order plans like the Basin Salinity Management Strategy.



ACTION #4.10

Use the model developed by the 'In-stream Health' project to evaluate the effect of predicted salinity rises on aquatic biodiversity, and develop locally specific guidelines to prevent unacceptable impacts.



4.3.2 Establishing operational protocols for salinity

In 2001, the Murray–Darling Basin Ministerial Council approved the 'Basin Salinity Management Strategy 2001–2015',⁶⁰ building on the earlier 'Salinity and Drainage Strategy'⁶¹ in 1988. It takes into account the '1999 Basin Salinity Audit'⁶² and the findings of the National Land & Water Resources Audit. The focus of the Basin Salinity Management Strategy (BSMS) is water quality outcomes for the shared rivers, but it applies to the Basin as a whole and is consistent with the 'Integrated Catchment Management Policy Statement 2001–10'⁶³.

The BSMS has been embodied in the Murray–Darling Basin Agreement⁶⁴ to which the Governments of the Commonwealth, Queensland, South Australia, Victoria, New South Wales and the ACT are signatories. Schedule C of the Murray–Darling Basin Agreement authorises the Commission to make any protocols necessary to give practical effect to the principles and accountabilities set out in the BSMS. Version 1.0 of the *Basin Salinity Management Strategy Operational Protocols*⁶⁵ were published in May 2003 and address in detail the within-valley and basin-wide working arrangements, including interim end-of-valley salinity and salt load targets and criteria for model assessment. The protocols also set out 'works and measures', such as prioritisation, operations and maintenance, and 'monitoring, reporting, auditing and review' arrangements.

4.3.3 Modelling salinity impacts on in-stream health

The *In-stream Health*⁶⁶ project developed a model for use by catchment managers for evaluating the effect of predicted salinity rises on aquatic biodiversity. The model provides an indication of the extent to which salinity should be lowered to prevent unacceptable environmental impacts. It evaluates the likely effects of salinity reducing strategies and saline water disposal and other actions that raise salinity in wetlands or rivers. It can be used to set locally specific guidelines for salinity in rivers and wetlands in order to prevent unacceptable impacts on aquatic biodiversity.

4.3.4 Using airborne technologies

Commonly used airborne geophysical systems include electromagnetic (aids mapping salt stores), radiometric (aids mapping soils) and magnetic (aids mapping geology) systems acquired from aircraft. The application of these systems needs to be carefully matched to each groundwater flow system and survey specifications rigorously assessed.

Recent mapping in eastern Australia, in catchments with highly variable salt stores and strong geological controls on the distribution of dryland salinity, indicates airborne geophysics may be able to assist conventional techniques to define areas that have the greatest influence on stream salinity levels. If located, these areas can be targeted with specific management actions, such as pumping or revegetation. Similarly, those areas that have a low risk or provide little salt to streams can be identified.

Not all geophysical systems need to be acquired in salt-affected catchments. For example radiometrics has been used alone to map soils and their correlation with salt stores in steep landscapes where airborne electromagnetic systems are unable to be used efficiently. Similarly, magnetics has been used to locate highly magnetic material often associated with palaeo-channels responsible for conducting water at depth across catchments.

Importantly these tools work differently in differently groundwater flow systems. In Western Australia, for example, magnetics is unable to locate palaeo-channels, as the basement is highly magnetic. Similarly the application of airborne electromagnetics is reduced because the whole landscape is relatively saline and targets may be better resolved by alternative methods.

A brochure called *Science for Decision Makers*⁵⁷ sets out a five-step approach to tackling salinity:

- Consult to specify management objectives
- Map salinity stores, identify risk areas
- Consult to identify management options
- Work with the community to develop and implement action plan
- Monitor and review.

It uses a case study of Billabung Creek⁶⁸ (930 km²) in the Murrumbidgee catchment of southern New South Wales. The study shows that changes in land use over only 160 km² of the Billabung sub-catchment could deliver half of the Upper Murrumbidgee's salinity reduction target of 30,000 tonnes per year at Wagga Wagga. Airborne salinity mapping for selected areas with soil and landform data was used to develop salinity management options for managing farm level salinity across the catchment, at a cost of 60 cents per hectare.

This brochure and its associated case studies should be considered in association with previous analyses of the application of airborne geophysics. Potential purchasers of these technologies should review the systems and their alternatives outlined in a review of mapping and monitoring⁶⁹. In particular, users should also review the conclusions from the National Airborne Geophysics Project⁷⁰, use the analytical tool developed to assess the benefits and costs of acquisition⁷¹ and review the paper *Critical factors affecting the adoption of airborne geophysics for the management of dryland salinity*⁷², together with the 12 core biophysical data sets required for salinity-related planning outlined in Table 2.3.

4.4 Vegetation options

4.4.1 Choosing from the vegetation options

The companion reports entitled *Effectiveness of current farming systems in the control of dryland salinity*⁷³ and *A revolution in land use*⁷⁴ discuss the vegetation options applicable to managing dryland salinity at landscape scale. The broad suitability of annual cropping, opportunity cropping, phase farming, companion farming, new agricultural plants, organic farming, high rainfall tree products, low rainfall tree products, agroforestry, perennial pastures and saltland farming are considered.

While *A revolution in land use* applies to the Murray–Darling Basin, it concludes that no land use options rate highly in every respect for relevance, effectiveness, robustness and profitability. It notes that current farming systems, even when applying current best practice, cannot control salinity across much of the Basin. Results from the 'Landmark' project support this conclusion for water balance in the Upper Condamine (Qld)⁷⁵, Upper Billabong (NSW)⁷⁶ and Upper Goulburn–Broken (Vic)⁷⁷ catchments.

Some land use options in the right location and in expert hands can satisfy the four criteria (relevance, effectiveness, robustness and profitability), however viable land use systems capable of controlling leakage over the Basin as a whole are not yet available. These results are supported by NDSP's production research,⁷⁸ which indicates that there are no 'stand-out winners' in terms of having widespread applicability and commercial viability for farmers.

ACTION #4.11

Consider the brochure 'Science for Decision Makers', together with the paper 'Critical factors affecting the adoption of airborne geophysics for management of dryland salinity', and use the five-step approach described, if a cost-benefit analysis indicates that airborne geophysics technology is appropriate to your circumstances.



ACTION #4.12

Try to achieve multiple outcomes from the vegetation options used to address dryland salinity management in your region, recognising that viable land use solutions that satisfy the criteria of relevance, effectiveness, robustness and profitability may not yet be available in all cases.



QUESTION 4

A straight forward spreadsheet model,⁷⁹ based on the Murrumbidgee catchment, to assess the economic benefits and costs of various tree planting configurations for salinity control over a 30-year time-span has been developed in New South Wales. Even when applied to local groundwater flow systems, the impact in terms of salinised land, salt loads and dollars was small, representing an impediment to tree planting and regeneration.

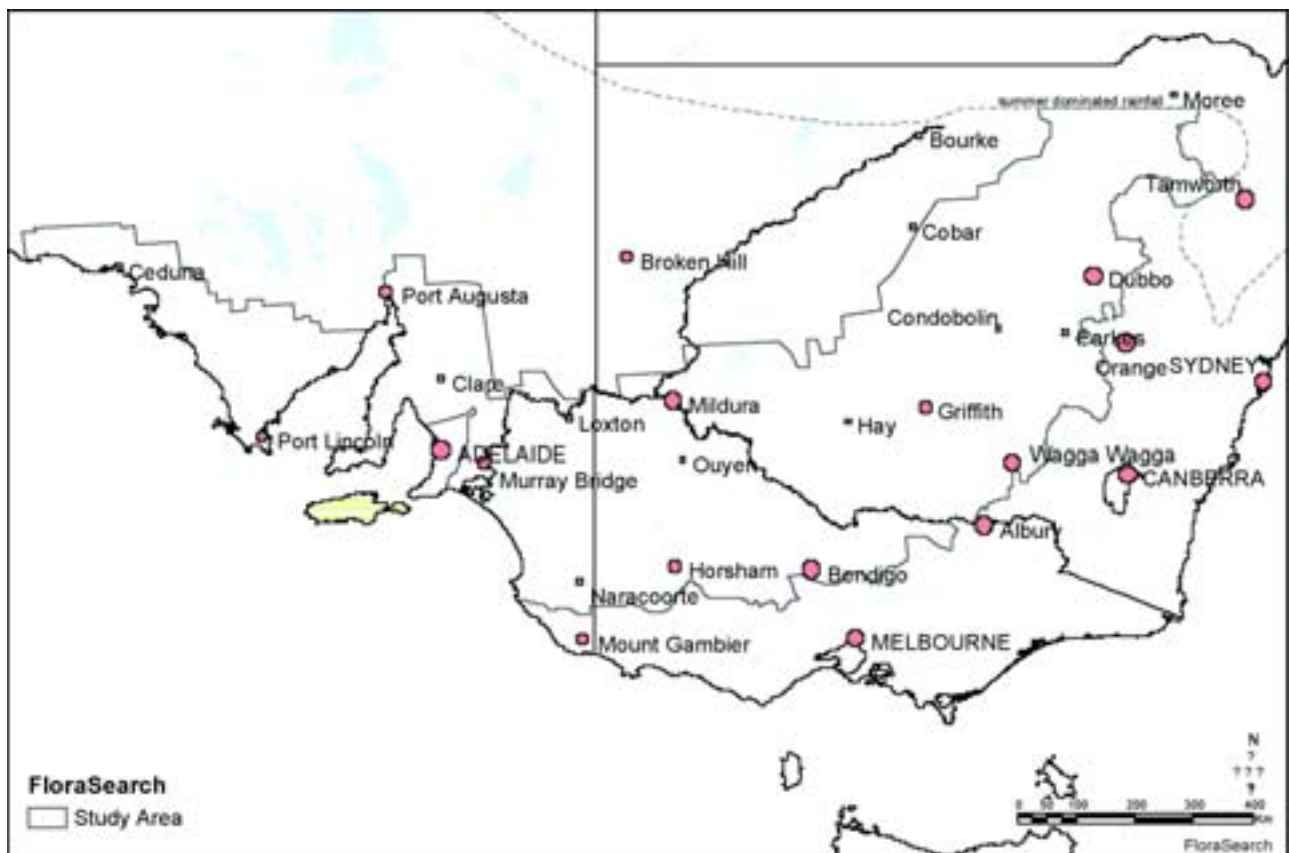
The 'FloraSearch'⁸⁰ project (see Figure 4.3), building on the 'WA Search'⁸¹ project, is systematically screening woody perennials suited to the 250–650 mm rainfall zone which have potential for novel products and are suitable for integration into existing agricultural systems at a broad-scale in recharge areas. The focus of the research is on native plants, but includes some exotic species. The most prospective industries determined by the work to-date include:

- Pulp and paper (Australian production and woodchip export)
- Composite woods (medium density fibreboard (MDF) and other fibreboards, e.g. particleboard), bioenergy (co-firing and renewables)
- Extractives (oil and tannins)
- Livestock fodder (*in situ* and processed).

Figure 4.3

The FloraSearch study area contains the dryland wheat-sheep zone of south-eastern Australia. It is bounded by the low rainfall limit of cropping (approximated in part by the 250 mm rainfall isohyet) and the 650 mm rainfall isohyet and extends north to the upper extent of annual, winter dominated rainfall region.

(Source: Bennell M., Hobbs T., and Ellis M., (in press), *FloraSearch species and industry evaluation*, Rural Industries Research and Development Corporation, Canberra ACT)



4.4.2 Establishing the role of lucerne and saltland pastures

The *Economic evaluation of salinity management options in cropping regions of Australia*⁸² project studied a suite of commissioned case studies in major grain growing regions affected by salinity. These studies revealed comprehensively that lucerne and saltland pastures were a profitable inclusion in many farming systems. On each farm there was an optimal area of lucerne, which depended upon the enterprise and role of livestock. These findings concur with the *Low Recharge Farming Systems*⁸³ project in Western Australia which examined the potential for lucerne pastures to be a profitable way of managing on-farm salinity.

The *Options for the Productive Use of Saline Land (OPUS)*⁸⁴ project investigated approximately 140 different innovations and enterprises built around the utilisation of saline land or water (see Table 4.4). One of the project's conclusions, that only saltland pastures will provide a means of adapting to salinity over extensive areas, formed the basis of a \$9 million R&D investment by Australian Wool Innovation and Meat & Livestock Australia under the Land, Water & Wool (LWW) Initiative. One of the eight sub-programs of the LWW Initiative is Sustainable Grazing on Saline Lands (SGSL) (www.lwa.gov.au).

The second edition of *Saltland Pastures in Australia – A practical guide*⁸⁵ considers salinity and options for saltland, grazing value and productivity of saltland pastures, and assessing their economic value.

Table 4.4

Categories of saline industries within the OPUS database

(Source: PPK Environment and Infrastructure, 2001, *Options for the productive use of salinity (OPUS)*, PPK Environment and Infrastructure Pty Limited, Adelaide SA.)

Industry Category – Level 1	Industry Category – Level 2
Agriculture	Salt-tolerant crops Salt-tolerant pasture (grasses) Salt-tolerant pasture (legumes) Forage/fodder Alternative meat production
Forestry and horticulture	Forestry products Non-timber forestry products Horticulture
Fauna and algae	Inland saline aquaculture Algae Seaweed
Minerals	Salt products Other mineral products Desalination
Energy	Thermal energy Biomass energy Heat convection

ACTION #4.13

Consider lucerne as a viable land use option for controlling recharge in the <600 mm winter-dominant rainfall zone – with particular potential to lower water tables in local groundwater flow systems – but limited to an optimal area for enterprise profitability and with some establishment and persistence limitations.



ACTION #4.14

Encourage and develop profitable enterprises based on the use of saltland pastures as a means of adapting to salinity over extensive areas.



QUESTION 4

ACTION #4.15

Consider the establishment of agroforestry plantings in your catchment that achieve multiple benefits, satisfying both commercial and environmental objectives, and use the 'Design principles' and 'Manual' series, together with resources from the 'Heartlands' initiative to assist your work.



4.4.3 Planting woody perennials for profit

The publication *Trees, water and salt – An Australian guide to using trees for healthy catchments and productive farms*⁸⁶ built on the earlier *Design principles for agroforestry*⁸⁷ and considers the following questions:

- How much of the catchment needs to be planted?
- What parts of the catchment should be planted?
- Which planting configurations should be used?
- How long will it take to see an effect from tree-planting?
- How effective and/or sustainable will different plantation designs be in different parts of the landscape?
- Which species should be selected and what silvicultural practices should be employed?

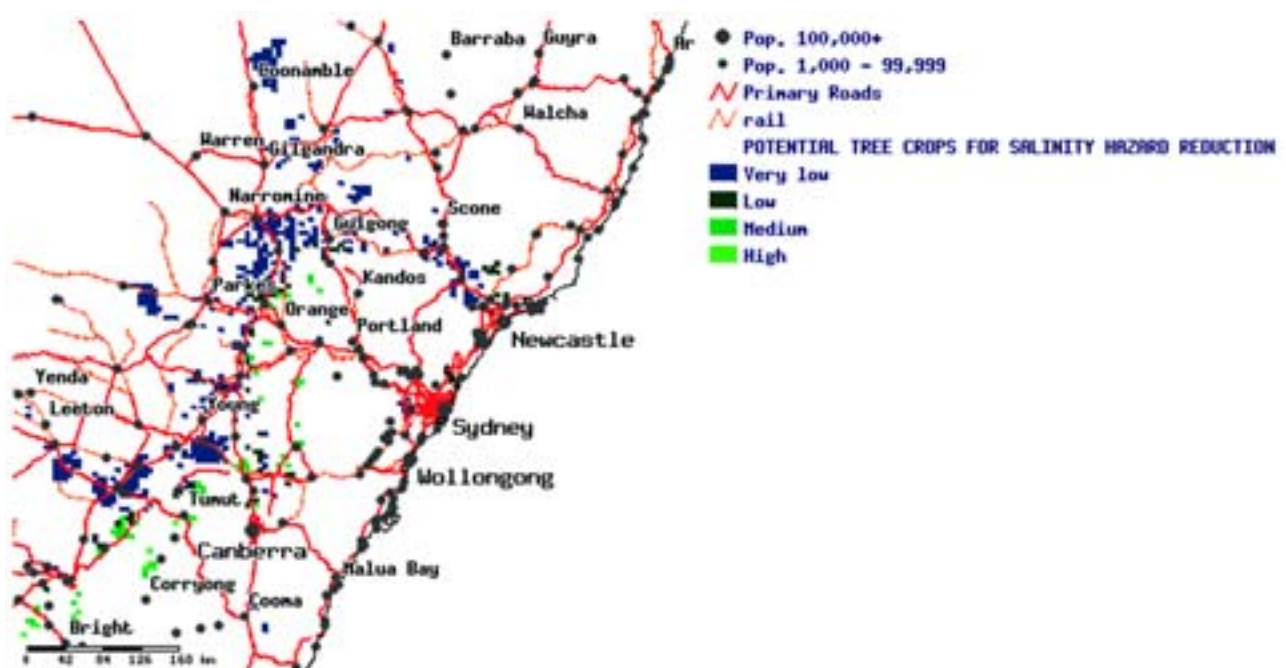
The second design publication considers the benefits and costs of trees for shelter,⁸⁸ and a fourth looks at trees and biodiversity.⁸⁹ Manuals on trial establishment,⁹⁰ site selection,⁹¹ silviculture⁹² and growing rainforest trees⁹³ are also available.

The 'Bioenergy Atlas of Australia'⁹⁴ is an online tool designed to assist in planning for an emerging bioenergy industry (www.brs.gov.au/bioenergy_atlas/). It uses data and information on existing and potential resources, industry and infrastructure. A detailed working example of a scenario of growing trees for bioenergy and salinity abatement is provided on the web-site. Figure 4.4 provides an example of an output from using the tool.

Figure 4.4

Potential tree crops for salinity hazard reduction in south-central NSW using the Bioenergy Atlas decision support tool.

[Source: Rural Industries Research and Development Corporation, 2002, *Bioenergy Atlas of Australia*, The JVAP Research Update Series No. 5, Rural Industries Research and Development Corporation, Canberra ACT.]



The *Heartlands*⁹⁵ initiative (www.clw.csiro.au/heartlands) is undertaking large-scale farm forestry research for dryland salinity management at sub-catchment level. Inventories were undertaken for the Billabong Creek⁹⁶ and Honeysuckle Creek⁹⁷ pilot catchments, and species, spacing and thinning trials are in progress.

4.4.4 Planting trees in the lower rainfall zone

A six-year trial at three sites in the 300–450 mm rainfall zone of the Murray–Darling Basin tested the effectiveness of alley farming and tree belts for recharge control. The 'Alley farming'⁹⁸ project investigated fodder shrub and tree belts separating winter cropping alleys at sites representing typical mixed cropping and grazing enterprises. The ENoR⁹⁹ model was developed to calculate the 'Equivalent No Recharge' zone of alley farming systems.

Financial analysis¹⁰⁰ over a 15-year period indicated that the value of crop losses due to displacement and competition close to the belts was higher than the benefits gained. To prove worthwhile, the value of public and private non-market benefits (e.g. biodiversity, water quality, aesthetic appeal, property value, recharge control, greenhouse abatement) must make up the financial shortfall.

Overall, the results suggested that the highest priority for public investment in revegetation for the purposes of salinity control comprised only a small proportion of this landscape in a 5–10km strip beside the River Murray from just south of Morgan to Loxton. Here, revegetation was likely to have the most significant impact on saline flows to the river in the immediate future.

Beyond 5–10 km from the river, the widespread establishment of deep-rooted vegetation to control groundwater recharge is considered impractical. This is because the Riverine Plain and Mallee are dominated by large regional groundwater flow systems. However, the case for alley farming is not closed. Development of more profitable alternative commercial products could make broad-scale planting of shrub and tree belts more viable; achieving long-term salinity control benefits, but without the need for substantial public investment.

A review¹⁰¹ of the impact of tree plantations and farm forestry systems on water tables in Western Australia was undertaken in 1999. Analysis of sites ranging from three to over 20 years old revealed that planting trees in groundwater recharge areas led to significant reductions in water levels if considerable areas of the catchment are planted. In discharge areas, the probability of achieving reduced water levels was lower and the magnitude of the response smaller. In discharge areas, the maximum reduction of water tables from revegetation was about 2.5 metres, and the effect was greatest where groundwater salinity was relatively low (< 5000 mg/L⁻¹). Best results from revegetation occurred in local-scaled aquifers.

Evidence presented in five case studies suggests that if the hydrogeologic conditions are well defined, tree plantations may be a useful tool for localised salinity management. However at all but three of the 80 sites reviewed, trees had little or no effect on the water tables more than 10–30 metres from the planted area. In these three studies the water levels were reduced at greater distances, as the area planted was large. In Western Australia, if the objective of land managers is to prevent the spread of salinity and reclaim existing areas, then only extensive plantings (targeted recharge blocks, widespread alleys) will be effective. Targets for recharge reduction of greater than 50 per cent will lead to reductions in water tables or buy time until more effective treatments are developed. Significantly higher targets, which vary within and between landscapes, will be required for stream salinity control.

ACTION #4.16

Recognise that investing public or private monies in vegetation management options for the purpose of dryland salinity management in a regional groundwater flow system will require high adoption levels and that realisation of gains will be very long-term.



QUESTION 4

Until recently, predicting the response of salinity management systems has relied on empirical observations from trials which rarely impact large areas, and detailed hydrogeological modelling which requires significant datasets that are rarely available at the temporal and spatial scales required. In Western Australia¹⁰², FLOWTUBE was used to model management options considered locally appropriate involving revegetation, alternative cropping systems and engineering (the models used the older version of FLOWTUBE, since updated). These systems were tested in three landscapes representing the variability of the WA wheatbelt to establish their impact on the extent of salinity.

Results showed that long-term salinity risk in relatively flat catchments (local to intermediate flow systems) in low to medium rainfall areas, representing over 60 per cent of the region at risk, only responded to significant reductions in recharge (> 50 per cent). While these levels of intervention bought a significant amount of time before salinity impacts were fully established, they did not significantly alter eventual extent in the very long term. By contrast, modelling in undulating landscapes with local flow systems indicated that groundwater and salinity levels could decline within 10–20 years with similar levels of treatment. The economic viability of the tree and lucerne based systems farming system were not reviewed.

ACTION #4.17

Assess the potential for reversing chemical, physical and biological changes in salinised soil using the eight simplified Soil Salinisation Categories and best management practices developed by the Saline Soils project, and monitor improvements in landscape health when the remedial treatments have been implemented.



ACTION #4.18

Consider the potential for applying (or adapting) the prioritisation framework developed by the Restoring remnant vegetation project based on an assessment of the degree of threat, value of the asset, and likelihood of successful intervention in your catchment.



4.5 Saline environments

4.5.1 Applying soil salinisation categories to manage saline soils

The 'Saline soils'¹⁰³ project investigated the potential for reversing chemical, physical and biological changes in salinised soils, studying 17 paired sites across southern Australia.

Preferred management options have been developed for 22 types of dryland saline soils with differing physico-chemical and hydrological properties. From these, eight simplified Soil Salinisation Categories have been developed, with a set of best management practices.

A preliminary approach to environmental risk assessment planning has been prepared to assist investigators and community groups dealing with reclamation of disturbed or drained dryland saline soils. Key indicators for assessing and monitoring physico-chemical changes have been presented for monitoring improvements in landscape health when remedial treatments have been imposed to reclaim or minimise further risks of soil salinisation.

4.5.2 Restoring remnant vegetation on salinised land

The *Restoring remnant vegetation*¹⁰⁴ project aimed to identify effective management priorities and strategies for native vegetation in the lower portions of landscapes at risk from rising groundwater and salinisation. The project was conducted in the upper and middle Blackwood Basin in Western Australia.

A prioritisation framework was developed^{105,106}, based on assessment of the degree of threat, value of the asset, and likelihood of successful management intervention, and has been included in the WA Salinity Investment Framework.

While the investigation concluded that all remaining native vegetation is valuable, the underlying hydrological processes driving development of dryland salinity cannot be simply or immediately reversed. Groundwater pumping and other engineering works could maintain the hydrological integrity of natural areas, but at very high cost.

It concluded that there is little prospect for restoration of salinised communities or for the movement of salt-tolerant species into areas becoming saline. Salinised vegetation communities generally collapse and are replaced with an extremely simplified system. Restoration to a very simple community may be possible with significant inputs, particularly earthworks. Without broader hydrological change it is unlikely that a 'natural' community will develop.

A report, *Managing groundwater and surface water for native terrestrial vegetation health in saline areas*¹⁰⁷, summarises the current understanding of the interaction between soil, vegetation, groundwater and salt in areas of shallow saline groundwater. The report:

- provides background material
- identifies the processes of salinisation and the responses of vegetation
- describes approaches and techniques for the assessment, monitoring and management of the health of native vegetation communities.

The 'Recruitment Biology'¹⁰⁸ project on naturally saline vegetation communities was undertaken in the south-west of Western Australia near Jerramungup on the Gairdner River. The aim was to develop a model for restoring saline land use by understanding recruitment biology of vegetation communities on saline soil. By examining vegetation responses after a disturbance and using this knowledge to develop more effective restoration techniques, this project can assist land restoration in the agricultural industry and maintain biodiversity in remnant riparian systems. Data and information generated from this study can be used to develop a conceptual model to identify safe soil and water regimes for yate woodlands, with the potential for use in other similar woodland, shrubland and samphire communities.

The guideline *Managing riparian land for multiple uses*¹⁰⁹ integrates the findings from four research programs. It outlines potential uses of riparian land, with management principles and practices. Some implications of dryland salinity research to riparian management are discussed in a related paper *Managing riparian lands in Australia for multiple uses – Towards a catchment scale framework*,¹¹⁰ with particular reference to groundwater flow systems.

4.5.3 Using saline land for productive purposes

The *Options for the Productive Use of Saline Land (OPUS)*¹¹¹ project focussed on the concept of using salinity as a new resource. It investigated approximately 140 different innovations and enterprises built around the utilisation of saline land or water. The main output was a database that contains a brief synopsis of each innovation, including key contacts to assist users with further information.

Collation and reviews of saltland production systems have identified industry options for the substantial areas of land that will remain affected by salinity. These cover 13 saline industries ranging from sheep grazing of saltbush, through saline forestry, to fish, aquaculture, algal production and desalination for domestic or industry uses. Five industries were singled out for economic evaluation. A range of economic outcomes were measured ranging from uneconomic, feasible in some circumstances to economic outcomes in a wider range of circumstances. For example, saltbush pastures were found to be economic within niche and traditional markets.

The report *Agroforestry over shallow water tables*¹¹² sets out some interim guidelines for revegetation areas with shallow, saline water tables, and provides the abstracts from

ACTION #4.19

Refer to the report Managing groundwater and surface water for native terrestrial vegetation health in saline areas for information on approaches and techniques for assessment, monitoring and management of the health of native vegetation communities, and review the model for restoring saline land use based on understanding the recruitment biology of vegetation communities on saline soil.



ACTION #4.20

Consider ways of using salinity as a resource, and use the Options for the Productive Use of Saline Land (OPUS) database on the NDSP web-site as a guide to the options available.



QUESTION 4

19 technical presentations on this topic. The presentations include case study examples from south-east Queensland, Western Australia, South Australia, and irrigation areas in northern Victoria.

A feasibility study¹¹³ for developing a solar saltfield at Toolibin Lake in the wheatbelt of Western Australia indicates that the enterprise would be uneconomic at existing levels of saline groundwater supply per year and under current market prices. The report provides information on design, geotechnical and operational aspects of the saltfield, together with market and financial analyses of establishing and operating a solar saltfield.

4.6 Engineering options

4.6.1 Assessing engineering techniques

Using case studies, the 'Engineering Options'¹¹⁴ project developed an on-line decision-support tool to help salinity managers to determine what engineering options would have high potential for success and be cost effective within their areas – either alone, or in conjunction with other tools. The project also considered environmental impacts and social issues in the decision-making process.

The value of this tool is that it can be used in a very broad context, looking at options across an entire region and also at a more local level. You can log in, click on a region within a map and see the engineering options considered relevant for the area. You can search for more detailed information on a particular option, such as groundwater pumping, or look at relevant case studies where a particular option has been applied.

The project considered only 17 case studies. Many were from Western Australia. Table 4.5 shows the available effective engineering. The effectiveness of any option varies with local conditions such as groundwater flow system, discharge sites, local environmental conditions and economics.

ACTION #4.21

Use the 'Engineering Options' on-line (www.ndsp.gov.au) decision support tool to determine what engineering management options might have high potential for success and be cost-effective in your region.



Table 4.5

Engineering options that can be used to manage dryland salinity

(Source: Sinclair Knight Merz, 2001, *Assessment of the efficacy of engineering techniques for the management of dryland salinity*, Sinclair Knight Merz Pty Ltd, Melbourne VIC)

Option	Sub-options	
Groundwater pumping	<ul style="list-style-type: none"> ■ Single bore ■ Multiple single bores 	<ul style="list-style-type: none"> ■ Bore or spear point ■ Relief bore/siphons
Shallow surface drains (recharge and soil erosion control)	<ul style="list-style-type: none"> ■ Spoon drains 	<ul style="list-style-type: none"> ■ 'W' drains
Deep surface drains (water table management)	<ul style="list-style-type: none"> ■ Open drains 	
Sub-surface drainage systems	<ul style="list-style-type: none"> ■ Mole drains ■ Tile drains 	<ul style="list-style-type: none"> ■ Biopolymer (deep) drains ■ Interceptor drains
Construction approaches	<ul style="list-style-type: none"> ■ Corrosion resistant construction materials and approaches 	<ul style="list-style-type: none"> ■ Adherence to construction standards

4.6.2 Deciding whether to drain

The WA database 'Drainwise',¹¹⁵ provides information for farmers and their advisors on making effective decisions about drainage and water management. It guides the user through a process of: (1) determining the issues affecting the land; (2) investigating the management options available; (3) developing an integrated plan; and (4) tailoring the information to the site.

Approximately 10,000 kilometres of deep drains have been constructed on rural properties throughout Australia, suggesting that farmers perceive some on-farm benefits associated with them. The 'Deep Drains'¹¹⁶ project found that, in some conditions, drains can effectively control watertables for 200 to 300 metres on either side. This finding helps to explain farmers' enthusiasm for constructing drains and demonstrates their potential to be a useful treatment for salinity in some circumstances. However, the results are not universal, and the adverse impacts of saline water disposal on the environment and water resources remain an outstanding issue.

In some locations, for example in the Murray–Darling Basin and in the Hunter River catchment (NSW), there are accountability frameworks where the salinity impacts of drains on rivers and water users must be assessed and off-set. Drained land may carry the effects of prolonged salinisation and require amelioration; recent research¹¹⁷ has shown that soil may exhibit a range of characteristics after drainage, which impact on the success of post-drainage land use.

The Engineering Evaluation Initiative (www.wrc.gwa.gov.au/protect/salinity) in Western Australia includes 11 trials of engineering options and one regional drainage analysis. A CD-ROM called *To drain or not to drain?*¹¹⁸ developed in South Australia considers engineering options for salinity management. The CD-ROM includes:

- abstracts and PowerPoint presentations from the 2003 forum of the South Australian Dryland Salinity Committee
- NDSP *Engineering Options* decision support tool
- six fact sheets from that NDSP project
- abstracts and PowerPoint presentations from two papers delivered to the NDSP Technical Forum (*Evaluating the Impacts of Deep Drains on Crop Productivity and Environment and Engineering Options for Dryland Salinity Management*)
- a draft *Review of Engineering Options for Salinity Management* by the Western Australia Water Resources Commission.

4.6.3 Evaluating desalinating technologies

The *Desalination Technologies*¹¹⁹ project examined the economic and technical factors surrounding desalination as a source of fresh water and salinity management tool applicable to the National Action Plan (NAP) regions of Australia. Existing knowledge and experience from desalination operations in Australia and abroad were studied.

Three desalination techniques were selected for detailed examination as these were considered most suited to the low-capacity production regimes likely to be required in the NAP regions. These were Reverse Osmosis Membrane (RO), Electrodialysis Reversal Membrane (EDR) and Multi-Effect Distillation (MED).

Desalination currently represents a cost-effective source of fresh water and salinity management in a limited number of scenarios in Australia – groups of about 25 or more people (communities or a collection of houses in a small town) would typically require at least

ACTION #4.22

Examine the applicability of deep drains in your catchment, including both beneficial and adverse impacts, and establish management arrangements to ensure their appropriate use.



ACTION #4.23

Identify whether desalination is a relevant and cost-effective option in your catchment, using the decision-tree developed by the Desalination Technologies project to guide your choice of technique.



QUESTION 4

5kL/day that is able to be supplied by RO or EDR plants at a minimum of \$1.00 (per kL). However, site specific analyses and data are needed before any thorough conclusion can be made. The study provides broad recommendations on which desalination techniques might suit particular conditions and indicative construction and operating costs, although costs have since fallen.

The report describes the cost variables and range within which particular desalination techniques are most suitable. A decision-tree diagram is provided which guides readers through to a recommended desalination technique(s) for their conditions.

4.7 Social and institutional capacity

4.7.1 *Adjusting for catchment management*

The 'Adjusting for catchment management'^{120,121} project developed a 'producer profile' for farmers most likely to implement catchment management plans. This describes the circumstances confronted by farmers such as structural change, biophysical processes, and social, cultural and demographic conditions that might contribute in different ways to influence the relationship between catchment management and structural adjustment.

The most important characteristics identified were large farm size, family operation with an expectation of succession, and the value placed on the farm and its long-term development. Characteristics of lesser importance were large value of production, high farm income, high levels of education and age of operators.

Nine indicators of structural adjustment were mapped for Statistical Local Areas across the Murray–Darling Basin, with an analysis of the implications for catchment management (to upland salinity control, pasture-based strategies, farm forestry and policy planning) and recommendations for further investigations. Figure 4.5 shows the relative adjustment patterns across the Basin.

The report *Understanding landholders' capacity to change to sustainable practices*¹²² distils the findings of a number of socio-economic assessments on the capacity of landholders to change. Capacity to change to more sustainable practices varies across and within catchments. It is a function of situation and individual circumstances and the suitability of practices. Take-up of sustainable practices will depend on how landholders assess their value. Generally, they will seek to reduce the risk of adopting a new practice. The work found that socio-economic factors that can influence adoption of sustainable practices include: farm income, age, training, having a farm plan, perception of financial security and community membership. Pro-environmental stewardship values have a relatively minor influence.

The report 'Influencing improved natural resource management on farms'¹²³ provides an overview of the factors influencing the adoption of sustainable resource practices. It presents the following six broad implications for policy development in natural resource management:

- Natural resource management practices are difficult to promote
- There are limitations to relying on a stewardship ethic
- Expect a limited response to messages about futures threats of land degradation
- Landcare is a tool to promote incremental, rather than radical change to existing agricultural systems
- The structural constraints in broadacre industries are a major barrier to change
- There is reticence to plan for catchment structures of the future.

ACTION #4.24

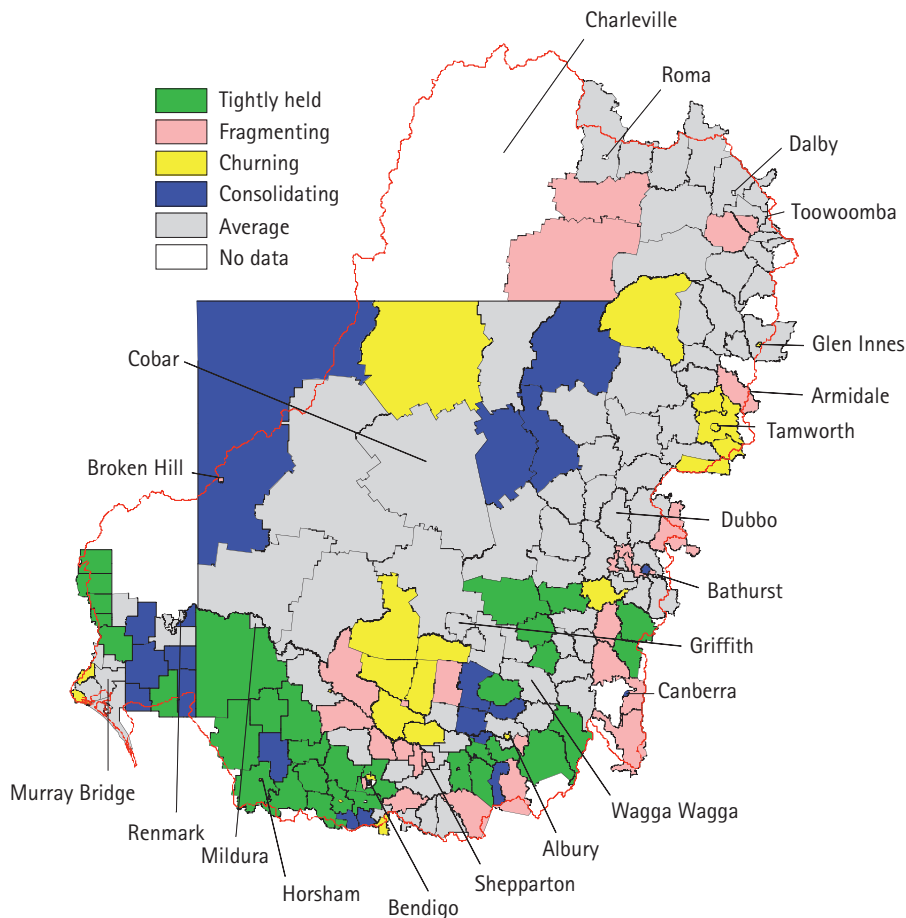
Review the structural adjustment indicators used to identify potential catchment management plan implementation problems shown in 'Adjusting for catchment management', and the socio-economic research findings in the reports 'Understanding landholders' capacity to change to sustainable practices', and 'Landmark', and consider the potential implications and your possible responses.



Figure 4.5

Relative adjustment patterns in Statistical Local Areas of the Murray–Darling Basin

(Source: Barr N., Ridges S., Anderson N., Gray I., Crockett J., Watson B., and Hall N., 2000, *Adjusting for catchment management – Structural adjustment and its implications for catchment management in the Murray–Darling Basin*, Murray–Darling Basin Commission, Canberra ACT.)



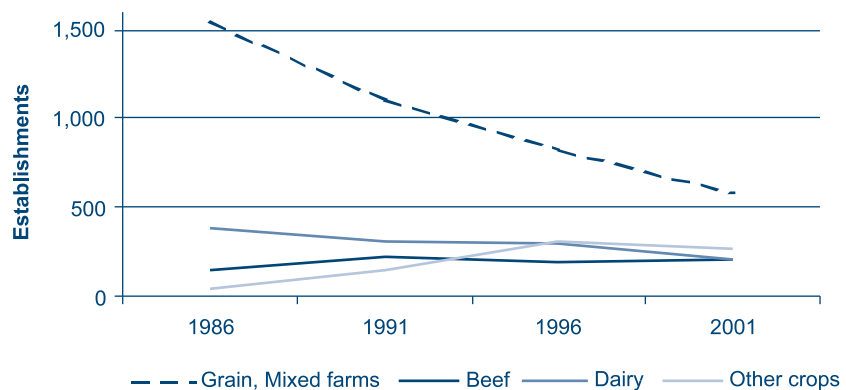
The Landmark¹²⁴ project used a combination of social profiling, regional input-output modelling and demographic modelling to understand the social structures and processes within three case study regions – Upper Goulburn–Broken (Vic), Upper Billabong (NSW) and Upper Condamine (Qld) catchments – and how they impact on the capacity of landholders to achieve and manage land use change. The social profiles comprise a set of 27 social and demographic variables covering population, age, farmer population, education, labour force and income. Input-output analysis estimated the regional economic consequences of changes to land practice, in particular the retirement of land from agricultural production. Regional demographic modelling estimated the future demographic structure of farming communities (see an example for the Upper Condamine case study at Figure 4.6). This approach was successful in identifying those dimensions important in appraising the likely human and social responses to management and land use change that may be needed to achieve sustainable land use.

QUESTION 4

Figure 4.6

The industries in the Upper Condamine case study region are quite disparate in their structure and show differing adjustment trajectories into the future (Establishment count by industry, 1986–2001)

(Source: Cary J., Webb T., Barr N., Charalambou C., and Pinge I., 2004, *Task 3c – Social impact assessment to identify regional capacity to achieve and manage land use change*, Murray–Darling Basin Commission, Canberra ACT.)



The project reported that the following indicators or characteristics were important in assessing social and economic impacts in the three case study regions:

- Level and distribution of regional income
- Diversity and scale of industry sectors
- Nature and economic characteristics of existing rural industries and land uses
- Age of farmers
- Demographic projections of changing age profiles of farmers
- Distribution of (economic) scale of property operations
- Extent and scale of external economic and social impacts – particularly of adjacent large cities and conurbations on land ownership and future land use in the region
- Level and distribution of property turnover and property subdivision
- Extent of opportunities for off-farm employment and income.

ACTION #4.25

Consider the approach and outcomes of the TARGET project in developing appropriate strategies to achieve salinity targets in small, medium and regional scale catchments.



4.7.2 Targeting change

The *Tools to achieve landscape redesign given environmental/economic targets*¹²⁵ (TARGET) project has been operating at a pilot scale in the Lachlan, Macquarie and Castlereagh catchments of New South Wales. It was designed to examine the social and economic barriers to achieving salinity targets through land use change and to develop ways to overcome these barriers, with a strong emphasis on landholder capacity-building. Its allocation of \$4.565 million over two years commits around 70 per cent to on-ground works. The study includes catchments at small (Warrengong, Mid-Talbragar), medium (Little River, Weddin, Castlereagh/Dunedoo) and regional (Lachlan, Macquarie) scales. The project includes implementation of on-ground works through incentives, landholder training, landholder profiles, farm economic analysis, biodiversity assessment and monitoring/benchmarking (also see Section 5.12).

4.7.3 Sustaining regional development

The report *Sustainable regional development*¹²⁶ and its companion *SRD kit*¹²⁷ present findings on the challenge of improving communities, economic performance and environmental management through regional initiatives. Seven regional case studies are detailed. An analysis together with 48 recommendations on what is needed to support SRD is provided.

The regional case studies considered are:

- South-West and Great Southern, Western Australia
- Eyre Peninsula, South Australia
- Launceston Tamar and North-East, Tasmania
- Greater Western Sydney, New South Wales
- Cape York Peninsula, Queensland
- Albury-Wodonga, New South Wales and Victoria
- Shepparton Irrigation, Victoria, and Murray Irrigation, New South Wales.

The critical issues for SRD identified are:

- understanding the implications of sustainable development
- developing and maintaining supportive institutional arrangements
- devolving responsibility and power
- enhancing the capacity of regional organisations
- improving coordination
- enabling participation
- improving knowledge systems
- improving processes of adaptive management and social learning.

The 'SRD kit', including CD-ROM, captures the experiences and learnings of the research. It provides a resource to assist the further development of partnerships within regional communities.

The history of policy in agriculture and natural resource management is analysed in a more recent report¹²⁸ that provides insights for regional development. Four discussion papers are appended to the report on: (1) Legal issues relating to water use; (2) Resource governance and integrated catchment management; (3) Issues in regional development; and (4) Human dimensions of structural change.

4.7.4 Changing institutions

The *Institutional Arrangements*¹²⁹ project considered the support needed to bring about changes needed to address dryland salinity. It examined the regulatory environment, incentive structures and support networks within which land managers and farmers operate.

The project developed strategies to be implemented at National, State and catchment scales for immediate and long-term impact. An outline of appropriate roles and responsibilities for individual land managers, catchment management bodies, Local Government and State and Commonwealth agencies is provided. Possible incentives and funding sources are identified, together with the conditions required for successful implementation of market instruments.

The following conclusions from the investigations and analysis were made:

- It is important to establish an appropriate and supportive operating environment in order to change behaviour so that we can manage dryland salinity

ACTION #4.26

Use the SRD Kit and associated report to inform partnerships in sustainable regional development.



ACTION #4.27

Consider the institutional capacity-building strategies developed by the Institutional arrangements project relevant to your region, including possible incentives and funding sources.



QUESTION 4

- Governments must change the operating environment perceived by land managers if practices and land use are to change
- Despite a major improvement in awareness of dryland salinity, there is still no consensus on how to manage it
- The most appropriate course for addressing dryland salinity (having regard for the net social benefits from public investment) will involve targeting interventions rather than blanket broad-scale measures
- A targeted approach to the allocation of public funding presents challenges that require strong leadership, transparency of purpose and effective communication
- Catchment and regional bodies have limited capacity to participate effectively in distributed governance and to take on devolved responsibility
- In the short-term, governments should provide leadership by identifying and committing funds to the highest priority targets using a transparent public benefit test
- In the longer term, governments should facilitate community discussion and debate on social goals and enhance the capacity for devolution of responsibility to regional and catchment levels.

ACTION #4.28

Use the 'Community engagement toolkit' to familiarise yourself with the diversity of tools and techniques available to support community consultation processes in natural resource management.



4.7.5 Facilitating community engagement

The resource *Towards whole of community engagement – A practical toolkit*¹³⁰ comprises four parts. Part 1 considers 'what makes for good community engagement?', while Part 2 looks at which tools and techniques to use. Twelve techniques are discussed in all, covering:

- General public involvement and participation tools
- Negotiation and conflict resolution tools
- Information, education and extension tools
- Stakeholder analysis and social profiling tools
- Survey and interview tools
- Planning and visioning tools
- Team building and leadership tools
- Participatory action research tools
- Deliberative democracy tools
- Lobbying and campaigning tools
- Participatory monitoring and evaluation tools.

Part 3 provides detailed advice on where to get further information. An annotated bibliography of 92 major references on community engagement provides an important resource, together with a list of useful web-sites. Part 4 looks at Rapid and Participatory Rural Appraisal tools.

4.7.6 Enhancing the capacity of local government

The 'Local Government'¹³¹ project produced an information kit on CD-ROM. Information from National and international literature on Local Government was collated and options for dryland salinity management were assessed. Case studies of successes and failures by Local Governments in Australia are documented and analysed. The project identified prospective development and planning policies for Local Government, as well as impediments to more effective Local Government management of dryland salinity. Incentives are recommended, together with strategies to promote awareness and adoption of salinity management practices and high priority knowledge gaps.

A Salinity Action Alliance has been formed between fourteen Councils in the Central West of New South Wales (see Figure 4.7). Led by Dubbo City Council, the Alliance has prepared a regional salinity action plan for local government¹³² for accreditation under the National Action Plan for Salinity and Water Quality.

Figure 4.7

Local Government Areas of the Central West Catchment – Showing the 'Salinity Action Alliance' in bold outline

(Source: New South Wales Central West Local Government Salinity Action Alliance, 2002, *Information Kit*, Dubbo City Council, Dubbo NSW.)



ACTION #4.29

Identify opportunities and the economic rationale for progressive Local Government planning and development policies to control dryland salinity in your region, and support their implementation through incentive options, capacity-building and research.



The Western Australian Rural Towns Program commenced in 1997 under the State's Salinity Strategy¹³³. Around 42 towns in the South West are involved in the Program (see Figure 4.8). It supports communities to:

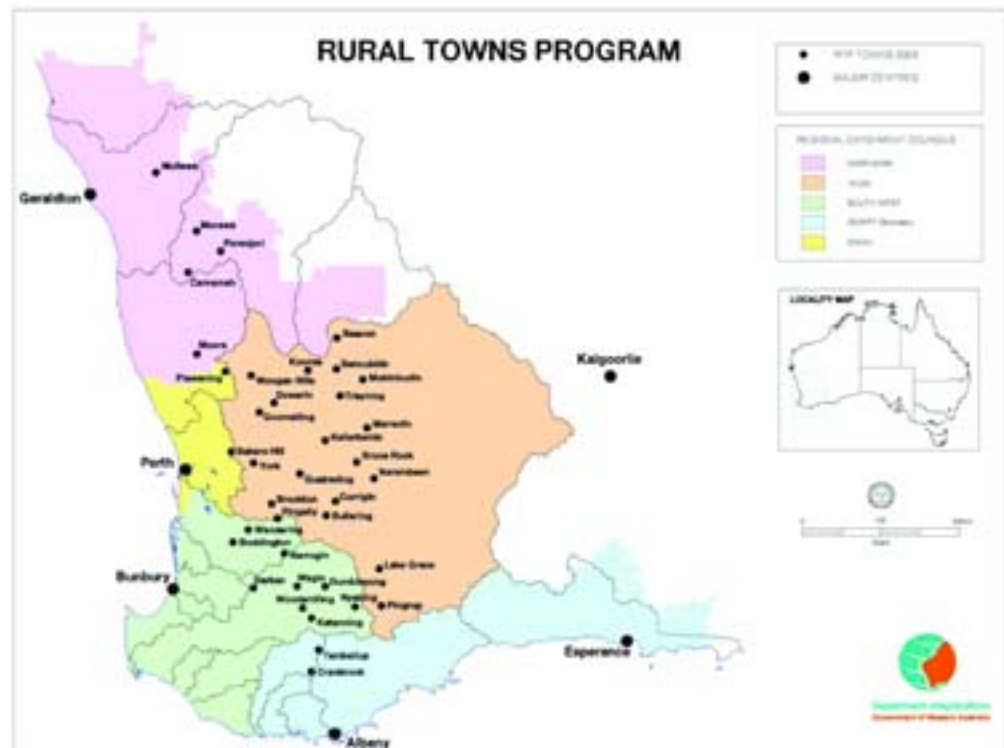
- Identify the causes of their salinity problem
- Monitor groundwater levels and quality under their town
- Conduct an assessment of the options of the current and likely future impacts and costs of their salinity problem
- Determine the costs and benefits of introducing salinity management strategies
- Identify treatments suitable to their town.

QUESTION 4

Figure 4.8

Location of towns participating in the Rural Towns Program, Western Australia.

(Source: Pridham M., 2001, *Rural Towns Program, Townsite salinity management in Western Australia, Outlook 2001*, Proceedings of the National Outlook Conference, Canberra 2001, Vol. 1 Natural resources, Australian Bureau of Agricultural and Resource Economics, Canberra ACT)



The *Local government salinity management handbook*¹³⁴ is designed for public works professionals. It outlines what salinity is, types and causes, the current Australian situation, the role of the public works profession, and management options. Case study examples are also provided.

The Local Government Salinity Initiative (LGSi) provides training and resources for Local Government throughout New South Wales. A kit of information tailored to Local Government is being developed. The first seven booklets in the series are described in section 3.2.2, and a further five are presently in press. The LGSi aims to raise Local Government awareness of urban salinity and provide access to information and technical support for the development and implementation of salinity management strategies and land use planning instruments.

The proceedings of the conference *National local government salinity summit – community based solutions* convened at Moama-Euchuca in July 2001 is available on CD-ROM¹³⁵ through the NDSP.

4.7.7 Meeting educational needs

The *Education Scoping Study*¹³⁶ explored current training for salinity and water quality in Australia and the role of the Vocational Education and Training accreditation system in providing a suitable framework under which to develop appropriate courses. It found that education and learning in salinity and water quality are disjointed and not currently meeting the needs of building capacity under the National Action Plan (NAP). Without a more coordinated and phased approach to education and training, the regions will be constrained in planning, in the development of effective management options and in meeting the targets which underpin community management of salinity.

The report *Education program scoping study*¹³⁷ highlights the low level of awareness and use of educational resources developed by the Murray–Darling Basin Commission at primary, secondary and tertiary education levels. A total of 1656 questionnaire surveys were distributed to 189 primary and high schools throughout the Basin. Completed questionnaires were returned by 166 teachers and librarians; representing 80 schools. Telephone interviews were conducted with informants in the TAFE, university and artistic media (art galleries, regional arts development organisations, art workers) sectors. The report suggests strategies and pathways for improving the current level of awareness and use. It also identifies innovative and effective educational strategies to contribute to achieving sustainable resource management within the Basin.

*Salinity in the classroom: A resource for Western Australia schools*¹³⁸ contains detailed curriculum material on dryland salinity, together with a CD-ROM and video. The video is introduced by Roy Slaven (of comedy duo HG and Roy) called *Salt of the earth, farming and sustaining the soil beyond 2000*. The kit includes graded activities, comprehensive background material, mind maps of issues, large format picture books, CD-ROM and maps, and links to web-sites. *The story of agroforestry in Australia*¹³⁹ forms part of *The Workboot Series* for children in late primary and early secondary school covering Australia's major primary industries. It has a strong emphasis on the role of trees in managing dryland salinity.

A community information kit on salinity called *Salt: Nature in the balance – Stopping salinity and saving our natural environment*¹⁴⁰ outlines the causes, costs and impacts of salinity, including impacts on wildlife. It provides a case study on the company SouthCorp, and considers the actions that the community and individuals can take.



WHERE TO FROM HERE?

National Land & Water Resources Audit

Current information available on which to base an assessment of on-ground change is limited by data gaps, form and accessibility. There is a paucity of National and State-based benchmarking, monitoring and evaluation frameworks in place upon which to access reliable data. Where surrogate frameworks exist, frequently the data collected in one period have been inconsistent with data collected later, which makes it difficult to draw sensible conclusions about the extent of progress from one period to the next.

ACTION #4.30

Identify the training and educational needs to support salinity management in your region, and consider regional options and partnerships for meeting priority needs.



R & D TIP #4.1

Consider the National Evaluation Framework project as a foundation from which to build benchmarking, monitoring and evaluation mechanisms at all scales of salinity management, using consistent and transferable approaches, and drawing on adequate and reliable data.

QUESTION 4

R & D TIP #4.2

Review the strategic plan for the National Land & Water Resources Audit Phase II and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.

The importance of coordination and rationalisation of monitoring networks has been discussed in previous chapters. Adequate and reliable data are needed to underpin the understanding of processes and impacts, and to test management options. The *National Evaluation Framework*¹⁴¹ project will provide for systematic and coordinated data collection based on groundwater flow systems, and a logically structured adaptive management cycle; however greater attention is more broadly needed to the area of monitoring and evaluation at all scales of planning and operation.

The NLWRA (1997–2002)¹⁴² assessments highlighted the need for a common framework, and consistent methods and standards if future audits are to provide a more accurate and useful assessment of the outcomes of land use change scenarios. Monitoring systems need to be designed to answer the specific questions being asked by Governments, and to capture efficiencies of information flow across the States. Research and development is required to improve the assessments of risk associated with land use system changes, particularly in assessing on-farm and in-catchment land use changes on salt loads to streams and stream flows.

The priorities for further research identified by the NLWRA included:

- Developing methods and standards for monitoring the effects of land use on the extent and impacts of dryland salinity at catchment scales, allowing the linkage of biophysical and economic dimensions
- Improving current groundwater and salinity monitoring and information systems to allow evaluation of land use changes
- Improving methods for tracking salt loads in streams
- Improving methods for monitoring of social and economic aspects of progress towards salinity control targets
- Improving saltland production systems and innovative options for living with salt
- Building technical and scientific skills available in Government support agencies, particularly in dryland salinity assessment and evaluation of land use impacts at regional, Local Government and catchment scales.

Models, frameworks and decision support tools

Future investment decisions will continue to be based on inadequate information unless we can improve our ability to predict future risk. We are yet to understand climatic variability, to properly characterise future salinity risk we need to separate the effects of climatic variation from land use change. Although it is now more widely appreciated that salt is unevenly distributed across some landscapes, the data are not yet readily available to account for this in our models. There has been significant investment and progress in improving modelling capabilities within the Murray–Darling Basin over the past two years with tributary and river flow and salinity modelling in the process of accreditation (including accreditation of the River Murray model). We need to dramatically improve predictive capacity for future stream salinity, since this may well be the critical issue of future debate.

The priorities outlined by the NLWRA with respect to modelling land use and management change scenarios were broadly supported by the recommendations made by some projects discussed. The need to consider the impact of climate variability and climate change on hydrology was highlighted as needing further consideration in catchment water balance

R & D TIP #4.3

Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au), developing the 'Catchment Modelling Toolkit' and providing information about the 'Catchment Modelling School' for training model users.

modelling. Further, estimating the impact of afforestation on flow regime using a daily time step was identified as deserving more attention to enhance the capability of current water allocation models, including IQQM and REALM.

Given the high cost of salinity control treatments, it will be imperative that a decision support system for prioritising expenditure to optimise the benefits for salinity control, water management and other natural resources be developed. More attention to risk assessment and environmental impact assessment is needed. Some environmental projects have started to feed into this process, but more work needs to be done.

Vegetation options

The use of vegetation to manage salinity is a complex issue. It requires good local information on the relationship between vegetative water use and stream and groundwater responses, as well as the economic, social and ecological dimensions of land use.

Targeted revegetation in recharge and discharge zones is just one part of managing dryland salinity. Broad-scale reforestation may be a poor investment in some landscapes from an economic and social perspective, including potential implications for stream flows and water allocation. Further, perennial-based farming systems are only commercially viable in certain circumstances under current market conditions. Profitable options for controlling the rate of salinisation at the scale required are limited, and present a significant constraint to our capacity to control salinity.

Profitable interventions exist for some catchments, from a public and/or private perspective, however, the capacity to implement these interventions at the scale necessary to address salinity may be limited. The *Groundwater Flow Systems Framework* indicates that revegetation treatments in local groundwater flow systems offer the most promise, as the response time is shortest.

To make major progress in extensive treatments to prevent further salinisation, it will be important to develop solutions that are profitable, including markets for ecosystem services. A wider range of commercially viable, deep-rooted perennial plants, including trees, shrubs and herbs is needed. We also need to refine land assessment techniques to identify the best locations for planting particular vegetation types, and retaining and restoring existing vegetation, including remnant vegetation and native grasses. It will be important to develop ways of rotating and mixing perennial plants with current crops and new agricultural plants, and to invent tools for land managers to monitor leakage and change land use and management accordingly.

The changes in land use and management that is required to control dryland salinity needs to be guided by a well-targeted program of research, development and innovation that transfers information between regions and supplies solutions designed specifically for the Australian landscape. As part of this, a national long-term program of R&D on new profitable farming systems (including radical notions of farming systems), transfer and adoption, is needed.

R & D TIP #4.4

Consider the three research programs of the CRC for Plant-based Management of Dryland Salinity on targeted revegetation and profitable and sustainable grazing systems from perennial pastures in recharge areas (www.crcsalinity.com.au).

R & D TIP #4.5

Consider the objectives and program of research and communication activities for Grain & Graze targeting mixed grain and meat enterprises (www.grainandgraze.com.au).

R & D TIP #4.6

Watch the progress of the National Market-based Instruments (MBI) Pilots Program (www.napswq.gov.au), and the NSW Environmental Services Scheme pilot project (www.dipnr.nsw.gov.au).

R & D TIP #4.7

Review the five-year plan for the Joint Venture Agroforestry Program for information on farm forestry research, development and extension (www.jvap.gov.au).

QUESTION 4

R & D TIP #4.8

Consider the research and associated networks established under the Sustainable Grazing on Saline Lands (SGSL) Sub-Program (www.lwa.gov.au) and PUR\$L (www.ndsp.gov.au).

R & D TIP #4.9

Consider the Engineering Evaluation Initiative in Western Australia, with \$2 million allocated to identify the most effective engineering options for salinity management.

Saline environments

Government policy support for saline industries exists at State and Commonwealth level. Findings from the OPUS project highlight the need for closer examination of the depth and type of support that Governments might provide. A core pool of technically qualified and committed people supporting the complete range of saline industries can be identified within Australia. However, most of the newer and innovative industries are in their infancy in terms of development and scale of adoption; and production levels and return on investment are not well demonstrated or documented for most industries, due to lack of commercial scale trials or existing commercial-in-confidence agreements. Saltland production systems require further development.

While research has contributed to our basic understanding of some types of environmental impacts, it has possibly raised more questions than answers with respect to management options. The impact of salinisation on natural ecosystems requires significant further investment.

Engineering options

Recent research has found that the protection of environmental assets from salinity will be costly. For example, previous hopes of saving remnant native vegetation along waterways by strategic reforestation of up-slope areas no longer show promise as a universally effective solution. While treatments in local groundwater flow systems hold greater promise, intermediate and groundwater flow systems will be highly reliant on engineering solutions. The time-lag in these systems between revegetation treatments and the desired impact will be very long. As such, many interventions will need to take the form of engineering works such as pumping, interception banks and drains, and desalination technologies in the shorter term until the effects of land use change are apparent.

Given that species loss is irreversible, it is often valuable to implement stop-gap measures that 'buy time' and keep open the option of a more permanent solution when and if this becomes available. Further work to assess actions that can be taken to 'buy time' is needed.

Studies on engineering options have highlighted a lack of effective documentation on the engineering activities that are being conducted and also the limited implementation of available engineering solutions for salinity management. Guidelines and procedures to support regional catchment managers in assessing engineering options to achieve end-of-valley salinity targets, with consideration of disposal options and costs, would be beneficial.

The effectiveness (and appropriateness) of shallow and deep drains, interception banks and surface soil configurations such as raised beds and controlled traffic tillage systems on waterlogging, deep drainage and run-off cannot be determined objectively without more detailed analysis and assessment on a site-by-site basis, considering landscape position, groundwater systems, soils and production systems. An over-riding requirement is to evaluate any of these practices on an integrated landscape/catchment basis within local catchment and State requirements and social constraints, so that all impacts/effects can be considered.

Desalination (such as reverse osmosis) may be more cost-effective than available revegetation options, which may reduce stream flows. The trade-off between water quality and quantity is an important consideration. The desalination technology study raised some important

unanswered questions. To date, it appears that no site-specific fully-specified economic analysis of desalination has been undertaken in Australia. Doing so would enable a more accurate assessment of its cost-effectiveness in particular applications. The compilation of GIS-based maps that overlay existing datasets would help identify the locations best suited to desalination in Australia, prompting regional decision-makers to consider its use. There is a paucity of information on less used techniques such as renewable energy powered desalination and smaller capacity units. These types of plants are likely to be suitable for remote and NAP regions in Australia.

Realising large-scale engineering schemes will require the backing of Governments to secure the significant commitment of investment needed. Identification of mechanisms for overcoming the following barriers to the implementation of engineering options should be considered: opposition to saline discharge, economic feasibility, technical feasibility, re-allocation or lack of resources, negative perceptions of the engineering option, and lack of funding.

Social and institutional capacity

Research has shown that landscape change must be seen as a multi-generational challenge. More often than not, the social upheaval from implementing large-scale revegetation will be far more damaging to the social fabric of country towns than 'living' with the problem, so treating the symptoms rather than the cause may apply. It is true that some pockets of rural Australia will be harder hit than others, and in extreme cases, where salinity is unresponsive to treatments, the rate of adjustment and farm restructuring is likely to accelerate. Constructive advice on designing public policies and plans to address these issues has been contributed by research to-date.

The 'Tools' project emphasised the need for well-developed networking and communication processes among catchment groups and technical skill providers, supported by appropriate targeted information systems. Adequate information and skills were highlighted as major deficiencies in most catchments.

Studies on building institutional capacity have indicated that further support is required to provide the tools and skilled analysis needed to manage dryland salinity effectively, and that the wider public needs to be involved in helping set goals for salinity management. Public funding should initially target activities with the highest national interest. Investment needs to be supported by further development of a mix of incentives and regulations, and the introduction of a 'duty of care' concept for compliance. The implementation of the National Action Plan needs to be supported with criteria for priority setting, realistic timetables and provision of technical support to communities.

There is a need to continue to raise Local Government's awareness of dryland salinity. Local Government has potential to contribute extensively to dryland salinity actions, but is constrained by lack of capacity, lack of specific authority/accountability and lack of real incentive to act.

A national approach to communication is needed to improve the level of understanding of the impacts of salinity, in partnership with all tiers of government. Information and education kits could be specifically designed to support this broader communication activity, including best

R & D TIP #4.10

Consider aspects of socio-economic research under the Social and Institutional Research Program (www.lwa.gov.au), the Human Dimension Program (www.mdbc.gov.au), the Human Capital, Communication & Information Systems Program (www.rirdc.gov.au) and the CRC for Plant-based Management of Dryland Salinity's Program 5 on People, Land & Water (www.crcsalinity.com).

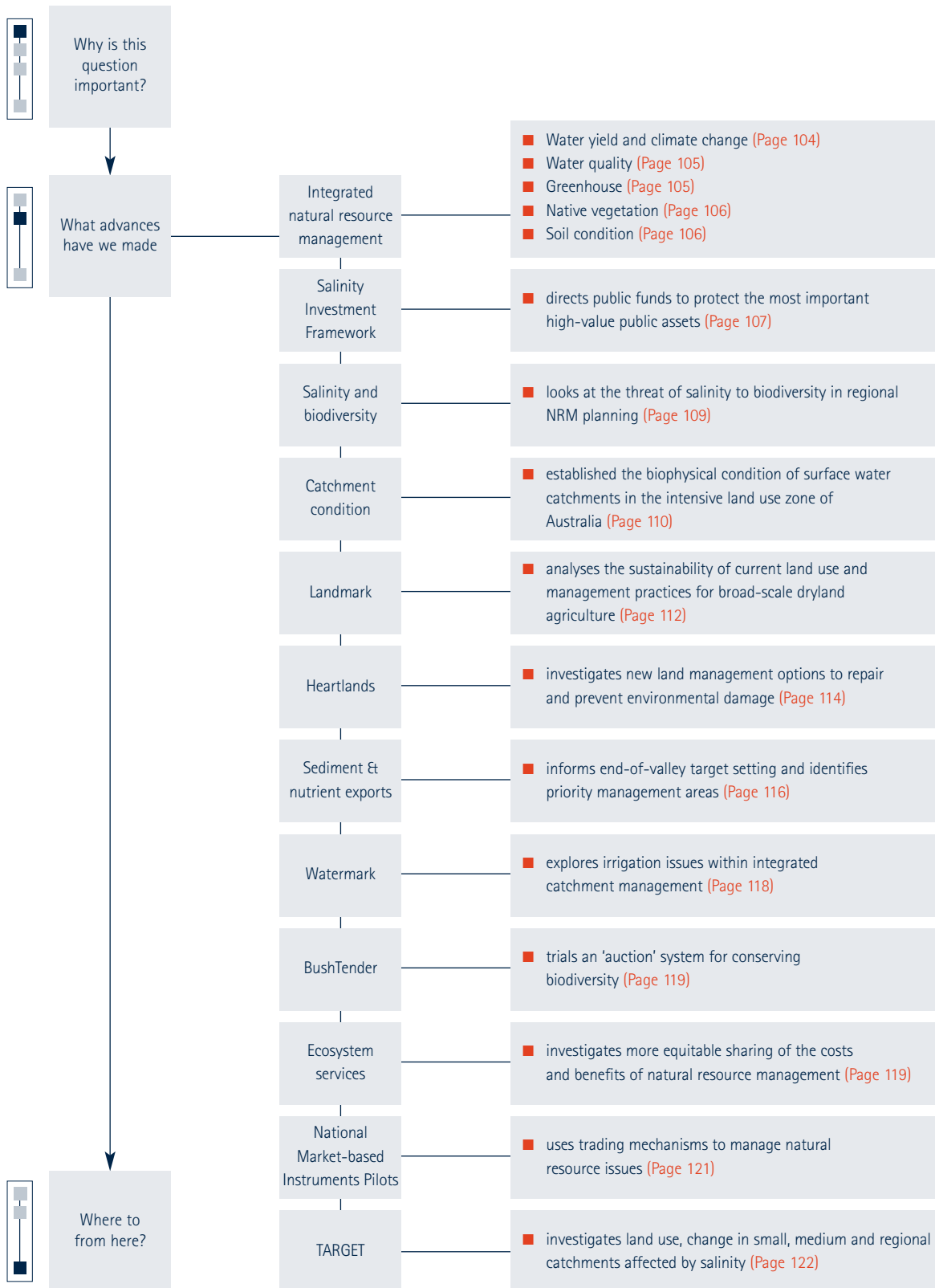
QUESTION 4

practice guidelines. As the engagement of Local Government is a significant and long-term undertaking, resources should be initially targeted to where they will achieve the best outcomes. In parallel, the Australian and State Governments should work pro-actively towards the development of consistent and comprehensive legislative State frameworks on land use planning.

QUESTION 5

Roadmap

How do we integrate with other natural resource management issues?



How do we integrate with other natural resource management issues?

WHY IS THIS QUESTION IMPORTANT?

The earlier chapters described current research findings that directly relate to dryland salinity management, with some discussion about water yield and in-stream salt load and concentration. While Question 3 looked at the impacts and costs of dryland salinity on other natural and human resources, this chapter considers the impacts of other natural resource management decision-making on our ability to manage dryland salinity effectively.

Many catchments have developed integrated catchment management plans, and some have set targets for catchment health that are more far reaching than end-of-valley targets for salinity. For example, the Murray–Darling Basin Ministerial Council in its policy statement¹ on integrated catchment management has outlined targets for water quality, water sharing, riverine ecosystem health and terrestrial biodiversity. In taking action to achieve end-of-valley targets for salinity it will be important to consider the linkages and impacts of management actions taken to address other aspects of catchment health. 'Integrated natural resource management' requires a more spatially targeted approach and implicitly calls for trade-offs between issues to achieve multiple outcomes.

ACTION #5.1

Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au) and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular regional needs.



WHAT ADVANCES HAVE WE MADE?

The complexity of dryland salinity is difficult to grasp in isolation, and the earlier chapters outlined both the advances and gaps in our existing understanding. Integrated decision-making is an area of research and implementation needing significant further development, and until our understanding of each element of catchment health is well understood, progress in this area remains hampered. While the National Land & Water Resources Audit Phase I has provided a wealth of information across natural resource management themes to support integrated planning and management, much more needs to be done. Together, the NLWRA Phase II and the models described in Question 4 for testing land use and management change scenarios have good potential for development to account for integrated outcomes, and are partly down that track.

Themes of the National Land & Water Resources Audit (1997–2002)

The NLWRA comprised six research themes in addition to dryland salinity. Scientific assessments were produced on the status of and changes in the nation's land, vegetation and water resources to assist decision-makers in their efforts to achieve ecological sustainability, and to serve as a baseline or benchmark for future trend analysis.

Economic, environmental and social assessments of land and water resource change (including land cover) and remedial actions were made. These resources are available on the NLWRA's on-line Atlas and provide valuable information for catchment managers in the investigation of integrated catchment management scenarios:

- Surface and groundwater management (availability, allocation, use and efficiency of use)
- Vegetation cover, condition and use
- Rangelands monitoring
- Land use change, productivity, diversity and sustainability of agricultural enterprises
- Capacity of and opportunity for farmers and other natural resource managers to implement change
- River, estuary, catchment and landscape health.

NLWRA Phase I's full recommendations on priorities for data collection, interpretation and storage are outlined in the final Audit report² (www.nlwra.gov.au).

5.1 Integrated natural resource management

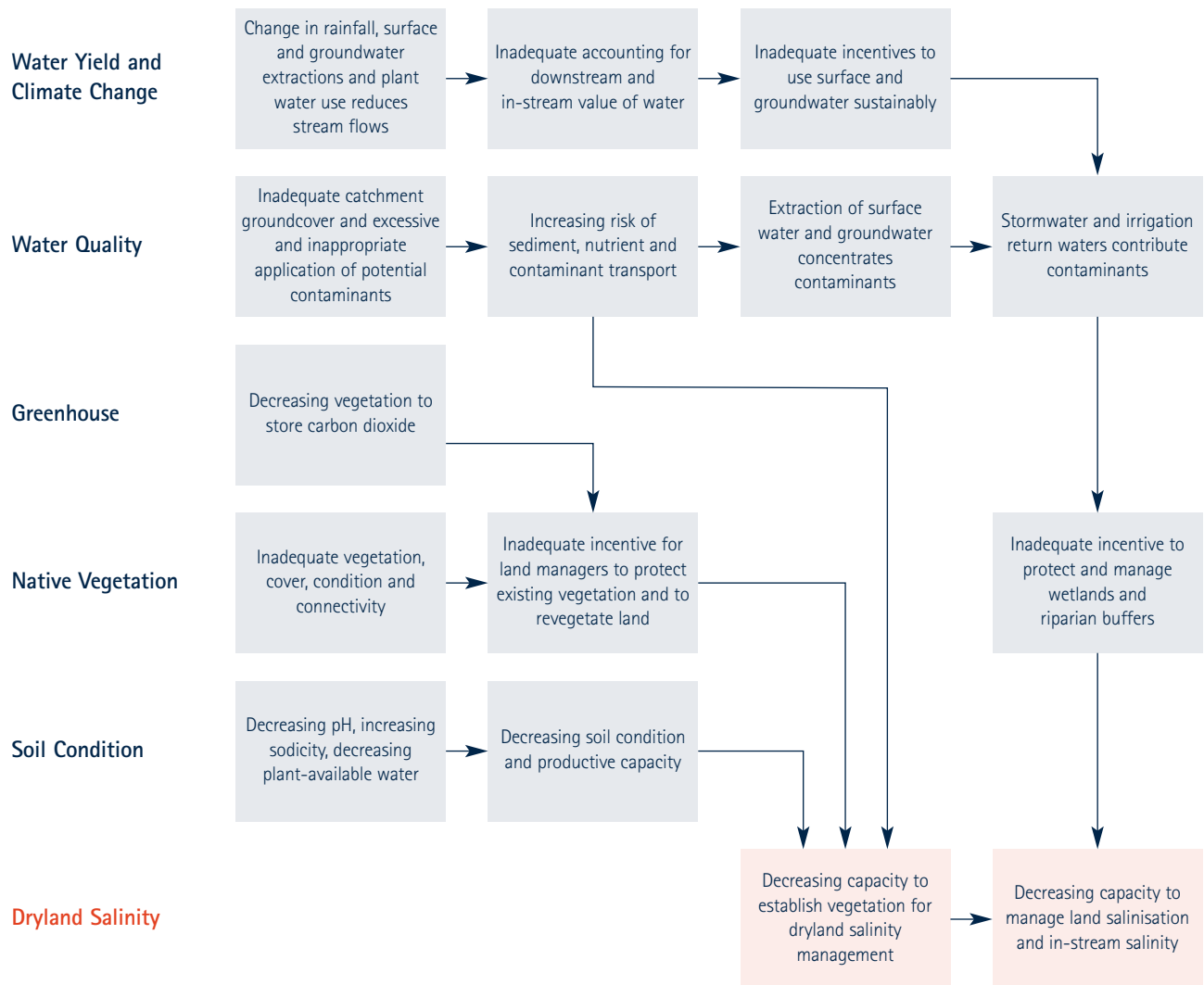
The sections that follow provide a general description of the major aspects of integrated natural resource management and their relationship to dryland salinity management, followed by some examples of significant work making progress in our thinking and understanding in this area. These working examples of 'integration' projects – developing approaches to consider multiple resource management issues – are provided as models from which you can learn and build.

Figure 5.1 is a simplified depiction of the relationship between five major biophysical aspects of catchment management – water yield and climate change, water quality, greenhouse, native vegetation (as a surrogate for terrestrial biodiversity) and soil condition – and dryland salinity within an integrated natural resource management framework. Management actions to tackle these issues can directly affect capacity to manage land salinisation and in-stream salinity, or have indirect impacts by decreasing capacity to establish vegetation. Each element of catchment management is briefly described below.

QUESTION 5

Figure 5.1

Diagram showing how major aspects of integrated catchment management link to dryland salinity



5.1.1 Water yield and climate change

Australia receives comparatively low rainfall which is distributed unevenly both in terms of location and season. River flow is highly variable, largely driven by an erratic climate. Climate and season have a significant influence on the surface and groundwater flows reaching waterways, and diversion of water for irrigation has significantly altered the flow patterns of water in some rivers, and has sometimes led to the reversal of the flow patterns. The National Land & Water Resources Audit³ reported that Australia's estimated total water supply in 1996–97 was 80,363 gigalitres (GL). Of this supply, 85 per cent was 'self-extracted', 14 per cent as mains supply, and <1 per cent as effluent re-use. In addition, some 49,480 GL was supplied as regulated discharge. Of 325 basins, 34 were assessed as being over-developed or highly over-developed, as were 59 of 538 groundwater management units.

Figure 5.1 illustrates that the volume of in-stream water is affected by the amount of rainfall, the water captured by catchment storages and used by plants (grasses, shrubs, trees), and extracted from groundwater and surface waters across the landscape. Many of our management actions for dryland salinity control are in direct conflict with the need to increase surface water flows and to recharge fresh water aquifers. The value of water to in-stream life and down-stream users (both in quantity and in quality) is not accounted for in management of catchment water supplies, and this reduces capacity to manage land salinisation and in-stream salinity concentrations and salt loads.

5.1.2 *Water quality*

The degradation of surface water and groundwater supplies by contaminants such as sediment, nutrients, salts or chemicals is a significant issue for catchment managers, and is exacerbated by water extraction that concentrates the contaminants. The National Land & Water Resources Audit⁴ reported that the dominant erosion processes vary from sheet wash erosion in Queensland, to gully erosion over much of southern Australia, and stream bank erosion particularly in eastern Victoria. River sediment loads are generally 10 to 50 times greater than pre-European loads in intensively-used river basins, and 90 per cent of the suspended sediment loads reaching estuaries are derived from only 20 per cent of catchment areas.

The relative importance of different sources of nitrogen and phosphorus varies between river basins. The dominant sources of phosphorus (over 50 per cent) are: hill-slope erosion in Queensland and New South Wales; gully and river bank erosion, and dissolved phosphorus in run-off in coastal Victoria, South Australia, Western Australia and Tasmania; and urban point source discharges in some basins (e.g. 30 per cent of the total load for Moreton Bay). Dissolved nitrogen in run-off comprises more of the total load than dissolved phosphorus. Total nitrogen loads come mainly from hill-slope erosion in Queensland and coastal New South Wales; contributions from hill-slope erosion and dissolved nitrogen loads in run-off in the Murray-Darling Basin are comparable in magnitude; and over 60 per cent of the total load occurs as dissolved run-off in coastal Victoria, South Australia, Tasmania and much of Western Australia.

Figure 5.1 illustrates that the risk of contaminant transport increases with inadequate catchment cover, and excessive and inappropriate application of nutrients and chemicals. Extraction of surface water and groundwater reduces dilution of these contaminants, and their concentration can be further increased by the addition of irrigation-return waters and urban run-off via stormwater drains. Inadequate incentives to use and manage water sustainably drive off-site impacts on water quality and in-stream life. The movement of soil, nutrients and chemicals diminishes the capacity of land managers to establish vegetation to control dryland salinity across the landscape. The capacity to manage soil and in-stream salinity is decreased by inadequate incentives for land managers to protect and manage riparian and wetland vegetation.

5.1.3 *Greenhouse*

Sustainable land management practices in forestry, vegetation management and agriculture provide important opportunities for reducing greenhouse gas emissions and enhancing greenhouse sinks. Limiting the loss of native vegetation and increasing greenhouse sinks through revegetation and plantation establishment provide effective and practical means for reducing emissions to help meet National and State greenhouse abatement strategy targets. It is widely recognised that vegetation and forestry activities can produce good greenhouse

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outcomes while helping to manage major natural resource issues, including mitigating dryland salinity, protecting water quality and conserving biodiversity at a landscape scale.

The Australian Greenhouse Office⁵ reports that greenhouse gas emissions from agricultural production represented 20 per cent of national emissions in 1999 (excluding land clearing), much higher than that of any other OECD country apart from New Zealand. The bulk of agricultural emissions come from livestock, particularly methane from sheep and cattle and nitrous oxide from animal wastes. The sector needs to consider both the potential impacts of climate change, to which it is vulnerable, and the national policy and program response to reducing emissions, which can offer both opportunities and challenges.

Figure 5.1 illustrates only the woody vegetation component of greenhouse abatement. It shows that vegetation clearance reduces the store of carbon dioxide in the landscape, and that creation of carbon sinks through woody perennial vegetation establishment is currently very limited. Inadequate incentives for land managers to protect vegetation and invest in revegetation for carbon sequestration or other purposes further decrease the capacity for retaining and establishing vegetation in the landscape. This, in turn, has implications for dryland salinity management, with consequent capacity to manage in-stream and soil salinisation diminished.

5.1.4 Native vegetation

The National Land & Water Resources Audit⁶ reported the first Australia-wide, regional level, collaborative assessment of the type, extent and change in native vegetation cover. It reported on the status of native vegetation using the *National Vegetation Information System* and other sources of mapped vegetation information.

The *Australian Native Vegetation Assessment 2001* presents a range of information products about native vegetation including examples and applications of the native vegetation information at scales appropriate for Australia-wide policy development and program evaluation. Knowledge and information gaps are also identified.

Figure 5.1 illustrates that declining vegetation cover, condition and connectivity is partly driven by inadequate incentives for land managers to protect and restore native habitat. The on-going clearance of native vegetation and its limited re-establishment for nature conservation benefits also impacts on capacity to manage leakage to groundwater and the mobilisation of salts in the landscape. This has implications for in-stream salinity concentrations and salt loads, as well as the spread of salinity on land.

5.1.5 Soil condition

Soil condition (factors such as pH, sodicity, water-holding capacity, erosion, nutrients) affects plant growth and farm productivity, and can impact on nearby streams. The National Land & Water Resources Audit⁷ reported that surface and sub-soil acidity exists in all States and is estimated to total eight to nine times the area affected by dryland salinity. The largest areas of acid soils are in New South Wales, Western Australia, Victoria and Queensland.

Figure 5.1 illustrates that declining soil condition and productive capacity reduce yield and farm profits, thereby reducing the capacity of land managers to invest in vegetation for dryland salinity management — either perennial grasses or woody perennials. Capacity to manage the spread of salinisation on land and the movement of salt to streams is diminished as a consequence.

5.2 Salinity Investment Framework

The *Salinity Investment Framework*⁸ (SIF) is a system developed in Western Australia to help ensure that public money to counter salinity is spent effectively, by directing it to projects with the best chance of protecting important high-value public assets.

Initiated in March 2002, the SIF identified important natural assets which fall into four main classes – biodiversity, water resources, agricultural land, and rural infrastructure such as towns and roads. It then set priorities based on eight principles related to the value of the natural asset, threat to it, and feasibility of options available to protect it.

The eight principles are:

- The top priority public investments are those that generate the greatest public benefits per dollar of public investment
- Direct financial assistance to landholders to undertake salinity action should be strategic and should not exceed the public benefits that result
- Where the priority is high and net public benefits are sufficient, Government should be prepared to take strong action to ensure protection of the asset
- Where the public priority is low but there are extensive private assets at risk, public investment should be aimed at industry development
- Inevitably, a targeted investment strategy in salinity management will result in an unequal distribution of investment across the State
- Government must fulfil its statutory obligations for land, natural resources and functions (such as research) when it sets its priorities for investment in salinity action
- The processes required for priority-setting will involve ongoing learning and need constant feedback
- Setting priorities must proceed even when there is only limited or imperfect information on prevailing environmental, social and economic circumstances.

Establishing the priority assets within the SIF threat and feasibility framework required analysis of the extent and trends in salinity not previously considered. Firstly, detailed assessments of the current extent of salinity and future valley hazard were updated from the Land Monitor project methods (see Figure 5.2, and discussed earlier in Question 1 section 1.3.3). Total area affected and times to equilibrium for each of the 31 Soil Landscape Zones (used as surrogates for groundwater flow systems in Western Australia) was then established. Management options (based on technical feasibility factors) and estimates of adoption were then used to create predictions of the amount of land that would be treated within the established strategies of recovery, containment and adaptation. Estimates of the impact in each zone were then assessed and the economic benefit of management evaluated. Sensitivity analysis was conducted on each of the factors.

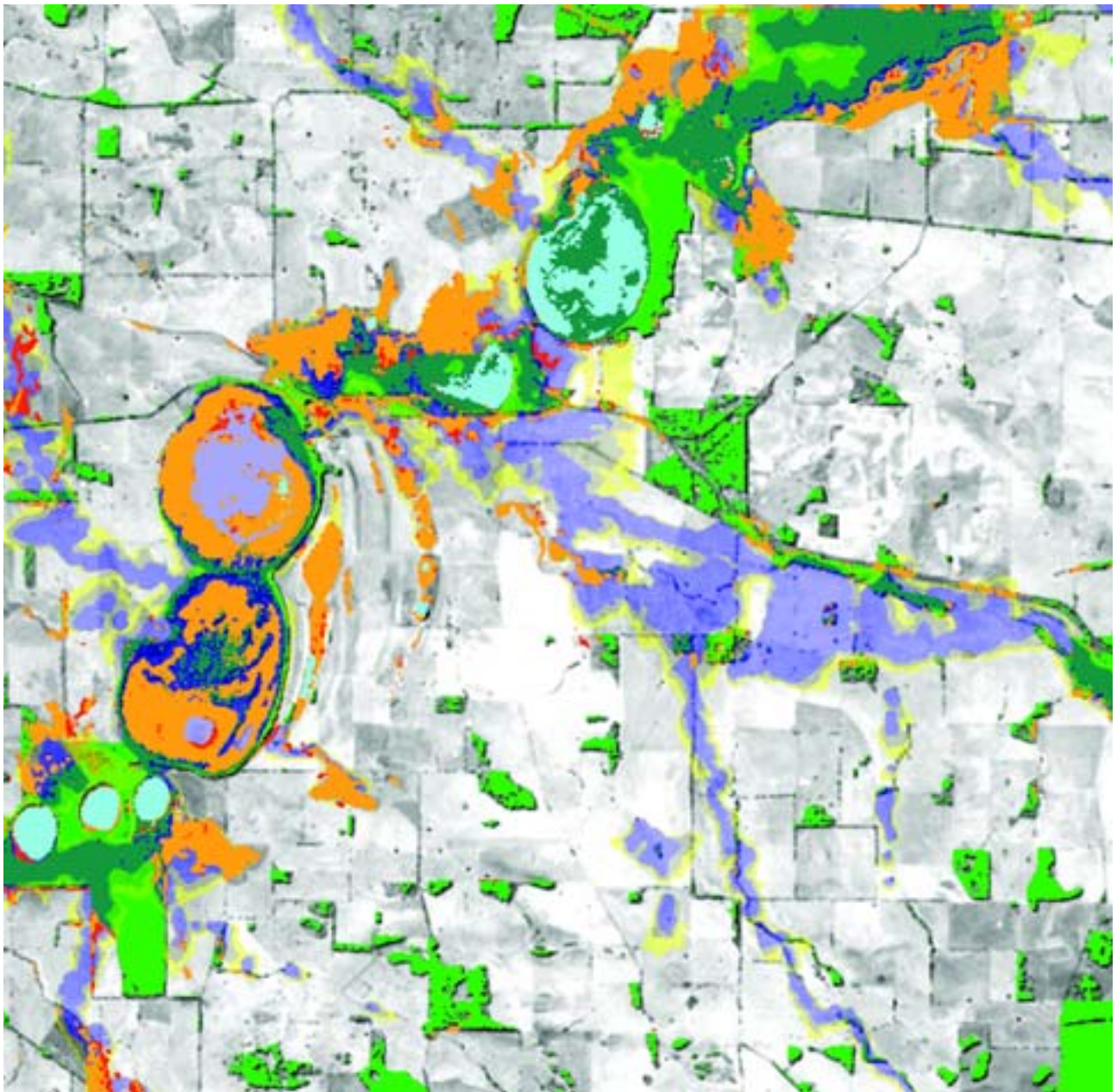
The following conclusions can be drawn from this analysis:

- Salinity currently affects 0.821 million hectares or threatens 4.4 million hectares of agricultural land and over 40 towns containing high value infrastructure. Over 3640 km of primary roads are affected, with 16,090 km at risk. Of the area at risk, current trends in adoption and analyses of the effectiveness of practices suggest that less than 800,000 hectares can be recovered or contained, and a similar area of land managed by systems of adaptation. A large area of the land at risk has no options for management (but may have in the future).

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Figure 5.2

An example of a map product from the Land Monitor project. The Landsat™ derived image shows Lake Toolibin (300 ha – north) and Lake Taarblin (900 ha – south) in Western Australia. (Source: Department of Environment, Western Australia – *Land Monitor* project.)



- Light blue Water
- Grey Crop and pasture
- Orange Current salinity derived by mapping areas of consistently low productivity
- Red Recently developed salinity (from multi temporal analysis of Landsat TM)
- Dark Blue Valley Hazard – forecast to have potential to develop a shallow water table (< 1 m above lowest point),
- Yellow Valley Hazard (<2 m above lowest point)
- Green Show extent and trends in remnant vegetation condition
 - Light Green – good condition
 - Dark Green – poor/worsening condition

- Most of the benefits (and losses avoided) for farmers from the adoption of factors assessed in this review stem from the containment of salinity. Benefits from recovery of salt-affected areas are imputed to be higher than those for the improved management of saline areas, although this is dependent on actual costs of recovery. Recovery technologies are poorly developed.
- There is a high degree of variability between the zones where benefits were incurred (or losses avoided), with many eastern zones having a lower return on investment than those to the west. Net return per hectare needs to be considered along with return per zone.
- Improving either the technical feasibility or adoption rate greatly boosts the potential returns on investment in many zones.
- Further analysis of the economics is warranted as this analysis was only undertaken at regional scale and was related to agriculture and infrastructure alone. An analytical tool that allows further sensitivity analysis to be undertaken and regional variations better accounted for, is being developed.

The second phase will address the feasibility of achieving the management goal for priority assets (to contain salinity, recover the assets, or adapt to salinity) and regional application in the Avon catchment. Regional groups will use it to assist with their regional plans.

5.3 Salinity and biodiversity

The report *Review of SA regional planning and investment concerning the impacts of salinity and salinity management on biodiversity values*⁹ seeks to identify the extent to which the threat of salinity to biodiversity has been recognised and integrated into natural resource management regional plans in South Australia. It also reviews regional initiatives and assessment processes for evident recognition of both positive and negative impacts of salinity management options on biodiversity conservation. The report collates several decision support tools (existing and under development), and makes recommendations on assessing and prioritising the impact of salinity and salinity management options on biodiversity.

The report discusses the following list of decision support tools:

- The Australian Natural Resource Atlas & Data Library
- The Groundwater Flow Systems Framework
- Managing groundwater and surface water for native terrestrial vegetation health in saline areas – a guideline report
- GIS mapping
- Economic and groundwater modelling
- Environmental weed risk assessment
- The biodiversity toolbox for local government (www.ea.gov.au/biodiversity/toolbox)
- Engineering options decision support tool
- A system for predicting the loss of aquatic biodiversity from changes in salinity
- A decision tree approach to management/restoration of remnant vegetation in salinising landscapes.

The report's primary conclusion is that the critical factors for effective regional natural resource management planning and investment into salinity/biodiversity issues is an adequate and accessible information base that can be meaningfully interpreted to inform priority-setting processes. Promotion of currently available decision support tools and those under development is needed, and regional groups require technical and facilitative support to access and interpret information to manage their investment strategies and proposed projects.

ACTION #5.2

Consider the application of the Salinity Investment Framework in your regional context as an approach to deciding between multiple objectives and prioritising investment.



ACTION #5.3

Review the SA report on salinity and biodiversity and the decision support tools identified and consider whether your regional plans give adequate recognition of the threat of salinity to biodiversity.



QUESTION 5

ACTION #5.4

Consider the map products and methods developed by the 'Catchment condition' project within the context of your regional planning.



5.4 Catchment condition

The report *Assessment of catchment condition*¹⁰ established the biophysical condition of surface water catchments in the intensive land use zone of Australia using land, water and biological measures as part of the National Land & Water Resources Audit river, estuary and catchment condition assessment.

The 14 individual indicators used in the assessment are shown in Table 5.1. These indicators were aggregated using a decision support system called CatCon, resulting in an overall catchment condition index, or sub-indices for water (6 indicators), land (3 indicators) or biota (6 indicators).

The result of the land condition assessment at ~500km² scale is shown in Figure 5.3 using the three indicators for the land sub-index shown in Table 5.1. The assessment indicates that poor condition areas are found in:

- South-west Western Australia where the largest area of poor land condition occurs compared with other regions
- Upper Condamine and large areas of the Fitzroy catchments in Queensland
- Coastal floodplains in parts of central Queensland
- Hunter River Basin in New South Wales
- Catchments west of Melbourne in Victoria.

This national-scale study was also trialed at the State and regional levels, for Victoria and the Sydney catchment. It provides a framework and selection criteria to establish indicators, and context and database to guide more detailed and specific assessments at State and regional scales.

Table 5.1

The 14 indicators used in the assessment of catchment condition

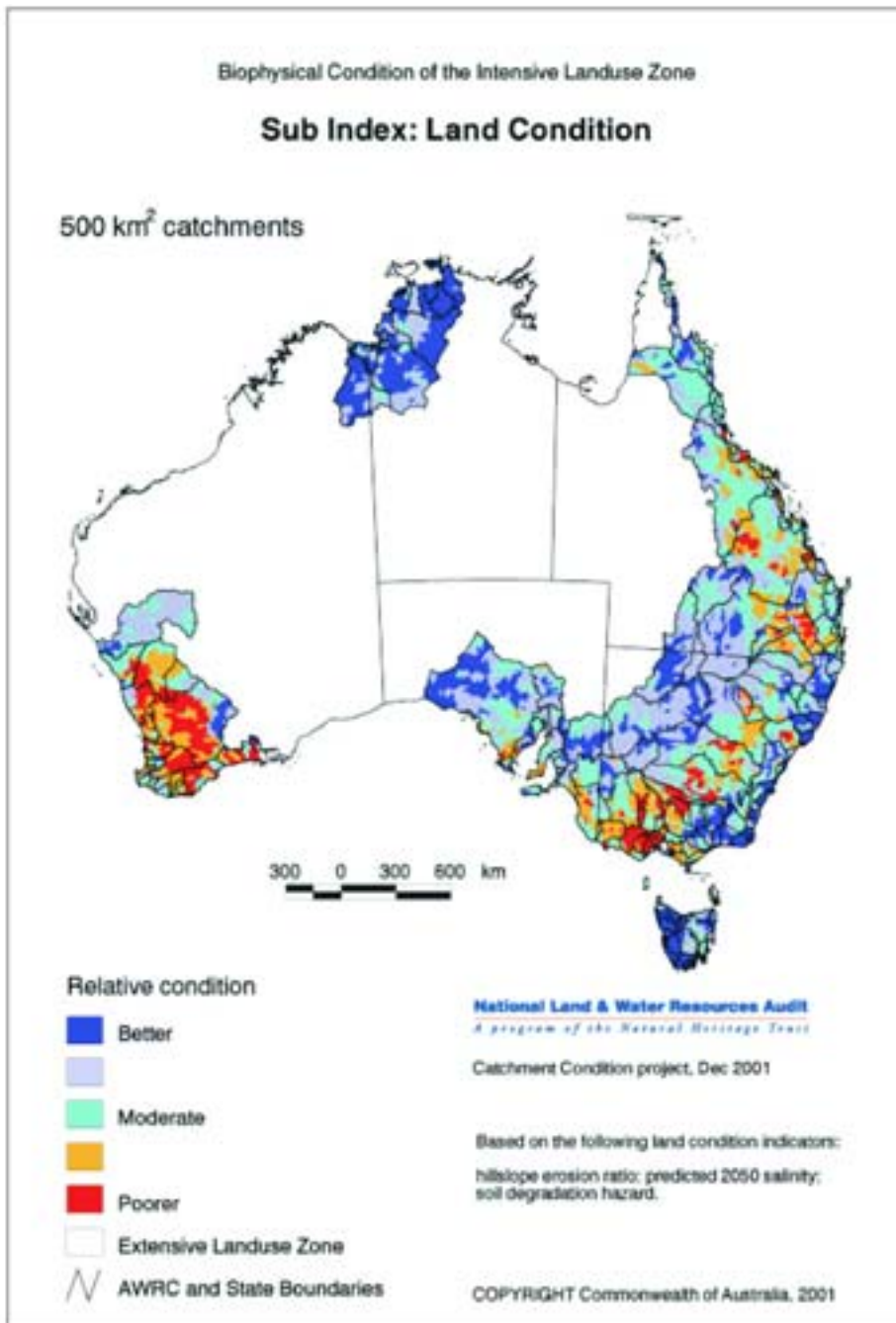
(Source: Walker J., Veitch S., Dowling T., Braaten R., Guppy L., and Herron N., 2002, *Assessment of catchment condition – The intensive land use zone in Australia*, CSIRO Land and Water, Canberra ACT.)

Water condition (sub-index)	Land condition (sub-index)	Biota condition (sub-index)
Suspended sediment ratio	Predicted 2050 salinity	Native vegetation fragmentation
Pesticide hazard	Soil degradation hazard	Native vegetation extent
Industrial point source hazard	Hillslope erosion ratio	Protected areas
Nutrient point source hazard		Road density
Impoundment density		Feral animal density
		Weed density

Figure 5.3

Land condition sub-index assessment at ~500km² scale

(Source: Walker J, Veitch S, Dowling T, Braaten R, Guppy L, and Herron N., 2002, *Assessment of catchment condition – The intensive land use zone in Australia*, CSIRO Land and Water, Canberra ACT.)



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5.5 Landmark

The primary objective of the Landmark¹¹ project was to identify the need for land use and land management change and policy responses to facilitate change in broad-scale dryland regions. Landmark provides the scientific foundation for determining whether current land uses and recommended practices achieve, or are likely to achieve, government and community goals for sustainability. It uses a logical approach to determine whether, what scale and what type of change might be required. This methodology is documented in detail in *Landmark: A method for testing dryland agriculture sustainability*¹².

The work was undertaken in three pilot regions – the Upper Goulburn-Broken (Vic)¹³, Upper Billabong Creek (NSW)¹⁴ and Upper Condamine (Qld)¹⁵ catchments. The Landmark project has produced a quantitative, spatial analysis of the sustainability of current land use and management methods for broad-scale dryland agriculture in these three focus catchments. The indicators used to assess sustainability include biophysical measures (soil acidity, soil erosion, nutrients, biodiversity, water balance), economic data (e.g. growth in regional productivity) and social factors (e.g. population age structure, access to services).

Reports can be accessed on the Landmark web-site (www.mdbc.gov.au/landmark/index.html).

Figure 5.4 provides an example of the acidity results for the Goulburn-Broken catchment, which show that direct off-site impacts from declining paddock soil pH, such as a decline in stream pH and inability to establish native vegetation, are not evident at this stage. Although declining stream pH has been measured for a number of years, such declines have been occurring in forested parts of the region. The causes of stream pH decline are currently unknown and more research and interpretation is needed before the off-site impacts from agriculturally-induced soil acidity can be assessed.

Landmark has developed and evaluated a set of methods, and applied them in three pilot regions. The broad results from these analyses provide a set of quantitative and spatial data that can be further interrogated to help guide catchment plans, program development and delivery, and the use of policy instruments to help improve sustainability. It provides valuable information to support decision-making processes at regional, State and National levels and will inform the implementation of the *Integrated Catchment Management in the Murray-Darling Basin 2001–10* and the *Basin Salinity Management Strategy 2001–15*.

ACTION #5.5

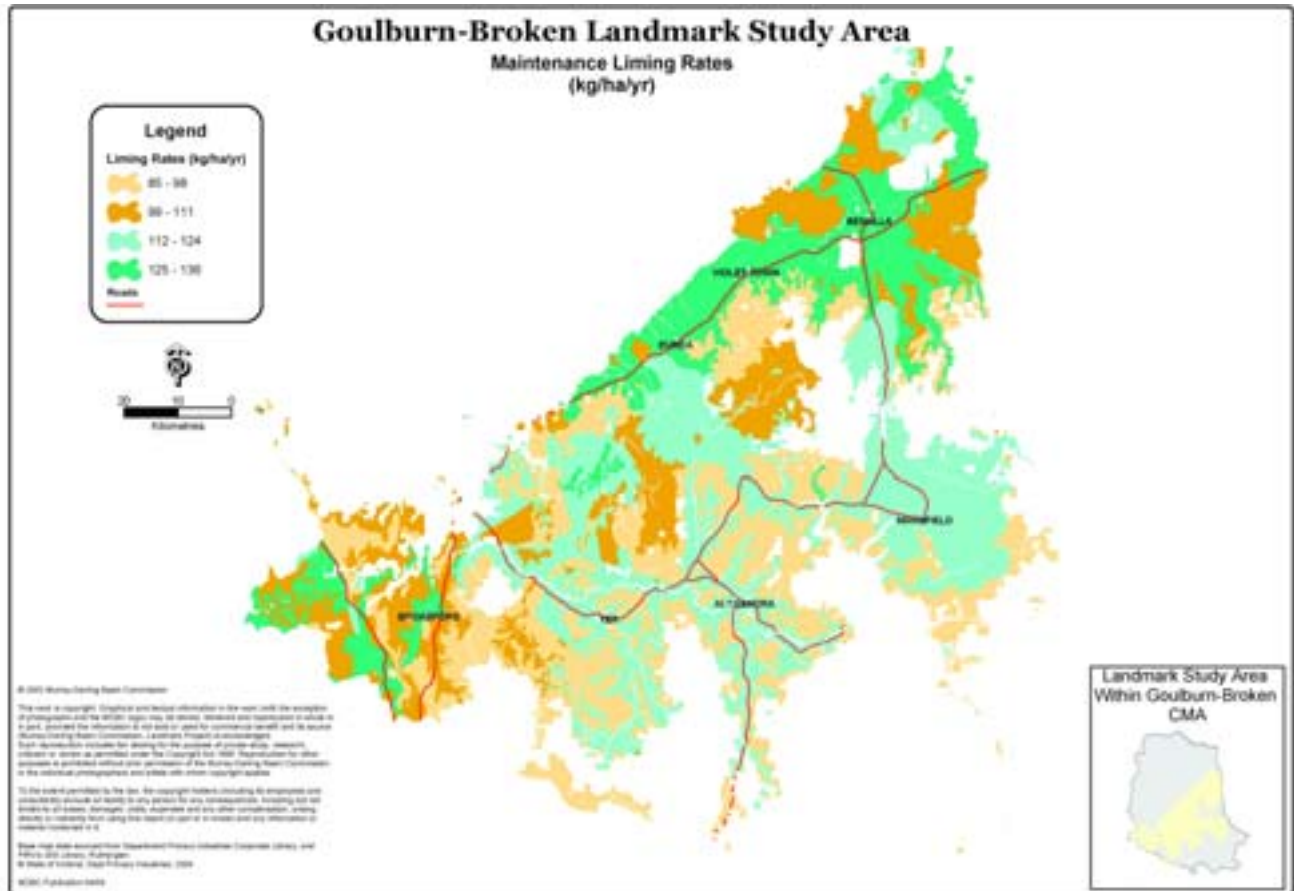
Consider the integrated, catchment-scale method developed by the Landmark project to assess the sustainability of current land use and scenarios for land use change for application in your region.



Figure 5.4

Map showing liming rates needed to maintain current soil pH levels in the Upper Goulburn-Broken pilot region.

(Source: Avery A, Barr N, Beverly C, Cary J, Clarke D, Clifton C, Eigenraam M, Gallant J, Madden B, McKenzie N, Price P, Ridley A, Robins L, Stoneham G, Thomson D, and Webb T, (in press), *Landmark: Testing sustainability of high rainfall grazing systems – Upper Goulburn Broken (Vic)*. Murray-Darling Basin Commission, Canberra ACT.)



QUESTION 5

5.6 Heartlands

The *Heartlands*¹⁶ initiative aims to improve land use in the Murray–Darling Basin to protect land and water resources and sustain commodity production. It combines a research program with implementation of on-ground works such as tree planting, protection of remnant vegetation, establishment of perennial pastures and erosion protection. The research guides on-ground works to ensure maximum environmental benefit from the investment. The close link with on-ground implementation ensures that the research remains relevant and well focussed.

In particular, *Heartlands* focuses on:

- Integrated catchment management strategies
- Salinity
- Water yield
- Water quality
- Biodiversity
- Carbon sequestration potential
- Commercially viable systems of farm forestry and mosaic agriculture.

Heartlands operates in four catchments to investigate new land management options that will be effective in repairing and preventing environmental damage. These strategies for targeted land use change will address economic and social objectives. The effectiveness of revegetation options will be measured to ensure their success, and support local communities in implementing improved management of their farms and catchments.

The focus catchments are:

- Billabong Creek, Upper Murray, New South Wales
- Kyeamba Creek, Murrumbidgee, New South Wales
- Honeysuckle and Sheep Pen Creeks, Goulburn–Broken, Victoria
- Mid Ovens basin, North–East, Victoria.

Figure 5.5 provides an example of the water yield results for the Ten Mile Creek pilot study. The water yield reduction shown is based on the integrated land use scenario modelled to achieve optimal outcomes across a range of land management objectives. The land use map does not represent a socially optimal outcome, and is only a working draft to inform on-going discussions with the community.

On-ground works such as agroforestry and environmental plantations are taking place in all four catchments, however most of the research will be focussed on the Billabong Creek and Honeysuckle Creek catchments. Technology developed from such research may later be applied and tested in the Kyeamba Creek and the Ovens Basin catchments. It is intended that results and recommendations can be extended to other areas.

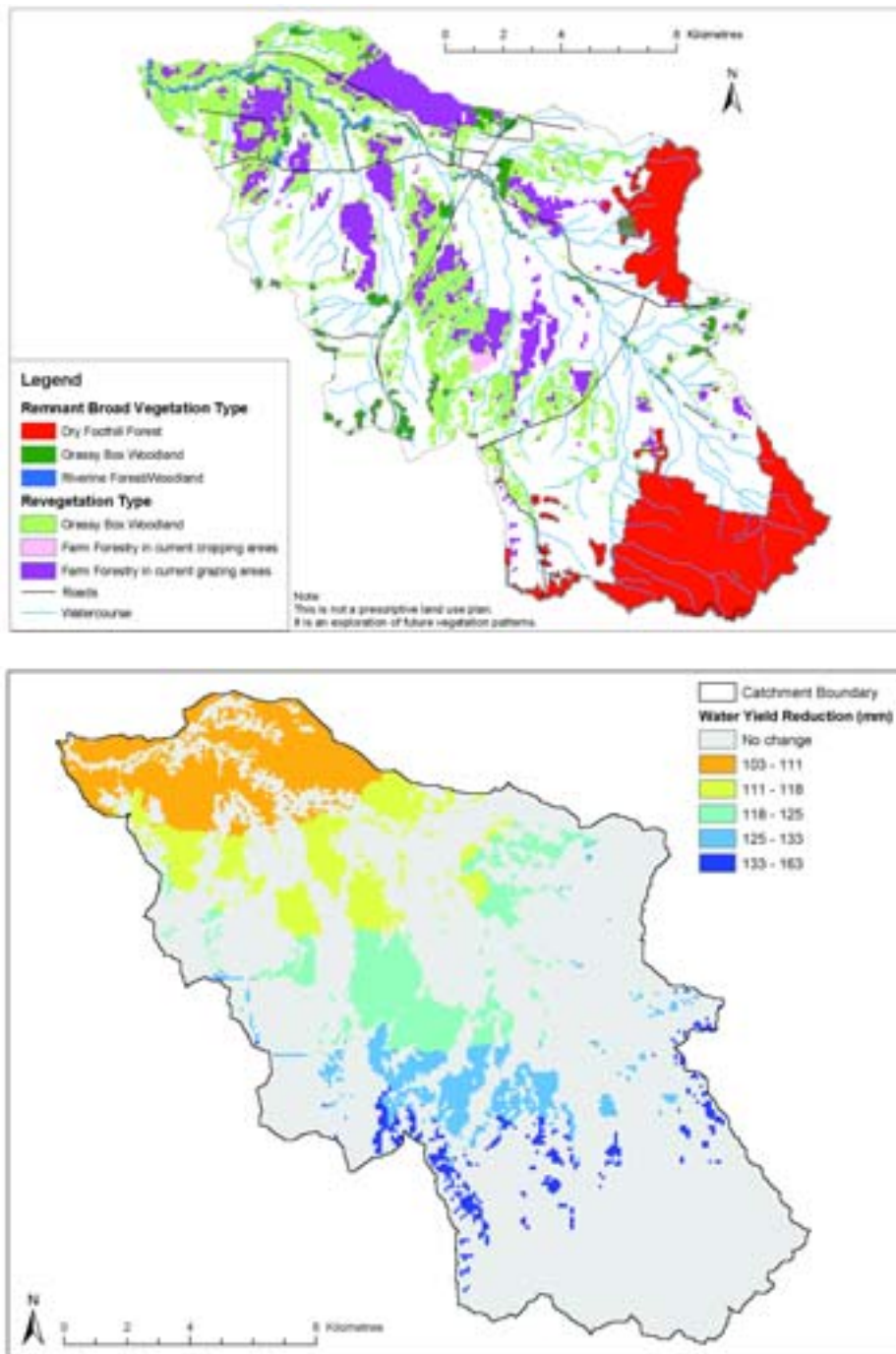
Several reports and a seven-part fact sheet series on findings from Heartlands are available, and include:

- *Learning from the Heartlands experience*¹⁷
- *Heartlands – Planning for sustainable land use and catchment health*¹⁸
- *Heartlands – Low to medium rainfall farm forestry*¹⁹
- *Heartlands – Mosaic farming feasibility*²⁰

Figure 5.5

Map 1 of Ten Mile Creek (NSW) showing the outcome of the integrated (multiple theme) revegetation allocation. Map 2 of Ten Mile Creek (NSW) showing the mean annual water yield reduction under the integrated revegetation scenario

(Source: Cresswell H. (ed), 2004 (in press), *Planning for sustainable land use and catchment health*, A report of the Heartlands Initiative, Technical Report No. 1, CSIRO and Murray-Darling Basin Commission, Canberra, ACT.)



ACTION #5.6

Consider the method trialed by the Heartlands initiative to develop an integrated land use map for sub-catchment-scale planning and implementation in your region.



QUESTION 5

- Fact sheets
 - No 1 – The *Heartlands* overview²¹
 - No 2 – Mosaic farming: Agricultural landscapes of the future²²
 - No 3 – Assessing and managing dryland salinity²³
 - No 4 – Low rainfall farm forestry²⁴
 - No 5 – Trees, groundwater and river flow²⁵
 - No 6 – Restoring biodiversity – Some practical guidelines²⁶
 - No 7 – Integrated land use planning.²⁷

Learning from the Heartlands experience is a plain-English publication summarising the project, its management structure and processes, and key findings. Other reports form part of a technical series.

Planning for sustainable land use and catchment health presents spatially explicit land use maps in draft form for three pilot areas within two focus catchments – Simmons Creek and Ten Mile Creek (sub-catchments of the Billabong Creek catchment), as well as Sheep Pen Creek. All three studies use spatial information derived from airborne geophysics investigations.

The work builds on the land use scenarios investigated in the 'Salt Delivery'²⁸ project for the Simmons Creek catchment. Complete assessments of priorities for restoration of biodiversity and landholder evaluation of the costs, synergies and trade-offs between alternative land use options are in progress. The web-based Billabong Land Information System²⁹ is being used to facilitate knowledge exchange and community engagement, and represents an innovative means of providing information to catchment managers and landholders. The aim of the work is to produce a balanced and spatially explicit land use plan that is acceptable to the community and one that is based on sound science.

ACTION #5.7

Consider the benefits from additional data and information to inform investment decisions, as demonstrated by the Sediment & nutrient exports project, and the potential to optimise investment benefits by using the prioritisation framework coupled with salinity modelling (such as BC2C) to prioritise work in your region.



5.7 Sediment & nutrient exports

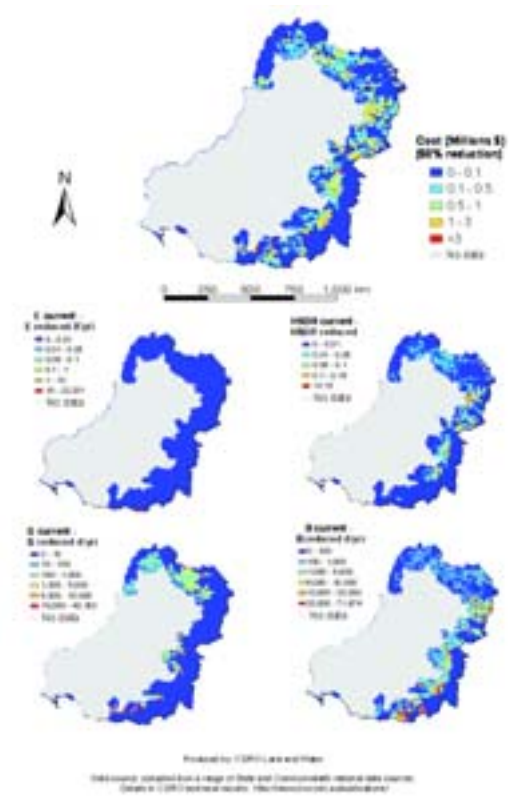
The *Sediment and nutrient exports*³⁰ project synthesised existing information on sediment and nutrient transport across the Murray–Darling Basin, improving upon earlier investigations undertaken for the National Land & Water Resources Audit. Tools were developed to inform decision-making on achieving end-of-valley targets, the most effective means of controlling suspended sediment loads, identifying priority management areas, and demonstrating water quality benefits downstream for different levels of investment and different investment strategies.

Spatial modelling was used to quantify the patterns and rates of current sediment and nutrient transport, and methods were developed for effectively controlling sediment and nutrient sources, and quantifying the benefits resulting from different investment scenarios. Results show that effective targeting of restoration work can reduce the cost by many times (see Figure 5.6).

Figure 5.6

Map showing some results from the *Sediment and nutrient exports* project on prioritising investment for soil erosion control – Total cost, reduction in hillslope, sheet and rill erosion, sediment delivery ratio, gully erosion and bank erosion for 60 per cent of fine sediment reduction at control locations.

(Source: Lu H., Moran C., DeRose R., and Cannon G., 2003, *Spatially distributed investment prioritisation for sediment control in the Murray Darling Basin – Report G to project D10012 of Murray Darling Basin Commission: Basin-wide mapping of sediment and nutrient exports in dryland regions of the MDB*, CSIRO Land and Water Technical Report 31/03, CSIRO Land and Water, Canberra ACT.)



QUESTION 5

5.8 Watermark

*Watermark*³¹ is a group of projects that aims to make a significant contribution to strategic development of sustainable irrigation practices by exploring irrigation issues within integrated catchment management.

Collectively, *Watermark* projects will develop an integrated package of measures to provide catchment managers with:

- Reliable information and decision support tools to establish irrigation water priorities, targets and response plans
- Policy options to underpin improvements to land use planning, groundwater management, water use efficiency and biodiversity.

Individually, projects will develop:

- A user-friendly, affordable method for measuring and recording on-farm water use efficiency for irrigated horticulture, linked to reporting water use efficiency at regional scale (*Improving water use efficiency across the Murray–Darling Basin*)³²
- A framework to facilitate basin-wide alignment of irrigation data collection, storage and retrieval enabling collection of consistent, repeatable and reliable irrigation data, accessible to all stakeholders (*Developing a management information and reporting system for the Murray–Darling Basin*)³³
- Planning guidelines for new and redeveloping irrigation areas to support sustainable irrigation practices and development (*Guidelines for land use, suitability and capability for irrigation planning and development*)³⁴
- A voluntary, user-friendly Environmental Stewardship Program to improve environmental management at farm-scale linked to catchment outcomes (*The environmental stewardship program*)³⁵
- A set of guiding principles to underpin strategies to achieve sustainable groundwater use in irrigated catchments (*Sustainable groundwater use within irrigated catchments*)³⁶
- A decision-support framework manual and software package that can be used to assess the most effective use of water available for irrigation (*A framework to optimise irrigation water use*)³⁷
- Tools to improve understanding, decision-making and uptake of best practice for water quality management by the irrigation industries (*Managing water quality in irrigated catchments*)³⁸
- Feasible options and opportunities for catchment water management through improved strategic management of water use efficiency of on-farm and delivery systems (*Developing a policy framework for water use efficiency*).³⁹

Most *Watermark* projects commenced in April 2002, and reporting is anticipated in 2004–05. An integrated report on outcomes should be available by mid-2005.

ACTION #5.8

Use the findings, guidelines and tools developed by the Watermark projects to link dryland salinity management decision-making more closely with irrigation management in your catchment.



5.9 BushTender

BushTender⁴⁰ is a biodiversity conservation program in Victoria applying an 'auction' system based on economic theory outlined in the report *Mechanisms for biodiversity conservation on private land*.⁴¹ Landholders make an offer to receive a given price for entering agreements to provide management services that improve the quality or extent of native vegetation on their land. These services are based on management commitments over and above those required by current obligations and legislation. This price forms the basis for their bid, which is compared with bids from other participating landholders. The successful bids are those that offer the best value for money.

This approach to biodiversity conservation was trialed in Gippsland in 2002–03, where there are 255,000 hectares of native vegetation on private land. Much of this vegetation is important for land protection, water quality, salinity control and environmental significance. The trial was conducted in Trafalgar, Bairnsdale East and Buchan-Snowy.

Seventy three bids were received from 51 landholders (some having bid separately on each of their sites). There were 33 successful bids and management agreements have been signed.

Management agreement periods of three or six years were offered to landholders in the Gippsland trial, with the further option of 10-year protection or permanent protection covenants. Of the successful bidders, all but one opted for at least a six-year management agreement period, with almost half committing to further protection.

In total, 1684 hectares of vegetation has been protected under 'BushTender' management agreements in Gippsland. About half of that area is vegetation considered to be of high or very high conservation significance. The program has been extended under the National Market-based Instruments Pilots described in section 5.10.

5.10 Ecosystems services

The *Ecosystem services* project (www.ecosystemsproject.org) is working to better understand the benefits and beneficiaries of ecosystem services, and provide direction on more equitable sharing of the costs and benefits of natural resource management. It is investigating these free natural services that support the production of goods such as fruit and grain, and other services such as cleaning water, keeping air breathable, controlling pests and diseases and providing other benefits.

The project is working to address questions such as who benefits from these services?; what are current land management practices doing to them?; what will happen under future land use scenarios?; and how far can land use intensification proceed before environmental thresholds are crossed and systems start to collapse?

ACTION #5.9

Consider the auction approach trialed in the 'BushTender' program in achieving multiple benefits from remnant vegetation protection in your region.



QUESTION 5

ACTION #5.10

Consider ways of valuing and investing in ecosystem services to support integrated catchment management in your region, using the resources developed by the Ecosystem services project (www.ecosystemservicesproject.org).



In many instances there is either no substitute or very expensive technological substitutes for these ecosystem services. The project is working with communities around Australia to understand and recognise the importance of ecosystem services, and consider them when making catchment-scale land use decisions. The regions include:

- Atherton Tablelands, Queensland
- Blackwood catchment, Western Australia
- Brigalow Region, Queensland
- Goulburn-Broken catchment, Victoria⁴²
- Gwydir catchment, New South Wales
- Onkaparinga catchment, South Australia
- Rangelands, New South Wales.

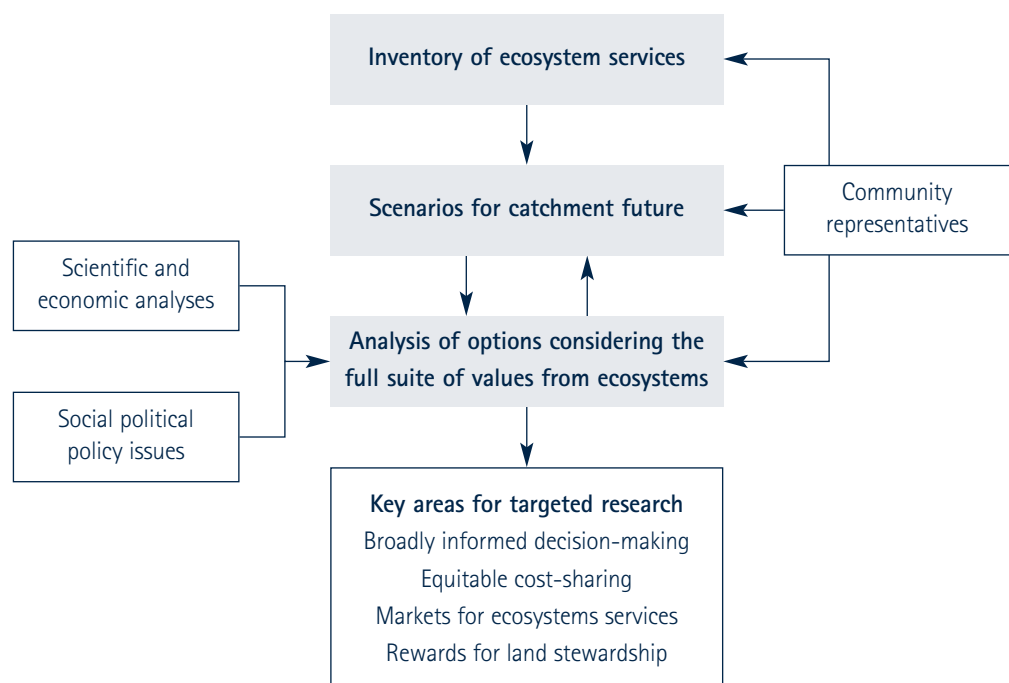
These seven different regions provide a diversity of approaches to studying ecosystem services, a mixture of regional economic and social issues and differing natural resource characteristics. The analysis framework used in these studies is shown in Figure 5.7. The project will provide a multitude of processes and tools with which to study ecosystem services including:

- Methods for inventory of ecosystem services at a catchment scale
- A scenarios and modelling process which illustrates the interaction of ecosystem services and the economic and social impacts related to different land uses
- Decision-making aids which incorporate preferences and values of community members
- Provision of an action research methodology that engages communities and stakeholders.

Figure 5.7

Ecosystem Services Analysis Framework used in the 'Ecosystems services' project

(Source: Abel N., Cork S., Gorrard R., Langridge J., Langston A., Plant R., Proctor W., Ryan P., Shelton D., Walker B., and Yialeloglou M., 2003, *Natural values: Exploring options for enhancing ecosystem services in the Goulburn Broken Catchment*, Ecosystem Services Project, CSIRO Sustainable Ecosystems, Canberra ACT.)



5.11 National Market-based Instruments Pilots

The National Market-based Instruments (MBI) Pilots Program (see www.napswq.gov.au) seeks to increase Australia's capacity to use MBIs in managing natural resource issues, in particular to address salinity and water quality. MBIs use trading mechanisms, auctions and price signals to change behaviour.

In April 2003 the Natural Resource Management Ministerial Council announced 10 pilot projects shown below, funded under a \$5 million first round. As a follow-up, the Ministerial Council launched the Tender for a Pilot of Dryland Salinity Trading and Offset Schemes in June 2003.

- 'Multiple-outcome auction of land use change'. Department of Primary Industries, Victoria to extend the auction approach trialed in the 'BushTender' program (Goulburn-Broken NAP region, Victoria) – see section 5.8 for more details.
- 'Tradable net recharge contracts in Coleambally Irrigation Area'. CSIRO Sustainable Ecosystems to test on the ground the effectiveness of trading schemes for managing salinity (Lachlan-Murrumbidgee NAP region, NSW).
- 'Farming Finance: Creating positive land use change with a Natural Resource Management Leverage Fund'. Greening Australia to set up a fund to leverage private sector investment to deliver natural resource management outcomes and private returns to investors (Lachlan-Murrumbidgee NAP region, NSW; South Coast NAP region, WA).
- 'Auction for landscape recovery (south west Australia)'. WWF Australia to design and trial an auction to provide incentives for diffuse source salinity and biodiversity outcomes (Avon NAP region, WA).
- 'Adoption of New Land Management Practices through Conservation Insurance'. Department of Water, Land and Biodiversity Conservation, SA to undertake a scoping study into the use of insurance as a means of supporting changes in farming practices where risk is perceived to be a major barrier to implementation (Lower Murray NAP region, SA).
- 'Cap and Trade for Salinity: Property Rights and Private Abatement Activities, a Laboratory Experiment Market'. Department of Primary Industries, Victoria to examine the economic efficiency and cost-effectiveness of a cap and trade approach to managing salinity from irrigated agriculture, compared to current policy instruments (Lower Murray NAP region, Victoria/South Australia).
- 'Catchment Care – Developing an auction process for biodiversity gains and water quality outcomes'. Onkaparinga Catchment Water Management Board to test a low-cost biodiversity and water quality assessment and auction tool for use by regional natural resource management bodies (Mt Lofty-Kangaroo Island NAP region, SA).
- 'Green Offsets for Sustainable Regional Development'. NSW Environment Protection Authority to implement three field-based salinity offset schemes to demonstrate how offset works can facilitate economic expansion, while avoiding addition of salt loads to stressed rivers in the Murray–Darling Basin (Namoi-Gwydir/Macquarie–Castlereagh/Murray NAP regions, NSW).
- 'Establishing East-west Landscape Corridors in the Southern Desert Uplands'. Desert Uplands Build-up and Development Committee to investigate the design of auctions to create biodiversity corridors (Burdekin-Fitzroy NAP region, Qld).

ACTION #5.11

Consider the wide array of mechanisms being tested under the National Market-based Instruments Pilots Program to value and invest in ecosystem services to support integrated catchment management in your region.



QUESTION 5

- 'Establishing the potential for offset trading in the lower Fitzroy River.' Central Queensland University to examine how a salinity trading scheme might work in new and developing irrigation areas (Burdekin-Fitzroy NAP region, Qld).

ACTION #5.12

Consider the final reports from the TARGET project within the context of your regional planning, particularly the integration of salinity and biodiversity using 'bio-indicators.'



5.12 TARGET

The *TARGET*⁴³ project (Tools to Achieve landscape Redesign Giving Environmental/Economic Targets) investigated land use change in small, medium and regional catchments affected by salinity. It identified the barriers to and incentives for implementing change, integrating social, economic and environmental factors in salinity management.

'Landholder Profile Surveys' examined the social and economic barriers to implementing land management change and a 'Farm Economic Analysis' evaluated the profitability of current enterprises, enterprises associated with the strategic management of salinity and the impact of a range of market-based incentives.

'Ecological Surveys' were conducted in catchments of small (Warrengong and Mid-Talbragar) and medium (Little River and Weddin) size, and birds were used as 'bio-indicators' to give a relative measure of catchment health. Within each catchment, the diversity and abundance of bird species was assessed and the existing native vegetation was surveyed. Data was collected on the structural and floristic diversity of the vegetation, and the condition of the vegetation and habitat was assessed.

The use of 'bio-indicators' (birds) was a valuable tool for determining catchment health. Land managers and agency staff increased their awareness of biodiversity issues and could relate the survey results to vegetation condition and catchment health. The size of the vegetation remnant and its location in the landscape was an important consideration for increasing biodiversity. Land managers used this information to determine where vegetation needed to be put back into the landscape for on-ground works to have salinity and biodiversity outcomes. This information will be used in New South Wales to help Catchment Management Authorities better target their management actions.



WHERE TO FROM HERE?

Modelling and methodological developments through the *Catchment condition* project, *Landmark* project, *Heartlands* initiative and TARGET project provide frameworks for advancing the integration of salinity management with other catchment health considerations, with potential for improved dryland salinity outcomes through linkages to models like BC2C, CAT and Catsalt.

The *Salinity Investment Framework* provides a model for guiding the cost-effective allocation of resources within an integrated natural resource management framework. Further refinement of the framework developed under the *Sediment & nutrient exports* project and its development to account for dryland salinity and other natural resource management priorities could significantly enhance its value in directing investment priorities for multiple benefits at the catchment to national level. It also clearly demonstrated the value of accurate data to inform investment decisions.

Finding ways of streamlining modelling approaches will be important, as we need relatively simple, cost-effective approaches at different scales, that can be transferred between landscapes, to confidently inform our decision-making processes.

The *Ecosystem services* project and the *BushTender* program provide both a theoretical foundation and operational tools for establishing instruments to account for non-market values such as nature conservation and greenhouse abatement, that require recognition and valuation in the market place. The *National Market-based Instruments Pilot Program*, including the *Pilot of Dryland Salinity Trading and Offset Schemes* will add significant understanding and tools.

Alignment of dryland salinity management with broader decision-making processes on catchment water yield and water sharing requires much greater attention. The *Watermark* projects provide some data, guidelines and tools for making in-roads to better define these potential opportunities and synergies.

The need to plan for and manage dryland salinity with other natural resource management issues within an integrated framework is critical for achieving effective on-ground results. The National Land & Water Resources Audit Phase II⁴⁴ will be important in collating data and information to support this need.
























A checklist of suggested actions

Question 1 – What is the current extent of dryland salinity and its risk of spread?

Section	No.	Action	Cost	Time	Confidence
NLWRA (1997–2002)	#1.1	Review data, information, reports and maps on the current extent of dryland salinity and its risk of spread compiled by the Audit relevant to your catchment, but with due consideration to work that has taken place since.			
	#1.2	Review data, information and reports on groundwater flow systems compiled by the Audit (www.nlwra.gov.au)			
Groundwater Flow Systems Framework	#1.3	Read the six-page summary of the <i>Groundwater Flow Systems Framework</i> , and understand its strengths and limitations in guiding your salinity management planning.			
	#1.4	Use the 'Tools' information packages, 'Rapid Catchment Appraisal' findings or 'Catchment Management handbook' for your region (or review them as a model for developing your own information) as a guide for assigning salinity risks to each of your major groundwater flow systems.			
	#1.5	Access the best available groundwater flow systems map for your region, and consider investing in the development of smaller-scale maps at 1:250,000 and 1:100,000 for more detailed identification of risks.			
Data	#1.6	Consult the guide on salinity mapping methods to refine your thinking on future regional investments in salinity mapping, prediction, monitoring and risk management.			
	#1.7	Explore the various geophysical techniques (ground and airborne) available for locating catchment salt stores and undertake a cost-benefit analysis to guide effective investment in your region.			
	#1.8	Use the results from assessments on the extent and hazard of dryland salinity to inform your decision-making processes with due consideration to the level of confidence in the underlying data sources applicable to your area.			
	#1.9	Consider the results of specific studies on the extent and hazard of dryland salinity in cropping areas to inform your decision-making processes with due consideration to the level of confidence in the underlying data sources applicable to your area.			
	#1.10	Take into account climate variability (rainfall and evapotranspiration), where possible, when determining the risk of dryland salinity spread.			
	#1.11	Review the 'status report' for your region and State in the <i>Groundwater Status Report for the Murray–Darling Basin</i> (or as a model for developing your own in other parts of Australia) and use the CD-ROM to tailor your own regional maps.			
	#1.12	Consider the concept of representative bores and the associated hydrographs for each groundwater flow system, and use this approach to guide future investments in bore installation and monitoring.			
	#1.13	Investigate salinity risk in more detail before proceeding with conversion of native vegetation to pasture or irrigated agriculture in the rangelands of the Murray–Darling Basin, especially north of Wilcannia.			
Modelling capability	#1.14	Read the paper <i>An overview of modelling techniques and decision support systems and their application for managing salinity in Australia</i> , and consult the PRISM CD-ROM and 'Catchment Modelling Toolkit' (www.catchment.crc.org.au) to help refine existing information on the extent and risk of dryland salinity in your region.			

Where to from here?	No.	R & D Tips
NLWRA	#1.1	Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au) and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.
Groundwater Flow Systems Framework	#1.2	For information on further development of <i>groundwater flow systems</i> visit the NLWRA (www.nlwra.gov.au) and Bureau of Rural Sciences (www.brs.gov.au), and for the Murray–Darling Basin (www.mdbc.gov.au), as well as at individual State and regional levels.
Data	#1.3	Consider the <i>National Airborne Geophysics</i> project (www.affa.gov.au) to keep up-to-date with activities and advances in airborne geophysics mapping and research.
	#1.4	The <i>Groundwater Status Report for the Murray–Darling Basin</i> is likely to be updated periodically while accessibility of groundwater and other natural resource management information for the Basin will be progressively improved (www.mdbc.gov.au).
	#1.5	Contact State agencies, NLWRA (www.nlwra.gov.au) or CSIRO Land & Water (www.csiro.au) for further information on development of programs or activities to collect data for salinity management in rangelands environments.
Modelling capability	#1.6	Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au), which is developing a 'Catchment Modelling Toolkit' and consider the program of the 'Catchment Modelling School' for training model users.

Question 2 – What are the causes and processes of dryland salinity?

Section	No.	Action	Cost	Time	Confidence
NLWRA (1997–2002)	#2.1	Recognise that there is no one single approach to dryland salinity management, and start to understand the differences and similarities between each groundwater flow system in your region by reviewing the relevant fact sheets produced by the National Land & Water Resources Audit (www.nlwra.gov.au).			
	#2.2	Evaluate the availability of local data for each groundwater flow system in your catchment, and assess the likelihood of gathering additional data and the extent to which you will need to draw on understanding of like systems elsewhere to inform management decisions.			
Groundwater flow systems	#2.3	Identify whether any of the groundwater flow systems in your catchment are of the same type as the 10 case study catchments investigated by the Audit and the 'Catchment Classification' project. If so, review the relevant technical reports for more detailed information.			
	#2.4	Refer to the 'Tools Information Packages', 'Healthy catchment guide', 'Salinity management handbook' and 'Rapid Catchment Appraisal' program to better understand the causes and processes of dryland salinity (or use them as a model), and consider developing conceptual diagrams for each major groundwater flow system using the <i>Wimmera Regional Information Package</i> as a guide.			
Salt and water transport & movement	#2.5	Use airborne geophysics in a strategic way to help understand the process by which salts move through the landscape where the available information supports its application.			
	#2.6	Consider the relevance of the sub-catchment scale approach used in the 'Salt Delivery' project and the <i>Heartlands</i> initiative to understanding hydrological function and the mechanisms of salt transport within parts of your region.			
	#2.7	Be aware that using the outputs of one-dimensional models for dryland salinity planning and management and water allocation in hilly terrain has limitations and that decision-making processes should take reasonable account of sub-surface lateral flow and vertical drainage.			








































Section	No.	Action	Cost	Time	Confidence
Plant water use	#2.8	Inform yourself about the trade-offs between managing the movement of salt versus the movement of water in the landscape before considering large-scale afforestation in any part of your region, and refer to Australian case studies where large-scale afforestation has taken place.			
	#2.9	Identify where woody perennial vegetation will be of greatest benefit in your catchment with due consideration to the location of salt stores.			
	#2.10	Establish the extent to which dryland salinity management is reliant on the development of alternative farming systems in your catchment.			
Saline ecosystems	#2.11	Use the classification system developed by the 'Saline Soils' project to identify the types of saline soils amenable to de-watering in your catchment.			
	#2.12	Apply a precautionary principle in the management of remnant vegetation affected by or at risk of dryland salinity, recognising that plant communities can collapse due to unusual or infrequent events, and consider opportunities for managing vegetation at a micro-scale.			
	#2.13	Identify remnant vegetation on riparian land, along drainage lines and in wetlands vulnerable to hydrological change or in need of restoration, and use the findings of the 'Recruitment Biology' project to support your management decisions.			
	#2.14	Study the relationship between increasing salinity and the health of wetland ecosystems in your region, using results of the 'Wetland salinity' project as a guide.			
Where to from here?	No.	R & D Tips			
NLWRA	#2.1	Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au), the 'Catchment Modelling Toolkit' (www.catchment.crc.org.au) and the 'National Evaluation Framework' project for information on proposed data and model development.			
Groundwater flow systems	#2.2	Further development of the <i>Groundwater Flow Systems Framework</i> will take place at several levels – nationally through the NLWRA and 'National Evaluation Framework' project (www.brs.gov.au), for the Murray–Darling Basin through the MDBC (www.mdbc.gov.au), as well as at individual State and regional levels.			
Salt and water transport & movement	#2.3	Keep abreast of activities and advances in airborne geophysics mapping and research (www.affa.gov.au).			
	#2.4	Follow up on the progress of the <i>Heartlands</i> initiative (www.clw.csiro.au/heartlands).			
	#2.5	Consider the on-going development and measures in place to implement and monitor the agreed end-of-valley targets under the Basin Salinity Management Strategy (www.mdbc.gov.au).			
Plant water use	#2.6	Review the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au) to keep abreast of improvements in modelling to account for plant water use and lateral movement of water in the landscape.			
	#2.7	Consider the CRC for Plant-based Management of Dryland Salinity (www.crcsalinity.com) Program 3, Subprogram 5, which includes research on native grasses.			
Saline ecosystems	#2.8	Consider the CRC for Plant-based Management of Dryland Salinity (www.crcsalinity.com) Program 2 on 'Function of natural ecosystems', which includes research on how ecosystems function in recharge zones, and how ecosystems function in soil affected by salinity and waterlogging, and Program 7 on opportunities for enhancing biodiversity in salinising landscapes.			

Question 3 – What are the current and predicted impacts and costs of dryland salinity?

Section	No.	Action	Cost	Time	Confidence
NLWRA (1997–2002)	#3.1	Identify the resources in your catchment that may be adversely affected by the current extent of dryland salinity and its risk of spread and list these 'assets' in order of priority for action.			
	#3.2	Use the Audit data to make a preliminary calculation of what dryland salinity is costing your regional economy, and the relative importance of off-farm versus on-farm costs, except where your catchment was part of the 'Costs' project (see Action #3.3).			
Current & future costs	#3.3	Use the 'Costs Guideline' to estimate current, marginal or future predicted costs for any region in Australia, but start by reading the 'Costs' final report to see what work has already been done and what sort of results you can expect.			
	#3.4	Refer to the 'Tools Regional Information Packages' for summary information on the findings of the 'Costs' project in your region, and consult the 'Salinity Information Package' for more general information on salinity costs.			
	#3.5	Refer to the 'Local government' project information kit on CD-ROM and the series of booklets on urban salinity to guide salinity identification and management for urban areas in your region.			
	#3.6	Consider the estimates for current and predicted impact costs on farm profits for agro-ecological zones for individual grain growers and the grains industry in your management response to dryland salinity.			
	#3.7	Ascertain whether an assessment of the current and predicted impact costs on farm profits for beef, sheep meat, wool or other industries is needed to inform your management response to dryland salinity.			
Ecosystem responses	#3.8	Estimate the loss of aquatic biota from a rise in salinity in your catchment using the preliminary methods developed by the 'In-stream health project' project to rapidly test the relative salinity tolerance of a large number of macro-invertebrate species.			
	#3.9	Test the decision-tree approach developed by the 'Restoring Remnant Vegetation' project in your catchment to predict likely ecosystem responses to changes in hydrologic balance.			
	#3.10	Use waterlogging and elevation as an initial indicator of the capacity of primary saline ecosystems to persist in a secondary saline environment.			
Cost sharing	#3.11	Investigate opportunities for cost-sharing arrangements to inform the development and support the implementation of your regional dryland salinity plan.			
	#3.12	Develop opportunities to market ecosystem services in your region to make sustainable land management more economically viable, and maintain a watching brief on the progress and relevance of programs and activities taking place elsewhere.			
Where to from here?	No.	R & D Tips			
NLWRA	#3.1	Review the strategic plan for the National Land & Water Resources Audit :Phase II (www.nlwra.gov.au) and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.			
Current & future impacts and costs	#3.2	Consider the on-going activities of the Salinity Investment Framework, Rural Towns Program and the implementation of the Basin Salinity Management Strategy (www.mdbc.gov.au).			
	#3.3	Consider the outcomes of research from the Sustainable Grazing on Saline Lands (SGSL) Program on the changing value of saline land as an agricultural resource.			
Ecosystem responses	#3.4	Consider the research portfolio of the CRC for Freshwater Ecology (www.environmentdirectory.com.au/research/crcfw.html) and the WA Engineering Evaluation Initiative for further information.			
Cost sharing	#3.5	Follow the progress of investigations by CSIRO Land and Water (www.clw.csiro.au) on efficient trading systems and on ecosystem services under the NAP (www.napswq.gov.au).			

Question 4 – What can we do and how to measure progress?

Section	No.	Action	Cost	Time	Confidence
Getting started	#4.1	Undertake a comprehensive review of all relevant regional plans in the light of current dryland salinity research outcomes, and assess the need to align the plans, with particular consideration to the suitability and feasibility of management options and measuring progress.			
	#4.2	Access the 'Tools Salinity Information Package', 'Salinity Management handbook', 'Rapid Catchment Appraisal' or similar resource to understand the broad salinity options available.			
	#4.3	Refer to the table on 'Suitability of options for managing dryland salinity' in the 'Tools Regional Information Package' for your region (or as a model to develop your own) to identify broad management options and ratings for each groundwater flow system type.			
NLWRA (1997–2002)	#4.4	Use the 'National Evaluation Framework' guidelines to plan how to systematically build on existing knowledge for each groundwater flow system type through coordinated management, monitoring and research. Refer to <i>Participatory evaluation for landcare and catchment groups – A guide for facilitators</i> for background information on monitoring and evaluation.			
	#4.5	Consider the broad scope of options available to manage dryland salinity – plant-based, engineering, saline industries, living with salinity – and select those that optimise the benefits to your region considering the short-term and long-term costs and benefits.			
	#4.6	Use the surveys and modelling tool developed by the Audit to examine potential social impacts of your proposed management approach to dryland salinity, and develop a better understanding of the social trajectory of your community.			
Modelling land use and management change scenarios	#4.7	Read the paper <i>An overview of modelling techniques and decision support systems and their application for managing salinity in Australia</i> and the booklet <i>Groundwater models – A community guide to better understanding</i> to get an overview of salinity modelling, and then consult the PRISM CD-ROM to help inform the choice of an appropriate approach for your region.			
	#4.8	Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au) to view the 'Catchment Modelling Toolkit' and consider the benefits of attending a 'Catchment Modelling School' to improve modelling capacity in your region.			
	#4.9	Ensure that your regional salinity management plan complies with the requirements of higher order plans like the Basin Salinity Management Strategy.			
	#4.10	Use the model developed by the 'In-stream Health' project to evaluate the effect of predicted salinity rises on aquatic biodiversity, and develop locally specific guidelines to prevent unacceptable impacts.			
	#4.11	Consider the brochure <i>Science for Decision Makers</i> , together with the paper <i>Critical factors affecting the adoption of airborne geophysics for management of dryland salinity</i> , and use the five-step approach described if a cost-benefit analysis indicates that airborne geophysics technology is appropriate to your circumstances.			
Vegetation options	#4.12	Try to achieve multiple outcomes from the vegetation options used to address dryland salinity management in your region, recognising that viable land use solutions that satisfy the criteria of relevance, effectiveness, robustness and profitability may not yet be available in all cases.			
	#4.13	Consider lucerne as a viable land use option for controlling recharge in the <600 mm winter-dominant rainfall zone – with particular potential to lower water tables in local groundwater flow systems – but limited to an optimal area for enterprise profitability and with some establishment and persistence limitations.			

Section	No.	Action	Cost	Time	Confidence
Vegetation options	#4.14	Encourage and develop profitable enterprises based on the use of saltland pastures as a means of adapting to salinity over extensive areas.			
	#4.15	Consider the establishment of agroforestry plantings in your catchment that achieve multiple benefits, satisfying both commercial and environmental objectives, and use the Design principles and Manuals series, together with resources from the Heartlands initiative to assist your work.			
	#4.16	Recognise that investing public or private monies in vegetation management options for the purpose of dryland salinity management in a regional groundwater flow system will require high adoption levels and that realisation of gains will be very long-term.			
Saline environments	#4.17	Assess the potential for reversing chemical, physical and biological changes in salinised soil using the eight simplified Soil Salinisation Categories and best management practices developed by the 'Saline Soils' project, and monitor improvements in landscape health when remedial treatments have been implemented.			
	#4.18	Consider the potential for applying (or adapting) the prioritisation framework developed by the 'Restoring Remnant Vegetation' project based on an assessment of the degree of threat, value of the asset, and likelihood of successful intervention in your catchment.			
	#4.19	Refer to the report <i>Managing groundwater and surface water for native terrestrial vegetation health in saline areas</i> for information on approaches and techniques for the assessment, monitoring and management of the health of native vegetation communities, and review the model for restoring saline land use based on understanding the recruitment biology of vegetation communities on saline soil.			
	#4.20	Consider ways of using salinity as a resource, and use the 'Options for the Productive Use of Saline (OPUS) Land' database on the NDSP web-site as a guide to the options available.			
Engineering options	#4.21	Use the 'Engineering Options' on-line decision support tool (www.ndsp.gov.au) to determine what engineering management options might have high potential for success and be cost-effective in your region.			
	#4.22	Examine the applicability of deep drains in your catchment, including both beneficial and adverse impacts, and establish management arrangements to ensure their appropriate use.			
	#4.23	Identify whether desalination is a relevant and cost-effective option in your catchment, using the decision-tree developed by the 'Desalination Technologies' project to guide your choice of technique.			
Social and institutional capacity	#4.24	Review the structural adjustment indicators used to identify potential catchment management plan implementation problems shown in <i>Adjusting for catchment management</i> and the socio-economic research findings in the reports <i>Understanding landholders' capacity to change to sustainable practices</i> and <i>Landmark</i> , and consider the potential implications and your possible responses.			
	#4.25	Consider the approach and outcomes of the 'Target' project in developing appropriate strategies to achieve salinity targets in small, medium and regional scale catchments.			
	#4.26	Use the SRD Kit and associated report to inform partnerships in sustainable regional development.			

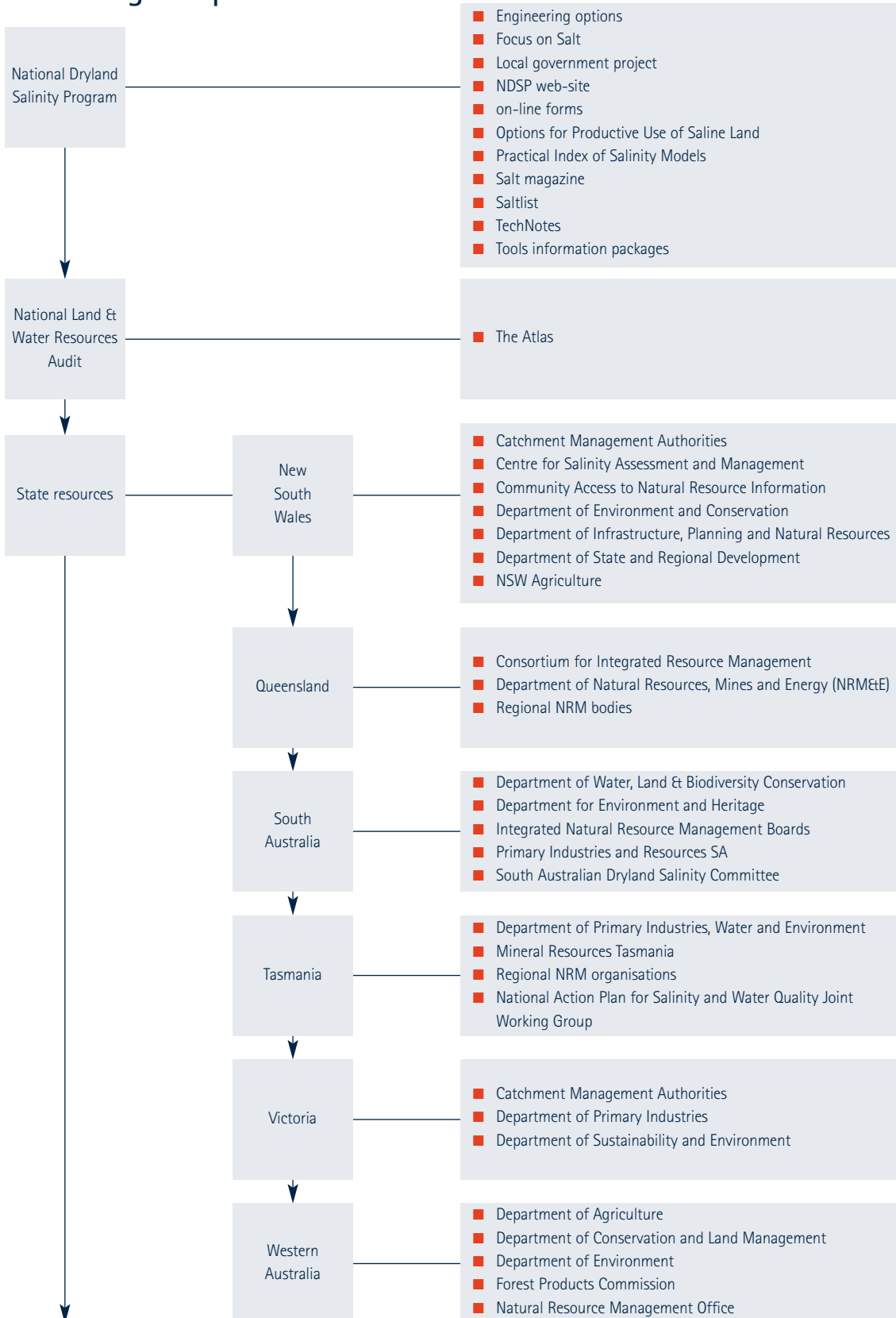
Section	No.	Action	Cost	Time	Confidence
	#4.27	Consider the institutional capacity-building strategies developed by the 'Institutional arrangements' project relevant to your region, including possible incentives and funding sources.			
	#4.28	Use the 'Community engagement toolkit' to familiarise yourself with the diversity of tools and techniques available to support community consultation processes in natural resource management.			
	#4.29	Identify opportunities and the economic rationale for progressive Local Government planning and development policies to control dryland salinity in your region, and support their implementation through incentive options, capacity-building and research.			
	#4.30	Identify the training and educational needs to support salinity management in your region, and consider regional options and partnerships for meeting priority needs.			
Where to from here?	No.	R & D Tips			
NLWRA	#4.1	Consider the <i>National Evaluation Framework</i> project as a foundation from which to build benchmarking, monitoring and evaluation mechanisms at all scales of salinity management, using consistent and transferable approaches, and drawing on adequate and reliable data.			
	#4.2	Review the strategic plan for the National Land & Water Resources Audit Phase II and/or speak with Audit staff to ascertain the extent to which the planned program of activities will meet your particular needs.			
Models, frameworks and decision support tools	#4.3	Visit the CRC for Catchment Hydrology web-site (www.catchment.crc.org.au), developing the 'Catchment Modelling Toolkit' and providing information about the 'Catchment Modelling School' for the training of model users.			
Vegetation options	#4.4	Consider the three research programs of the CRC for Plant-based Management of Dryland Salinity on targeted revegetation and profitable and sustainable grazing systems from perennial pastures in recharge areas (www.crcsalinity.com.au).			
	#4.5	Consider the objectives and program of research and communication activities for Grain & Graze targeting mixed grain and meat enterprises (www.grainandgraze.com.au).			
	#4.6	Watch the progress of the National Market-based Instruments (MBI) Pilots Program (see www.napswq.gov.au) and the NSW Environmental Services Scheme pilot project (www.dipnr.nsw.gov.au).			
	#4.7	Read the five-year plan for the Joint Venture Agroforestry Program for information on farm forestry research, development and extension (www.jvap.gov.au).			
Saline environments	#4.8	Consider the research and associated producer networks established under the Sustainable Grazing on Saline Lands (SGSL) Sub-Program (www.lwa.gov.au) and PUR\$L (www.ndsp.gov.au).			
Engineering options	#4.9	Consider the Engineering Evaluation Initiative in Western Australia, with \$2 million allocated to identify the most effective engineering options for salinity management.			
Social and institutional capacity	#4.10	Consider aspects of socio-economic research in the 'Social and Institutional Research Program' (www.lwa.gov.au), the 'Human Dimension Program' (www.mdbc.gov.au), the 'Human Capital, Communication & Information Systems Program' (www.rirdc.gov.au) and the CRC for Plant-based Management of Dryland Salinity Program 5 on 'People, land & water' (www.crcsalinity.com).			

Question 5 – How do we integrate with other natural resource management issues?

Section	No.	Action	Cost	Time	Confidence
Integrated natural resource management	#5.1	Review the strategic plan for the National Land & Water Resources Audit Phase II (www.nlwra.gov.au) and/or speak with Audit staff to ascertain the extent to which the planned activities will meet your particular regional needs.			
Salinity Investment framework	#5.2	Consider the application of the Salinity Investment Framework in your regional context as an approach to deciding between multiple objectives and prioritising investment.			
Salinity and biodiversity	#5.3	Review the SA report on salinity and biodiversity and the decision support tools identified and consider whether your regional plans give adequate recognition of the threat of salinity to biodiversity.			
Catchment condition	#5.4	Consider the map products and methods developed by the 'Catchment condition' project within the context of your regional planning.			
Landmark	#5.5	Consider the integrated, catchment-scale method developed by the <i>Landmark</i> project to assess the sustainability of current land use and scenarios for land use change for application in your region.			
Heartlands	#5.6	Consider the method trialed by the <i>Heartlands</i> initiative to develop an integrated land use map for sub-catchment-scale planning and implementation in your region			
Sediment & nutrient exports	#5.7	Consider the benefits from additional data and information to inform investment decisions, as demonstrated by the <i>Sediment & nutrient exports</i> project, and the potential to optimise investment benefits by using the prioritisation framework coupled with salinity modelling to prioritise work in your region.			
Watermark	#5.8	Use the findings, guidelines and tools developed by the <i>Watermark</i> projects to link dryland salinity management decision-making more closely with irrigation management in your catchment.			
BushTender	#5.9	Consider the auction approach trialed in the <i>BushTender</i> program in achieving multiple benefits from remnant vegetation protection in your region.			
Ecosystem services	#5.10	Consider ways of valuing and investing in ecosystem services to support integrated catchment management in your region, using the resources developed by the <i>Ecosystem services</i> project.			
National Market-based Instruments Pilots	#5.11	Consider the wide array of mechanisms being tested under the <i>National Market-based Instruments Pilot Program</i> to value and invest in ecosystem services to support integrated catchment management in your region.			
TARGET	#5.12	Consider the final reports from the TARGET project within the context of your regional planning, particularly the integration of salinity and biodiversity using 'bio-indicators'.			

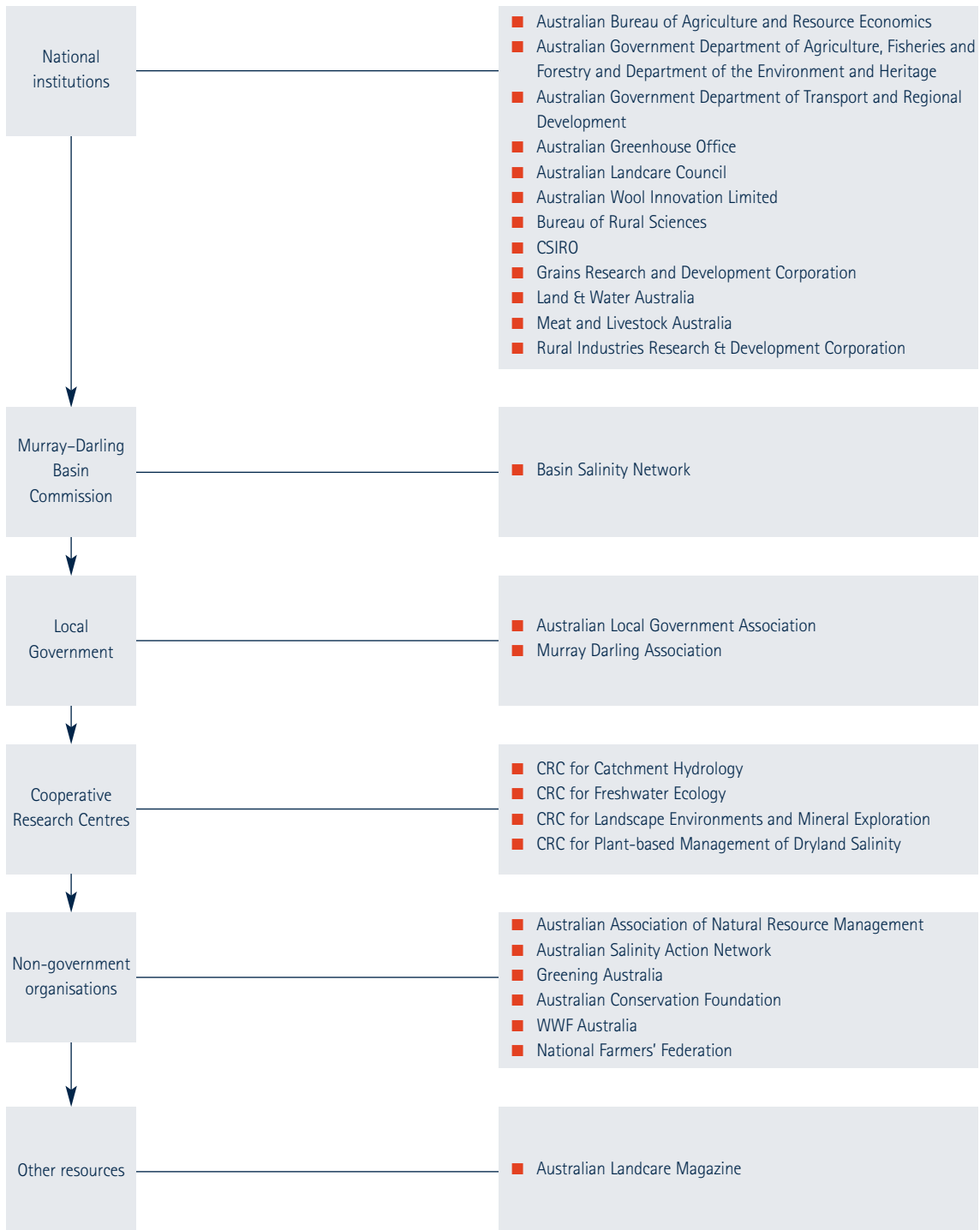
Roadmap

Where to get help?



Roadmap *continued*

Where to get help?



Where to get help

This chapter provides some direction on where to get help when it is required. It describes networks that you can join or tap into, databases, maps, web-sites, publications, contact lists and other useful information. Details are listed in alphabetical order within sections.

NATIONAL DRYLAND SALINITY PROGRAM

All NDSP information and resources are available on www.ndsp.gov.au.

Engineering options

A CD-ROM from the South Australian Dryland Salinity Committee's 2003 forum *To Drain or not to Drain* features:

- abstracts and PowerPoint presentations from the forum
- the 90 Mb NDSP *Engineering Options* decision support tool
- six fact sheets from that NDSP project
- abstracts and PowerPoint presentations from two papers delivered to the NDSP Technical Forum (*Evaluating the Impacts of Deep Drains on Crop Productivity and Environment and Engineering Options for Dryland Salinity Management*)
- a draft *Review of Engineering Options for Salinity Management* by the WA Water Resources Commission.

It is available from CanPrint Communications (freecall 1800 776 616).

Focus on Salt

Focus on Salt newsletter is produced three to four times a year for technical advisors, planners and researchers. The stories on projects and issues always have a contact listed, so you can follow up if needing additional information. Back issues may also be relevant, as many of the projects discussed operate over several years.

Local Government project

The *Local Government* project produced a CD-ROM for councils containing an information kit on dryland salinity and key contacts. Additional local government contacts are available on the CD-ROM¹ produced by the Murray Darling Association from the conference *National Local Government Salinity Summit – Community-based solutions*, held in Echuca-Moama in 2001.

NDSP web-site www.ndsp.gov.au

If you're looking for anything on dryland salinity management in Australia, then the NDSP web-site is a good place to start. The web-site has been updated to provide the best possible service to users with easy access to *Key Messages*, *Catchment and Property* level information and *Networking* resources.

On-line forum

The NDSP on-line forum, accessed from the web-site, provides an opportunity to explore salinity issues with colleagues and peers. Subscribers can initiate topics or participate in existing discussions, can be alerted to any responses to their post and can establish closed forums that are accessible only to nominated subscribers.

Options for Productive Use of Saline Land (OPUS)

The NDSP *OPUS* project investigated about 140 different innovations and enterprises built around the utilisation of saline land or water, and created a database containing a brief synopsis of each innovation. The database includes key contacts for further information and is easily accessible from the NDSP web-site.

Practical Index of Salinity Models (PRISM)

PRISM is a comprehensive collection of natural resource and salinity management modelling tools and frameworks, now available on CD-ROM as a single electronic resource. It is available from CanPrint Communications (freecall 1800 776 616).

Salt magazine

Salt magazine provides case study examples of dryland salinity management problems and solutions from across Australia. While it primarily targets farmers, many of the stories have a broader catchment dimension. Each story has a contact so you can follow up on further information. Recent editions feature short by-lines by researchers who bring the scientist's perspective to issues on the farm.

Saltlist

Saltlist is an e-mail-based network where about 600 subscribers share information about salinity research and management. You might like to join if you are a researcher, extension provider (government or private), in local government, a land manager, environmentalist, project officer, landcare group, policy advisor or educator.

The minimum level of participation is to read your e-mail from time to time. The facility has thrived because many people use it to:

- Promote events (field days, seminars, conferences, etc.)
- Alert others to new research, developments or discoveries
- Raise questions
- Contribute answers or references to these questions
- Engage in debate.

Saltlist is a moderated list, which means someone controls who is on it and the messages they can send, protecting participants from viruses, e-mail avalanches, irrelevant and unwanted messages. Subscribe by e-mailing majordomo@list.senet.com.au with the message <<subscribe saltlist>>.

TechNotes

NDSP *TechNotes* are fact sheets that represent a valuable summary of each project undertaken through the NDSP. They can be downloaded directly from the web-page.

TECH NOTE 001 – Structural adjustment in agriculture and capacity to implement catchment plans

Project Team: Read Sturgess and Associates; Neil Barr, Victorian Department of Sustainability & Environment

TECH NOTE 002 – Predicting the combined environmental impact of catchment management regimes on dryland salinity

Project Manager: Lu Zhang, CSIRO

TECH NOTE 003 – Appraisal of infrastructure assets under threat

Project Team: Mike Young, CSIRO/Dames and Moore with RECC/PPK

TECH NOTE 004 – Technical assessment of desalination technologies in Australia

Project Manager: Geoff Moyle, URS Australia

TECH NOTE 005 – Evaluating the efficacy of engineering options

Project Manager: Chris McAuley and Martin Robinson, Sinclair Knight Merz

TECH NOTE 006 – Risk and restoration potential for remnant vegetation in salinising landscapes

Project Manager: Richard Hobbs, Murdoch University

TECH NOTE 007 – Biogeochemical and physical processes in saline soils and potential reversibility

Project Manager: Rob Fitzpatrick, CSIRO

TECH NOTE 008 – Understanding the recruitment biology of vegetation communities on saline soils

Project Manager: Michelle Carey, Murdoch University

TECH NOTE 009 – Determining the costs of dryland salinity in the Murray–Darling Basin

Project Team: Dr Suzanne Wilson, Wilson Land Management Services and Richard Ivey, Ivey ATP

TECH NOTE 010 – Generation and delivery of salt and water to streams on a catchment scale

Project Manager: Hamish Cresswell, CSIRO

TECH NOTES 011 – Evaluating the impacts of deep drains on crop productivity and the environment

Project Manager: Tom Hatton, CSIRO

TECH NOTE 012 – Catchment classification for salinity management

Project Team Leader: Glen Walker, CSIRO

TECH NOTES 013 – Developing a national evaluation framework for dryland salinity management

Project Manager: Jane Coram, Bureau of Rural Sciences

TECH NOTES 014 – Delineation of potential salinity hazard in Queensland cropping lands

Project Manager: Ian Gordon, Qld Dept of Natural Resources

TECH NOTES 015 – Water table change in Western Slopes cropping areas of NSW

Project Manager: Richard Cresswell, Bureau of Rural Sciences

TECH NOTES 016 – Enhancing institutional support for managing dryland salinity

Project Manager: Greg Hayes, Virtual Consulting Group

TECH NOTE 017 – Assessment of a system to predict the loss of aquatic biodiversity from changes in salinity

Project Manager: Ben Kefford, RMIT University

TECH NOTE 018 – Farming systems with lower recharge for Western Australia

Project Manager: Jon Warren, Western Australian Department of Agriculture

TECH NOTE 019 – Million Hectares for the Future

Project Team: Jon Warren, Western Australian Department of Agriculture; Jay Cummins, Primary Industries and Resources South Australia

TECH NOTE 020 – Options for the Productive Use of Salinity (OPUS)

Project Team: Stephanie Bolt, Parsons Brinckerhoff (formerly PPK)

TECH NOTE 021 – Simple device for monitoring deep drainage

Project Manager: Paul Hutchinson, CSIRO

TECH NOTE 022 – Tools to Investigate and Plan for Improved Management of Dryland Salinity in the Murray–Darling Basin

Project Team: Darrel Brewin, Darrel Brewin and Associates; Stephanie Bolt, Parsons Brinckerhoff (formerly PPK) and Phil Dyson, Phil Dyson and Associates

TECH NOTE 23 – Enhancing the capacity of Local Government to contribute to the management of dryland salinity

Project Manager: Trevor Budge, Research, Planning and Design Group

TECH NOTE 24 – FLOWTUBE rapid catchment appraisal model

Project Manager: Christopher Clarke, Murdoch University

Tools information packages

The *Tools information packages* provide key contacts for dryland salinity management. The *Salinity Information Package* contains over 40 information sheets, which provide a step-by-step framework to understand the complex relationships between salinity, socio-economics, land systems and management options. *Regional Information Packages* have been structured on the *Groundwater Flow Systems Framework* to provide regional stakeholders with access to the best scientific information about their groundwater flow systems.

NATIONAL LAND & WATER RESOURCES AUDIT

The Atlas

The Australian Government Department of the Environment and Heritage (www.deh.gov.au/atlas) manages the *Australian Natural Resources Atlas* (the Atlas) on behalf of the National Land and Water Resources Audit (www.nlwra.gov.au), an internet-based 'one-stop-shop' for information on Australia's natural resources. The Atlas provides summary data and information at National, State and regional scales and the full *Australian Dryland Salinity Assessment 2000* report.

Audit Phase II (2002–07) will build on existing data, maps and information. Its Strategic Plan2 is available via the web-site.

STATE RESOURCES

New South Wales

Catchment Management Authorities (CMA)

The catchment blueprints are advisory "whole-of-government" plans for integrated catchment management that will guide the long term management of natural resources in NSW for the next 10 years. Prepared by catchment management boards, the Hunter Catchment Management Trust, the Coxs River and Wollondilly Catchment Management Committees and the Hawkesbury Nepean Local Government Advisory Group, the blueprints set overarching priorities for investment in natural resource management, consistent with NSW and Commonwealth Government policy.

Border Rivers/Gwydir	(02) 6764 5906; Adrian.Harte@dipnr.nsw.gov.au
Central West	(02) 6393 4322; Kate.Lorimer-Ward@dipnr.nsw.gov.au
Hawkesbury-Nepean	(02) 4828 6702; Bernie.Bugden@dipnr.nsw.gov.au
Hunter/Central Rivers	(02) 4930 1030; g.evans@hcmt.org.au
Lachlan	(02) 6341 9311; Peter.Sparkes@dipnr.nsw.gov.au
Lower Murray Darling	(03) 5881 9205; Kaye.Dalton@dipnr.nsw.gov.au
Murray	(03) 5881 9205; Kaye.Dalton@dipnr.nsw.gov.au
Murrumbidgee	(02) 6923 0439; John.Searson@dipnr.nsw.gov.au
Namoi	(02) 6764 5915; Tony.Page@dipnr.nsw.gov.au
Northern Rivers	(02) 6640 2183; Michael.Pitt@dipnr.nsw.gov.au
Southern Rivers	(02) 4224 9606; Noel.Kesby@dipnr.nsw.gov.au
Sydney Metro	(02) 9895 7536; Peter.Dixon@dipnr.nsw.gov.au
Western	(02) 6883 3046; Daryl.Green@dipnr.nsw.gov.au

Centre for Salinity Assessment and Management (CSAM)

CSAM (www.agric.usyd.edu.au/csam/index.html) has been established within the University of Sydney, conducting research into generic aspects of salinity such as mapping and assessment techniques, as well as focusing on aspects of dryland, irrigation and urban salinity. The education program aims to teach the causes of soil and water salinity and options for management and will provide education resources for both secondary and tertiary education sectors.

Community Access to Natural Resource Information (CANRI)

The CANRI web-site, www.canri.nsw.gov.au, combines environmental information from NSW Government agencies and other organisations tailored for community-based local and regional environmental management. It is the first program of its kind to offer integrated access to maps and other data held at various internet sites by a diverse group of natural resource agencies and other stakeholders.

Department of Environment and Conservation

The *National Parks and Wildlife Service* (NPWS) (tel: (02) 9585 6444; www.nationalparks.nsw.gov.au) is part of the *Department of Environment and Conservation* – the main government conservation agency in New South Wales. NPWS is conducting projects on Aboriginal heritage and salinity and the impacts of salinity on biodiversity.

Department of Infrastructure, Planning and Natural Resources (DIPNR)

DIPNR (tel: (02) 9762 8044; www.dipnr.nsw.gov.au) coordinates land use and transport planning, infrastructure development and natural resource management. The DIPNR web-site contains information on types of salinity, as well as the causes, impacts and management options in both rural and urban areas. It contains information on the NSW Salinity Strategy, with a number of downloadable research reports and an extensive reference list.

Department of State and Regional Development

DSRD (tel: (02) 9228 3111; www.business.nsw.gov.au) has developed a Salinity Business Development Program to encourage and assist businesses to take advantage of opportunities arising from productive uses of salt-affected land and water. Information about the program and potential business opportunities arising from salinity in fields such as agriculture, forestry, aquaculture and salt harvesting is available on the web-site. The report *A Solution to Urban Salinity* is on the web-site – search for salinity.

NSW Agriculture

NSW Agriculture (tel: (02) 6391 3100; www.agric.nsw.gov.au/reader/salinity) is involved in agricultural research, advisory services, education and regulation and provides practical farm production solutions for profitable agriculture and a better environment. The web-site contains information on some of the measures that have been implemented to manage both dryland and irrigation salinity.

A Strategic Framework for Salinity Research and Development in NSW, a *Register of Existing Salinity R&D Projects* and *NSW Salinity R&D Investment Portfolio* are all available from the web-site.

Queensland

Consortium for Integrated Resource Management (CIRM)

CIRM (tel: (07) 3896 9471; www.cirm.org.au) aims to facilitate collaborative research across and beyond its consortium of seven organisations – three government departments (DPI&F, EPA and NRM&E), three universities (Griffith, University of Queensland and Central Queensland University) and CSIRO.

Department of Natural Resources, Mines and Energy (NRM&E)

NRM&E (tel: (07) 3896 9645; www.nrm.qld.gov.au) plays a critical role in the stewardship of Queensland's natural resources. The department manages and allocates the State's land, water, mineral and petroleum resources, and manages native vegetation and the control of pest plants and animals. The web-site www.nrm.qld.gov.au/salinity has salinity fact sheets, hazard maps and information about the National Action Plan for Salinity and Water Quality.

Regional NRM Bodies

Fifteen Community-based NRM bodies have been established in Queensland. Each NRM group is currently developing a natural resource management plan that aims to achieve the best and most effective NRM results for their region. These plans and associated investment strategies will be loaded on to a Queensland Whole-of-Government web site to be released in April.

The NRM bodies are:

Burdekin Dry Tropics Board	(07) 4724 3544; kim@burdekindrytropics.org.au
Burnett-Mary Regional Group	(07) 4132 8324; deborah.scott@burnettmarynrm.org.au
Cape York	(07) 4046 6767; bruce.rampton@env.qld.gov.au
Condamine Alliance	(07) 4620 0101; kathryngalea@netspace.net.au
Desert Channels	(07) 4658 0600; leanne.kohler@nrm.qld.gov.au
FNQ NRM Ltd	(07) 4061 6477; nrmboard@znet.net.au
Fitzroy Basin Association	(07) 4921 2843; s.m.Christensen@cqu.edu.au
Mackay Whitsunday	(07) 4957 9526; julia@mwnrm.org.au
Northern Gulf	(07) 4031 3432; mitchell@cypda.com.au
Old Murray Darling Committee	(07) 4637 6276; g.penton@landcare.org.au
SEQ Inc	(07) 3211 4404; adrian@nrmseq.com
SEQ Western Catchments	(07) 3816 9713; operations@seqwcq.com.au
Southern Gulf Catchments	(07) 4749 4805; ccurry@southerngulfcatchments.com.au
South West NRM	(07) 4654 7382; exec.officer@southwestnrm.org.au
Torres Strait	(07) 4069 1446; victor.mcgrath@icc.qld.gov.au

South Australia

Department of Water, Land & Biodiversity Conservation (DWLBC)

DWLBC (tel: (08) 8463 6800; www.dwlbc.sa.gov.au) is the lead agency with responsibility for the Natural Resources Management Bill 2003, the River Murray Act and the Upper South East Dryland Salinity & Flood Management (USE DS&FM) Act. It also provides executive support to the SA Dryland Salinity Committee (tel: (08) 8303 9345). The DWLBC web-site gives access to information on dryland salinity and how it is being addressed in SA – go to *Natural Resources* then *Soil*. It carries numerous fact sheets that are also available on the SA DSC web-site (www.saltcontrols.com).

The Centre for Natural Resource Management (tel: (08) 8303 9703) undertakes research-related roles, including oversight of the South Australian R&D component of the National Action Plan for Salinity and Water Quality. It facilitates and encourages collaboration amongst researchers and supports regional delivery of improved on-ground outcomes. The Centre identifies and negotiates supplementary funding sources for NRM research, from both the public and private sectors, with the aim of leveraging NAP research funding.

Department for Environment and Heritage (DEH)

DEH (tel: (08) 8204 9000; www.environment.sa.gov.au) has a particular interest in the impact of salt-affected land and water on biodiversity. It provides technical support to the wetlands conservation component of the USE DS&FM Program and its biodiversity trading model. The Environment Protection Authority (EPA) presents the State of the Environment Report for SA, outlining the current state or condition of South Australia's environment, the pressures on it and trends over time.

Integrated Natural Resource Management (INRM) Boards

Community based INRM groups have been established in eight regions covering the entire State. Each INRM group has developed or is currently developing a natural resource management plan that aims to achieve the best and most effective NRM results for their

region. These plans, and associated investment strategies, where they have been developed, can be accessed at www.nrm.sa.gov.au.

The NRM regions are:

Aboriginal Lands	(08) 8260 0266; jhammat@alt.sa.gov.au
Eyre Peninsula	(08) 8680 2653; wnacrisp@bigpond.com
Kangaroo Island	(08) 8553 3136; richards@kin.net.au
Mt Lofty Ranges & Greater Adelaide	(08) 8391 7501; Burston.Jim@saugov.sa.gov.au
Murray–Darling Basin	(08) 8532 1432; mdbinrm@lm.net.au
Northern and Yorke Agricultural District	(08) 8842 6253; Stanley.trudie@saugov.sa.gov.au
Rangelands	(08) 8648 5194; white.andrew2@saugov.sa.gov.au
South East	(08) 8723 1057; senrcc@lcrdb.com

Primary Industries and Resources SA (PIRSA)

SA Research & Development Institute (SARDI) (tel: (08) 8303 9577; www.sardi.sa.gov.au) undertakes research into pastures, soils and sustainable resources including their relationship to dryland salinity. SARDI is a major participant in the CRC for Plant-based Management of Dryland Salinity with research undertaken at the Waite Institute and at Struan.

Rural Solutions SA (tel: (08) 8568 6418; www.pir.sa.gov.au), the service provider arm of PIRSA, is actively involved in salinity management through the SALTSMART Program (Salinity Management Action Response Team). The SALTSMART team undertakes:

- Regional and catchment planning for salinity management within INRM (see www.saltcontrols.com)
- Implementation of catchment plans using a multi-disciplinary skills base
- Salinity mapping and monitoring
- Salinity research
- Identifying new opportunities and formulating investment strategies
- Catchment and groundwater modelling
- Training and education programs.

South Australian Dryland Salinity Committee (SA DSC)

The SA DSC (tel: (08) 8303 9345; www.saltcontrols.com) oversees implementation and periodic review of the *SA Dryland Salinity Strategy*. This strategy can be found on the web-site www.saltcontrols.com that also features updates on State salinity projects such as Salt Mapping, the USE DS&FM Program, Sustainable Grazing on Saline Lands, individual catchment salinity plans, and numerous fact sheets.

Tasmania

Department of Primary Industries Water and Environment (DPIWE)

DPIWE (tel: (03) 6233 8011; www.dpiwe.tas.gov.au) is the lead agency for salinity management in Tasmania, being responsible at State level for the National Action Plan (NAP) for Salinity and Water Quality, and supporting Regional NRM Committees and the NAP Working Group.

It also facilitates dryland salinity management through industry development, natural resource management, land information services, environmental protection, policy development and the conservation of natural heritage and other salinity prevention and management activities.

Mineral Resources Tasmania

Mineral Resources Tasmania (tel: (03) 6233 8377; www.mrt.tas.gov.au) provides essential information for land management (geological, groundwater geophysical data and information) and salinity project support.

Regional NRM organisations

These organisations are responsible for the development and implementation of regional NRM plans in Tasmania:

NRM North (03) 6336 5219; www.nrmtas.com.au

NRM South (03) 6234 2248; www.nrmtas.com.au

NRM NW (03) 6431 7186; www.nrmtas.com.au

The National Action Plan for Salinity and Water Quality Joint Working Group

This is a joint committee of the Northern and Southern regions that develop and deliver strategies to address specific salinity and water quality issues in the Tasmanian NAP region.

It can be contacted through the NRM North or NRM South regional organizations (www.naptas.com.au).

Victoria

Catchment Management Authorities (CMA)

Victoria has an integrated catchment management system established under the *Catchment and Land Protection Act 1994* (the CaLP Act). Under the CaLP Act, Victoria is divided into 10 catchment regions and a Catchment Management Authority established for each.

CMA Boards are responsible for the development of strategic direction for land and water management. They set priorities, evaluate the effectiveness of outcomes, monitor the external and internal environment and identify opportunities.

Implementation Committees are the conduits for local community input, and are responsible for development of detailed work programs and oversight of on-ground program delivery for specific issues or sub-catchments.

CMA staff oversee development and implementation of programs and liaise with the community, government and other catchment-focused organisations.

Corangamite (03) 5232 9100; www.ccma.vic.gov.au

East Gippsland (03) 5153 0462; www.egcma.vic.gov.au

Glenelg-Hopkins (03) 5571 2526; www.glenelg-hopkins.vic.gov.au

Goulburn-Broken (03) 5822 2288; www.gbcma.vic.gov.au

Mallee (03) 5051 4377; www.malleecma.vic.gov.au

North Central (03) 5448 7124; www.nccma.vic.gov.au

North East (02) 6043 7600; www.necma.vic.gov.au

Port Phillip & Westernport (03) 9785 0183; www.ppwcm.vic.gov.au

West Gippsland (03) 5175 7800; www.wgcma.vic.gov.au

Wimmera (03) 5382 1544; www.wcma.vic.gov.au

Department of Primary Industries (DPI)

DPI's Agriculture Division (tel: 136 186, e-mail: customer.service@dpi.vic.gov.au; www.dpi.vic.gov.au) is concerned with improving the profitability and market competitiveness of agricultural industries while ensuring that such operations remain sustainable and environmentally responsible. The Department aims to achieve this through research, industry development and extension activities. The web-site has extensive information on salinity – go to *Agriculture Et Food* and then *Soil and Water*.

Primary Industries Research Victoria (PIRVic) is the R&D division within DPI with capabilities in specific fields of science including: plant production sciences, landscape systems and soil and water sciences. PIRVic centres undertaking dryland salinity R&D are:

- Bendigo Centre (tel: (03) 5430 4444; www.dpi.vic.gov.au/clpr) specialising in natural resource management including salinity and land capability
- Rutherglen Centre (tel: (02) 6030 4500; www.dpi.vic.gov.au/rutherglen) with expertise in modelling, farming systems and landscapes for production and environmental gains
- Hamilton Centre (tel: (03) 5573 0900; www.dpi.vic.gov.au) developing and evaluating annual and perennial plant species and livestock systems for recharge and discharge management.

Department of Sustainability and Environment (DSE)

DSE (tel: 136 186, e-mail: customer.service@dse.vic.gov.au; www.dse.vic.gov.au) is responsible for managing Victoria's natural and built environments and for providing a policy focus on sustainability. Its responsibilities include catchment management; conservation, recreation and public land stewardship; water sector development and services; forests and fire management; sustainability policy and programs; sustainable cities and regions; biodiversity; heritage; parks and Crown land; land information; greenhouse and sustainable energy policy.

The NAP/NHT office is located in the DSE at Epsom in Bendigo (tel: (03) 5430 4432, e-mail: NAP.NHT@dse.vic.gov.au).

Western Australia

Department of Agriculture (DAWA)

DAWA (tel: (08) 9368 3333; www.agric.wa.gov.au) is responsible for policy, research and information provision on dryland salinity affecting agricultural areas and rural towns. Main project areas include engineering water management, chemical and sediment export, land use assessment and farming systems including sustainable grazing on saline lands. The web-site has a large number of reports and fact sheets dealing with salinity – go to *Land Water + Environment*. The State branches of the Natural Heritage Trust and National Landcare Program are located within the South Perth head office.

Department of Conservation and Land Management (CALM)

CALM (tel: (08) 9334 0333; www.calm.wa.gov.au) deals with conservation of ecosystems, oil mallee research, wetlands, biodiversity and other issues. The web-site has many reports on these issues – search for *salinity*.

Department of Environment

This department (tel: (08) 9278 0300; www.environment.wa.gov.au) brings together the former Department of Environmental Protection (DEP) and the Water and Rivers Commission (WRC).

WA's key regulatory body, it manages water quality, particularly for irrigation water and stream flows, and administers the Salinity Investment Framework. The web-site has salinity information under the following headings:

- Dealing with Salinity in Wheatbelt Valleys
- Engineering Evaluation Initiative
- Salinity and Land Use Impacts Series
- Salinity Engineering Newsletter.

Forest Products Commission (FPC)

FPC (tel: (08) 9475 8888; www.fpc.wa.gov.au) is WA's trading enterprise for plantation management and commercial production from renewable timber resources. It manages tree-planting programs, sometimes in association with private landholders (e.g. the Infinitree Program which aims to increase tree planting rates to 20,000 ha per annum, partly with the aim of addressing salinity). FPC has a dedicated research program which has identified tree and shrub species with the ability to withstand defined salt levels.

Natural Resource Management Office

This aims to co-ordinate State Government activities across agencies in the natural resource management field. It is located at the Department of Agriculture (tel: (08) 9368 3164) and has close links to the regional NRM groups which are recognised for funding applications through the Natural Heritage Trust, National Action Plan for Salinity and Water Quality and the National Landcare Program. The regional groups are (from north to south):

- Rangelands NRM Coordinating Group (08) 9455 5477;
kelvin.baldock@greenbase.com.au
- Northern Agricultural Catchments (08) 9954 3354; www.calci.org Council (NACC)
- Avon Catchment Council (ACC) (08) 9690 2251; www.avonicm.org.au
- Swan Catchment Council (SCC) (08) 9374 3309; www.wrc.wa.gov.au/swanavon
- South West Catchments Council (SWCC) (08) 9780 6168; swcc@agric.wa.gov.au
- South Coast Regional Initiative (08) 9892 8537; Planning Team (SCRIPT)
www.script.asn.au

NATIONAL INSTITUTIONS

Australian Bureau of Agriculture and Resource Economics (ABARE)

ABARE (tel: (02) 6272 2000) provides quarterly forecasts for the full range of export commodities. Its recent research on the economics of salinity control and related policy issues has made an important contribution to the development of the Murray–Darling Basin Salinity Strategy (www.abareconomics.com/research/landwater/salinity.html). ABARE has also provided insights into the problem of salinity control that will be considered in regional plans being developed under the National Action Plan for Salinity and Water Quality.



Australian Government Departments of Agriculture, Fisheries and Forestry (DAFF) and Department of the Environment and Heritage (DEH)

DAFF and DEH jointly administer the National Action Plan for Salinity and Water Quality (NAP). The web-site (www.napswq.gov.au/index.html) provides information on the history of the NAP and lists current events. Fact sheets, reports, maps, discussion papers and media releases can be accessed. Links are provided to a range of useful web-sites and an e-mail subscription service is available.

Australian Government Department of Transport and Regional Services (DOTARS)

The DOTARS web-site (www.dotars.gov.au) lists dryland salinity among a range of environmental issues affecting regional Australia. Its corporate plan acknowledges 'the increasing importance of environment issues, particularly salinity and global warming, and the need to factor environmental impacts into decision making.'

Australian Greenhouse Office (AGO)

The AGO's web-site (www.greenhouse.gov.au) provides information on the implications of climate change on agriculture and other industries. A range of fact sheets and other publications can be downloaded from the web-site.

Australian Landcare Council (ALC)

The ALC (tel: (02) 6295 8199; www.daff.gov.au and search for landcare) is the Australian Government's key advisory body on landcare policy. It provides advice on issues relevant to the sustainable management of natural resources including salinity, sustainable agriculture, catchment management, greenhouse and weed management.

Australian Wool Innovation (AWI) Limited

AWI Limited (tel: (02) 9299 5155; www.wool.com.au) is a fully independent public company owned by Australian woolgrowers. Almost 25 per cent of wool producers say that salinity is an on-farm issue. A five-year research partnership between AWI and Land & Water Australia aims to find productive and sustainable solutions to salinity and other natural resource management issues for wool producers. Part of the program involves new research on maximising farm returns through the Land, Water and Wool *Sustainable Grazing on Saline Lands (SGSL) sub-program*. Further information can be found at www.landwaterwool.gov.au. *Beyond the Bale* is AWI's free bi-monthly newspaper providing project and technical information for woolgrowers, including updates on research, trials, farmer activities and case studies.

Bureau of Rural Sciences (BRS)

The BRS (tel: (02) 6272 4282; www.daff.gov.au then following the link under the specialist areas menu) is the scientific bureau within the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF). BRS provides nationally focused scientific advice to support evidence-based policy development and decision-making by government. The Bureau's Salinity Risk Management Sciences Program provides data on land condition to support the NAP. Multi-disciplinary research techniques, including airborne geophysical survey techniques, are used to develop models to predict the outcomes of various salinity management scenarios.

CSIRO

CSIRO Forestry & Forest Products (tel: (02) 6281 8211; www.ffp.csiro.au) researches forestry, wood and paper sciences. Some of this research is relevant to recharge management and productive use of saline land.

CSIRO Land and Water (tel: (02) 6246 5700; www.clw.csiro.au) and its partners seek to develop innovative solutions to Australia's land and water management challenges. Land and Water's skill base includes expertise in hydrology, hydrogeology, soil science, biology, ecology, atmospheric science, remote sensing, physics, chemistry, economics and social science.

CSIRO Plant Industry (tel: (02) 6246 4911; www.pi.csiro.au) applies strategic research in the plant sciences to promote profitable and sustainable agri-food, fibre and horticultural industries, develop novel plant products and improve natural resource management.

CSIRO Sustainable Ecosystems (tel: (02) 6242 1600; www.cse.csiro.au) focuses on research to underpin the sustainable development of rural and regional Australia.

These Divisions of CSIRO are active and important participants in research currently conducted by the CRC for Plant-based Management of Dryland Salinity.

Grains Research and Development Corporation (GRDC)

GRDC (tel: (02) 6272 5525; www.grdc.com.au) is responsible for planning, investing and overseeing research and development, and delivering improvements in production, sustainability and profitability across the Australian grains industry. Information on dryland salinity on the web-site is organised into topics of interest relevant to growers, researchers and consumers. GRDC's quarterly newsletter *Groundcover* brings grain growers some research information on salinity management.

Land & Water Australia (LWA)

LWA (tel: (02) 6263 6000; www.lwa.gov.au) invests in more than 20 R&D programs in five arenas: sustainable primary industries; rivers; vegetation; future landscapes; and cross-cutting activities. The NDSP is one of these R&D programs, but many others are relevant to salinity and its impacts. LWA has a comprehensive database of stakeholders in dryland salinity management, used by NDSP to distribute *Salt* magazine and *Focus on Salt*.

Meat and Livestock Australia (MLA)

MLA (tel: (02) 9463 9333; www.mla.com.au) provides research and development, market information and marketing to benefit the red meat industry. MLA's *Sustainable Grazing Systems (SGS)* program developed *The Professional Producer's Guide* that incorporates a comprehensive collection of best farming practices including management of soil, water resources and pastures. Also from SGS is *Tips & Tools*, practical and easy to follow information sheets on a range of topics including pastures and grazing management, and natural resource management. A monthly newsletter *Feedback*, sometimes profiles grazing issues related to salinity.

Rural Industries Research & Development Corporation (RIRDC)

RIRDC (tel: (02) 6272 4539; www.rirdc.gov.au) manages and funds research and translates results into practical outcomes for industry development. Salinity risk and management issues are investigated under the *Resilient Agricultural Systems Research Program* that aims to foster the development of agri-business systems that have sufficient diversity, integration, flexibility and robustness to be resilient enough to respond opportunistically to change. Fact sheets and a range of free research publications are available from the web-site. RIRDC is also a major partner in the Joint Venture Agroforestry Program (JVAP).

The JVAP (www.rirdc.gov.au/programs/aft.htm) has the following key roles:

- Initiating, coordinating and communicating agroforestry research and development
- Assisting in the removal of policy and institutional impediments
- Assisting in the development of new tree-based industries
- Designing large-scale commercial agroforestry systems in lower rainfall areas to address environmental issues.

JVAP communicates research via its Agroforestry Guideline Series, a Manual Series (which includes *Trees, water and salt: an Australian guide to using trees for healthy catchments and productive farms*), the Master TreeGrower training program and Research Reports & Updates, Short Reports and Newsletters.

MURRAY–DARLING BASIN COMMISSION

The Murray–Darling Basin Commission (tel: (02) 6279 0100; www.mdbc.gov.au) has a charter 'to promote and co-ordinate effective planning and management for the equitable, efficient and sustainable use of water, land and environmental resources of the Murray–Darling Basin'. *The Basin Salinity Management Strategy 2001–2015* guides communities and governments in working together to control salinity and protect key natural resource values within their catchments, consistent with principles of the *Integrated Catchment Management Policy Statement*. It establishes targets for the river salinity of each tributary valley and the Murray–Darling system itself, that reflect the shared responsibility for action both between valley communities and between States.

Many MDBC publications and reports can be downloaded from the web-site (go to *Publications*) or ordered on-line.

Basin Salinity Network

Basin Salinity Network (www.ndsp.gov.au/salinity/tools/) links people across the Murray–Darling Basin who require support for local and regional salinity planning or can offer experienced salinity management advice. The aim is to develop stronger links so that people can gain access to information, technical advice and support. Members of the network come from a broad range of backgrounds.

LOCAL GOVERNMENT

Australian Local Government Association (ALGA)

ALGA (tel: (02) 6122 9400; www.alga.asn.au) is a federation of associations in each of Australia's six States and two Territories. It is a member of the Council of Australian Governments, alongside the Commonwealth, States and Territories, as well as numerous ministerial councils and intergovernmental committees. Local government is also an active partner in a range of national strategies for environmental management. Information on ALGA and its role in dryland salinity management can be found at its web-site.

Murray Darling Association (MDA)

The MDA (tel: (08) 8226 0582; www.mda.asn.au) has developed a Dryland Salinity Project as a pilot project to provide local government with data and information on the impact of salinity. This encourages local government to undertake salinity risk assessment and provides management tools.

COOPERATIVE RESEARCH CENTRES

CRC for Catchment Hydrology

This CRC (tel: (03) 9905 2704; www.catchment.crc.org.au) provides land and water managers with capability to predict, in an operating environment of high climatic variability, the hydrologic impacts of catchment management. It runs six multi-disciplinary research programs:

- Predicting catchment behaviour
- Land use impacts on rivers
- Sustainable water allocation
- Urban stormwater quality
- Climate variability
- River restoration.

CRC for Freshwater Ecology

The CRC for Freshwater Ecology (tel: (02) 6201 5168; www.environmentdirectory.com.au) is a national research centre specialising in temperate river and wetland ecology. The CRC develops ecological understanding to improve and protect Australia's inland waterways by collaborative research, education, resource management, policy advice and community liaison.

CRC for Landscape Environments and Mineral Exploration (CRC LEME)

CRC LEME (tel: (08) 6436 8695; <http://leme.anu.edu.au>) has four core research programs:

- Regolith geoscience
- Mineral exploration in areas of cover
- Environmental applications of regolith geoscience
- Salinity mapping and hazard assessment.

CRC for Plant-based Management of Dryland Salinity

This CRC (tel: (08) 6488 8559; www.crcsalinity.com) focuses on developing profitable and sustainable farming systems to manage both recharge and discharge. The CRC brings together research effort from six State government agencies, three universities and CSIRO to address these issues through seven research programs:

- Education
- Function of natural ecosystems
- New and improved plant species
- New farming systems
- Economic and social assessment
- Animal systems
- Biodiversity.

These research programs are outlined in the strategic report *Research Portfolio 2002/3*³ that can be found at the web-site.

NON-GOVERNMENT ORGANISATIONS

Australian Association of Natural Resource Management (AANRM)

AANRM (tel: (02) 6247 4137; www.soil-water.org.au) is a network of groups and individuals with a common interest in natural resource management including salinity. It publishes a journal and maintains a web-site.

Australian Salinity Action Network (ASAN)

ASAN (www.asan.net.au) seeks to coordinate and share information between all stakeholders involved in addressing the impact of salinity. It provides members with:

- Networking
- Information sharing
- Advisory services and problem solving
- Promotion of technologies
- Trialing and testing salinity initiatives
- An advocacy group for emerging industries
- Community education and awareness raising campaigns
- Salinity-based research

Greening Australia

Greening Australia (tel: (02) 6281 8585; www.greeningaustralia.org.au) is a national organisation with a network of over 300 staff in 80 locations. Many of these are involved in on-ground and strategic dryland salinity management planning and management at regional, State and National levels. The national web-site is a good source of information and contacts.

Greening Australia has an initiative called *Changing lives + Landscapes* that aims to achieve river and landscape repairs worth \$10 million. It will use its regional networks to bring farmers, indigenous communities and scientists together to tackle land and water degradation. Land & Water Australia, CSIRO and the CRC for Freshwater Ecology will provide the scientific back-up for public participation programs.

Australian Conservation Foundation (ACF)

The ACF (tel: (03) 9345 1111; www.acfonline.org.au) has an alliance with leading winemaker Southcorp Ltd to raise awareness of salinity. An output of this alliance is a community information kit *Salt: Nature in the Balance* that can be ordered on-line. The ACF has campaigned for a national policy and investment response to salinity, including biodiversity conservation and commitment of necessary funding.

WWF Australia

WWF Australia (tel: 1800 032 551; www.wwf.org.au), formerly known as World Wildlife Fund and World Wide Fund For Nature, works to help protect and sustain biologically diverse environments via on-ground field projects and seeks to influence policy formulation.

National Farmers' Federation (NFF)

The NFF (tel: (02) 6273 3855; www.nff.org.au) is the peak lobby group for Australian farmers and farmer organisations.

OTHER RESOURCES

Australian Landcare Magazine

Australian Landcare Magazine is published quarterly and features regular articles from LWA (including the NDSP), MDBC, RIRDC and AANRM. Selected articles are available at www.australianlandcaremagazine.com.au.



Glossary

Airborne geophysics	Remote sensing from the air of geophysical properties using electromagnetic induction, magnetics or radiometrics.
Agronomy	Biophysical science supporting agricultural production.
Agroforestry	A land management system enabling the production of trees and agriculture products from the same land unit.
Alley (farming)	A farming system in which belts of perennial vegetation (e.g. trees, saltbush) are interspersed with alleys of land, for productive use of annual species (crops, understorey).
Alluvium	Unconsolidated sediments (clay, gravel, sand) deposited by rivers in low-lying areas and flood plains.
Annuals	Plants that live for one growing season only.
Aquaculture	Farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants.
Aquifer	A layer of rock or unconsolidated sediments which holds and allows water to move through.
Aquifer, confined	An aquifer overlain by a confining bed (e.g. clay).
Aquifer, perched	An aquifer above and separated from a major aquifer by an impermeable layer of rock or sediment (clay).
Aquifer, unconfined	An aquifer in which there is no confining bed between the groundwater and the soil surface. The water table is the upper boundary of the groundwater.
Aquifer transmissivity	The ability of an aquifer to transmit groundwater.
Bedrock	Unweathered hard rock at the base of a soil profile.
Biodiversity	The variety of life forms – the different plants, animals and microorganisms, the genes they contain and ecosystems they may form.
Biophysical	Relating to biological and physical processes.
Break of slope	The line across a landscape at which the surface slope is reduced and where the hydraulic conductivity of the underlying material or the hydraulic gradient decrease.
Capillary rise	The drawing up of groundwater through soil pores caused by evaporation and the upward pull of surface tension forces overcoming the downward pull of gravity.
Catchment	The area of land drained by a river and its tributaries.
Colluvial (deposits)	Deposits of loose material that have been carried by gravity and are usually found at the foot of slopes or cliff lines.
Crop rotation	The growing of different crops and pastures on the same paddock in annual succession. e.g. pasture-grain-legume or pulse-legume-grain; etc.
Deep drainage	Water that drains from below the root-zone into underlying aquifer systems. Also called leakage. In some States the term 'deep drain' is used to describe an engineered drain that intercept lateral flow, through-flow or base-flow.
Desalination	Removal of salt from water.
Direct seeding	Sowing seeds directly into the ground for revegetation.
Discharge	Seepage of groundwater into streams and/or to the land surface, actively from springs or passively by evaporation.
Discharge area	Area affected by groundwater discharge.
Drainage paths	Naturally defined pathways through which run-off flows. Generally used to describe drainage depressions, gullies, drainage lines, creeks and rivers.
Drawdown	Lowering of the water table due to drainage or groundwater pumping.
Dryland salinity	Expression of salt at the soil surface or within capillary range, concentrated by the evaporation of saline groundwater discharging as a result of land use or land management.
Ecological zonation	Distribution of plant species across ecological zones because of variations in the environment (e.g. soil salinity, waterlogging and inundation).
Ecosystem	A community of organisms, interacting with each other, and including the environment in which they live.
Electrical conductivity (EC)	Ability of a substance to conduct electricity, used as a measure of water salinity. See conversion table at end of Glossary.

Electromagnetic induction	Process whereby a changing magnetic field causes an electric current to flow in conductive material (e.g. saline soil or groundwater).
End-of-valley target	A 'big picture' goal indicating how much salt will be discharged at the end of major catchments when management strategies are implemented.
Episodic recharge	Recharge as a result of unusually intense or prolonged rainfall events.
Evaporation basin	A shallow pond into which saline water is discharged to evaporate, leaving a residue of salt.
Evapotranspiration	Loss of water resulting from both transpiration by plants and evaporation.
Extension	The process of advising and providing information to land and water managers.
Geomorphology	Science of describing and interpreting landform patterns and processes of landscape formation.
GIS	Geographic Information System.
Ground truthing	A system where remotely sensed data is tested against direct measurements conducted on the ground.
Groundwater	Water beneath the surface held in or moving through saturated layers of soil, sediment or rock.
Groundwater base-flow	Stream flow that results from groundwater seepage.
Groundwater flow system (GFS)	A conceptual model to describe the response of groundwater to recharge.
Groundwater through-flow	Lateral movement of perched groundwater, often in a non-permanently saturated zone.
Halophytes	Salt-tolerant plants.
Hard water	Water containing high concentrations of calcium and magnesium salts. Hard water makes soap difficult to lather and may cause scaling or corrosion in water pipes, boilers, water heaters and other appliances, and industrial equipment.
Hydraulic conductivity	The physical property of the aquifer which determines the rate of movement of water.
Hydraulic gradient	The slope of the water table (change in hydraulic pressure over distance in the direction of flow) which helps determine the rate of movement of groundwater.
Hydraulic pressure	The pressure exerted by groundwater in an elevated part of the aquifer. This usually causes groundwater movement, possibly resulting in lateral or upward discharge.
Hydrogeology	The study of groundwater movement through soil, sediment or rock under natural or induced conditions.
Hydrology	The study of water movement.
Hypersaline	More saline than seawater.
Infiltration	The process by which surface water from rainfall, streams and irrigation channels enters the soil and is added to the groundwater.
Integrated catchment management	A process through which people develop a vision, agree on shared values and behaviours, make informed decisions and act together to manage the natural resources of their catchment.
Inundation	A condition in which free standing water occurs above the soil surface (sometimes called flooding). Waterlogging usually coincides with inundation, but many waterlogged soils are not inundated.
Land managers/holders	Those who manage land, including farmers, graziers, irrigators, cultural and environmental land holders, councils and government agencies.
Landscape	An area of land and its physical features.
Lateral flow	Groundwater flowing parallel to the natural surface. Normally confined to near-surface movement above the main aquifer.
Leaf area index (LAI)	The ratio of leaf area in a plant canopy to the area of the land beneath that canopy.
Leakage	The movement of water (rainfall or irrigation) below the root zone. In eastern Australia, deep drainage has been used interchangeably with leakage
Local groundwater system	Aquifer with a flow length of only a few kilometres.
Magnetics	Magnetic data can reveal buried drainage patterns, dykes, faults, fractures and deeper structural geology that assist our understanding of the hydrogeology of catchments.
Model	Conceptual models allow us to simplify complex systems (such as groundwater) and predict qualitatively their behaviour under various conditions. Computer models assign numerical values to many of the features of the model, input water as recharge then calculate the output (in time and space) as discharge.

Opportunity cropping	Sowing a crop only when climatic conditions present a suitable opportunity.
Percolation	The downward movement of water through soil.
Perennial	Plant that lives for several years (annuals live for only one growing season).
Permeability	The capacity of a substance (for example, soil or rock) to allow water to pass through it. Sand, for example, is said to have high permeability.
Phase-farming	Alternating farming land uses over time between annual and perennial vegetation (e.g. annual crops-lucerne-annual crops).
Piezometer	A tube (usually PVC, slotted and screened at the bottom) inserted into a confined aquifer to measure the relative groundwater pressure.
Porosity	Permeability by water, air or similar through small holes, or pores.
Radiometrics	Radiometrics detect radiation from the upper 30cm of the soil which may provide information about different types of clays or drainage patterns linked to areas where salt outbreaks occur.
Recharge	The process that replenishes groundwater, usually by rainfall infiltrating from the ground surface (river or lake bed) to the water table.
Recharge area	The area in which surface water (from rainfall, irrigation or streams) infiltrates into the soil and is added to the groundwater (c.f. discharge area).
Regional groundwater system	Aquifer with a flow length from recharge area to discharge area of hundreds of kilometres.
Regolith	Weathered or sedimentary material between the ground surface and bedrock.
Remote sensing	Collecting data using instruments remote from the data source, such as satellites or aircraft, but also ground-based instruments that collect sub-surface data.
Remnant vegetation	Native vegetation remaining after an area has been cleared.
Residual salt	Salt that is left in the landscape after the water has evaporated or receded.
Revegetation	Replacing the plants in an area which have previously been cleared.
Riparian	Belonging to the bank or shore of a river, stream or lake.
Root zone	Near-surface part of a soil profile where roots are active.
Salinisation	The accumulation of salts via the actions of water in the soil to a level that causes degradation of the soil.
Salinity hazard	Salt which, if mobilised has the potential to cause harm by discharging on the land surface and/or in streams. (See page 8 of ' <i>Catchment Management</i> ')
Salinity management	Intervention needed to mitigate or control salinity. Can be biophysical (plants) or engineering (e.g. drains).
Salinity mitigation	Any activity that reduces the salinity problem. For example, revegetation, improved cropping practices, reducing fallow and cultivation, planting salt tolerant species, and so on.
Salinity province	That part of the landscape in which a particular GFS (or several GFSs of the same type) operates.
Salinity risk	The probability of salt (salinity hazard) being mobilised and affecting natural, cultural or man-made assets. (See page 8 of ' <i>Catchment Management</i> ')
Salt, salts	'Salt' is a general term for many soluble chemical compounds, of which sodium chloride is generally the most abundant. Some salts cause hardness in water while others, in the right concentration, can be beneficial.
Salt accumulation	Salt deposited on the land from groundwater discharge or evaporated surface water.
Salt concentration	Level of salts on the land surface or in soil, rocks or water.
Salt interception scheme	Pumping or drainage that lower the water table by discharging groundwater into evaporation basins or elsewhere, thereby intercepting salt before it enters a river or reaches the soil surface.
Salt load	The amount of salt carried in water flow in rivers, groundwater or off the soil surface, in a given time period.
Salt scald	An area of land where the ground surface has been left bare after salt has destroyed the vegetation.
Seepage	The process by which water percolates downwards and/or laterally through the soil, often emerging at ground or stream level lower down the slope.
Sodicity	A measure of the amount of 'exchangeable' sodium ions in the soil. As sodicity increases so does the likelihood of soil structure decline, waterlogging and erosion.
Soil profile	A vertical section of earth from the soil surface to parent rock material, that shows the different soil horizons.

Soil water	Moisture stored in soil pores.
Sub-surface flow	Water moving laterally beneath the surface of the soil.
Sustainability	Managing our natural resources in a way that maintains their environmental, economic and cultural values, so that they continue to be available in the long-term.
Topography	The detailed description and analysis of the surface features of the landscape.
Transmission zones	Areas where water moves from recharge areas to discharge areas.
Total dissolved solids (TDS)	A measure of the salinity of water, sometimes referred to as total dissolved salts usually expressed in milligrams per litre (mg/L). An alternative measure is total soluble salts (TSS) (See Electrical conductivity (EC)).
Transpiration	The process by which water is extracted from the soil, transmitted through plants, evaporated from the leaves and enters the atmosphere.
Tributaries	Watercourses (rivers, creeks, streams) which flow into another watercourse.
Water balance	A state of equilibrium when rainfall or irrigation water in a landscape is accounted for by the sum of run-off, plant water use, evaporation, recharge and changes in soil moisture content.
Waterlogging	Waterlogging will occur when the water table is at or close to the surface. Soil pores are then filled with water, plant roots become starved of oxygen, and plant growth is inhibited or even ceases.
Water table	The water table is the upper surface of groundwater. The soil profile is fully saturated below the water table and unsaturated above it.
Weathering	Chemical, physical and biological decomposition of rocks that can result in formation of a soil profile.
Wetlands	An area that is permanently, periodically or occasionally covered by fresh, brackish or saline water to a shallow depth. They support a unique range of plants and animals.
Woodlot	A small area devoted to growing trees, usually on a farm for firewood and posts.

Salinity unit conversion table

↓Start here	mS/m EC	dS/m EC	uS/cm** EC	mS/cm EC	mg/L (ppm)* TDS	gpg* TDS
1 mS/m =	1	0.01	10	0.01	5.5	0.38
1 dS/m =	100	1	1000	1	550	38
1 uS/cm** =	0.1	0.001	1	0.001	0.55	0.038
1 mS/cm =	100	1	1000	1	550	38
1 mg/L (ppm)* =	0.18	0.00018	1.8	0.0018	1	0.06
1 gpg* =	2.63	0.0263	26.3	26,300	14.3	1

* Conversion from Electrical Conductivity (EC) to Total Dissolved Salts (TDS) varies depending on the salts present and concentration. These figures are a guide only.

** Eastern States of Australia often refer to 1 uS/cm as an EC Unit

This glossary was prepared with reference to:

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